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HANDBOOK OF HUMAN PERFORMANCE MEASURES

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July, 1972

(UNEDITED FIRST DRAFT)

HANDBOOK OF HUMAN PERFORMANCE MEASURES

Robert D. O'Donnell, Ph.D.

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July 31, 1972

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This volume was prepared by Robert D. O'Donnell, Major, USAF, while assigned to the Space Biology Laboratory for post-doctoral training as a student in the Air Force Institute of Technology, Wright-Patterson Air Force Base, Ohio. The literature search and other bibliographic work was done by Mrs. Lois Treichler Gehringer, bibliographer, of the University of California, Los Angeles. We gratefully acknowledge the Air Force Office of Scientific Research of the Office of Aerospace Research for their support of this work under Grant AFOSR-71-2005.

INTRODUCTION

Perhaps the first question which must be considered in a handbook of performance measurement is why such a book is necessary at all. "Performance" is a term which is generally understood by everyone, particularly by basic researchers who deal most often with laboratory situations where the dependent variable is a small segment of behavior, such as reaction time or mental arithmetic. In these situations, the terminal question of interest to the experimenter frequently deals with whether there is a change in that particular small segment of behavior itself. Thus, performance is defined as reaction time or mental arithmetic. This is frequently the best strategy where the goal is to provide basic information about that behavior. In such a case, there is no need to further specify how the performance defined in the laboratory "fits into" more complex tasks in other laboratory questions or in the "real" world. Thus, there can develop an over-simplified view on the part of many people that if you measure reaction time under a given stress, you have contributed an interpretable piece of information to the world of automobiles or aircraft, and to the questions of atmospheric pollution or man-machine systems.

The fact is that this is not the case. While it is true that research on such "molecular" samples of behavior may provide an important reservoir of information on basic parameters of the "performance"

defined. In this way, there still remains the monumental task of applying this information to situations involving even a small increase in complexity.. One of the leading researchers in this area has summed up the present state of affairs in performance measurement in these words:

"When one attempts to answer questions about human performance as it occurs in operational situations, one becomes painfully aware of the inadequacies of the extrapolations that must be made in attempting to apply research data to the practical problems of the real world. And when one attempts to design research to attack such questions -- either specifically or in general -- one becomes painfully aware of the absence of a body of generally accepted experimental methodology. For there is in fact no methodology that is generally accepted by researchers on such problems, and there certainly is none that is accepted by those who ultimately make decisions about the implementation of the resultant recommendations" (Chiles, 1967, p. 325).

The significance of this statement for the entire field of human performance can be sensed if it is compared to a state of affairs which would exist in medicine if there were no generally accepted methodologies for clinical evaluation, and no adequate theories to interpret the results of whatever clinical tests were being used. One group of physicians would be using blood pressure measures to assess overall health, another group would be using core temperature, and a third group would say you were certainly not sick until you showed abnormal x-rays. Some physicians would use a battery of tests and, after administration of this long and complex battery, would make the solemn pronouncement that the patient was sick or well. However, without any methodology for interpreting the meaning of the tests, they could not say exactly how sick he was, nor what needed to be done to make him well. Finally, there would certainly be a group of basic researchers -- providing the only hope of getting us out of such a nightmare -- who would study each measure in detail. With respect to core temperature, for example, they would be interested in what regulated it, what made it

vary, what it's ranges might be and what variation in this measure would mean. The only problem with these researchers would be that frequently, because they were intensely studying one measure, they would fail to recognize that there was a measurement problem in the whole field, and they would speak of "diagnostic tests" as glibly as social scientists speak of "measuring performance."

Fortunately, the above situation does not exist in the medical field, at least not to the degree that it does exist in psychology. There may be disagreements of interpretation from one physician to another, but basically they all use many of the same tests to assess health. Furthermore, these standard tests have been subjected to intense basic investigation so that one is at least fairly certain what each test measures and what deviations from the norm mean to the individual.

The field of performance measurement is far from this goal. As noted above, there is certainly no universally attractive methodology which would encourage all researchers to use the same or even similar tests to assess a given operational question. But the situation may be even worse than that. When one surveys the literature which has used "performance" measures of one type or another, the results are extremely disappointing. Performance tasks appear and disappear from study to study like spirits that remain too briefly to be grasped. In one group of studies, a particular task is studied intensively, often without even specifying the physical characteristics of the task completely, and almost always without relating the task to any other laboratory tasks. In another group, the tasks appear almost as necessary evils which do little more than prove that the "stressor" being

studied really stressed the subject. These tests are usually "home grown," unvalidated and probably unreliable instruments, or else they are old tests (usually used in some new and ingeniously unrepeatable way) which happened to be lying around unused when the experiment began. Even a casual review of this literature reveals a bewildering disarray of tests. With the "basic tools" of investigation in such a state of confusion, it is small wonder that theory is lagging so far behind.

It is our contention that the first step in remedying this problem is to take a comprehensive, organized look at just what does exist at the present time. Let us gather all the tools into one place and, without being too critical, let us look at the characteristics of each tool, the uses it has had, and -- at least in a very general and descriptive way -- the categories of performance it might measure. The magnitude of this task is overwhelming. Only a few previous attempts have been made to do such a thing, some on a limited scale (), some extensively (NASA CR-1614). These attempts have made certain assumptions in order to organize the effort and, inevitably, these assumptions have led to a product of primary value to individuals already supporting one theoretical viewpoint or attempting to extrapolate to one operational setting such as space or aircraft flight.

The present effort attempts to be more generally useful to a variety of researchers, independent of their own theoretical orientation. Thus, it attempts to be more truly a "handbook." Obviously, some organizing assumptions must be made in the present effort, but a conscious attempt has been made to keep these as broadly descriptive as possible, and to avoid predetermining test descriptions by some

pre-existing theoretical organization. By thus limiting value judgments in the inclusion of tests and their descriptions, it is hoped that a more complete handbook will result. This will obviously result in inclusion of a lot of "poor" tests. But we hope that the very inclusion of these tests, along side their more efficient and powerful competitor tests, will lead to their disuse by any trained researcher.

In general, then, the present handbook will, hopefully, have the following results:

1. To encourage the use of the most efficient, successful and appropriate test in a given situation (while discouraging the proliferation of inadequately validated "home grown" tests).
2. To increase the comparability of test results from different laboratories, and
3. To give new impetus to theorization about performance measurement and encourage development of new and creative ideas in this area.

Definition of "Performance Tests"

In its most general form, "performance" may be thought of as any behavior. In this sense, taking a personality test might be considered to be "performance testing." A more narrow definition might consider performance as an interaction between a man and a machine (Teichner,). Thus, "Behavior" would be defined as the organism acting alone, and the subject would be considered to be performing only when the behavior was carried out on some system. The measure-

ment units of performance of this type are system performance units, and therefore measures such as sensory thresholds are not considered to be "performance."

The present effort attempted to strike a balance somewhere between these two extremes. To define performance as including all behavior would result in unmanageable classification problems, and probably would add a massive number of tests which would be useless to most of the users of this handbook. For the most part, those who are involved in testing the human's capacity to perform do not classify personality, preferences, intelligence, etc. as dependent variables, but as independent variables to be controlled (if indeed they are considered at all). Thus, the present effort will not include projective or objective personality tests such as the Rohrschach, MMPI, TAT, KTSA, or any of the other tests which attempt to assess the subject's current personality state. Similarly, tests of preference or vocational interest will be excluded. In addition, intelligence tests and tests of academic achievement are excluded. In this same category would be any tests of motor skill which are designed to be one-time devices used to assess whether a training program has or has not produced a given level of skill. Such things as drivers' licensing tests and industrial job knowledge tests would fall in this category. One final category of tests must be excluded. These are tests which are designed to predict the capability of the subject to acquire a skill at some later point in time. Thus, a "mechanical aptitude" test would not be considered a "performance" test for the present purpose if it did not sample a significant amount of the subject's present

capacity to perform in some skill category. Usually, of course, such aptitude tests do sample relatively obvious skills, but this is not always the case.

An initial working definition of "performance test" as used here can be inferred from the criteria set up above:

A performance test will be considered to be any instrument, printed or mechanical, which attempts to assess the subject's present capability in a learned or developed psychomotor skill or skills.

These psychomotor skills may be largely mental in nature -- such as mental arithmetic tests -- but the subtle distinction usually applied to psychomotor tests is used here. For instance, a child struggling to repeat the "times tables" is probably not showing much psychomotor involvement since he is relying on relatively recent training to "produce" the answer. We seldom time such performances, and do not even count total errors very often. On the other hand, the experimental adult subject doing mental arithmetic is probably using different brain structures, and is essentially exercising a well-practiced skill. We are crucially interested in how fast he performs the task and how many errors he makes on the way because we are assessing the status of a psychomotor skill, not monitoring the development of that skill. This distinction is not always easy to make, but it was attempted in decisions made in the present case.

The "system interaction" definition of performance was also rejected for the present case because it would involve elimination of many tests -- most notably sensory capacity tests -- which do not per se involve system interaction. Yet, these tests may be of extreme

value in assessing the current state of the subject's capacity to perform. It was felt that while the system interaction definition can be defended when one is actually applying research results to an operational problem, the present effort calls for a more primitive and elementary definition.

Given the above working definition for performance tests, it was then necessary to further delimit the criteria for inclusion or exclusion of a given test. Anyone familiar with performance literature realizes that many studies use tests peculiar to the particular needs of the study being done. To attempt to include all of these "single use" tests would be tantamount to simply listing thousands of studies individually. In most such studies not enough information is given about the test used to reconstruct its essential elements, and almost never is the information extensive enough to allow one to determine if the test is appropriate for a given need. Thus, in the present effort, this type of "single use" test will be excluded in most cases.

What will be especially chosen for inclusion will be tests which are well established enough to have been used a number of times, either in one or more than one type of application. A major effort will be expended in the attempt to find and describe all such tests -- with, of course, the certain knowledge that such an attempt is doomed to fail. We hope that these tests will form the "core" of the handbook and that the data presented on these more extensively used tests will encourage their further development and use if they are found to have been effective, or their rejection and demise if they have been ineffective.

In addition to these tests, the handbook will, hopefully, allow a wider scope for test inclusion. For example, in a particularly significant or well-known piece of research, performance tests may have been used which had never been used before (and may not have been used again). Because of the wide distribution of such a study, there might be increased probability that someone would want to use one or more of the performance measures in the original work. That such measures be included in the handbook is, therefore, desirable. Similarly, if a certain test constitutes a new or unusual type of measure of a given function, consideration will be given to including it in the handbook even if it has not had extensive past use. This is done in order that the handbook will have maximum utility for someone interested in exploring new theoretical directions in performance measurement.

A third category of test may also be included even if it has not had extensive use in the literature. This is the test which has been used in factor-analytic studies and on which there is some objective information about the skill actually being measured. While some of these tests may be unwieldy, or inappropriate for a number of applications, the data available on them might be used as criterion measures by investigators interested in developing new and more appropriate tests. Thus, to exclude such tests would tend to defeat one of the prime purposes of the handbook -- to present whatever objective information is available so that future developments in performance measurement will be as well grounded in fact as possible.

Deciding on general criteria such as those above does little to eliminate other difficulties of classification. Some "tests" must actually be considered as "categories" of performance rather than

discrete measurements of a particular skill. For example, to speak of measuring "reaction time" is deceptively simple. Obviously, there are many kinds of reaction time -- visual, auditory, simple disjunctive, etc. Even within one type of reaction time, say the auditory reaction time, there is a multitude of variables which will determine the kind of test that will be used to measure the skill. Is the auditory signal to be very loud or near threshold? Is the response required to the auditory signal a finger movement, a verbal response, or a change in the size of the subject's pupil? Is the auditory signal a tone, an emotional word, or a train of pulses? One can see that if this kind of classification is carried to an extreme, there could be a different test for every permutation of the above factors (and many others not mentioned). This would result in hundreds of reaction time tests alone, and would be obviously unmanageable.

To solve such a dilemma, a more generalized approach was taken in the present case. A test was considered a "reaction time" test, or as a test belonging to any other general category, if it appeared to be primarily a measure of that skill. Thus, with respect to reaction time, if a test requires a subject to monitor a console for long periods to detect relatively infrequent signals, it would probably be considered a test of vigilance, even though the test might be scored in terms of the subject's reaction time to the event. Similarly, if a test battery contains a tracking task which is used in conjunction with another task to assess the subject's "workload capacity," the tracking task in this case would not be listed separately. In another situation, where the tracking task per se was of interest, the test might be listed as a tracking task.

What this amounts to is simply that not all variations of a given skill test were listed. Major sub-categories of a certain type of test, e.g., auditory reaction time, visual reaction time, etc., were listed separately, and a representative sample of the tests used to measure such skills were presented. However, no extensive efforts to present all of the varieties of auditory reaction time tests were made. It is hoped that from the representative samples given, the user will be able to decide whether it is worthwhile pursuing the inventory of that skill's measurements further.

A further classification difficulty arises from the use of test batteries. These usually consist of a number of discrete tests, each of which have some independent value for performance measurement. The question, therefore, is whether the test battery should be listed separately, or whether each test in the battery should be listed alone. This question was resolved by including a completely separate section for test batteries in the handbook. In this section the test battery was treated as a unit, and its particular advantages and disadvantages will be considered as a single test instrument. In actual fact, most of the elements which make up that unit will have been described as individual tests in other sections of the handbook. In this way, we hope that the handbook will retain its most general utility, so that it will be useful to individuals whether they are interested in an integrated battery or a single test.

Somewhat along the same line, there are separate sections for "Simulation of Systems" and for "Tests Using Real Systems." Both of these areas are large and unwieldy from a classification viewpoint. If all systems simulations were to be included, the literature of interest would probably be doubled. In the same way, if all the

"check flights" and "field" experiments of performance were to be included, the handbook would soon take on such a degree of specialization (say to airlines and automobiles) as to be useless to a more general audience. Therefore, in both of these sections, testing methods are used as a major classification scheme, and representative examples of each type of method are given. Again, one hopes that in this way the user will be able to make a decision about whether a given performance measurement technique is worth following further.

One should point out, if not already clear in what has been said thus far, that the author's primary orientation in performance measurement revolves around a general interest in the area of stress research. Thus, one can see that in many of the decisions made about inclusion and exclusion of tests, the ultimate criterion was whether a given test might or might not show change in capacity to perform under some "stress." The definition of stress in this context is fortunately very broad, so that virtually every environmental situation, internal or external to the person, fits within the definition. However, such a set does account for the exclusion of tests designed to evaluate long-term states relatively insensitive to acute change such as personality, or job knowledge. Although these may certainly affect system (i.e., man-machine) performance, they are not readily disrupted over the short term by some acutely applied stress. We recognize that adoption of such a "set" by the authors constitutes an example of the test selection bias which they attempted to avoid. However, this bias, hopefully, is not general enough to negate the overall value of the handbook.

Methods of Literature Search

In order to achieve a broadly-based literature search for tests to be included, a multi-faceted approach was taken. It is recognized that nothing but the most exhaustive search of the literature in all fields could produce certainty that no significant tests had been overlooked. However, by searching across several major fields of interest, it was hoped that the vast majority of significant tests would be isolated.

The primary reference work consulted was the Psychological Abstracts. These volumes were covered from the years 1927 to 1971, with greater emphasis placed on the later years. Approximately 230 key index words were chosen, and the titles under each of these words were individually inspected. If a performance task was mentioned or inferred, the abstract was consulted. If the required information was available in the abstract, the original article was not consulted. However, in over 50 percent of the cases, and in virtually all initial source documents on a test, it was necessary to consult the original article.

An important source of information for the present work was a series of volumes produced for NASA by the Bunker-Ramo Corporation. (Finley et al, 1969). Working on the aspect of performance prediction in man-machine systems, these volumes listed extensive information on over 400 tests, most of which are also presented in the present handbook. Appreciation is extended to the authors of these works, and to the Bunker-Ramo Corporation for permission to quote from the volumes where appropriate. For the reaction time section, the prime reference was an outstanding compilation of abstracts prepared by (). These two volumes must be recommended most highly to anyone wishing to work intensively in the

area of reaction time measurement, particularly from the viewpoint of information theory.

To supplement the literature searches, personal visits were made by the authors to several centers for performance testing in order to gather firsthand information. These visits included the Aerospace Medical Research Laboratory at Wright-Patterson AFB, Ohio; the Federal Aviation Agency Research Laboratory at Oklahoma City, Oklahoma; and the Performance Research Laboratory at as well as the Life Sciences Division of NASA, Langley. At these facilities, individuals such as Dr. Walter Grether, Dr. Julien Christensen, Dr. Dean Chiles, Dr. Earl Alluisi, and Dr. Randal Chambers spent considerable time reviewing our efforts and suggesting improved presentations as well as aspects of the problem we had overlooked. An additional supplement to the literature search was a request sent to _____ producers of commercial performance tests for information on their tests. These mailings produced _____ replies which added considerably to the handbook in providing information on tests still in the developmental or normative stages.

Information Given on Each Test

A narrative rather than an enumerative format has been used throughout the handbook in order to allow as much flexibility as possible. However, an attempt has still been made to present information on each test in a generally standard way. Obviously, due to lack of information on some tests, this was not always possible. Nevertheless, the following outline of test information can be considered the general model. If a given piece of information is missing, it can be assumed it was not readily available in the sources used.

1. Test Name: If possible, a generally accepted name for the test, or the name used by the test's author, will be given.

Where no particular name has been given or used, an arbitrary name will be given which will attempt to include both the general nature of the test (e.g., mental arithmetic, tracking) and the particulars of that test as opposed to others of that type (e.g., mental arithmetic -- addition and transposition; critical instability tracking). Frequently, the test name will have to be a general class of tests, such as "Time Estimation." In this case, there are so many variants of time estimation that it is most economical to list them not as separate tests but as examples of the general class.

2. Abilities Measured: Wherever possible, abilities will be listed in factor analytic terms along with the loadings found on each factor. However, one recognizes that this type of information will be available for only a small number of the listed tests. When no factor analyses have been reported using a given test, a more superficial approach will be taken, and this section will list the abilities that the test appears to measure. These subjective opinions may represent what the test's author intended to measure, or what the authors of this handbook think the test might measure. In any case, where no objective data are given to support the contention that a test measures a certain skill, the statement must be interpreted very cautiously. Certainly such a lack of objective data should indicate that research is needed.

The terminology of the abilities section posed special problems. There is little agreement as to what to call human skills, and the authors did not wish to adopt any one taxonomy of skills too strongly in order not to bias the presentation of test information. Therefore, we have been willing to adopt almost any terminology, from almost any source, as being a "skill name." In addition, we have

chosen to classify tests, where possible, by appropriate task-taxonomy so as to provide at least a tentative basis for relating a given test to a real-world task. Obviously, this is an "arm chair" exercise, and many of our guesses about what a test measures will be wrong. But it is our desire to provide as generally useful a handbook as possible, and to this end we desire as extensive a cross-referencing as we are able to achieve. The ability terms used in discussing the test will provide much of the basis for that cross-referencing so, at this stage, we are willing to risk interpretational errors for the sake of completeness.

3. Environments in Which Test Has Been Used: Because of the particular concern of "stress" researchers in performance measurement, mention will be made of all the known stresses and environments in which the given test has been used. The term "environments" is probably to be preferred in this context since we desire to include those studies where performance did not change (and therefore, by some definitions, where no stress was involved). Again, there can be no assurance that every use of the test can be listed here, but a sufficient sample should be provided so that the interested user can probe further into the literature. A very broad definition of "environments" will be adopted, so that internal states of the subject, such as fatigue, sleep deprivation, and sensory overload can be included. One limitation was placed on this broad definition. There is a vast literature on the performance effects of drugs and other therapeutic agents. Much of this literature is not of direct interest in most operationally oriented or basic research contexts. For instance, it would be of little interest whether an anesthetic used for

surgery interferes with abstract reasoning during the surgery. On the other hand, it might be of interest if the anesthetic has a longlasting effect on abstract reasoning. Therefore, in the area of pharmacological agents, a decision was made as to the utility of reporting a given study with a given performance test. Certainly, all psycho-active agents which might be taken by the performing individual will be included, and this is meant to include antihistamines, cough suppressants, motion sickness pills, and the like.

4. Descriptive Details of the Test: In providing a description of the test itself, we hope that the interested user will be able to accomplish several things prior to the necessity of going to original sources. In the first place, test specifications will be given in as much detail as possible. This will include physical size, operating characteristics, electrical requirements, auxiliary equipment required, and any other information which might affect a decision to use the test solely on the basis of convenience or feasibility. Wherever possible, cost information and commercial availability data will be presented in Appendix _____. Where a test is not commercially available but where enough information is given that the test might be fabricated, this fact will be pointed out and fabrication cost will be estimated to be either "low" (under \$50), "moderate" (\$50 to \$100), or "high" (over \$100). In all cases where the test is not commercially available, its author or prime user will be given as a source of further information.

A short section on each test will describe the procedure used in administration. The purpose of this section, again, is to allow the handbook user to determine whether the test is close enough to his need to warrant further research. Therefore, this section will

not present a detailed list of procedures, but rather will strive to give the reader an impression of just what the subject is required to do, of what is required of the experimenter, of times involved in test administration, and of the amount of practice required before a performance plateau is reached. Whenever information is available, particular attention will be paid to the test's learning curve and the effect of practice, since this is frequently critical in deciding the number of subjects required for a given experiment. This obviously would be an important factor in the decision to use or discard a test.

The final type of information to be presented on details of the test itself will be statistical and evaluative in nature. When available, validity and reliability data will be presented. Beyond this, any comments from reviewers or previous test users will be mentioned if they appear valuable in helping one decide whether to use a given test. In this section, also, will be placed information on such things as peculiarities of measurement units used in the test, data transformations usually applied, and whether the measurement scale is interval or not. This type of information is not available in a large number of cases, but will be mentioned where possible. It is designed to assist the user in anticipating data reduction techniques and problems, as well as allowing more informed decisions on details of the experimental design required with a given test.

5. Additional References: In some cases, references may be listed which are not central to the test itself, but may contain information on the test's experimental parameters, variations in procedure that have been used by various investigators, and on other,

non-test, uses of the test. Whenever it is deemed appropriate, these references will be annotated with enough information to allow the handbook user to decide whether it is worth going to the original source. Again, it should be remembered that this section does not attempt to present a definitive bibliography on the test, but simply a sufficient sample of references to allow further investigation.

Organization of the Handbook

As mentioned earlier, the overall rationale in organizing this handbook has been to keep it as generally useful as possible by making as few biasing assumptions as possible. Obviously, then, the overall organization could not revolve around some well-defined theory -- such as factor analysis. While such organization would maximize utility to a user who wished to operate within the factor analytic framework, it would make the book extremely difficult (if not impossible) to use by someone who wished to take a more applied, system-analytic approach. It therefore was clear that the key to retaining overall utility was to use the most simple, externally descriptive terms possible in setting up the book's overall organization. If, in this way, we could achieve a classification scheme which could be accepted by everyone, then we would have a "core" of basic raw material which could then be molded into different shapes to meet different theoretical needs. This is not a case of trying to "water down" the handbook's contents. No effort will be made to avoid presenting the most opinionated statements by test authors as to what the test measures. Nor is this attempt at generality a way of avoiding a strong position about what a test measures. In the cross-reference section discussed below, we take extremely strong (and often uncomfortably poorly-based) stands on where a given test fits in a given theoretical framework.

In any case, the categorization which was finally adopted represents an attempt to achieve the above goal. The basic descriptive terms chosen for tests revolve around whether they appear to test primarily "sensory," "motor," or "associational" processes. Again, we must strongly emphasize that these terms are to be considered descriptive, not interpretive. One may become quite philosophically entangled arguing whether it is possible to test a purely sensory function such as absolute visual threshold since there is always a motor element present in the subject's response that he either sees or doesn't see the light. However, on a descriptive level, the measurement of sensory thresholds is generally acknowledged to be primarily a measure of the subject's sensory capacity, and it is this, admittedly oversimplified, view that is taken here. If the classification achieves its goals, then a person with no particular theoretical position could use the handbook profitably simply by considering what the skills he wishes to measure "look like." Is he interested in knowing whether a given stressor affects the subject's "higher mental processes?" Then these would certainly be found under the heading of "associational processes." Similarly, if he were interested in knowing if a stressor affected the subject's absolute capacity to receive information, with a very low requirement to process the information, he would go to the section on sensory processes.

In order to further clarify the meaning of the various categories used here, the terms used in the index are defined below:

1. Evaluation of sensory processes: This section contains tests which primarily measure the subject's capacity to receive simple sensory stimulus information. Obviously, the capacity to perceive and respond to the stimulus are also measured by these tests, but the criterion here is that both of these functions are kept relatively simple. For example, if an auditory differential threshold test simply requires discrimination between two pure tones, it would be classified as a test of sensory function. If, however, the choice were to be made between symbols, digits, or other interpretive information, the test would be classified as a reaction-time test and would be listed as a discrimination motor response. Similarly, the response must be simple and not a highly dependent variable in the overall score of the test. Simple button pressing, turning off switches, and other discrete and relatively less variable movements would fall in this category. On the other hand, a continuous tracking task would be considered a test of motor response even though simple sensory processing might be involved. In this case, the motor response is a critical part of the overall score.

Under the category of sensory processes, three main subheadings were used. The first deals with sensory thresholds in the classical sense. Both absolute thresholds (RL) and differential thresholds (DL) are considered for each sensory modality. The second subheading has been called "sensory integration." Under this heading, for each sense modality, can be found those tests which involve some secondary sensory operation other than simple reception and response. For example, tests of critical flicker fusion are certainly sensory tests. However, they require more than just a response to the light

in that a secondary "fusional" ability is involved. The same would be true of auditory flutter fusion and certain tests which require sensory integration of pulsed or intermittantly presented information. The third sensory subheading deals with the maintenance of sensory function over time. This is a difficult category to define since it could be confused with sensory tests which simply last a long time. What are intended here, however, are measurements where the time element itself is of critical interest to the experimenter. This would be the case in tests of monitoring or vigilance which are here defined as prolonged maintenance of a given system status, such as watching a dial for deviations from zero or the prolonged capacity to respond to rare signals in an otherwise inactive system. In both of these cases, the extended nature of the task and the relative infrequency of the stimulus are critical factors in the final score.

2. Evaluation of Motor Responses: In this section, the tests deal primarily with the subject's capacity to make responses, rather than simply to receive and process simple sensory information. Hopefully, this distinction was clarified in the preceding section. Still, additional clarification might come from considering the types of tests listed under the three main subheadings of this section.

The first subheading deals with "non-discrimination" responses. Here the primary interest is in the subject's capacity to make discrete or continuous responses to either single stimuli or a single set of instructions. Tests of muscular endurance, such as the Harvard Step Test, would constitute a non-discriminative motor response test. Although simple reaction time in the classical sense would also fit here, it is included in a later section to maintain the integrity of the reaction time heading. The second major subheading is "discrimination responses." This is defined very broadly to include motor

response tests where there is more than the simple choice of whether or not to respond. In other words, in this class of tests, an error may be made by doing something other than just "missing" a response. This subcategory is itself divided into two sections, one dealing with "control precision" for visually and non-visually guided tasks, and the other dealing with "decisions" between two or more overt motor responses. The former type of test deals primarily with the subject's attempt to achieve or maintain control over a task which will be unsuccessful if his muscular movements are not relatively precise. In this category would fall most tracking tasks, whether the element to be tracked is a needle dial, a tone, or input from the subject's own vestibular apparatus. Under the heading of "decisions" would fall most discriminative reaction-time tests where the choice is not symbolic or near threshold. Since this is a broad category of reaction time, it was decided to put all reaction-time tests here. The third major sub-category is really just a specialized case of the first two. This deals with "autonomic" responses, and is included as a separate heading in recognition of the recent advances in this area. Under this heading are listed those "motor" responses which have traditionally not been thought to be under voluntary control. Without entering into the controversy as to the truth of this statement, one can at least say that these tests measure the integrity of certain motor systems. Examples of these tests are the pupillary response to light, heart rate, respiration, and even some of the recent techniques of standard EEG analysis.

3. Evaluation of Associational Processes: The tests included in this section are designed primarily to evaluate the subject's ability at internal, "mental," processing of information. As poorly defined as the term "mental" may be, it has a certain descriptive attraction. Clearly, on a purely descriptive level, a choice between a loud and soft tone is not considered "mental" activity by most people. Conversely, the choice between two symbols (verbal, numerical, or geometrical) which "stand for" a category, a concept, or a state of affairs, is usually considered to be a "mental" activity. Again, we need not even postulate, for this purpose, the use of different brain structures or different skills, if the classification is operationally real to most users of the handbook, that is enough.

Again, this sub-category is divided into three sections. The first section has been called "classification or definition." In it, the tests are concerned with the development or maintenance of concepts, usually along with some objective indicator of these. Tests such as "cancellation" and "card sorting" fall in this category. The second section deals with "internal standards for comparison or production." Here the primary interest is with previously established internal representations of real world characteristics such as time, length, pitch, color, etc. The experimenter is usually trying to detect some change in these internal standards for the subject. Tests in this category include time estimation, length estimation, or interpulse interval estimates. These tests may all be done either by having the subject produce or recognize the desired standard. Finally, the third section has been called "manipulation of abstractions." Again, this section contains elements of the first two, with

one additional element. Not only must the subject have or produce a classification, concept, or standard, he must also work with it to choose one of a variety of possible answers. Listed separately under this heading are spatial tests ("rotational velocity estimates," "object orientation test"), verbal tests ("anagrams," "analogies"), and numerical tests ("mental arithmetic").

This completes the listing of "single purpose" tests. Clearly, though, there are three other types of testing not covered by the above list. The second section of the handbook therefore deals with these three types.

4. Combined Tests: In this category, we are concerned with all batteries of tests designed to measure more than one aspect of performance, either sequentially or simultaneously. As has been noted previously, these batteries frequently are made up of tests which were described in previous sections as measuring one aspect of performance. In this section the concern is particularly with those aspects of the task battery which attempt either to measure more than one function or to evaluate the effect of changes in one performance on other independent performances. Thus, while reference will be made to all of the individual tests in a battery, the multiple-measure aspects will be emphasized.

For classification purposes, we decided to divide this section into two major sub-categories, depending on whether the task battery attempted to achieve its goal through simultaneous presentation of two or more tasks, or whether it used sequential tasks. In the former classification, tests such as "time sharing" and the "Neptune" panel would be included where these were concerned with "workload"

capacity. Sequentially presented tasks might include the "Guilford-Zimmerman Aptitude Survey," which yields a profile of different "skills."

5. Simulation of Systems: A type of test which is radically different from those presented up to this point is represented by the attempt to simulate, as closely as possible, actual systems or, in more recent applications, classes of systems. The vast, computer directed, flight simulators of the airlines and military come immediately to mind in this respect, although extensive work has also been done on systems such as automobiles and operational command and control centers. The scope of such simulations range from the use of a small system component which is integrated with other test parameters, which may not simulate the system, all the way up to elaborate attempts to simulate not only internal system dynamics, but even external forces acting on the system such as buffeting and temperature. In the latter case, the classification of a "test" as a simulation is obvious. However, when the simulation is less than complete, sometimes it is difficult to determine whether to classify the test as a simulation or not. For instance, if a real control stick for a given aircraft is used as the controlling element in a tracking task, but the forcing function fed into the controlled element is a sine wave, should the task be considered a simulation or a test of motor control precision? A very simplistic view was also taken here in order to avoid theoretical positions as much as possible at this point. If the intention of the experimenter was to derive applied information about a given system or class of systems, with little basic or generalized interest in tracking per se, the test was considered a simulation. In some more complex types of simulation currently being considered, such as

the use of drones or radio-controlled cars with the operator somewhere else, the distinction becomes even more obscure. However, throughout the handbook the primary question was the intention of the experimenter, and in most cases this allowed a more or less clear distinction to be made.

6. Use of Actual Systems: The final classification represents the most "realistic" form of performance testing. In this, the actual system of interest to the experimenter is used to answer questions of interest about that system or class of systems. Thus, an automobile instrumented to record control movements is actually driven by the operator on a road or a test track. A relatively rigid definition of this category was adopted here. A test was included only if it used an actual system. The system could be modified to record data, but if any modifications were made which significantly affected the stimulus input or the required control movements for the subject, it was then considered a simulation. Thus, if the operator was not actually in the system being controlled, the test was considered a simulation. Such a situation might arise in some remote control setups, where the operator may be in a real system (say an aircraft) but he is controlling a drone of that system by radio. In any case, this category is, in practice, relatively easy to classify and represents a significant portion of certain kinds of performance testing being done at the present time.

The Cross-Reference Section

To state that the ultimate utility of this handbook will be totally dependent on the quality of the cross-reference section is not an exaggeration. Deficiencies in the presentations of tests, disagreement in the basic classification of tests, and even errors in interpretation could all conceivably exist without negating the basic

utility of the book. The user might readily compensate for these problems. However, if a potential user is never directed to the kind of test he is looking for, then the handbook might just as well be discarded. Yet, this is a monumental task to set. It amounts to, in effect, taking every major approach to performance testing, and classifying the basic "core" of tests in the terminology of each. To do this in a totally exhaustive way would be a prohibitive task for one volume (although it could be done piecemeal at some later date). What has been attempted has been slightly less ambitious and, hopefully, only slightly less useful. By taking the major approaches to performance measurement and referencing all of the tests described in the handbook by all of these categories, we hope that the vast majority of the handbook's users will be able to pick it up and locate appropriate tests of any category within their own particular theoretical orientation. Those who have no particular orientation can still use the basically descriptive labels used in the general classification and, thus, we expect that virtually all individuals will be able to use the handbook with great efficiency.

The difficulty of cross-referencing in this way cannot be minimized. If one recalls the bleak statement by Chiles presented at the beginning of this chapter, one can see that any authors who attempt to fit the whole area of performance measurement into any theoretical framework (let alone all of them) are exposing themselves to mental turmoil, absolutely certain and devastating criticism from both test authors and users, and possibly professional suicide. The only thing that could motivate authors to go on and

attempt the classification in view of these painful prospects is the absolute conviction that the present state of affairs is so bad in the area of performance measurement, that even a totally wrong classification would be an improvement.

We have decided to go on and attempt the classification.

To use the cross-reference section as it is organized, the user of this handbook should first determine the system within which he prefers to work. This advice may seem trivial to many researchers (and is for some). But if one remembers that there is a long history of performance testing based on no rationale at all, the advice is not as superfluous as it might seem. Having chosen a general system -- e.g., factor analysis, a certain task taxonomy, or simply a given sense modality -- the researcher can then inspect the general headings under this system. This inspection should reveal subcategories of particular interest to him. For example, a person interested in the effects of fatigue on automobile driving, who adopts a factor analytic approach, will find under the factor analytic section those factors which he considers important to automobile driving. This will then give him a preliminary list of tests. He can then turn to the section which classifies tests by stressor, and under "fatigue" he can find which of his preliminary tests have been used in this stress. From this information, he can either decide to use some of the previously used tests, or he might decide to use different ones. In any case, his decisions will be much more informed due to his use of the handbook.

The above result would certainly justify the work put into the handbook. However, there are several other ways in which the book could profitably be used. Large laboratories which do a great deal of performance testing frequently desire to have maximum interrelatability among different projects done in their lab. For this reason, they frequently choose a loosely defined battery of tests which are used in most research done in that lab. In the past, the tests that went to make up this battery were determined by some undefined interaction between cost, environments of interest, and available researchers' past experience. With the advent of this handbook, it should be possible for a laboratory to survey an extremely large number of tests and to choose those which are completely appropriate to their needs. This "battery" of available tests could then be made readily available to researchers in the laboratory on a standardized basis, resulting in a significant saving in time and money for the lab. In addition, such a result should also produce greater uniformity in research reported in the literature. Since, presumably, the better tests will become more widely used, a kind of evolutionary development should also result in the measurement area through "natural selection" and refinement of the best tests, along with rejection and eventual demise of the worst.

It might appear that the above development, if it occurs, would put an end to development of new tests and freeze the field in its present state. Precisely the opposite result is hoped for. If, by presenting an overview of the entire field, we can stimulate thought in new directions, then perhaps theoretical breakthroughs will be

encouraged. In the past, theoreticians have been hampered by necessarily restricted views of performance measurement. Researchers have tended to become "tied" to one test or one test battery because they knew it and because the time necessary to investigate alternatives was prohibitive. What was worse, some investigators created a new test for every occasion. In any case, it is now possible for interested researchers to survey a whole area of testing at one time. Given this added perspective, one hopes new ideas will definitely emerge. If this happens, then we would expect and encourage a flood of new tests, all tied to the new theoretical positions. Such a development can only be good. The proliferation of poorly defined tests, loosely (or not at all) tied to any theoretical basis, is the cancer that has stifled the field thus far. On the other hand, the development of new tests clearly tied to a strong theory should provide testable hypotheses which will lead to meaningful and scientifically ordered developments in the area of performance measurement.

Limitations of the Handbook

The basic limitation of this handbook is the most important and the most obvious one. Information given here is not sufficient to allow the researcher to use a test. This handbook is designed solely to allow the user to formulate ideas about what tests should be used in given situations. Usually, in order to make the final choice of tests and, always, in order to use the test, the original references must be consulted. To avoid this step would be to risk inaccurate use of an inappropriate test.

One should also recognize from what has been said that not all information about a given test has been included here. Thus, this is in no way to be considered an exhaustive bibliography. We hope that enough information has been given to allow the user to eventually locate all the pertinent references on a test, but cognizance must exist that this will sometimes require a bit of detective work. Finally, we must state that while every effort has been made to provide up-to-date data on such things as cost and availability, this type of information changes too rapidly to be guaranteed accurate.

SENSORY THRESHOLDS

Perhaps the most elementary question that can be asked in the field of human performance, at least as we have defined it here, is that of the sensitivity of the sensory apparatus to minimum quantities of energy impinging on them. Thus, prior to asking how well the subject can integrate, manipulate, or respond to a given stimulus, we may be interested in knowing whether the receptors responded to the stimulus at all, or at least to the degree that the subject was able to report reception. Such a question involves the thresholds of sensitivity for the sensory receptor, and has stimulated a vast quantity of basic research which has stretched across many disciplines, including psychology, physics, and medicine. The absolute threshold refers to the minimum energy the receptors can respond to. It is frequently called the RL (which stands for reiz limen, a German term meaning lower threshold) and this designation will also be used here. The differential threshold refers to the minimum difference between two stimuli which is necessary before the subject reports that they are different. This is designated DL. The purpose here is not, of course, to discuss the many basic aspects of research into the thresholds of various senses (see Stevens, 1951; Osgood, 1953; Woodworth and Schlosberg, 1954). Such investigations have used extremely sophisticated techniques which, in most cases, would be impractical and unnecessary in the majority of the performance-test situations. Nevertheless, in attempting to present operational principles for

's and DL's, we will have to indicate certain basic
 h may have a bearing on the type of measurement that
 osen. Such presentations will, of necessity, be sketchy,
 intended only to alert the reader to their existence,
 rate definitive parameters. If a particular design con-
 appears important to a problem, the reader should search
 nal articles.

VISION

th most questions of sensory function, the sense of
 ceived the greatest attention with respect to thresholds.
 he absolute amount of physical energy necessary for the
 a visual experience, Zegers (19) has calculated that
 only two quanta per cone are sufficient to achieve a
 reshold in practiced subjects (see also Pinegin, 1944;
 i the most sensitive part of the eye, a visual experience
 nsue if 5 to 14 quanta reach the rods (Hecht, Shlaer,
 942). Practically, of course, this quantity varies
 ght variation from optimal conditions, and with every
 al location. Thus, from the viewpoint of interest
 not a single RL for vision, but a series of thresholds
 uite different in absolute-energy terms and which,
 y, may respond differently to a stress and may each
 implications for extrapolations to "real-world" per-
 ith many things, this may sound like an obvious point,
 theless, often been violated. For instance, changes in
 vision were reported by MacFarland, et al (1944)

after exposure to low doses of carbon monoxide. Federal agencies have inferred from this result that such a change constitutes a hazard to automobile drivers (EPA Report #AP-62). Aside from the obviously large extrapolation necessary for such a conclusion, there was apparently little concern with how MacFarland measured such thresholds. As a matter of fact, the changes in question were of the order of .1 log unit at a fairly high CO level, and they were in the differential threshold; i.e., the ability to see a difference between a very dim light and a slightly brighter one. Viewed from this aspect, it would appear that 1) if the driver is in light conditions where the discriminations required are that small, then he is already in trouble and the lowering of his threshold will have no additional effect on his driving, and 2) if that is the magnitude of the carbon monoxide effect, then the conclusion should have been that it will not affect the driver in any appreciable way. The study, as MacFarland intended, is a valuable contribution to the field of basic physiological and psychological effects on the human. The spurious extrapolation of the results to a complex real-world task bearing almost nothing in common with the task used by the experimenter is, unfortunately, an all too common event.

To make it as difficult as possible for such extrapolation to occur, the experimenter should present as much critical information as possible on the limiting parameters of the test used. This, of course, is necessary in every form of performance test, but it is perhaps more critical with basic sensory tasks such as thresholds, which appear so deceptively simple. The discussion to follow should alert the experimenter to some of the parameters in visual threshold

testing which can limit the generalizability of results.

Physical Parameters of Stimulation

We know, generally, that certain very specific relationships hold between the intensity of a visual stimulus and the time over which it must be presented in order to have a given physiological or psychological effect. This is known as the Bunson-Roscoe law and, of course, is true only for short durations of stimulus presentation. However, it is just such durations which are frequently used in visual threshold work. A similar law deals with the effect of the size of the stimulus and its ultimate visual effect. This law (Rico's) holds that there is a multiplicative effect between area and intensity of the flash, again within limits. One should also note that if, for some reason, two spots of light are given which are separated by a very small distance, the threshold will be lower, i.e. spatial summation will occur. Although these relationships are well known, they have sometimes been ignored in research dealing with performance, and one will occasionally find reports where the time of presentation or the size of the target was uncontrolled. Such studies, to say the least, are in a difficult interpretational position when it comes to determining what caused any observed effects.

Location and Wavelength of Stimulus on Retina

More common than the above problem is a lack of control over just where a stimulus falls on the retina. The retina, of course, is basically composed of two types of cells, the rods and the cones. Moreover, these are distributed differentially over the surface, with the cones concentrated in the center and the rods at the periphery. Functionally, the rods are much more sensitive, and they yield a sensation which is generally devoid of color. The cones are less sensi-

tive, but yield finer discrimination and sensations of color. Vision in very dim light with a dark adapted eye, where the rods are primarily involved, is called "scotopic" vision. If the light is stronger, above the threshold of the cones, it is called "photopic" vision.

Since these cells are distributed differently over the retinal surface, the thresholds will be different for a given stimulus if it falls on different parts of the surface. For fairly large targets, this is not a very great problem. On the other hand, the determination of thresholds is often done with very small targets. Here the question becomes how to be sure the subject's eye is always positioned in such a way that the stimulus will always fall on the same spot. Frequently, a fixation point is provided which is, in itself, very dim and usually of a wavelength (color) that does not destroy dark adaptation. In the case of foveal thresholds, several small lights can be placed to form a figure (square, triangle, etc.) and the subject is required to look in the darkened center of the figure. This probably does not drastically affect the thresholds obtained and certainly aids in delivering the stimulus to the same spot. But it does introduce an additional factor to be controlled, and its effect must be considered if results from such experiments as these are to be related to real-world tasks. If no fixation point is used, it is even more important to consider possible variations in obtained results as due to changes in the location to which the stimulus was delivered.

The distribution of absolute retinal sensitivity has been studied by a number of authors (see Riopelle and Beven, 1953). Maximal sensitivity is found on either side of the fovea, about 20 to 30

degrees into the periphery. Generally, the temporal side appears to be more sensitive, and the upper half is slightly more sensitive than the lower half (but see deGroot, Dodge and Smith, 1952). Riopelle and Beven provide a polar map of isosensitive areas which should aid in interpreting the data obtained by some methods.

From what has been said about the rod-cone distribution in the retina, one might guess that the surface will not be equally sensitive to light of various wavelengths, or colors. This is, in fact, true. As soon as the phenomenon of color is introduced in fact, the whole problem of measuring visual thresholds becomes much more complex. In addition to variations in sensitivity to a given color over the retinal surface, there is also variation in sensitivity at a given retinal location to light of various wavelengths. Standard curves of retinal sensitivity are available which indicate maximum sensitivity in the area of 560 millimicrons for the cones, and somewhat less for the rods (Le Grand, 1968; Stevens, 1951; Graham, 1965). To the researcher interested in questions of visual threshold, this means that the spectral sensitivity of the stimulus must be given careful consideration. Failure to do so could result in performances which would be extremely hard to interpret even within the framework of the experiment, let alone within the framework of extrapolating the results to other tasks and other situations.

Adaptation

The sensitivity of the eye is obviously determined by its state of prior dark adaptation. The eye which has been in the dark for an hour or so is nearly a million times more sensitive than one exposed to bright light prior to the test. These changes in sensi-

tivity over time in the dark have been plotted for the various parts of the retina (Stevens, 1951), and such changes in themselves constitute a method of measuring visual function. Basically, we know that if the eye is exposed to bright light, it rapidly loses sensitivity, reaching near-maximum insensitivity in about one minute. If the light is then turned off, the eye begins to recover sensitivity --- rapidly at first. Over the first five to seven minutes, sensitivity continues to increase, but at a smaller and smaller rate. If the test stimulus is confined to the fovea, a point is reached by seven minutes where no further sensitivity increase takes place. This corresponds to the maximum sensitivity the cones can achieve. However, with peripheral stimulation or whenever the rods are involved, there is a second rapid increase at about seven minutes. The sensitivity then continues to increase for another 25 minutes or more, but at a decreasing rate. By about 35 minutes, the greatest part of adaptation has taken place, and the subject is functioning at near maximum sensitivity.

For the researcher who wishes to interpret his experiment in terms of the eye's maximum sensitivity, this has important implications. If the stimulus is to be located entirely in the fovea (and in the 2° center of the fovea) then a dark adaptation of about five minutes will certainly yield maximum cone sensitivity. On the other hand, if the stimulus light is larger than this, or if it is located in the periphery, then adaptation will not be reasonably complete for at least 20 minutes, and not really complete for up to an hour. Rarely will it be necessary to carry adaptation for the longer time. In any case, adaptation of less than this should be interpreted in light

of the fact that the subject was not operating at maximum efficiency. Therefore, conclusions can not be drawn about his performance over the entire range of ability.

Absolute Threshold Tests (RL)

Although there has been a large number of investigations which have used the RL of vision as a dependent variable, there has not emerged a single, dominant piece of apparatus which is readily available from commercial sources. In such a situation, one has to discuss measurement of visual RL in very general terms. This will be done by attempting to specify general methods which have been used in the past, rather than specific tests. Where appropriate, specific pieces of apparatus will be described under a general test category. Otherwise, apparatus of more general utility, which may be used in a variety of measurement categories, will be described in the separate section entitled "Other RL Apparatus."

Dark Adaptation Curves: The classical way to measure visual RL, and the way that is almost always used in basic research, is to obtain a dark adaptation curve over some period of time. Most simply, the subject is exposed to a bright light for some period of time over one minute in order to assure a uniform bleaching of all the photosensitive pigment. The light is then extinguished and, in total darkness, the subject either adjusts a small light until he sees it, or the intensity of a flashing light is increased until the subject reports seeing it. The light intensity is then either increased above threshold and decreased until the subject cannot see it, or it is again reduced below threshold and increased until the

subject sees it. This procedure is carried on for an extended period of time (typically from 10 to 30 minutes) and the intensities at which the subject saw the light, when plotted against time, reveal his changing absolute threshold values as the visual pigment is replaced. In this type of test one sees the familiar "rod-cone break" at between five and ten minutes, as the cone vision becomes maximally sensitive while the rods continue to increase sensitivity. (Of course, to see such a phenomenon, the test object must be large enough, and placed properly, to include both rods and cones.)

This technique undoubtedly provides the greatest quantity of information on the absolute condition of the subject. With it, information is obtained not only on a single RL, but on the rate of change in the RL over a variety of conditions of dark adaptation. Theoretically, one could then construct curves of predicted sensitivity loss under certain stresses for known lighting conditions, e.g. driving on a dark highway at night, scanning the horizon at sea with a given moonlight, or flying at night with a given cockpit lighting. In addition, separate data are obtained for scotopic and photopic vision, as well as on the relative differences between the two. These may reveal effects of certain stresses which would be missed with less sophisticated testing. However, this technique is not without disadvantages. It is time consuming and requires almost total darkness. These requirements preclude its use in many situations. From a basic viewpoint, there are some problems introduced by the fact that, during testing, the target light itself is bleaching some chemicals, so that the recovery curves are not as rapid as they might be in the absence

of continuous testing. The biggest problem, however, is still one of extrapolation to real-world tasks. If a change is found in the curve after some treatment, we know that the treatment affected the subject's absolute visual mechanism. In some cases, knowledge of the nature of the change, and of the underlying mechanism, may permit extrapolation to specific tasks. But the fact remains that changes seen at threshold levels will not necessarily be reflected in changes at supra-threshold levels. Thus, because we see changes in the adaptation curve, we can not necessarily infer that the subject will function less well in a performance where the lighting is not extremely marginal. There are enough valid uses for such a test as this to make it a worthwhile consideration for the researcher, but the tendency to rush into using this test because of its apparent "sensitivity" to stress effects must be looked at carefully, and the possibility that its very sensitivity could foster spurious conclusions about human performance must be considered.

Examples of various types of adaptometers which have been used are presented below. Generally, these appear to cover the range of different types, although obviously there are many specific pieces of equipment not mentioned due to space limitations.

TEST RL-1: DARK ADAPTATION CURVES: SPLIT FIELD METHOD. The basic components of adaptometers are largely identical. Virtually all contain a method whereby the subject sees a fixation point. By adjusting this point and assuming that when the subject stares at it he is locating the central fovea on it, the stimulus light can be delivered to a known point on the retina. There must also be some way of increasing the intensity of the test light along a known scale of values.

Finally, there must be some way of indicating the intensity-time relation in the scoring of the test.

One variable which has been different over different apparatus is the nature of the target light. In an apparatus described by McLaughlin (1954) and used at the U. S. Naval School of Aviation Medicine, a split field target was used. In this, the field was circular and subtended 1.5 degrees of visual arc. The subject had a control knob with which he was able to adjust the intensity of the entire field. However, half the field was covered with a neutral density filter which, of course, makes one side of the circle much brighter than the other. The subject is to manipulate the knob so that at all times he is able to see one-half, and only one-half, of the test field. Thus, if he sees the entire disc he is to reduce the intensity and if he sees nothing, he is to increase it. In this way, the subject is always "tracking" a narrow band of threshold intensity above which he always sees the light and below which he never sees it. To minimize the effects of the test light destroying or reducing the build-up of dark adaptation, the test stimulus was not presented constantly, but was "flashed" for .1 second every 2 seconds. The intensity at which the subject was adjusting the knob was continuously recorded by a mechanical linkage to a drum recorder. The model used by McLaughlin was small enough to fit on a desk, but was not really portable. Dixon (1958) has described an apparatus which permits independent stimulation of the two eyes. Such an apparatus could be used as an extreme modification of this split-field technique.

TEST RL-2: DARK ADAPTATION CURVES: SOLID TEST FIELDS. The more common way to obtain dark adaptation curves depends on using solid test fields and some form of psychophysical method to determine the statistically defined threshold. Here, instead of "tracking" his own threshold as in the split field method, the subject is presented with changing intensities, either as discrete presentations or as a continuously changing intensity level. He indicates in some way that the light has been seen, and this effectively terminates a "trial." Various forms of discrete presentation are possible, from elaborately controlled, pre-programmed stimuli which yield very standard stimulus conditions (Blackwell, Pritchard, and Ohmart, 1954) to cases where the subject initiates his own stimulus at will by opening a shutter (Wald, 1945). In some cases, the method of limits is used, with the experimenter increasing the intensity until the subject sees the target, then decreasing it until the target disappears (the adaptometer). In any event, one must realize that the threshold obtained in this way is a statistical approximation defined, for instance, as the average between consecutive ascending and descending trials in the above method. It may differ somewhat from the threshold obtained with a split field or with other techniques.

Among the apparatus used to test thresholds in this way, the portable device described by Wald (1941, 1945) is representative. In addition, however, to the standard features, this apparatus allows presentation of ten monochromatic regions of the spectrum through use of filters. Several adaptometers of German construction have been described (Glees, 1939; Schaefer, 1949; Weidemann, 1952). One of

these, the is a highly portable instrument which contains a viewing dome into which the subject looks, a pre-adapting light, two sizes of visual field, continuous intensity control by the experimenter, and a direct linkage to a paper-roll record which produces a punched-hole curve of thresholds. An older design upon which many subsequent ones were based was the Craik adaptometer (Craik, 1943) which also used a mechanical linkage between stimulus intensity and recorder. None of the companies contacted in the survey for this work reported marketing adaptometers as such.

Maximum Adaptation RL: For some purposes, it may not be necessary to obtain a complete dark adaptation curve, and the question of interest is strictly in determining a subject's maximum capacity for adaptation. In such cases, it would save time (at least for the experimenter) if the subject could dark adapt completely before the testing began. Several such "night vision testers" have been used; several used by the Army Air Force will be described here.

TEST RL-3: MAXIMUM ADAPTATION RL; USE OF LANDOLT RING. Two tests of RL after maximum dark adaptation have been described by Lowland and Mandelbaum (1944) which both use the Landolt Ring (see p. on visual acuity) to insure that the subject actually is able to see the test object. The first of these is the AAF Eastman Night Vision Tester. Basically, a box contains the mechanism which projects a Landolt Ring onto its front surface, which is a glass plate. From six to twelve subjects are placed twenty feet from this box and, at pre-determined intervals, a shutter exposes a Landolt C for seven

seconds at low intensity. Each subject has a small response box on which he indicates the position of the ring's opening. At the end of the exposure, the responses are recorded electronically, the position of the ring is changed, and a new trial is initiated. After five trials at one intensity, a lower intensity is chosen and five more trials are given. Eight series of five trials at increasingly difficult (lower) intensities take approximately 11 minutes.

A smaller instrument using the same principle is the Aviation Medicine Portable Night Vision Tester (Pinson and Chapanis, 1945). This is designed to operate at a distance of 15 inches, with the ring subtending a visual angle of two degrees. This is a self-contained unit and illumination is provided by a disc of luminous paint mounted behind the ring. The examiner can set the ring in one of four positions, and can control the light intensity by placing filters in front of the luminous area. The sequence of presentation is similar to the Eastman apparatus, although obviously not as standardized. Correlations are reported to be "high" between the scores on this test and the Eastman test, and the correlation between this test and night vision "as measured in practical field tests, is also high."

TEST RL-4: MAXIMUM ADAPTATION RL: USE OF FORMS. The tests presented here differ from those already described only in the object to be identified by the subject. In one case, the Craik adaptometer (Craik, 1943; Rycroft, 1942) was used as the Army Night Vision Tester (Lister and Bishop, 1943). The object to be identified consisted of discriminable sides of a pentagon. After the subject dark adapted for 30 minutes, he was presented with a side of the pentagon to be identified. These were continued and made increasingly difficult until

the subject was unable to identify a side twice in a row. The test lent itself to group administration and it is reported that five or six subjects could be tested in five minutes.

Another test of this type was the Hecht-Shlaer Night Vision Tester also reported by Rowland and Mandelbaum (1944). The test object has the form of an aircraft subtending a visual angle of three degrees. A fixation light is provided to insure that the subject receives the stimulus in a constant area and viewing is accomplished through a binocular viewing tube. The aircraft is presented in one of four positions for 1/5 of a second and the subject's task is to identify the position.

The Della Casa dark adaptometer (Della Casa, 1946) was devised to provide a simple method of testing for dark adaptation as part of the Swiss automobile driver examination. The object to be identified actually has three levels of difficulty built into it. The dark adapting subject is first able to see a disc. Later, he is able to see a ring in the disc and, finally, he can resolve a break in the ring. Norms are given for adequate and inadequate performance in each part of the test.

With most of the above tests, adaptation needs to be complete prior to testing. Otherwise, the adaptation level will still be changing as the test proceeds. In most cases, 30 minutes of dark adaptation will be sufficient, unless the subject has just been exposed to very bright sunlight. In that case, a time period up to an hour might be required. If the adapting room is not perfectly dark, red goggles may be used, since light in the red portion of the spectrum has little effect on the course of dark adaptation.

TEST RL-5: MEASUREMENT OF THRESHOLD: AMBIENT LIGHT. In many practical situations it is now more productive to ask about thresholds from a strictly operational viewpoint. Thus, from the view of the human engineer, knowing the minimum light necessary to perform a given task is more valuable than simply seeing a test patch of light. If more applied studies asked questions in this way, instead of as generalized, non-specific basic functions, the questions of interpretability would be greatly reduced.

Several techniques for reducing the level of ambient illumination are obvious including, of course, actually reducing the light in the test room. However, there are some difficulties with these, revolving mainly around the difficulties of measuring the actual light received by the subject. An early solution to this problem was proposed by Luckiesh and Moss (1934), who designed a "Visual Thresholdometer" consisting of goggles worn by the subject. In this, the amount of light reaching the subject is controlled by adjusting the grids of photographic film so as to produce reductions in intensity of known quantity (more precise measurement of the intensity of attenuation would certainly be possible today). Use of such a device allows the experimenter to maintain constant brightness in the test room during the entire procedure. Changes in intensity can be controlled independently for each eye and, when desired, can be made very precisely in discrete steps. The minimum light necessary for various tasks, such as reading type of different sizes, was determined by this method and appeared to produce reliable results.

A technique for evaluating this "luminance threshold" in such a way that complete dark adaptation curves are obtained has been explained by Brown (1953). In this system, the subject's task is to resolve various widths of grating lines during the course of dark adaptation. The threshold illumination necessary to do this at a given point in time is recorded, and it is evident from the curves obtained that, with the finest gratings, cone function alone is evaluated. With coarser gratings, both rod and cone functions are evaluated. If the pre-adapting light is low, then curves of rod function alone may be obtained.

In addition to the above, a method of obtaining a "recognition threshold" in low illumination after exposure to a glare stress was described by Brown (1941). This apparatus provides an index of recovery of visual function after bleaching of the photochemical substances based on the amount of time necessary before adaptation reaches a point where the subject can recognize an object. Obviously, one must be cautious in inferring to real-world tasks from this test.

One should note that what is being measured in all of these tests is really a recognition threshold or an acuity threshold. This is also true in varying degrees with the "maximum adaptation" night-vision type of test previously described. Lister and Bishop (1943) maintain that there is a high degree of relationship between such recognition tests and more classical RL results. But this may only be true where the recognition required is relatively simple and does not involve a great deal of "associational" process ("thinking"). Finding the open space in a Landolt Ring, or determining the orientation of an aircraft, and perhaps even reading typed letters fit

this "simplicity" criterion. On the other hand, if the task becomes much more complex, or requires more abstract manipulation, it is doubtful that threshold illuminations necessary for it could be predicted by measuring absolute thresholds in the classical way. For making inferences to such tasks as driving, locating and differentiating targets or other dimly lit objects, or performing other complex tasks, the present technique would seem to be much more direct and desirable.

TEST RL-6: DARK ADAPTATION CURVES BY MEANS OF THE ELECTRORETINOGRAM.

A method of obtaining a retinal sensitivity curve showing good agreement with those obtained in other ways, but not requiring the verbal report of the subject, is the electroretinogram (Bartley, 1951; Woodworth and Schlosberg, 1954). This method is quite difficult to use and results show considerable variability unless great care is taken. However, in situations where other techniques are inappropriate, this certainly should be considered as a valid alternative.

A typical technique for recording the electroretinogram (ERG) has been described by Johnson (1949). In this system, an electrode is permanently attached to a contact lens so that the surface of the disc and lens are flush with one another. When the lens is inserted in the eye, this electrode makes contact with the physiological saline over the cornea. Another electrode is placed somewhere on the head where it can be expected to be influenced by the rear of the eyeball (usually the temple). Typical amplification and recording are used.

The signal recorded when a light pulse is seen in the dark adapted eye consists of a number of recognizable patterns which have been related, with varying degrees of success, to subjective phenomena (see Bartley, 1951). Basically, however, two distinct parts of the ERG can be identified in the above conditions. A photopic part is a short diphasic potential where the cornea is initially negative. This part changes little during dark adaptation. The second part is scotopic and is a prolonged monophasic potential where the cornea is positive. The size of this potential varies with the degree of dark adaptation and is directly related to visual sensitivity. Such a component could be used to approximate the dark adaptation curve. But there are a number of thorny methodological problems in using the ERG. For instance, the scotopic response can decay rapidly with repeated testing; the form of the response is very dependent on the wavelength of the light and the position of the test light on the retina; and the various components of the response are quite complex and not well understood, not to mention the obvious discomfort of the subject.

Differential Threshold Tests: Measurement of the smallest difference which can be perceived between two visual sources is a technique which requires the subject to make an extremely fine discrimination. The quality of his discrimination may reveal a great deal about underlying retinal and neural processes and, in some cases at least, may have direct bearing on real-world performance. The discrimination required may be between such things as two intensity levels, between colors, or between brightness of two different

colors. Through such techniques, a great deal of basic information about the retina has been obtained. In the context of the present effort, though, the prime differential threshold which might be of interest to the performance researcher is that of brightness matching. It is in terms of this "ability" that we will most often ask questions about how well the human can differentiate two visual sources which may be delivering similar amounts of energy to the retina, e.g. seeing a plane coming toward you in the sun or differentiating a dial from its background in various lighting conditions. Therefore, brightness DL's will be discussed here in some detail. Questions of color comparison are left for the section on color (pp.

) and more basic or unusual question of DL's are referred to Stevens (1951) or Woodworth and Schlosberg (1954).

TEST RL-7: DIFFERENTIAL BRIGHTNESS THRESHOLDS: SIMULTANEOUS PRESENTATION. In order to determine a differential threshold, the most basic requirement is that (at least) two stimuli be presented for the subject's comparison. The first question that must be faced, however, is how to present both stimuli in such a way that the physical interaction between them is minimal and yet they are both available to the subject for comparison. One answer to this, of course, is to present the two stimuli simultaneously. Such a presentation is the most straightforward method of measuring visual brightness DL.

Perhaps the most basic form of apparatus for such a presentation is manufactured by Lafayette (Cat. #14011, "Light Discrimination Apparatus," price \$48.00). This system consists of a box with two 1 3/8" light stimuli on one face. The light stimuli are illuminated from a common source, but the intensity of each light can be varied

independently. The unit is useful in that it can be used with almost any psychophysical method. But it would be rather difficult to use in experiments involving very low levels of ambient illumination (since the values of each light must be read from a dial) or very great precision with respect to retinal area stimulated or amount of illumination actually reaching the eye. The subject, of course, must shift his gaze from one light to the other, introducing a great deal of uncontrolled variability into the stimulating conditions.

A much more elaborate system useful for several other types of study (RL, critical flicker fusion), but still using the same basic principle, is manufactured by Research Media, Inc. (Cat. #PR-27, "Multi-purpose Perceptual Device," price \$435.00). In this, a light case, 33" long and 7" high, is the exposure source. On this bar can be presented one or two light sources (or figures) which the subject compares simultaneously. The intensity of the lights is controlled by a master unit which can be remote from the lights, thus avoiding the data recording problems in the Lafayette unit. The problems of subject scanning and control of retinal location, etc. are still present, though, and unless the experiment does not require a good deal of precision, this apparatus would, like the Lafayette instrument, seem to be of limited utility.

A much more sophisticated apparatus which does away with many of the above difficulties is manufactured by the Polymetric Company (Cat. #V-0659, "Brightness Comparator," no price given in catalogue). Originally designed by Professor Hans Wallach, this instrument uses electroluminescent elements which have the advantage of avoiding the "hot spots" of normal lamps. The subject's

viewing panel measures 8.5" on each side, and on this square are two circles, one within the other. The larger circle is 8" in diameter and the smaller is 4". These circles are controlled individually by a master control unit, which is equipped to operate two separate panels simultaneously. The experimenter, therefore, has the option of presenting the stimuli to be compared in either circle of both panels simultaneously, as in the previously described machines, or to use only one panel and introduce the intensities to be compared into the two circles. The latter method reduces the subject's scanning behavior somewhat and, where even moderate precision of stimulus delivery is required, is probably to be preferred. The panels supplied are achromatic from white to black, but special panels -- varying in size, configuration, and color -- are available.

TEST RL-8: DIFFERENTIAL BRIGHTNESS THRESHOLDS: SUCCESSIVE PRESENTATION. The technique of presenting a luminous field and then presenting a portion of the field with slightly incremented intensity, as is possible in the apparatus described above, has been the most frequently used method of studying visual DL's in basic research. However, we have noted that this method may use entirely different mechanisms than that where both lights are presented side by side simultaneously (Bartlett, 1942). Similarly, Blackwell (1963) believes that different discriminatory processes are involved in the two methods. Stecher (1968), in an ingenious experiment, demonstrated that there were indeed differences in the results obtained with the varying techniques, and that "the underlying bases of the discriminations may be different under those conditions producing temporal interaction from under those conditions leading to the spatial inter-

action between visual fields." Thus, it may well be that the functions being measured by the simultaneous presentation technique are much more involved with "spatial" visual capabilities and those measured by the successive presentation technique are more involved with the capability of the visual system to handle temporal factors. Such differences have sweeping implications when results using the two methods are to be applied to "real-world" tasks. For instance, it would be questionable to use differences in the DL found by the successive presentation technique to make inferences about the subject's ability to discriminate between two lights in the distance which are presented to him simultaneously.

Other than the Polymetric Company's "Brightness Comparator" described above, no commercially available instrument designed to present comparison stimuli sequentially was reported by the manufacturers contacted. Most often, elaborate systems have been designed for this purpose by individual investigators (see e.g., the "Visual Discriminometer" of Crozier and Holway, 1939). These frequently involve split-beam techniques in which the light from two individual sources can be directed to precisely the same retinal location. Such devices are rather difficult to construct, and perhaps are justified only when the research question demands the absolute precision which they afford. In less demanding situations, utilization of existing commercial apparatus (e.g. by appropriate timing of a single light from an apparatus designed for simultaneous presentation) should be possible or the construction of a simple unit which would utilize two sequential lights delivered to approximately the same retinal location.

Visual Acuity

The absolute resolving power of the eye is its acuity, here included under visual thresholds because it represents an example of minimal sensory capability. We are not referring here to the ability to interpret that which is seen, but simply to the ability to see it. Thus, this section will deal only with those tests which are relatively "content-free," i.e. require, at most, an ability to call out letters, not to read words, answer questions, etc. Further, some of the more traditional clinical techniques used in conjunction with tests of visual acuity will be omitted since they either are designed for evaluating specific clinical pathologies or are too cumbersome and specialized for general performance testing.

TEST RL-9: VISUAL ACUITY: RESOLVING LINES.

Apparently one of the most direct measures of visual acuity should be reflected in the smallest object or line a person can see, or the smallest space between two lines that is reliably seen. The former technique was used by Hecht (1947) in an experiment to determine the ability of humans to report the presence or absence of a fine wire silhouetted against a bright sky. Using a criterion of 75% correct response, he found that such discriminations could be made when the diameter of the wire subtended an angle of only .43 seconds and its length subtended about one degree. Similarly, a silhouetted square could be recognized when one side subtended 14 seconds. This technique has not been standardized and probably is of extremely limited value except in investigating certain very basic questions.

A variation of Hecht's technique, however, has been used

successfully in a number of situations and a recent form of this type of test will be described. If the subject is presented with a series of lines and asked to indicate the direction in which the lines are going, he will be able to do so accurately only as long as he is able to resolve the "breaks" between the lines. When this resolving power is exceeded, the lines will appear as a solid figure. Obviously, one could simply present a series of such figures, each with finer and finer breaks. This, or variations of it, has been done in a number of cases. A more sophisticated form of this test has been developed by _____ at Wright-Patterson Air Force Base (_____). In this instrument, a series of gears position interference patterns in such a way that the subject sees a lighted display consisting of lines oriented in one direction. If he indicates the correct orientation of the lines, the experimenter shifts to a new orientation and a finer series of lines. This procedure is carried out until the absolute resolving power of the eye has been exceeded. Among the advantages of this machine are its durability (it was initially designed to operate on a human centrifuge) and the fact that the experimenter can precisely control stimulus presentations while being physically distant from the subject.

TEST RL-10: VISUAL ACUITY: USE OF CHARTS. The standard clinical screening for visual defects involves use of charts with various figures graded in size. These are placed at a fixed distance from the subject (typically, 20 feet) and the smallest line of figures which the subject can identify is taken to reflect his visual acuity. Over the years, many forms of this test have been used, (see Cowan,

1928; Sloan, 1951) and a sample of these are presented below.

The Landolt Ring: Still one of the most common chart-type devices for measuring visual acuity, the Landolt ring was adopted in 1909 as the standard test object by the International Ophthalmological Congress in Naples. The figure in this case consists of a black circle on a white ground. The thickness of the black stroke should be one-fifth the diameter of the ring, and at various positions on the ring there should be a break whose length is equal to the stroke width (Cowan, 1928). The subject's task is to describe where the break is on the ring and the smallest ring which can be correctly resolved describes his visual acuity. Sloan (1951) suggests that this test overestimates the acuity of a subject with an uncorrected astigmatism. However, along with other tests involving position identification rather than letter identification, it is perhaps somewhat more appropriate for repeated testing since it may be slightly more difficult to memorize positional sequences.

The Snellen Chart: Snellen, in 1862, was the first person to propose a system of objects graduated in size which would yield a numerical estimate of visual acuity. Modifications of this original Snellen chart are still used; the notation he suggested is still the standard way of expressing acuity. In this notation, a fraction is used, with the numerator expressing the distance at which the test was administered (e.g. "20" ft.) and the denominator expressing a number assigned to the smallest line of letters the subject can read correctly. Snellen's test objects were block letters with black strokes equal in width to the white spaces between them. The letters are enclosed in a square whose sides are five times the width of the letter strokes (Sloan, 1951). Although there are con-

siderable difficulties associated with the use of letters, they are sensitive to a number of types of acuity impairment (e.g. astigmatism) which could be missed with simpler objects such as the Landolt Ring, checkerboard patterns, or resolution lines.

The Sloan Charts: One of the most recent modifications of the Snellen charts has been reported by Sloan (1959). The charts contain ten capital letters (Z, N, H, R, V, K, D, C, O, and S) selected because of their vertical, horizontal, oblique, and curved contours. Overall height and width are made to be five times the width of the strokes. These letters have been tested for legibility and appear to be "about as nearly equal in legibility as can be obtained when simple capital letters of familiar form are used." Further, the legibility of these letters has been shown to be directly related to the difficulty in resolution of the Landolt Rings. Thus, the researcher requiring repeated testing could utilize both tests with some assurance of reliability (Sloan, Rowland, and Altman, 1963).

Other Charts: Many other forms of test chart have been devised. These include requiring the subject to identify black circles and squares, read various sized type, pick out broken lines from a series of unbroken lines, and indicate the direction in which the "arms" of a series of "E"s point. Obviously, the main points in considering any of these tests are their validity and applicability. Many of these tests are backed with tenuous statistical validation. Few have been directly related to standard tests such as the Landolt or Snellen series, and many are so poorly standardized and controlled

that it would be incredible if they showed any reliability or sensitivity. This is not true for all such "other" chart tests, of course, but the researcher must be aware of the possible dangers in using these tests, and be sure the need justifies whatever risks are taken.

A final point of technique should be mentioned with these tests. Many require that standard distances such as 20 feet be used. In many cases the experimental situation does not afford this much space. To forego these tests in such a situation is not absolutely necessary. To increase the effective distance by use of a plane mirror is optically correct. In this way, a normal 20 foot chart can be used in even a very confined space. Nonetheless, it should be obvious that great care must be taken in setting up such a system so that additional factors are not brought into the test (e.g. distortion, glare, etc.).

TEST RL-11: VISUAL ACUITY: OPTICAL DEVICES. A number of commercial devices have been produced which provide rapid, reliable screening of visual acuity. All of these, we must emphasize, are screening devices and one must not assume that because they are mechanical or have an aura of sophistication about them that they are necessarily any more precise than the chart methods noted above. One should also note that these devices are designed to measure other functions in addition to visual acuity. Thus, the decision to use an apparatus of this type can be based as much on its versatility as on its unique applicability to acuity measurement.

The Armed Forces Vision Tester: This is an extremely rugged apparatus which has had wide use in industrial and Defense Department settings.

The Keystone Telebinocular:

The Ortho-Rater: A current modification of the ortho-rater () is manufactured by Lafayette Instrument Co. (Cat. #14016, Modified Ortho-Rater, price \$425.00). In addition to permitting test of acuity for both eyes at both far and near points, cards are supplied for measuring phoria, stereopsis, and color discrimination. The acuity test used in the ortho-rater consists of increasingly smaller squares. Each square has four smaller figures in it, one at each corner. One of these squares is a "confusion pattern," and the subject's task is to identify the corner in which this pattern is located. It has been pointed out (Sloan, 1951; Sloan, Rowland and Altmar, 1952) that such a test can be insensitive to certain kinds of astigmatism. But the ortho-rater has enjoyed great popularity and is referenced frequently in performance experiments.

The Sight Screener: Unlike the previous three devices, the sight screener was developed primarily as an acuity test device. It has been used for this purpose in a number of large studies and has shown high correlation with the Sloan Charts (.80) and impressive stability of scores over various testing conditions.

AUDITION

The absolute and differential thresholds of hearing are important to the performance researcher from many viewpoints. Yet, determination of these thresholds with any kind of precision whatsoever is a very delicate procedure requiring expensive apparatus and equally expensive environmental controls. If achieving absolute darkness for visual testing is difficult, achieving absolute quiet for auditory threshold testing is even more difficult. Obvious solutions, such as the use of earphones and other localized sound attenuators, are not absolutely satisfactory since it has been shown that such a device placed at the ear causes low frequency noise in the canal (Miller, 1947). One should recognize at the outset, therefore, that there is no "easy" way to obtain precise auditory thresholds, and results obtained with short-cut techniques or without sufficient attention to the many variables should be interpreted with extreme caution.

There are not a great many performance studies which have included auditory thresholds as a dependent variable. This may be related more to the problems of measurement than to a lack of application or interest in such thresholds. Nevertheless, researchers in certain stress areas in which the auditory sense is the prime target of insult cannot avoid the question of auditory threshold shifts. For such researchers, elaborate test and environmental equipment is usually available in the form of anechoic chambers, extremely precise and flexible oscillators, and elaborate electronics for the control and measurement of the physical parameters of the stimulus. To give extended descriptions of such facilities would be useless (and

sadistic) since the average researcher in performance measurement will never have access to them. For the most part, the researcher who finds the need to measure auditory thresholds is limited to techniques which are less than optimal and which, at best, may barely be sufficient to answer a well-defined applied question. Some (not all) of the problems faced by such experimenters will be discussed briefly. Again, such a discussion is intended to alert the researcher to the kinds of problems that can be encountered, not to be a definitive list of such problems.

Stimulus Problems

That the stimulus must be measured with precision in auditory research goes without saying. The absolute threshold varies over about 60db within the range of frequencies generally considered to be audible (see Licklider, 1951). But this measurement requirement is deceptive in its apparent simplicity. Just what is to be measured? Some investigators have measured the sound pressure at the eardrum (the "minimum audible pressure --- MAP") and others have measured the pressure at the point in space occupied by the listener's head, after removing the listener from the field (the "minimum audible field --- MAF"). Such precision is seldom obtainable in a smaller laboratory and sound intensity is frequently measured in terms of the calibrated output of the oscillator, or at the observer's earphones.

If the tones presented in auditory threshold research are of extremely short duration, then there is a problem of temporal summation. Under about 100 milliseconds, the threshold energy necessary to detect tones of a given frequency is not constant, but generally increases with shorter presentation times. This is also true for the

DL. Thus, if short presentation times are to be used, the length of stimulus presentation must be rigidly controlled.

It is also important, at least for precise work, to be aware of the fact that the RL and DL may be different if the stimulus is presented monaurally rather than binaurally. The binaural threshold is lower than the monaural by about 1db on the average. But this amount depends on the initial condition of the two ears and is maximal when both ears are of approximately equal sensitivity (see Pollack, 1948).

Testing of differential thresholds poses virtually insurmountable problems to the researcher not equipped with reasonably elaborate equipment, unless special electronic switches are used. Any attempt to shift from one frequency to another, or to change sound intensity rapidly, produces unwanted transients which are impossible to define. For this reason, any attempt to measure DL's in the auditory modality without controlling these switching problems must use the indirect techniques described below if they want any kind of temporal contiguity in the comparison. Studies which do not, and which simply present one intensity and then shift to a higher intensity are not measuring the DL for those intensities.

Response Problems

Auditory thresholds are extremely variable. Licklider (1951) reports studies showing that day-to-day variability within a subject may be five times his average variability on a given day. In addition, one subject can show as much as 5db variation from one half-minute to the next. Such factors point to the need for either using practiced subjects, or using a large number of subjects and measures. Neither of these alternatives is always practical.

The response requirements imposed on the subject can also influence the kind of curves which will be obtained. Brown (1965) discusses the difference between free- and forced-choice response requirements and presents a method of scoring the free-choice tests in terms of an augmented "receiver operating characteristics --- ROC" notation. He feels this provides a more comprehensive measure of overall performance.

Summary

One may think that the thrust of what has been said so far is intended to discourage anyone from using auditory thresholds in performance measurement. This is only partly true. It is intended to make anyone not extremely sophisticated in this area extremely cautious and, hopefully, seek qualified technical assistance before plunging into a project where they naively expect to measure auditory thresholds with great ease. This caution holds equally well for experimental psychologists, human engineers, industrial engineers, and perhaps particularly for clinicians who feel that because they can take a clinical audiogram, they are actually measuring thresholds.

Audiograms and other fairly imprecise measures obviously are all that are necessary in many applications. For this reason, several types of such apparatus will be described below. However, if one is interested in true thresholds, testing can not be done haphazardly. The Grason-Stadler Company, which markets a large number of audiometric devices, appears ready to provide expert advice along with their systems, and the first step for any non-expert is obviously to contact a source such as this. But in any event -- if precision

is the requirement, then be prepared to spend both time and money.

TEST RL-12: AUDITORY THRESHOLDS: BÉKÉSY METHOD. In 1947, Békésy proposed a method to determine the RL which has gained wide acceptance and is used in many clinical settings today. In this technique (Békésy, 1947) the subject controls the intensity of a tone. As long as he depresses the button, the intensity increases, and as long as the button is not depressed, intensity decreases. The subject is instructed to hold the button down until he hears the tone, then to release it until he can no longer hear it. A direct-writing recorder shows the intensity of the tone over time, and the resulting "curve" represents the subject "tracking" his own threshold. Békésy claimed that the amplitude of the oscillations about threshold defined the DL for intensity and that this "usually indicates whether a hearing loss depends on a conductive or perceptive lesion."

Other investigators have used the traditional technique, along with periodically interrupted tones, to define five types of Békésy patterns (Rintelmann and Harford, 1967) which attempt to localize lesions to the middle ear, cochlea, or VIIIth nerve, and to diagnose simulated hearing loss. Byer (1963) used the Békésy technique along with periodic determination of thresholds after subjects were exposed to short duration auditory fatigue. After six minutes, there was a 7db difference in threshold revealed by the two methods, with the Békésy method not being as descriptively accurate as the other. Lightfoot (1955) used a similar technique in studying the effects of loud and fatiguing sounds. Order effects between continuous and pulsed tone thresholds were studied with a Békésy procedure by Bradford (1964) who found differences dependent on whether the

test was conducted in quiet or in noise. Brandt and Hollien (1967) devised and successfully used a technique where Békésy type thresholds could be determined under water. Reliable thresholds in terms of sound pressure levels were obtained.

The Grason-Stadler line of audiometers uses a Békésy-type presentation. This line ranges from desk-sized apparatus to full consoles incorporating an intercom system and capabilities for addition of a tape deck, phonograph, and loudspeakers.

TEST RL-13: AUDITORY THRESHOLDS: DISCRETE TONES. In presenting a discrete tone for the subject to respond to in audiometric research, there are several options open. The most obvious is the continuously pulsing tone which is simply responded to when heard. In such a technique the experimenter would use the psychophysical method of limits (Woodworth and Schlosberg, 1954) to present ascending and/or descending trials at each desired frequency. This is a laborious technique and one which requires care that unwanted transients are not introduced each time the tone goes "on" and "off."

A somewhat more complicated procedure involves the subject's response to individually presented discrete tones, using a psychophysical method like that of constant stimuli. In this, the subject is given some warning that a stimulus may occur within a given time period and he responds whether he heard it or not. With this technique one must include an adequate number of "catch" trials where no stimulus is presented in order to obtain a measure of whether the subject is faking his responses. The stimulus intensities must adequately span the threshold, preferably going from intensities the

hears only five percent of the time to those he hears ninety-five percent. The threshold is then defined as an intensity with a certain percentage of positive responses. This is an extremely time consuming technique.

A variation of the above techniques has been described by Reger (1957). In this, discrete tones are presented in coded form as one, two, or three pulses which may appear in one of three time positions during a finite presentation time (signaled visually). In a forced-choice type of response situation, the subject reports on the nature of the stimulus by pressing one of a set of response keys. This response is automatically compared to the stimulus and future stimulus presentations are determined by the quality of response. Subject testing time is reported to be about 20 minutes, although this is variable.

Most of the commercial apparatus available can be designed to present stimuli in one or more of the above ways. In addition to the Grason-Stadler line mentioned previously, Lafayette Instrument Co. also produces an audiometer (Cat. #15014, price \$440.00) which weighs eleven pounds and tests the audiometric range over the standard 11 frequencies. Also, as with other commercial units mentioned, a form of DL can be obtained.

TEST RL-14: AUDITORY MASKING THRESHOLDS. For some purposes, it has been more desirable to determine the minimum intensity of a tone which could reliably be distinguished from a background "masking" signal than from absolute silence. Such a technique, at the very least, has the advantage of eliminating the need for sound-attenuated rooms and

such devices. In its most general form, a "noise," usually defined by some criterion as a "white noise," is introduced into one or both ears. The signal tone is then presented in this noise by any of the standard techniques mentioned above, and the subject's threshold is obtained. Obviously, this threshold will be different from the absolute threshold, and will differ depending on the intensity of the masking tone. Thus, it takes the form of a special kind of DL (the visual analogue of this might be considered to be the visual threshold in ambient light -- see Test RL-5).

This technique is very useful in a practical sense. It reduces the need for a great deal of environmental control apparatus and, since the results are so obviously dependent on the masking intensities used, the tendency to overgeneralize is more easily controlled. On the other hand, interpretation of these results can be difficult. If the subject becomes less able to differentiate a 1000hz pure tone from a background of noise, just what has changed is difficult to know. Was it the absolute threshold, was it due to a greater effect of the noise after stress, or was it some form of attention or scanning capacity? Extrapolating to the real world is thus all the more perilous in view of this uncertainty.

A technique to absolutely standardize the noise presentation in this type of experiment is described by Pfafflin (1968). It uses a computer to generate a series of random numbers. These are then converted to an analog signal and form the basis of the noise signal presented as the masking stimulus. Since the same numbers are used every time, the masking signal is always absolutely identical, providing a good control over this normally uncontrolled variable.

TEST RL-15: EVOKED RESPONSE AUDIOMETRY. The evoked potential of electroencephalography can be used in situations where subjects can not be expected to cooperate, or where one desires to bypass certain variables such as subject distractability. Several such instruments have been used in clinical settings and a simplified description of one is presented by Davis and Niemoellen (1968). Basically, the stimulus is delivered to the subject several times at each intensity. An EEG channel (the above authors recommend a vertex-mastoid derivation) is fed into an averaging computer and time-locked to the stimulus. When the signal is above threshold, the averaged evoked potential should be clearly different than when it is not; in this way a classical RL measurement can be obtained. The parameters of signal duration and rise time are obviously important to the evoked potential. Skinner and Jones (1968) found that as the signal rise time was decreased, there was a tendency toward increased peak amplitudes in the evoked potentials. No consistent pattern was seen with changes in signal duration.

Grason-Stadler markets a packaged "Evoked Response System" (Cat. #3951) which consists of a number of components designed to automate procedures in evoked response research. The system includes a Fabri-Tek Model 1010 Signal Averager, a Neurological Amplifier, a Hewlett Packard X-Y Recorder, and a series of modules. It does not include the auditory stimulus equipment.

TEST RL-16: BONE CONDUCTION AUDIOMETRY. Direct cochlear pickup of vibrations transmitted from an external source through the bone is reliably reported by subjects and forms the basis of the standard

clinical technique of bone-conduction audiometry. In the clinical setting, differences between air and bone conduction may help locate the source of a hearing defect; such a technique forms the basis for a number of older clinical tests such as the Rinne Test, the Schwabach Test, the Weber Test, the Gelle Test, the Lewis Test, and the Bing Test (Watson and Tolan, 1949). In some rare performance test situations, obtaining a bone conduction audiogram might be desirable, either alone or in conjunction with one of the standard air-conduction tests.

Typically, tuning forks have been used as the basic tool in clinical bone conduction tests (Lafayette produces a series of eight, Cat. #15017, price \$39.00, or a series of six, Cat. #15018, price \$34.00). However, imagining a situation where these would produce sufficiently accurate data to be used in performance studies is difficult.

Most of the commercial apparatus mentioned previously (the Grason-Stadler line and the Lafayette audiometer) have the capability of generating a precise bone conduction stimulus. In using these devices, the subject typically holds the vibrator against his mastoid bone, and the threshold of vibration is determined in the same way as for an air conduction test. Standardized data are available for this type of test (National Health Survey, 1935-36). A method to increase reliability was devised in which the vibrator is included in a helmet-type device which allows it to maintain constant contact with the mastoid. Harris, Haines, and Myers (1953) used a Sonotone Model 21-308 vibrator mounted on a helmet and supported by arms connected to a coiled spring. Precise adjustments of force and angle could thus be made.

TEST RL-17: THE ACOUSTIC REFLEX TEST. By directly measuring the impedance changes in the ear during stimulation one can measure the reflex contractions of the middle ear muscles. This measure has had some success in being related to threshold changes under some conditions. (Johansson, Kylin, and Langfy. 1964). However, it is such a specialized test, and so little subsequent data were found on it, that it is mentioned here only as an experimental procedure needing further data before being used as a performance test.

TEST RL-18: SOUND AS A STRESS: THE TEMPORARY THRESHOLD SHIFT. If a subject is exposed to rather loud noise for an extended period of time, his threshold will show a change from baseline levels. This effect is analogous to the changes in visual threshold which occur when the eye is exposed to a bright light. Similarly, somewhat analogous to the dark adaptation curve is the method of auditory measurement known as the temporary threshold shift (TTS). The amount of "decrement" in the threshold as a result of such exposure to various kinds of noise is used to gauge the extent to which the noise constituted a stress, and the phenomenon is usually referred to as "auditory fatigue."

The time for threshold to recover to within 10 db of pre-exposure has been studied after repeated exposure to various sound pressure levels for 21 minute periods by Bragg (1963). He found that below 95 db (3000 hz tone) there was apparently an adaptation, whereas above this point there is a cumulative fatigue. Lightfoot (1956) investigated some of the parameters of fatiguing sound and demonstrated basic differences in the response of various threshold functions to

differing stress stimuli. Loeb, Michel, and Fletcher (1970) mention conversion techniques with TTS data discussed by Kryter. These authors also give data on the threshold effect of high energy, short duration pulses. They caution that it is possible to cause permanent high-frequency loss in subjects if allowable TTS values are exceeded in the speech-range frequencies. Ward (1963) provides an example of how the TTS measure can be used effectively to make inferences about structural mechanisms. He used the amount of threshold shift to evaluate the amount to which a pre-arousing tone can activate the acoustic reflex and thus yield protection against the stress of impulse noise. In this way, a 1000 hz tone at 100 db SPL was found, generally, to maximize middle-ear muscle contraction if presented 150 milliseconds ahead of the impulse noise.

TEST RL-19: AUDITORY ACUITY TEST. With the typical threshold test in clinical settings, the smallest steps used for presentation and/or scoring are usually plus or minus 5 db. With such steps, the subject hears a "pure" tone as a tone the first time he hears it at all. If smaller steps are used (1 or 2 db) there is a point where the subject hears "something" but does not hear the tone as a "pure" tone. This "zone of detectability" has been characterized by Harris and Myers (1949) as being analogous to the visual phenomenon of being able to see something, but not clearly. Thus, we may speak of an auditory "acuity."

In studying this phenomenon, two thresholds can be obtained simultaneously. The above authors used a criterion of 50% transition from reporting "nothing" to reporting "something," and a 50% criterion for the transition from reporting "something" to reporting

"tone." Stimuli were presented randomly in discrete 1 hz steps with a warning signal. The authors warn against using a continuously varying ascending or descending tone in this case since subjects soon allow the regularly occurring interval between recognition and tonal quality to influence their judgment. One might also suggest that "catch" trials of silence and above-threshold white noise be introduced to detect subjects with erroneous or inconsistent criteria.

The concept of a test for auditory "acuity" of pure tones has an appeal in some performance contexts. Absolute changes in this point may be a sensitive, early indication of stress effects. But one must again warn of overgeneralizing from such a test to "real world" situations. We are still dealing here with a simple threshold, and a psychophysically determined change in this ability cannot be used to infer that subjects will have less understanding of speech, will not be able to interpret marginal sonar returns, or will not hear small noises or indications of trouble in a car or plane.

Testing Rooms in Auditory Research: If conducting precise audiometry is desirable, then some form of environmental control is essential in most contexts. Watson and Tolan (1949) discuss general criteria for such sound-proof rooms, and a commercial line of rooms is available from Industrial Acoustics Company which range from about \$2,000 up to about \$14,000.

CUTANEOUS AND PAIN SENSITIVITY

Procedures for studying the thresholds of cutaneous sensitivity are not well standardized and use of such measures in performance type experiments is virtually non-existent. At the root of this is certainly the lack of basic information available on the various kinds of "touch," as well as the difficulty of measuring them. The researcher is frequently unwilling to spend a great deal of time in obtaining very precise measures of a sensory function about which so little is known. Since even the basic anatomy and physiology of cutaneous sensation still has many open questions and is not tied to any universally accepted theoretical framework, it is perhaps too much to expect that changes in this function could be related to more complex "performances." Further, since the significant basic parameters of these functions are probably not all known, it is difficult to know whether, for any given measurement technique, all necessary controls have been used. Thus, a change may reflect a change in the actual sensory function, or it may be an experimental artifact due to an uncontrolled variable. For example, until the importance of the rate of skin deformation in experiencing "touch" became known, experiments on cutaneous RL and DL were subject to serious misrepresentation (see Jenkins, 1951). A safe assumption probably is that many basic surprises still await us in this area, and that some of them will affect our interpretation of the results of past studies as well as

the conclusions which can be drawn from the tests to be described here. Therefore, in using any of these tests, extreme caution is recommended, especially in extrapolating results to more complex behaviors.

Not all methods of measuring the various kinds of cutaneous sensitivity will be described here. Some are simply so elaborate and specified (e.g. involving the determination of long-term changes in a single sensory "spot") that they would be impractical in a general performance context. As in other sections, we will attempt to cover here the general types of test which might yield operationally important information about the system in general.

TEST RL-19: CUTANEOUS THRESHOLDS: ELECTRICAL STIMULATION OF THE SKIN.

One can determine a threshold amount of electrical energy which will just produce a sensation on the skin of a subject. Such sensations are usually referred to as "burning," "pricking," "itching," and "tapping" or "vibrating." To some extent these categories may represent different thresholds, or at least different criteria, in the subject. Commercial stimulators are available which can be used to deliver pulsed or direct current (circuit diagrams for construction of a "skin stimulator" are given by Bishop, 1953). Typically, an active electrode is applied to a smooth, relatively hairless skin surface such as the volar surface of the forearm. This electrode should be large enough to cover many sensory units (about two inches square) (Sigal, 1953). Care should be exercised to depress or stretch the skin as little as possible if results are to be consistent. Also,

if the same subject is to be used more than once, the area of skin used should be the same each time since sensitivity is drastically different in different areas over the body surface. An ascending and descending method of limits may be used to determine the threshold, or the method of constant stimuli may be used. However, in using a "painful" stimulus of any sort, one should be aware of both the psychological and the physiological effect on the subject. Therefore, in general, the technique which will result in the fewest number of "painful" experiences at the lowest absolute intensities is preferred.

The parameters of pulsed square-wave stimulation have been studied by Sigel (1953) who defined the relationship between impulse duration and minimal voltage. With frequency at 50 hz, the threshold voltage was found to be relatively constant as long as impulse duration was above 1 millisecond. Below that, threshold rose and, with durations shorter than .01 millisecond, the rise was extremely sharp. Sigel also described the use of the concepts of rheobase and chronaxie as applied to sensory thresholds. Rheobase, as modified in the above study, has been defined as the lowest voltage of a 10 millisecond impulse duration square wave which will produce reported stimulation by the subject. When this is determined, the chronaxie is defined as the impulse duration necessary to produce a threshold response when the voltage is set at twice the rheobase. Another value can be derived from these two. Sigel used the reciprocal of the rheobase times the chronaxie as an "index of excitability" of tissues, as well as another derived value which agrees closely with

this index. In 55 normals, the index ranged from 0.1 to 0.8, with 78% of the readings between 0.1 and 0.4. Electrical square wave pulses have been used by Beck and Rosner (1968) to obtain averaged evoked potentials. These data were then fitted by various mathematical functions, and a power function was found to provide the best fit.

TEST RL-20: CUTANEOUS THRESHOLDS: PRESSURE STIMULATION OF THE SKIN.

The oldest method of experimentation on the cutaneous sense is probably direct stimulation of the skin by pressure. This has a certain appeal since it seems to be the way we experience most "feeling," but this appeal may be illusory. Many factors are operating during even the simplest pressure sensation, and there is confusion as to even what constitutes the critical element of a pressure stimulus in producing the sensation.

Von Frey Hairs: In the classic experiments in this area, a series of hairs of graduated thickness and stiffness were used (see Woodworth and Schlosberg, 1954). The blindfolded subject was asked to determine the presence or absence of sensation as the experimenter placed the hair on a certain spot and exerted a minimal pressure so that the hair was just slightly bent. A standardized series of such stimuli has been developed by Sidney Weinstein and is available from Research Media, Inc. (Cat. # , price). In spite of the obvious problems of standardizing area, pressure, angle, etc., this technique yields moderately consistent results. That experiments requiring any degree of precision should use a system which leaves so much to the experimenter's skill (and dedication) in using the test is, however, questionable. Meyer, Gross, and Teuber (1963) report success, however, in using modified von Frey hairs, not only in

testing one skin area, but in delivering the stimuli to two or more areas simultaneously. They found elevated thresholds with multiple stimulations, with stimulation of palm and contralateral thumb and both palms and one thumb producing the highest thresholds.

The Pressure Aesthesiometer: Recent modification of a traditional apparatus has become commercially available under the title of "the pressure aesthesiometer." Developed by Dr. Sidney Weinstein, the device is available from Research Media, Inc. (Cat. # , price). Variations of this device, as well as techniques for its use, are described by Semmes et al (1960) and by Weinstein (1962). Basically, it consists of a ruler which has, on one side, a single stimulator point. On the other side there are two points, one of which is movable. The single point is used for RL determination and the double pointed side is used to determine the "two-point threshold" or the smallest separation between points which the subject can perceive as two separate points.

Mechanical Delivery of Pressure: The devices described above all suffer from the problem that the experimenter is handling the pressure mechanism. Aside from the difficulty of delivering the same amount of pressure on each trial, there are bound to be differences introduced as a result of different rates of application, tremor, and use of slightly different spots on each trial. These problems are overcome to some extent through use of a mechanical device to deliver stimuli.

One such device has been described by Carmon (1968). An electrical device is used to suspend either one or two "rods" (for RL or two-point threshold) above the subject's resting hand. When the contact is tripped, the rods fall into contact with the hand and the subject reports his sensation. A scissors-like device controls the spacing of the rods. Since the subject's hand, the weight of the rods, and the distances involved all remain stationary, this technique should provide greater reliability of measurement than hand-held devices. Carmon (1968) defines variations in the two-point threshold which occur as the result of variations in intensity, area, rate, and time of stimulus application.

Other mechanical devices have used springs or other calibrated devices which permit relatively precise control of the stimulus pressure (Kharkevich, 1968). Such devices are to be preferred, in general, over those with less precision. But we must again point out that precision can not solve all the basic interpretational problems that exist in this area. Even after the stimulus pressure has been measured precisely, there are still bothersome questions about precisely what is being measured.

Air Pressure as a Stimulus: An attractive type of stimulus in cutaneous threshold work is the use of air to produce deformation of the skin. Shewchuck and Zubek (1960a, 1960b) describe a system which uses pulsed air jets to determine what they call "tactual acuity." This is defined in terms similar to the "fusion" phenomena of vision (see Critical Flicker Fusion, page) and hearing (see Auditory Flutter Fusion, page). As the frequency of the pulses is increased from some low level, the subject reaches a point where he can no longer distinguish individual pulses, but rather feels a constant pressure. This "threshold" frequency is his score. Aftanas and Zubek (1963a, 1963b) report that "isolation" of the skin of the forearm for a week resulted in an increase in tactual acuity, whereas application of light pressure to the arm for a week resulted in a decrease. These effects were measurable three days after the experiment.

A portable pneumatic instrument, the "sensometer," has been described by Streeter (1969). This apparatus delivers short, intermittent air bursts of variable intensity, and is designed more specifically to measure thresholds of touch and pain than the "acuity" instrument described above.

TEST RL-21: CUTANEOUS THRESHOLDS: VIBRATORY STIMULUS. The use of a vibrating medium to determine thresholds for vibration is very old, and has had more applied use than any other form of cutaneous threshold, primarily in the diagnosis of various neurologic disorders. Tuning forks or primitive electrical vibrators such as the "biothesiometer" or "pallesthesiometer" were used (Laidlaw and Hamilton,

1937). Differences in response of the threshold for vibration to moist heat and infra-red rays have been reported between normals and patients (Toomey, 1946). We need not here enter into a discussion of whether the vibratory threshold measures an entirely separate sensory system than touch (see Jenkins, 1951), but this question should be considered in interpreting results from such studies.

Gregg (1951) presents details of an extremely simple vibrator setup which is coupled to an amplitude-measuring device at the vibrator head. This system converts the vibrator's motion into an electric signal which is then measured by an electronic voltmeter. Such a system leaves many uncontrolled parameters, but the author reports that relative measures are accurate to within 1%, and absolute measures are accurate to within 5%.

A further development described by Hodge and Diespecker (1968) allows remote signaling of two separate vibrators by the experimenter. Standard vibrators are used (see Sherrick, 1953 for details), and the experimenter can control them either singly or simultaneously. As described, the apparatus is powered by a small transformer.

A significant advance in the measurement of cutaneous thresholds was made when Verrillo (1962) introduced a fixed platform with the vibrator tip protruding through a hole in the platform. The subject's hand was placed under, and in contact with, the hole and the resulting stabilization of the skin reduced the spread of surface waves, resulting in a great increase in the stability of the threshold measurement. Using such a system, Verrillo found that for vibratory

frequencies between 30 and 250 hz, there is a 3 db decrease in the threshold displacement amplitude every time the area of the vibrator skin contact is doubled. More recently, the parameters of subjective magnitude of vibration have been explored by Verrillo, Fracoli, and Smith (1969). Craig and Sherrick (1969) give details of an adaptation of such a system, including a description of their technique for stabilizing the subject's arm and preventing ballistic motions of the arm from pulse or muscle tremors.

A somewhat more elaborate system of measuring vibratory thresholds has been described by Eskildsen, Morris, Collins, and Bach-Y-Rita (1969). In this, contactors were used in a video-tactile substitution type system in order to determine two-point thresholds. Such a system allows very precise stimulation. However, unless one has the basic apparatus available, there are perhaps few performance situations where the cost of such a system could be justified.

An "electrostatic field" technique for producing vibratory sensations in the subject without actually having any object in direct contact with him was described by Moore (1968) based on work by Sommer and von Gierke (1964). In the above system, the principle component of the apparatus was a two-channel, high-voltage, direct-coupled amplifier (developed by Systems Research Laboratories, Dayton, Ohio, and described in SRL Engineering Report 577-1, March, 1966). This amplifier provided both an adjustable DC output and an AC output. The output of the amplifier was led to brass electrodes, and the active electrode was positioned .7 mm. from the site to be stimulated.

A biasing DC voltage was applied and then an AC modulating voltage was added and increased until the subject reported a sensation. Biasing DC voltages of 1000-1600 V. DC were required for the finger, 1800-2400 V. DC for the hand, and 2400-3200 V. DC for the arm, with the peak-to-peak AC modulating voltage never allowed to exceed half the biasing voltage. Thresholds were expressed in force units (dynes/cm²) by means of a formula.

TEST RL-22: THRESHOLDS FOR PAIN. Pain thresholds hold great interest for researchers in certain areas of performance measurement. While this threshold is perhaps not of direct interest to an operational, real-world task per se, it may have indirect effects on the subject's performance through induction of fatigue, irritability, distraction, etc. The question of the effect of analgesics on non-debilitating pain has frequently been studied, and techniques have been developed for studying both surface and deep pain.

The production of pricking or burning pain on the skin has been the most popular method of studying pain in the human subject. Heat has been applied both by contact and by the use of radiant energy. Techniques which have been used to accomplish this are presented in greater detail under "Reaction Time" (pp.) and include the use of electrically heated surfaces and of focused light beams. Thresholds obtained with the two methods are not identical (see Jenkins, 1951).

With respect to aching pain from deep structures, studies have used distending force exerted on a hollow viscus, pressure on subcutaneous and periosteal tissues, and voltages applied to various struc-

tures (see Hardy, Wolff, and Goodell, 1952 for references). The most frequently used method is that of exerting pressure on subcutaneous tissues, and the above authors present details of a simple device used for this purpose. A plunger is attached to a steel spring whose compression indicates the force in grams being exerted by the plunger. The plastic tip of the plunger is 1 cm. in diameter. Using such an apparatus, the pain threshold was determined for forehead spots by placing the plunger on the spot to be stimulated and increasing pressure until the subject reported pain. The subjective experience using this type of stimulation is one of increasing pressure until minimal aching pain was felt. It was not one of pricking or burning pain. From this, the authors concluded that the subcutaneous and periosteal tissues were the primary sites of the noxious stimulation. The variation in threshold by this method was relatively large (plus or minus 21%, compared with plus or minus 4% by thermal radiation), but the authors point out that this may be a reflection of the true physiological condition rather than the measuring instrument.

Sensitivity for pain was studied under the stress of hypoxia by Ognjenovic (1969). This author found significant changes in the sensitivity for warmth, cold, and touch under hypoxic stress, but found no significant changes in the threshold for pain.

OTHER THRESHOLDS

Although a great deal of work has been done on the thresholds of chemical and proprioceptive senses, it is not typically considered relevant to many performance studies. For this reason, tests of these

functions will be treated lightly here. Vestibular function is perhaps more directly related to real-world performance tasks. On the other hand, there is some question whether the threshold of vestibular function is of great significance to such tasks; therefore, tests of vestibular function are discussed more thoroughly under the headings of "Sensory Integration" (pp.) and "Reaction Time" (pp.).

TEST RL-23: OLFACTORY THRESHOLDS. The reader requiring basic information on techniques and results in the area of olfaction is referred to a series of volumes edited by Zotterman (1963), Hayashi (1967), and Pfaffmann (1969). The problems in studying olfaction with any precision are obvious if one considers the tortuous path which the stimulus must take in order to reach the receptors located high up in the nose. Control of effective stimulus intensity requires elaborate apparatus, and only where changes are expected to be extremely great would one expect to find stress effects with any other type of apparatus.

A simple machine for determining absolute threshold has been described by Elsberg and Levy (1935) and used by Jones (1953). In this the odorous substance was placed in a stoppered bottle filled with two protruding tubes. One tube was attached to a hypodermic syringe which was used to compress the odorous air in the bottle. The second tube was closed off by means of a pinchcock. When the pinchcock was opened, the pressure in the bottle caused a blast of the odorous air up the tube and into the subject's nose. The end of the delivery tube was flared to form a seal so that the subject received only the

desired air. In use, this technique requires great care and subjects must be very cooperative. However, it does provide a reasonably simple and defensible technique for obtaining an estimate of olfactory thresholds, although thresholds obtained with this technique are not comparable to those obtained with other techniques, and Jones (1953) believes that they can not be translated into molecular terms.

A method of determining the mean absolute olfactory threshold for a group of subjects was described by Cheesman and Mayne (1953). This technique actually uses a masking stimulus and measures the "change in sensitivity to the test stimulus" due to adaptation. What is being measured in such a case is not absolutely clear since the technique resembles a type of differential threshold under these conditions. However, as a method of rapid screening of large numbers of subjects, the task might sometimes be useful.

TEST RL-24: THRESHOLD OF PASSIVE JOINT MOVEMENT. Although one would not expect that perception of passive joint movement would be involved heavily in many real-world tasks, there is the possibility that questions of changes in this ability could arise in terms of a subject receiving "feedback" from a control device, such as an automobile steering wheel. Several studies have attempted to determine the amount of angular displacement which must occur at a joint before a sensation of movement is reported (see Cleghorn and Darcus, 1952). Most of these studies have used an arm support of some kind which is moved in a controlled fashion by a system of pulleys or by a hydraulic system. The subject's arm is held in such a way that superficial sensations are minimized, but in most cases either visual or verbal

information is given regarding the start of a trial. The apparatus used by Cleghorn and Darcus (1952) employed a trough moved on ball-bearings to move the subject's arm. The arm was wrapped in a layer of cotton wool and enclosed in lead sheeting. Movement could be initiated at any angle from horizontal to 45° from horizontal. Speeds up to $0.5^{\circ}/\text{sec.}$ for up to 40 seconds could be produced. A method of constant stimuli was used, with different combinations of speed, amplitude, and direction of movement. A number of "catch" trials with no movement were also used.

TEST RL-25: THRESHOLDS OF VESTIBULAR FUNCTION. The threshold of vestibular function, or the perception of motion from vestibular input alone, is studied directly through the use of rotation, or indirectly by the caloric nystagmus test and the ocular counter-rolling test. Rotational stimuli are discussed under "Reaction Time" (pp.). A listing of rotation devices available as of 1961 was given by Guedry and Graybiel (1961).

The Caloric Nystagmus Test: A classic clinical test of vestibular function, the caloric test, depends on the fact that if a temperature gradient is introduced between the two middle ears, the subject's eyes will show a rhythmic side-to-side swing. Variations in this motion, or delays in its appearance, are thought to be related to changes in the vestibular mechanism itself, or in the vestibular portion of the 8th cranial nerve.

Atkinson (1939) recommended a standardized version of the caloric test, but no such standardization has been adopted, especially for laboratory work. He recommended that the head be tilted

to the horizontal position so that one ear is directly above the other, and that the chin be tilted upward through 45° . Other authors (Loch and Haines, 1946) have inclined the head backward 60° and irrigated the canal in this position. A syringe was then used to deliver 1cc of ice water to the subject's ear canal, being careful not to trap air in the canal. The time of injection was noted. The time of onset of nystagmus was noted, and the subject's ear was immediately emptied. Then the head was tilted forward 30° and backward 60° "to test all canals." The subject was then watched again for cessation of the nystagmus. Atkinson recommends fixating the eyes, while Loch and Haines report "special care was taken to avoid fixation of the eyes." It does appear that visual input can facilitate inhibition of the nystagmic response, so that if maximal response is desired, fixation should be prohibited. Visual observation of the response is facilitated with lenses on the subject's eyes (20 diopeters) but such observation is, at best, crude. Greater accuracy can be obtained, as well as adding the capability for several additional kinds of measure (e.g. amplitude of the nystagmus) if eye movements are recorded directly (Graybiel,). Many other modifications of the technique for delivery of the thermal stimulus are possible, including gravity-fed devices (Graybiel,). The caloric nystagmus test has been used in a variety of stress situations, including zero-G (Kellogg,) and prolonged slow rotation (Graybiel,).

In addition to stimulation by cold, it is of course possible to produce the temperature differential between ears by applying a warm stimulus. In this case, the direction of the nystagmus is

reversed. In addition to the use of water to produce the warmth, a "inle-pipe" technique has been developed (). In this, the tube is actually fitted in the subject's ear and controlled temperature variations are introduced directly. Although this is obviously a more elaborate system, the precision it allows may be useful under some circumstances.

Ocular Counter-rolling Test: A rather complex test of vestibular function has been used by Miller () and Kellogg () at the Naval Aerospace Medical Institute in Pensacola, Florida. This test depends on the fact that if the head is tilted to the side, the eyes will "roll" about their x-axis in the opposite direction. At maximum, the eyes will show about a 7° compensatory roll, and variations from the subject's normal pattern and degree of roll may indicate altered vestibular function. Apparatus for passively rotating the subject is specialized, and ranges from a fmolded form in which the strapped subject is tilted into a position and maintained there until the ocular measurement is made (static counter-rolling) to an elaborate "counter-rolling chair" in which the subject is rotated about his own semi-circular canals at controlled speed (dynamic counter-rolling) (). Data recording is typically accomplished by photographing the subject's eyes at the various tilt positions and then determining the degree of counter-rolling by reference to various landmarks in the subject's iris. Obviously, this is a somewhat expensive and laborious procedure. The technique offers great promise in answering basic research questions, particularly if the dynamic counter-rolling system can be operated in unusual

environments such as weightlessness, heat, and rotation.

TEST RL-26: THRESHOLDS FOR TASTE: To conceive of a single situation where the absolute taste threshold could be operationally meaningful to a stress-performance study is difficult. But since there could be specific performance-type studies where such a threshold might be of interest in its own right (e.g. effect of ingesting certain substances) or as a secondary factor (esthetic or morale effects on other performances), the methods used are sketched briefly here.

Pfaffmann (1951) indicates that because of the relatively discrete taste receptors on the tongue, it is possible to stimulate single receptors by using fine hairs dipped in the solution to be tasted. Clinically, a drop of the substance is usually placed on the tongue and the subject reports the nature of its taste. Obviously, these methods are not acceptable for very precise work or for studies where certain factors, such as amount of saliva or tongue-temperature, are to be controlled. An apparatus which permits control of these variables was developed in 1938 by Hahn et al (Pfaffmann, 1951). This "gustometer" consists of a U-shaped tube with a small hole at the end of the U. The tube is placed in contact with the subject's tongue, thus exposing the tongue area under the hole to any substance flowing through the tube. By first passing air or pure water through the tube, saliva content can be controlled. Similarly, the tongue can be brought to any temperature or level of adaptation prior to determining the threshold. Because of its simplicity, this device is probably to be preferred whenever any degree of accuracy is required.

One can also stimulate the taste receptors of the tongue with electrical energy. Allas and Jauhianen (1968) describe a clinical DC "electrogustometer" which is used at the Helsinki University Otolaryngological Hospital in Finland (see Jauhianen, Allas, and Aho, 1967, for diagram). With such an instrument, DC stimuli ranging from 30 to 50 microamps are delivered to the subject's tongue. Usually, the subject reports a sour-salty or bitter sensation (Pfaffmann, 1951) and little or no discrimination is possible among the various tastes. On the other hand, von Békésy (1964) found all four tastes represented on the tongue when he used pulsed DC stimulation. The above article gives an extensive discussion of the parameters to be controlled in testing taste electrically, as well as detailed descriptions of the electrodes used in his experiments. In general, it would seem that for purposes of performance measurement, the use of electrical stimulation has distinct advantages leading to greater precision. However, extrapolation to real-world questions -- even simple questions of real taste -- are not easy, and the method is certainly not overly-pleasant to the subject.

SENSORY INTEGRATION

Tests described in this section are a bit more complicated from the subject's point of view than the simple threshold tests described previously. However, the distinction between the first section and this one is purely arbitrary. Many of the tests described here are threshold tests of their own particular quality or skill (e.g. color discrimination, CFF, etc.). As explained in the introduction, the arbitrary differentiation used here is that the present tests require some secondary sensory function over and above the minimal ability to perceive or to discriminate minimal energies. Thus, it is not just the ability to "see" a light, but to tell, after seeing it, its color. It is not just the ability to "see" flashes, but, in addition, to separate rapidly occurring flashes. These are still sensory skills, but they require perhaps a bit more sophistication and physiological integrity than simple RL or DL determinations.

Again, the tests are broken down by primary sense modality involved. This introduces some repetitive categories (e.g. there are "size estimation" categories for both vision and touch) and some problems in cross-modality comparisons, but we feel that this format provides the simplest and most useful general classification scheme.

VISION

Sensory integration using vision encompasses a great many functions, each with one or more test techniques. There is no consistent thread running through these functions, such as increasing complexity; therefore, there is no logical sequence in which to list them. Areas having the largest number and types of test were, consequently, listed first, with more exotic areas -- for which there are few tests -- being listed later.

Tests of Color Vision

Clinical testing of humans for defects in color vision is a very old procedure, and a great many techniques for doing such tests have been developed. For the present purposes, these can be broken down into several large categories, and the more popular, more readily available tests from each category discussed.

Operationally, color vision is probably related to a number of real-world tasks. Obviously, in the extreme, adequate color vision is necessary for differentiating traffic lights and the other light signals, for determining the significance of flags, signs, and vehicles which are color coded, for identification of equipment handles, dials, etc., which differ only in color, and for a number of other tasks (Sloan, 1946). Tests used to screen candidates for specific jobs, such as flying or driving, are generally geared to detection of such gross malfunctions of visual reception, and are not concerned with making fine discriminations within the normal range. Thus, one

should remember that the majority of tests to be described are not particularly suited for use in situations where only small changes in color perception are expected. In such situations, the few more elaborate tests which will be described must be used.

TEST RL-27: COLOR-VISION TESTS USING CARDS AND PLATES. By far the most frequently used form of color vision test is that which uses printed cards or plates to elicit from the subject a color identification response. Great difficulties have been experienced in the past in obtaining plates in which the colors are consistent from one set of plates to another and where there is no fading or wear in a given set of cards (Neuhert, 1947). Newer versions of the test should be less affected by these problems. Obviously, lighting must be completely adequate when such tests are administered, yet in many clinical situations this variable is given little attention. In spite of these factors and problems, Lichter (1953) feels that for general screening, pseudo-isochromatic plates remain the most popular and yield fairly reliable results.

The Ishihara Pseudo-Isochromatic Plates: These plates, or variations of them, are the most frequently used form of color test in general practice. Basically, they consist of cards containing random-appearing dots and shapes of various colors. The normal subject is able to make out a number or figure on these cards, whereas the subject suffering from color deficiencies of various types will be unable to resolve the number. The original plates, first published in Japan and then in an English version, contained a large number of cards. Later, this number was reduced to between 11 and 18 cards. In

various versions. The Ishihara plates (and others of similar design) appear to be conservative tests, i.e. they indicate deficiency in more cases than other tests. Thus, a large number of "false positive" results should be anticipated. In part, this is why such tests are good screening instruments, since they miss few genuinely defective individuals. However, they should usually be followed with a more discriminating test if the false positives are to be identified. At one point, White (1941) tested a modified Ishihara test against criterion measures involving performance related to military flying. He concluded that failure to pass the test should constitute grounds for immediate disqualification.

Rabkin Polychromatic Plates: This is a Russian test, similar to the Ishihara test except that geometric figures are presented on a neutral gray of approximately equal albedo (Rabkin, 1947). This test has not had much use in the United States (see Sloan, 1946).

American Optical Company Pseudo-Isochromatic Plates: This series consists of 46 plates copied in some cases from the Ishihara series and from others. In its original form it was one of the official tests of the Army Air Force, but was replaced in 1944. Gallagher, Gallagher, and Sloan (1943) proposed a shortened version of the test containing only 10 plates, and others have used versions containing 12 and 17 plates (Sloan, 1946). A U.S. Navy version of the test was issued in 1944 containing 36 plates, some of which were modifications of the original plates. Thomas (1943) found a correlation of .62 between the Ishihara test and this one.

Farnsworth Pseudo-Isochromatic Plates: This is a series of plates similar to the above (Farnsworth and Reed, 1943). The test has been used by Verriest (1963) in comparison with a number of other tests.

Other Tests Using Printed Cards: Medrow (1931) reports a simple and inexpensive group test which was used in the German postal and telegraph service. It consists of a card containing 50 colored samples. The subject must indicate which of five standard colors is closest to each of the samples. Ray (1952) reports use of pigmented cards under outdoor illumination. The colors of the cards are specified by spectroscopic measurement. This test was designed for field use by anthropologists.

TEST RL-23: COLOR-VISION TESTS USING COLORED OBJECTS: Several popular color-vision tests are based on the use of colored objects to be identified or classified by the subject. These objects are carefully calibrated and retain their color characteristics for a long time. In some cases, color standardization is obtained by reference to the Munsell colors (), a system which allows objective specification of minimal variations in hue, while keeping brightness and saturation constant.

The Inter-Society Color Council (ISCC) Single Judgment Test: This is a test of red-green discrimination only (Hardy, 1943). It consists of 20 pairs of chips, 10 pairs of purple-red and 10 pairs of red. These differ from each other slightly, and the subject's task is to tell which of the chips of each pair are redder. Rowland (1942) found that scores were not reproducible on this test, and that some subjects with definitely deficient color vision were able

to use brightness cues to obtain a perfect score. However, Thomas (1943) used the test and found adequate agreement between it and both the Ishihara and the American Optical Co. Pseudo-Isochromatic Plates.

The Farnsworth-Munsell 100-Hue Test: This test consists of 35 colored discs which differ in small steps over the Munsell scale. The subject receives a box into which he is to place about 20 of the discs in the order of their color change, i.e. the subject organizes the discs into a graded series. He does this four times, so that all 35 discs are eventually classified. Discs placed out of sequence are scored as errors, and the results are plotted on a circular chart which reveals the subject's color-deficient areas (Farnsworth, 1943). This is a time consuming test to give and score, and the interpretation is not always clear from a clinical point of view.

Thomas (1943) found that when "normal" and "color-blind" subjects were tested with this test, there was "much overlapping for the two groups." In addition, when five color-blind and eight normal subjects were retested, improvements of from 4 to 40 points and dramatic error increases were found in various subjects. Consequently, the reliability of the test is questioned. Correlation of this test with the Ishihara plates was $-.25$ for the color-blind and $+.50$ for the normal subjects. One should note, though, that the above results are not inconsistent with an hypothesis of increased discrimination for the Farnsworth test over the Ishihara. Verriest (1963) used the Farnsworth test to determine the effect of age and sex differences.

A variation of the Farnsworth test has been described by Burnham (1955) as the "Hue Memory Test." This is an attempt to test immediate memory for hue dissociated from configuration. Twenty Farnsworth chips are used, and the subject is required to select the matching chip after a brief exposure to a test chip. Obviously, this test requires not only adequate color vision, but an ability to retain and/or visualize the color in its absence.

The Terrain Test: This is another modification of the Farnsworth test, with twenty chips chosen to include the two regions in which hue discrimination is poor for persons with red-green deficiency, and because the reds, yellows, greens, and blue-greens used represent the colors of the natural terrain (Sloan, 1946; Rowland, 1943). The subject's task is the same as in the original Farnsworth test, but scoring is greatly simplified.

The Peckham Color-Vision Test: As described by Sloan (1946), this test consists of twenty Munsell colors which are of equi-distant hue. The twenty hues are presented mechanically in random order for comparison with standard red, yellow, green, blue, and purple hues. The subject reports when he sees a perfect match. However, because of differences in the illumination of the hues to be matched, probably even color-deficient subjects could make discriminations. No further references were found to this test.

Yarn Tests: There are several tests which use yarn dyed to specific colors (e.g. Jennings Yarn Test; the Holingren Test). These operate basically on the same principle as the Farnsworth Test. But there are several uncontrolled factors introduced in the case of using

yarn which make it undesirable. For instance, the size of the sample is obviously variable, and the color is somewhat less stable.

TEST RL-29: COLOR VISION TESTS USING ANOMALOSCOPES, COLORIMETERS, AND

LANTERNS. Under this heading are included three mechanical methods of

studying color vision. Lanterns, the simplest of the three, simply project one or more patches of light onto a surface. Neubert (1947) compared the effectiveness of single light lanterns with that of double and triple lights, and found that, in clinical situations, the triple light lantern is most sensitive and reliable. Colorimeters utilize mechanical mixtures of pure colors to present a given hue to the subject. Anomaloscopes present split-field views in which, typically, one half is constant and the other half is made up of a combination of colors which the subject adjusts to match the first half. That the last two types of instruments are more complicated to use than any of the tests seen so far should be clear. Precision of stimulus delivery, and perhaps more precise quantification of small changes in color vision, are distinct advantages of such a system. But such advantages come at a cost of time, money, and extreme care in conducting the experiment. For simple screening, or where dramatic effects are expected, these techniques are unnecessary. Where subtle changes are expected, they are essential.

The Royal Canadian Navy Lantern: This device shows two lights, one inch apart, and each adjustable to either .2" or .02" in diameter (Solandt and Best, 1943). As developed, nine possible pairs of lights are shown to the subject, consisting of red, green, and white lights.

This test has also been described by Sloan (1946)

The Pickford-Nicholson Anomaloscope: Homberg (1963) provides standardization data for this apparatus in a homogeneous student population. These data allow testing of blue/green, red/green, and yellow/blue functions. References are given to original standardization by Pickford and Lakowski, and one concludes that the instrument is a sensitive tool for color vision testing and psychophysical investigations.

The Four-Color Replacement Colorimeter: A modification of standard colorimeters is described by Bongard (1957). In this, the light may be added directly to the illumination being measured, eliminating measurement errors due to the dilution of light in the colorimeter. The instrument described allows experiments to be conducted 1) in a broad brightness range, 2) at various wavelengths, 3) at various angular dimensions of the field, and 4) in both darkness and "bright encirclement of the colorimetric field."

TEST RL-30: TESTS OF COLOR SENSITIVITY IN VARIOUS PORTIONS OF THE VISUAL FIELD: Several techniques have been developed to evaluate the extent of visual fields for color. Various kinds of perimeters have been used, each providing a quantitative way to plot the limits of sensitivity in various retinal areas (see Traquair, 1931, for basic text). The Ferree-Rand perimeter is typical of older versions whose basic principles are still used (Ferree and Rand, 1922). Modern perimeters are marketed by a number of companies, including

The technique of using perimetry to evaluate color fields is not some-

thing which the average experimenter would be expected to know. It is a difficult task and, if an experimental design called for such determinations, then either an individual experienced in perimetry should be employed or the experimenter should devote considerable time to developing the skill. However, even with skill, there are great difficulties in measuring the sensitivity of points within the retina because of the great number of factors which influence retinal sensitivity.

An alternative method for studying sensitivity of discrete retinal areas to color has been proposed by Arakawa (1953) based on the work of Motokawa. This has been called "the D.C. method" of retinal color sensitivity. It consists essentially of measuring the electrical sensitivity of the dark adapted eye after exposure to colored light. Two small electrodes are applied, one slightly above the eyebrow and the other on the homolateral temple. After a 20-minute dark adaptation, a DC pulse of 0.1 second duration was given at a level high enough to produce an experience of distinct phosphene. Then the voltage was reduced step by step until one level was reached where the subject could no longer report a phosphene. This threshold value was obtained in ascending and descending trials 20 to 40 times. These values determined an "unstimulated" baseline. Determination of thresholds during color stimulation were done in the same way. But prior to each determination a 4-second illumination of a given color was delivered to a 2° retinal point. From differences between these two thresholds, one could infer sensitivity in these rather small retinal regions. This method is not without difficulties, even in

addition to the obvious ones of time and subject inconvenience. The first threshold reached in a given series is not always the only one found. For instance, in a descending trial, a second phosphene sometimes appears if voltage is further reduced below the point where the first phosphene disappeared. Thus, there may be multiple electrical thresholds to color in the retina. The experimenter contemplating use of this technique must be prepared to deal with these and other problems, and should be certain that the costs in time and other limitations are required by the experiment. Clearly, very basic processes are being measured here, and it would be very difficult to relate these processes meaningfully to any real-world task.

TEST RL-31: OTHER COLOR VISION TESTS. A "self-administering color vision test" has been described by Schmidt (1953a). This apparatus allows color vision testing and registration of score without the help of an examiner. In comparison with other tests, this one was very conservative, misclassifying many normals, but correctly screening all color defectives. Differential diagnosis of color defectives was only approximate.

Another instrument has also been described by Schmidt (1953b). This is a transportable unit which can test five subjects simultaneously. Each subject sees a set of three signals (designed to correspond to airfield signals). Eleven sets of these signals are presented at fixed exposure times and interexposure periods. The device has been called the "Color Vision Multitester."

Flicker Fusion (Critical Flicker Fusion)

If light is flashed at a rapid enough rate, the subject will report that the light is not flashing, but is steady. This phenomenon

has formed the basis of a large number of studies, and has been variously called the critical flicker fusion (CFF) threshold, the flash fusion frequency (FFF) threshold, flicker fusion (FF), and critical flicker frequency. A number of studies have been attempted to determine whether the fusion point is dependent on the retina, the visual pathways, or the visual cortex; theoretical models have been advanced supporting each of these views. Landis (1953; 1954) prepared a bibliography of over 1100 titles for the period up to 1952, but the most recent summary of research in the area has been presented by Piéron (1965).

Various factors have been found to affect the CFF threshold. and laws describing the relationship of the measure to changes in stimulus parameters have been formulated (see Woodworth and Schlosberg, 1954; the Talbot-Plateau law and the Ferree-Porter law). Generally, the eye is more sensitive to flicker 10 to 30 degrees in the periphery than in the fovea. The more intense and the larger the light source, the lower the flicker threshold will be. The variability of the CFF point is extremely small. Day to day variations within a subject only ranged from 0.6 to 2.9 percent in one study (Lythgoe and Tansley, 1939) and such results are common. The measure is, therefore, capable of showing significant differences with rather small effects and with relatively few subjects. But subject-to-subject variability is quite large. There appears to be only a very slight learning curve in the task, and most subjects produce stable thresholds after a few trials.

CFF has had a long history of use as both a clinical and research instrument (Hiles, 1950). Currently, there is renewed interest in the possibilities of using this as a standard test in

diagnosis, and there appears to be widening use of CFF as a research tool in fields such as clinical neurology, ophthalmology, neurophysiology, gerontology, and psychopharmacology (Misiak, 1967). The fact that this test is so sensitive to small stresses on the subject and that, despite theoretical differences as to its physiological basis, it can be traced to certain kinds of functional mechanisms tends to recommend its use in a great deal of performance research. This, of course, should be done with necessary caution. Perhaps because CFF is such a stable and sensitive measure, lack of standardization of stimulus, environmental and subject variables can cause differences to appear or disappear without reference to independent variables. For example, instructions to the subject can affect the threshold (Knox, 1951). But with adequate care, the measure can be quite valuable. The authors of a 1953 study (U.S. Dept. of the Army, 1953) concluded, after conducting 20 potentially stress sensitive tests, that CFF was one of the few meriting further study. As with other threshold tests, changes in CFF must be interpreted in terms of the basic implication of the test; tendencies to make easy generalizations to real-world tasks must be avoided. The test probably measures small changes in the relative integrity of a physiological system --, and does it very well. What, if anything, this means in terms of larger behaviors is still to be determined.

Flicker fusion thresholds have been obtained under a large number of stress situations; the reader is referred to the reviews noted above for the complete list. However, representative examples will be given to indicate the range of stressors which have been used.

One of the most frequently used stressors with CFF has been reduced oxygen or high altitude. Since anoxia would be expected to show effects early in the central nervous system, one is not surprised that CFF has been shown to change reliably in such conditions. Scow (1950) found decrements at 18,000 ft. for one hour, and McFarland et al (1959) found consistent changes directly related to altitude, time, and, of course, the buildup of anoxia. A similar stressor is carbon monoxide (CO), which also deprives the tissues of oxygen, and several studies have tested CFF in subjects exposed to CO (McFarland et al, 1959; O'Donnell, Chikos, and Theodore, 1971). Generally, decrements are not found until the CO-induced oxygen deprivation reaches a point equivalent to an altitude well above 10,000 ft. Strangely enough, fatigue does not seem to disrupt CFF very readily. Tyler (1947) reports that no CFF change was found in subjects who remained awake from 30 to 60 hours. Similarly, subjects who did prolonged visual work (3.5 hours of reading) did not do consistently worse on CFF (Ryan, Bitterman, and Cottrell, 1953). On the other hand, Hansel (1953) found that when young men rested for two half-hour periods, their CFF point was considerably lower (worse) at the end than at the beginning. Finally, a great number of studies on the effects of drugs and other chemical agents have used CFF as a measure (see e.g., Misiak, Zenhausen, and Salafia, 1966; Misiak and Rlzy, 1968). In the stress study by the U.S. Department of the Army (1953), subjects undergoing their first parachute jump were tested with CFF and showed decrements. In addition, subjects were exposed to 90 db noise while taking the CFF test and showed stress effects. Pulsed

auditory noise was unable to induce flicker when it was absent, but when flicker was already present, it became more pronounced with auditory input (Knox, 1952). It is clear from this brief sampling of stress situations that the CFF test is applicable to a large number of situations. Consideration should certainly be given to its more extensive use.

TEST RL-32: CRITICAL FLICKER FREQUENCY TESTS. The classic technique for measuring CFF has been to interrupt a light beam with a revolving disc or drum. In this, the open section of the disc allows the light to reach the subject's eye, and then, as the leading edge of the closed section passes before the light, it is effectively turned "off." Calculation of disc rotation and size of the openings allowed calibration of the frequency of flicker. The problem with such an apparatus, of course, is that the light does not simply go "on" and "off." There is a finite time during which the edge of the disc is passing in front of the light, during which the light is going off. Thus; the light-dark sequence is not a square wave. What is worse, the speed at which the light goes off changes with differing rotation speed in the disc.

Recent CFF apparatus avoid this difficulty to a great extent (see Ireland, 1950; Fritze and Simonson, 1951; Pudritzki, 1957; Miles, 1950; Reuning, 1955). Various electronic circuits are used to produce impulses which are capable of triggering square waves. A significant advance became possible with the development of "glow modulator tubes" such as Sylvania's R1131A and other such light sources which emitted smooth light and had virtually instantaneous on-off characteristics (Fritze and Simonson, 1951). An additional development was described

by Berger, Mohnke, and Mortensen (1955). Prior to that time, the flicker rate was changed by hand during the course of a trial. Since the change affects fusion, these authors designed a circuit which allowed automatic variation of the rate of flicker at variable speeds.

Several commercial flicker fusion devices are available. Research Media, Inc. markets the "Multi-Purpose Perceptual Device" described previously under thresholds (see pp.) (Cat. #PR-27, price \$435.00). This device is particularly useful if there is a need to have control over the area and intensity of the stimulus for a wide range. Lafayette markets a complete line of equipment for CFF determination. The simplest instrument is designed to demonstrate flicker fusion or the phi phenomenon. This is not an extremely precise apparatus as it stands (Cat. #58017, price \$124.00, including #12029 stimulus unit). A more accurate instrument provides dial-adjusted flicker from 2 to 128 flashes per second with less than 0.5% fluctuation. Also, two lamps may be operated either together or alternately. No stimulus unit is supplied with this instrument. The catalogue number is 12020 and it sells for \$300.00. The most elaborate unit manufactured by Lafayette is the model 12025 "Research Flicker Fusion Control" which sells for \$1,485.00. This device provides flicker from 1 to 100 pulses per second in at least 0.1 pulse per second steps. Flicker rate is read digitally and updated every 0.1 seconds. Stability is 0.1% or better. Light-dark ratio is variable from 1% to 99% in 1% increments. No stimulus unit is provided with the set, but it can be used with any available stimulus unit. Lafayette manufactures a line of such units ranging in price from \$30.00 to \$310.00, depending on light source and viewing chamber.

A timer is also available for use with this unit (Cat. #12028, price \$280.00) which allows extremely sophisticated timing, including insuring that the first and last pulses of a discrete presentation will be identical.

Clearly, standardization of stimulus parameters and even apparatus would be a very desirable feature of CFF testing. This is particularly true of CFF because of the sensitivity of the measure. Misiak (1967) and Dr. Armand W. Loranger have drawn up a set of requirements which should be included in any such standardized apparatus, and one which approximated these was constructed by International Applied Science Laboratory (Misiak and Rizey, 1968). This instrument was simple to operate and maintain and was portable. It incorporated 1) a variable frequency oscillator producing a rectangular light wave at frequencies from 10 hz to 90 hz, 2) variable light-dark ratio control, 3) light intensity regulator, and 4) electronic timers to control the light presentation and the dark interval independently. The target is viewed monocularly through an artificial pupil, and subtends a visual angle of 2° . The light source is a Sylvania R1131C glow modulator tube.

Using the apparatus with these characteristics, Misiak is currently developing standardization data on all ages from 6 through 80. When such a data bank is completed and thoroughly analyzed, it will provide a valuable basis for comparison in other performance studies. There is much to recommend the use of CFF as a performance measure, and all the more so if a standardized apparatus can be used.

Depth Perception Tests

The human is capable of making accurate judgments of the relative depth of two objects over a wide range of distances. This skill is thought to be important to a great number of practical tasks where depth cues are used as a basis for judgments which often result in complex control movements. The car driver is constantly called upon to make depth judgments; in the military, there are unique tasks, such as gunnery and range determination, which require extremely accurate depth perception (Grossman, 1943). There have been various attempts to measure depth perception using extremely sophisticated and complex apparatus. For example, von Bahr (1952) used an optical system in which the subject adjusted the length of the path of one beam of light from an object so that its image was clear with reference to the image carried over a standard path (see also Koch, 1946; Wallach and Zuckerman, 1963; Lawson, 1968). But none of these have achieved wide acceptance and there appears to be little evidence that such sophistication adds a great deal of validity to the relatively simple and crude measures described below. The question of validity is certainly open in considering these tests, since depth perception in operational practice is dependent on a large number of cues in addition to the binocular parallax which most of these tests measure. Thus, it is not well established that impairment in the test will necessarily be reflected in impairment in all kinds of real-world depth perception (see Warren, 1940). To the extent that these tests measure the subject's ability to use binocular parallax as a depth cue, one can certainly assume that the subject's depth perception in the real world will be made that much more difficult.

TEST RL-33: DEPTH PERCEPTION TESTS: STEREOSCOPES. The principles of simple stereoscopic viewing through optical devices has been used in a large number of tests to determine depth perception. Typically, a row of figures (circles, letters, etc.) is presented independently to each eye through a stereoscopic viewing device. The figures are positioned in such a way that the separate images coincide exactly in both eyes so that fusion occurs. However, in one of the figures, the images are displaced an appropriate amount so that the impression of depth is created for that figure. Thus, in each row, there is one figure which should "stand out" from the rest. Successive lines of the test card present increasingly more difficult depth discriminations to the subject, and the first line in which he is unable to identify the stereoscopic effect constitutes his depth perception limit of ability. Virtually all of the devices described previously for measuring visual acuity with optical devices come equipped with cards for evaluating depth perception in this way. These include the Keystone Telebinocular (p.), the Military Vision Tester (p.), the Orthorater (p.), and the

The measures obtained with this test may or may not be clinically meaningful (Warren, 1940). But they will rarely be discriminating enough for most performance research situations. The above author found low correlations between the Keystone stereopsis test and the Howard-Dolman apparatus described below. In addition, the Keystone test had a reliability of .86, which was lower than the comparison apparatus.

TEST RL-34: DEPTH PERCEPTION TESTS: THE VERHOEFF TEST. A test was developed and described by Verhoeff (1942) which presents misleading monocular cues (size differences) to the subject, so that the binocular parallax is the only correct cue on which to make judgments of depth. The original device was a 9 cm. x 17.5 cm. screen with a rectangular window in it. Behind the main screen was a sliding screen which was 11 cm. x 6.9 cm. and 2.5 mm. thick. When viewed by the subject, the rear screen appeared as a clear, backlighted window in the front screen. On this window were three thin black strips of different sizes, some attached to the back and some to the front of the rear screen. In successive presentations of different "patterns" of these strips, the subject was to tell which one was different from the other two. Thus, the actual depth difference to be discriminated was 2.5 mm. The instrument was presented to the subject at various distances, and the first distance at which he was unable to discriminate the 2.5 mm. depth difference was converted into an equivalent Snellen notation (see pp.) and defined the subject's depth perception. Factors which could influence the test, as well as more technical details for its construction, are presented in the above article. The test has undergone several modifications. Standard and modified versions were used by Niven, Johnson, Rand, and Pettit (1952). Reliability of the standard form was .75, and of the modified form, .80. Neither form was clearly superior to the other.

This test is relatively easy to use and, once constructed, should provide a rapid, approximate evaluation of some aspect of depth perception. It is, of course, a crude technique and should not be overgeneralized.

TEST R:-35: DEPTH PERCEPTION TESTS: THE HOWARD-DOLMAN APPARATUS.

By far the most frequently used technique of studying depth perception for laboratory purposes has been the instrument first described by Howard (1919) from one originally devised by Brooksbank James in 1908. In its original form this consisted of three sides of a box ---- the back, bottom, and front. The front and back were 58 cm. high and 75 cm. wide, and the floor was 55 cm. from front to back and 75 cm. wide. The floor and front were painted black, while the back was painted white. In the middle of the front partition there was a window 20 cm. by 12 cm. whose upper edge was 38 cm. from the bottom of the partition. The subject sat exactly six meters from the center of the apparatus, with his eyes at the same level as the window. Inside the box a "track" was laid out from front to rear behind the window, and this was calibrated with marks of 0.5 cm. each. In the original version, the experimenter adjusted vertical rods, 6 cm. apart, to different distances and the subject determined their equivalence. In later versions (Howard, 1919b), manufactured by Bausch and Lomb Optical Co., the vertical rods were able to be moved directly along a sliding track. Thus, the subject could perform the adjustment which positioned the two rods at equivalent distances from him by turning pulley wheels placed in front of him. Since the vertical rods were viewed against the white background through the window, which prohibited the subject from seeing their top or bottom, the only cue left was binocular parallax. Many variations of this basic instrument have been used in studies (see, for example, Edwards, 1953; Taylor and Summer, 1945; Loy, 1930). A form of the test is currently manufactured by

The suggestion has been made that two separate scores can be obtained with this test (Sloan and Altman, 1953). This is based on the observation that some subjects make settings of the moving rods which are consistently wrong in one direction. This "constant error" may indicate the amount of aniseikonia in the subject, which may be of value in its own right in addition to the usual scoring technique of considering absolute distance between the rods. But such constant error measures are an adequate measure of horizontal aniseikonia only if all depth cues other than binocular disparity are eliminated (see Sloan and Altman, 1953).

Depth perception has been studied with this equipment under the stress of low ambient temperature (Kobrick, 1969) where significant main effects and interactions were found for temperature, wind, and viewing distance with exposures as brief as one minute. Sasaki (1963) found no appreciable changes in depth perception using a modified version of this equipment with subjects exposed to zero, one, and two G forces. After sensory deprivation of up to 72 hours, subjects showed no significant effect upon depth perception.

Warren (1940) compared the Howard-Dolman unit to the Keystone stereoscopic test. Reliability was .93 for the Howard-Dolman test and .86 for the stereoscopic views. However, correlation between the two was only .12, indicating that they do not measure the same thing. The experimenter, therefore, should be extremely careful to avoid a too-easy interpretation of this task, or a too-sweeping generalization of its applicability to real depth discriminations in operational practice.

Perception of Movement

There are a great number of practical situations where the ability to make inferences about movement is critical to the human. In the visual area, such questions most often arise in terms of thresholds for movement detection (e.g., determining when an object begins to move, or when it has moved slightly) or in terms of velocity estimates. In view of the importance of these questions, one is surprised that a great many tests of movement detection and velocity estimates do not exist. This is not to imply that the phenomena have not been studied extensively (for example, see Roff, 1953). What has happened is that, most often, experimenters have used individualized apparatus constructed in their laboratory. A few such devices will be described below. But one should note that no completely standardized unit has been found which is generally available.

TEST RL-36: MOVEMENT PERCEPTION. Detection of the threshold for movement perception is a very difficult task. The human is able to respond to extremely small movements, and this places strong demands for precision on the experimental apparatus. Rohrer (1954) discussed the requirements of such an instrument using a light source: 1) The light should be moved at a given constant speed over a given distance; 2) the direction of movement should be readily variable; 3) the movement should be automatically repeatable; and 4) the controls should allow the experimenter to keep the light stationary while giving all the additional movement cues normally given during a trial.

Objects can also be used in determining the movement threshold. In this case, the object should occupy a well-defined retinal space, and movement should be relatively equivalent over that space (i.e., there should not be a differential in movement between various parts of the object, such as might be present if a rod were rotated about a center). One solution to these requirements was used by Gordon (1946). Landolt rings were modified for rotary motion. In this way the subject was only able to respond to the open edge of the ring, which moved at a constant rate over its entire width.

A somewhat more elaborate method of studying visual movement thresholds has been described by Conklin, Baldwin, and Brown (1953). This apparatus requires the subject to report not only the existence of movement, but its direction. Such a method provides an estimate of the subject's certainty in his reported perceptions, and provides the experimenter with an additional control on the criterion for moving among subjects.

TEST RL-37: VELOCITY ESTIMATES.

Two forms of estimate:

1. Elapsed time during which an object passed over visual field.

(see "Velocity Estimate" (movement))

(Bezák and Dornič, 1968).

2. Object passes behind screen and subject estimates how long it will take to traverse screen.

(see "Velocity Estimate" (movement))

(Reynolds, 1968)

(also see Fleishman's factor analysis of this test).

Visual Discrimination in Noise

Object Identification:

Eriksen, 1953.

Dots:

French, 1954; Kaufman, Lord,

Reese, and Volkmann, 1949.

Hidden Figures Test:

Boersma, 1968; Barrett, Cabe,

and Thornton, 1968; French,

Ekstrom, and Price, 1963.

Embedded Figures Test

see Witkin.

Visual Identification

Apparatus:

Neely, 1953.

Color Slides:

Frederiksen, 1965; 1966.

See also Gregory (1969) for 'point-source shadow-image system' instruments and results on movement observation.

Monocular vs. binocular spatial discrimination: Wyke and Chorover, 1965

Identical Pictures Test: French, Ekstrom, and Price, 1963.

Paper and pencil test. From five geometrical figures the subject identifies which one is identical to a "standard" Copyright ETS.

Dominance over tactual discrimination: Rock and Victor, 1964.

Apparatus for presenting letters for recognition: Brozek, 1947.

Evaluated fatigue. Gave a list of "requisites of a good visual performance test."

On "visual fatigue" see also: Weston, 1952; 1953.

Tachistoscopic Exposure (included here as a general topic relating to recognition of briefly presented targets):

Taylor, 1953; Pearson and Tong, 1968; Boardman and Gunter, 1963; Klopfer, 1953; Farrimond, 1968; Karlin, 1955; Tinker, 1931 (the Dodge Tachistoscope); Kupperian, 1951; Ferec, 1936; Howard and Evans, 1964 (split-beam); Robertson, 1935; Dahmen, 1931; Butov and Chartorizhskii, 1964; Harcum, 1967; Buchanan and Weiss, 1969; Winnick, 1969; Kephart and Reevesman, 1953; Soar, 1955; Dick, 1969; Andreassi, 1965.

Span of Apprehension (Visual)

Number: see Ancona, 1952
 Span of Apprehension Test: Lerner, 1968.

Visual Judgment of Object Characteristics.

Distance: Clark, 1952; Weymouth, 1944;
 #534 ; #400
 ; #469
 ;
 #624
 Nearer Point Test: French, Ekstrom and Price, 1963.
 Curvature: Carlson, 1963.
 Surface and Volume: Stanek, 1968.
 Slant: Audley, 1960; Flock, 1963.
 Size: Borozdina and Gippenreiter,
 1969; Girard, 1936; Holmberg
 and Holmberg, 1969; Lutze, 1931;
 #302 ; #345
 ; #468 ;
 #564 ; #565
 ; #824 ; #942
 ; #802 ;
 #864 ; #303

Binocular Fusion

Stereoscopic views in Ortho-rater, AF Vision Tester, Keystone Telebinocular, etc.:

Incomplete dot patterns: Eriksen and Collins, 1968.

Perceptual Stability Tests

see McKinney, 1967.

Other Topics in Visual Perception

Audio-visual interaction: Terstenjak, 1963.

Entopic visual images: Hall, Karsh, and Wilsoncroft, 1969.

Presents an apparatus suitable for obtaining reliable reports of entopic images.

Effects of head tilt on visual perception: Knoll, 1959; Wade, 1969; see also section on visual-vestibular-kinesthetic estimation.

AUDITIONIntroduction

Includes: Forbes, 1946; see Bricker, Johnson and Matzke, 1969:

Factor analysis: O'Hare, Harris, Ehmer, and Cohen, 1959.

Methods of comparing auditory signals: Coltheart and Curthoys, 1968.

Pitch Discrimination

- Underwater: Harris, 1947.
- Apparatus: Jeffries, 1948; Wallis and Audley, 1964.
- Auditory fatigue: Skinner and Antinoro, 1968.
- Difference between pulse tones and sinusoidal tones: Zeitlin, 1957.

Loudness Judgment

- SISI Test: Young and Wenner, 1969;
- Parameters: Geiger, 1932; Rschevkin, 1938; Guelke, 1952; Parducci, Thaler, and Anderson, 1968; Holland and Lockhead, 1968; Hellman and Zwislocki, 1968; Reason, 1968;
- Auditory loudness matching: Black, 1954.

Sound Localization

- Apparatus: Trimble, 19 ; Hughes, 1939.
- With visual conflict: Mankovskii, 1969.

Speech Perception

Underwater: Brandt and Hollien, 1967.

In Helium and O₂ at Altitude: Nixon, Mabson, Trimbo, and Welch, 1967.

Semi-Diagnostic Test, Rhyme Test, Harvard PB-50 Test, CID

Auditory Test W-22, Simultaneous Voices Test: Lovrinic, Burgi, and Curry, 1968; Karlin, 1945.

Kimura digits: Brunt and Goetzinger, 1968.

Auditory Pattern Perception

Pattern preferences by subjects: Royer and Garner, 1970.

Auditory Flutter Fusion Test

See: Newbrough, 1968; Harbert and Wenner, 1968.

In parachute training: Miller, 1953.

Perception of auditory gap: Huppert and Singer, 1967.

Perception of more intense pulses in a monitoring task:

Loeb and Binford, 1968.

Auditory Perception With Masking Noise

- Auditory Recognition Test: Frederiksen, 1966.
- Sone functions in noise: Richards, 1968.
- Effect on binaural summation: Hirsh, 1947.
- General: Richards, 1968; Harvard University Psycho-Acoustic Laboratory, 1945.

Tactile, Kinesthetic and Vestibular Perception

- Introduction:
- Tactile form perception: Bose, 1926; Vaught, 1967; Austin, 1952; Crandell, Hamill, Witkowski, and Barkovich, 1968.
- Tactile texture discrimination,
oral region: Ringel and Fletcher, 1967.
- Tactile size discrimination: Graf, 1933; Cheng, 1968; Bartley, 1953; McPherson and Renfrew, 1953; Breternitz, 1934.

Two-point threshold: See thresholds; also Alajouanine,
Scherrer, Barbizet, LeHenaff,
and Buser, 1953.

Tactile vibratory sensitivity: Smith, 1949.

Muscle vibration test: Hagbarth and Eklund, 1968.

Tactile-kinesthetic localization: Tsao, 1962; Elithorn, Piercy,
and Crosskey, 1953.

Size of angles: Calabresi, 1933.

Tactile judgment of direction: Bice, 1969.

Judgment of weight: Stoddard, 1947; Donavan and Ross,
1969; Taylor, 1930; Fernberger,
1931; Hartman, 1954.

Judgment of firmness: Sheppard, 1953; Sheppard and
Scott-Blair, 1952.

Kinesthetic distance estimation: Underwood, 1969.

Kinesthetic aftereffect

The bar test: Spilker and Callaway, 1969.

Kinesthetic position estimation: Wapner, Weinberg, Glick, and
Rand, 1967; Norman and Kiker,
1969; see Carnes, 1946, for
background; Wapner, 1952; Edging-
ton, 1953; see Henry, 1953;
Garvey, 1954; Caldwell, 1955;
Chapanid, 1950a and 1950b;
Vidacek, 1958.

Vestibular-kinesthetic position estimates: Fleishman, 1953;

Clegg and Dunfield, 1954;

Smith, 1968.

Visual-vestibular-kinesthetic position estimates: Mann and

Boring, 1953, Boring, 1952;

Fleishman, 1953a,b; Ballou and

Corah, 1965; Naylor, 1963; Eben-

holtz, 1969; Wade, 1969;

Rod and frame test:

Solar, Davenport and Bruehl,

1969; Barrett and Thornton,

1969; Cabe, 1969; Adevai, Silver-

man and McGough, 1968; Cabe,

1968; Lester, 1968; Adevai and

McGough, 1968; Barrett, Cabe and

Thornton, 1968; Oltman, 1968;

Mansueto and Adevai, 1967.

VIGILANCE

Introduction

Historical:

see Verwoerd, 1929.

Definitions:

'vigilance':

'monitoring':

Information theory, modeling, and vigilance: Hatfield and Loeb,

1968; Thurmond, Binford and Loeb,

1970, Debecker and Desmedt, 1970;

Askren and Regulinski, 1969.

Experimental Parameters:

Signal and non-signal timing: Debecker and Desmedt, 1970;

Warm, Loeb, and Alluisi, 1970;

Klippel and Scelfo, 1969; Wilkin-
son, 1964; Kidd and Micocci,
1964.

Signal and response duration or complexity: Kidd and

Micocci, 1964; Hatfield and
Loeb, 1968; Warm, Loeb, and
Alluisi, 1970.

Age effects: Thompson, Opton, and Cohen, 1963.

Effect of auditory stimuli on visual vigilance: Davis,
Hockey and Taylor, 1969.

Normal responses in vigilance: Hatfield and Loeb, 1968.

End spurt: Bergum and Lehr, 1963.

Knowledge of results: Hardesty, Trumbo, and Bevan,
1963; Wilkinson, 1964.

Effect of experimenter's presence: Fraser, 1953.

Physiological Correlates: Pooch, Tuck, and Tinsley, 1969.

Stresses:

Excessions: Chiles, Fox, Rush, and Stilson,
1962.

General Types of Vigilance Tests:

Very long term monitoring or responding, involving days or longer:

Vigilance for a "signal" compared to a "null state." ('Nonsig-
nal' is the absence of a signal):

Threshold determination:

Non-threshold determination:

One locus:

Multiple loci:

Vigilance for a "signal" compared to an occurring "non-signal":

Threshold determination:

Non-threshold determination:

Locus of signal vs non-signal:

Modalities of vigilance tests:

Vision: see Kennedy, 1969.

Audition: see Gulian, 1966.

Other senses:

Special Vigilance Test Techniques

Visual:

Multiple signals (lights and dials): Broadbent, 1951:

The 20 Dials Test: Sharp, ; Loeb and Binford,
1968; Jarison, 1957.

Single Signal, (lights and dials): Ormiston and Finkel-
stein, 1961; Altman and Haythorn,
1967; Pope, 1962.

The Synthetic Radar Test: Mackworth, 19 :

The Mackworth Clock Test: Mackworth, 19 ; also
Hardesty, Trumbo, and Bevan,
1963.

Related to tracking: Pope, 1962.

Auditory:

The listening tests (preliminary and main): Mackworth,
19 .

The Wilkinson Vigilance Test: Taub and Berger, 1969;
also see Wilkinson references.

Others: see Kidd and Micocci, 1964.

Using numbers: Thompson, Opton and Cohen, 1963.

Related to tracking: Pope, 1962; Gullian, 1966.

SECTION II A

EVALUATION OF MOTOR PROCESSES

Introduction and Definition

Non-discrimination responses:

General reviews: see Vernon, McGill, Gulick,
and Candland, 1959; Carver and
Winsmann, 1968a,b; Lynch, 1964;
Fleishman, 1964; Thompson,
Thompson, and Dusek, 1953;
Brown, 1954.

Upper limb responses

Finger and hand tremor:

Light beam interruption: Eagles, Halliday, and Redfearn;

Halstead's Finger Oscillation Test: Vega, 1969.

SAM Steadiness Test: Grether, 1945.

Stasiometer: Gray, Sustare, and Thompson,
1953.

Trembleometer: U.S. Dept. Army AGO, PRB, 1953;
Miller, 1953.

Others: Parsons, 1954; Simon, 1969;
Lockhart, 1968.

Tests of turning and cranking wheels: Jones, 1968; Bilodeau, 1952 and 1953.

Tapping - endurance, speed and pace:

Endurance and speed: Lockhart, 1968; Groden, 1968; Fleishman, 1964 (loads .39 on explosive strength and .44 on speed of limb movement).

Printed Tapping Test: Brozek and Taylor, 1954.

Pacing and Intersensory effects: Rabinovich, 1969; Karlovich and Graham, 1967 and 1968a,b; Kennan, 1968; Hishima, 1968; Denner, Wapner, McFarland, and Werner, 1963; Hoffman, 1969.

Shoulder stamina: arm circling: Fleishman, 1964 (loads .52 on explosive strength and .39 on speed of limb movement).

Arm strength or stamina:

Arm pull (dynamometer): Fleishman, 1964 (loads .71 on static strength).

Arm support of body (Bent arm-hand, timed): Fleishman, 1964 (loads .73 on dynamic strength).

Myograph: Dearnaley, 1963.

The Pull Test: Mackworth, 1950 (used with heat stress).

Punching Test:	Sinha, 1958; see Smith, 1968a,b; Boldt, 1954;
Ergograph:	Kozlowski, 1952.
Hand grip:	
Dynamometer:	Fleishman, 1964 (loads .68 on dynamic strength); Jeanneret and Webb, 1963.
Measurement of hand movement:	Birmingham, 1955.

Lower limb responses

Foot tests:

Two-foot tapping:	Fleishman, 1964 (loads .46 on speed of limb movement).

One-foot tapping:	Fleishman, 1964 (loads .58 on dynamic flexibility).

Knee Jerk test:

Barry, 1931.

Leg tests:

Fleishman, 1964.

Leg raiser:

loads .35 on dynamic strength
and .43 on trunk strength.

Leg lifts:

loads .32 on dynamic strength
and .47 on trunk strength.

Leg circling:

loads .27 on explosive strength
and .48 on dynamic strength.

Deep knee bends:

loads .25 on dynamic strength,
explosive strength, and weight
balance.

Body Responses (all the following are referenced to Fleishman, 1964)

Stretching, Twisting and Bending

- Abdominal stretch (loads .55 on extent flexibility)
- Bend, twist, and touch (loads .50 on dynamic flexibility)
- Lateral bend (loads .58 on dynamic flexibility)
- Squat thrust (loads .45 on dynamic strength and .40 on athletic experience)
- Squat, twist, and touch (loads .53 on dynamic strength)
- Toe touching (loads .28 on explosive strength and .39 on extent flexibility)
- Twist and touch (loads .49 on extent flexibility)

Jumping and Climbing

- Cable jump test (loads .56 on gross body coordination)
- Rope climb (loads .67 on dynamic strength and .41 on explosive strength)
- Standing broad jump (loads .35 on dynamic strength and .66 on explosive strength)
- Vertical jump (loads .30 on dynamic strength and .64 on explosive strength)

Strength tests

- Dips (limit and time limit, load .68 and .70 on dynamic strength; .27 and .33 on explosive strength; and -.30 on athletic experience)
- Pull-ups (limit and time limit, load .78 and .81 on dynamic strength; .29 and .40 on explosive strength)
- Pull-weights (arms, loads .33 on static strength, .50 on weight balance)

Push-ups (limit and time limit, load .68 and .74 on dynamic strength).

Push-weights (feet and arms, time limit, load .35 and .51 on static strength, .43 and .44 on weight balance, and .38 on dynamic strength).

Trunk pull (loads .59 on static strength).

Chin-ups: Evans and Consolazio, 1967.

Sit-ups (Fleishman, 1964, again: load .31 and .30 on dynamic strength, .33 and .26 on explosive strength, and .45 on trunk strength).

Stamina tests

Bicycle ergometer: Gerben and House, 1969; Moss, 1931; Ryan, 1944; Evans and Consolazio, 1967.

Harvard step test: Ariel, 1969; Srivastava et al., 1968; Montoye, 1953.

Treadmill: Evans, 1963; Lukin, Polissar, and Ralston, 1967.

Running tests (back to Fleishman, 1964)

Speed

Ten yard dash (loads .28 on dynamic strength and .70 on explosive strength).

Shuttle run (loads .39 on dynamic strength and .77 on explosive strength).

600 yd. run-walk (measures cardio-vascular endurance).

50 yd. dash (loads .44 on dynamic strength and .75 on explosive strength).

Circle run (loads .59 on explosive strength).

Agility and speed

Dodge run (loads .69 on explosive strength).

Figure 8 duck: Alluisi, Chiles, Hall, and Hawkes, 1963 (loads .68 on explosive strength).

Grass drill: Alluisi, Hall, and Chiles, 1962 (loads .62 on explosive strength).

Throwing, pushing, and moving objects

Medicine ball put (standing and sitting): Fleishman, 1964; Evans and Consolazio, 1967 (load .44 and .71 on static strength).

Softball throw: Fleishman, 1964 (loads .32 on static strength and .54 on explosive strength).

Tongue (lingual strength): apparatus, Sanders, 1969.

Verbal production (repeating a word for one minute):

Charlip and Burk, 1969 (used under noise stress).

Stick balance: Fleishman, 1964 (loads .33 on balance-visual clues).

Ball balance: Fleishman, 1964 (loads .47 on speed of limb movement).

Vestibular-Kinesthetic Movement Tests

Standing sway and ataxia:

Ataxiameter test: Seashore, 1932.

Balance tests (one and two foot lengthwise, eyes open and closed; one and two foot cross balance, eyes open and closed): Fleishman, 1964
(load .53 and .44 on gross body equilibrium;
.32, .26, and .64 on balance-visual cues;
.31 and .33 on speed of limb movement).

Romberg test: Grant, 1942.

Effect of noise: Bensei, Dzendole, and Meiselman,
1968; Garmize and Marcuse, 1969;

At altitude: Birren, 1945.

At altitude and under CO: Vollmer *et al*, 1945.

Apparatus: Furneaux, 1951; Leavitt, 1968;
Brown and Whitman, 1963; see
also Jones, 1959.

Dynamic sway and ataxia:

Rail-walking tests:

Pensacola Ataxia Battery: see Graybiel and Frégley,
19 ; Heath, 1942 and 1944.

Brief vestibular disorientation test: Ambler and Guedry,
1965 and 1967.

Sitting, movement:

The Chair Stabilometer: Fujita and Spitzer, 1964.

SECTION II B

MOTOR DISCRIMINATION RESPONSES

In previous sections dealing with tests of motor responses, the concern has been with tests of what might be termed the subject's physical integrity, or an evaluation of the quality of the subject's "pure" response. The tests were limited to those which required very little choice from the subject other than the decision to start or stop an action. Precision, stamina, strength or dexterity may have been required to perform such tests, but in all cases these qualities were elicited in a discrete way which did not require the subject to calculate changing functions (as, for example, in a compensatory tracking task), respond differentially (as in a choice reaction situation), nor even to follow complex, nonchoice directions in making a series of motor responses.

In the present section, the concern is broadened to include tests of motor function in which the elements of choice, decision, flexibility, etc., are significant components of the final performance quality. Thus, in this section, we are no longer limited to the determination of whether the subject is physically intact, or whether he has some basic motor deficiency. Now we are interested in whether he is able to use motor capabilities in some unified, complex, goal directed task which will normally require a significant amount of coordination or decision. The distinction is equivalent to the difference between knowing that a subject's auditory acuity is normal,

and then asking whether he can track a sound source in space. The one is an elaboration and significant extension of the other.

The one unifying principle which operates in all these tests is a requirement for control precision. There is always an external object of control. Thus, there is always an object involved in these tests -- such as a control stick, response board, or even a sheet of paper. This was not necessarily true in previous tests, e.g., balance, running, etc. Further, the question of interest to the experimenter is the precision with which the subject is able to control this object. So, unlike say the key tapping described in the previous section, the subject in the present case must be concerned with the way in which he interfaces with the external object, i.e. how well he does it, not just whether he taps the key.

We see, therefore, that these tests are more specific in some respects than those presented previously. They do not ask the most general question of whether the subject is physically able to respond, but rather, can he respond in this type of real-world control situation? Put differently, can he interface precisely with this class of system? Obviously, this question begins to get closer to "real world" concerns, and face validity begins to increase. However, this is done at certain costs in terms of generalizability and interpretability. These costs will be briefly indicated as various tasks are described.

Aiming Tests

Visual-motor coordination is a broad topic with many possible schemes which could be used to subdivide it. In the present case, a scheme oriented to the tests themselves has been chosen, in keeping

with the overall desire to classify tests in the most simplistically descriptive way possible. Thus, a form of visual-motor coordination is embodied in those tests which require the subject to hit a target or targets accurately with a controlled object. Such tests range from those requiring the use of small tools or objects (e.g., using a pencil or a stylus) to using a large object to propel another object, whose accuracy in hitting the target is then measured. In the test types considered below, tests requiring predominantly discrete aiming movements will be noted first, and later types will move to those tests requiring more sequential patterning of the aiming responses.

TEST 11 B (1): SIMPLE THRUST AIMING. One can devise a number of tests which require the subject to simply aim at a target at arm's length and to make a rapid or slow approach to the target with a stylus of some sort. Perhaps the simplest version of such a test was used to test "eye-hand coordination" in weightlessness (Gerathewohl, Steughold, and Stallings, 1957). In this, the subject simply stabbed at a paper bulls-eye. A number of trials were given and the test was scored in terms of the distance and direction of errors. Obviously, if the experimenter is interested in a gross score such as this, a great many variations are possible on this simple design. Direction of thrust might be varied; the test might be combined with a signal in order to determine reaction time or accuracy with various signal rates or target positions; or the task might be combined with another primary task to determine accuracy with varying workload. The test might even be used with legs instead of arms. A possibly fruitful variation might involve use of targets designed to be visually illu-

sory (e.g., Muller-Lyer figures) to determine the visual-motor coordination under atypical visual input. All of these uses, of course, would constitute new tests of rather unknown quality, since no standardization or experimental study of this type test was uncovered. The user, therefore, is left with a unique test for which he has no empirical basis and little chance of relating the task to other work. In some senses the test probably measures eye-limb coordination, involving at least visual pathways, proprioceptive kinesthetic sensitivity, and deep brain structures. On the other hand, one would think that except for specific system questions or in specific environments (such as weightlessness) a number of better defined tests described below might be more advisable.

Another form of the simple thrust aim involves placing a stylus in a "home" position and moving it to a target. This movement can be made to a signal or it can be a self-cued movement. Clearly, some precision is gained in analyzing the results, since where the subject's movement started and when are always obvious. With such a device, travel time can be obtained (see RT section) and a variety of techniques are opened up to the researcher. For example, Keele and Posner (1968) used such a system to determine the processing time of visual feedback. When the subject's stylus left the "home" position, all lights went out on half the trials. In this way they were able to determine that for travel times of 260 milliseconds or longer, the lights facilitated aiming. Such sophisticated use of a basically simple performance task illustrates the flexibility which many of these tests can have and the complex questions which can be addressed through their use.

TEST 11 B (2): PATTERNED THRUST-AIMING. In this class of tests, the subject is required to aim at a target some distance less than arm's length from him. However, there is more than one target, and the task includes hitting the targets in a particular sequence. The task is similar to that described in 11 B (1) except for the addition of patterned aiming. Two examples of this type test will be described, one involving use of a stylus and one not. Because both of these versions have been subjected to extensive statistical treatment and have a great deal of information available, they would seem to deserve serious consideration if the experimenter has determined that the overall "thrust" type of aiming test is desirable.

The Ten Targets Test: The apparatus for this test is a box measuring $13 \times 11\frac{1}{4} \times 10$ inches. Ten holes of varying sizes are cut in the front face of the box, and the subject thrusts at the holes in a predetermined sequence with a stylus $8 \frac{3}{4}$ inches long. The panel is connected to counters so that correct thrusts, as well as misses, can be counted. As used by Fleishman and Ellison (1962) six 30-sec. trials were given with some rest allowed between trials. Thus, administration time would be six to seven minutes. The test has been used to obtain error and correct scores on alternate trials; reliabilities of .94 and .91 have been reported for errors and corrects respectively.

This test has been subjected to extensive factor analysis by Fleishman and his associates (see Parker and Fleishman, 1960; Parker, Reilly, Dillon, Andrews, and Fleishman, 1965). A factor loading of .31 was found for the "corrects" score on "aiming," with loadings of from .50 to .72 on "speed of arm movement" and from .05 to .42 on

"manual dexterity." The "error" scores loaded .35 to .43 on "manual dexterity" and from -.70 to .63 on "speed of arm movement." Seemingly, this test is subject to strong influences from practice, the particular sequence of holes chosen, the stylus dimensions, distance from the target, and a variety of other experimental considerations. Therefore, the potential user of this test should follow past procedures with great care, or be aware that the nature of the task itself can change drastically with small changes in technique.

Rotary Aiming Test: This test is very similar to the one described above except that the subject does not use a stylus. The apparatus consists of a horizontal panel containing 12 buttons in a circular pattern. The subject's task is to strike at the buttons, going from one button to the next as rapidly as possible. As used by Fleishman (1958) the subject was given four 30-second trials with 25-second rests between trials. The test was scored simply in terms of the number of buttons struck during the trials. The reliability of this test is reported to be .92. Several factors have been identified in this test, including speed of arm movement (.02 to .53), aiming (.22 to .38), and wrist-finger speed (.36) (see Parker, Reilly, Dillon, Andrews, and Fleishman, 1965; Parker and Fleishman, 1960).

This test would seem to involve a somewhat different task than the ten targets test described above, since there is somewhat less requirement for manual dexterity and possibly more for wrist-finger speed. The subject in this test, of course, is not manipulating a stylus. Further, there is less requirement for remembering a response pattern. Errors in this test are not scored separately, but one can probably assume that such errors as might happen usually

result in lower scores for the subject. In general, this test would appear to be a reliable, rapid, and relatively simple way to measure "aiming" of a particular kind. If fine manual dexterity is not a significant requirement for this test, the experimenter would be well-advised to consider this simple test.

TEST 11 B (3): PENCIL AIMING TESTS. There are a number of tests which are very similar and which require the subject to put one or more marks in a small area of an answer sheet. Most of these tests load on the same factors to roughly the same degree. However, close inspection will reveal small differences between these tests; if such detail is called for by the experimental design, one should be able to choose from the following list a test which will be appropriate to a given requirement.

Tapping Tests (Large, Medium, Small): These are a series of rapidly administered tests which present the subject with a sheet of paper on which have been printed a series of small circles. The subject has a 60-second time limit and, in that time, he is to place a required number of dots in as many circles as possible. For the Small Tapping Test (also called the Aiming Test) the circles are $1/8$ inch in diameter, and the subject is to put one dot in each circle (Fleishman and Hemple, 1954). For the Medium Tapping Test, the circles are $3/8$ inch in diameter, and in the Large Tapping Test, they are $1/2$ to $7/16$ inch in diameter. In both of the latter two tests, the subject is to place three dots in each circle (Fleishman and Ellison, 1962). Reliability for the large test is reported to be .94, and for the small test, .89. The small test loads on aiming

(.36 to .57) and on wrist-finger speed (.42 to .52). The medium test has shown loadings on wrist-finger speed (.74 to .77) and speed of arm movement (.28). The large test has shown factor loadings on aiming (.33), wrist-finger speed (.43 to .75), speed of arm movement (.21 to .31), and manual dexterity (.28). This test has been used with subjects undergoing the stresses of parachute training (Miller, 1953).

Pursuit Aiming (I and II): These tests are similar to the tapping tests except that the subject must follow a pattern in placing the dots. He is presented with a series of circles which are connected by lines. These lines define his route, and he must place one dot in each circle. In Pursuit Aiming I, the circles are $3/16$ " in diameter, and the route through the circles is fairly regular. In Pursuit Aiming II, the circles are $1/8$ " in diameter (the same as the Small Tapping Test), but the route is highly irregular (see Fleishman and Ellison, 1962). The subject has 30 seconds for test I and 60 seconds for test II; his score is the number of dots placed correctly in these time periods. For both tests, factor loadings have been reported on aiming (.63 to .68), wrist-finger speed (.48 to .54), and finger dexterity (.23). The loading on "aiming" appears especially high in this test, and its simplicity recommends it whenever there is no need for a more complexly structured task.

Square Marking Test: In this paper and pencil test, the subject is given a printed series of squares with small $1/8$ " squares marked off in the corners of the larger square. His task is to place X's in as many of the smaller squares as possible in a 60-second trial. A reliability of .92 has been reported for this test, and it

has shown factor loadings on aiming (.30, .31, .55, and .71) and on wrist-finger speed (.29 and .46) (Fleishman and Ellison, 1962; Fleishman and Hempel, 1954; Parker, Reilly, Dillon, Andrews, and Fleishman, 1965).

Marking Accuracy Test: Again, this test is virtually identical to some of those presented above. But, in this case, Fleishman and Hempel (1954) used IBM marking sheets on which certain slots were circled. The subject's task was to mark in the circled slots as fast as possible. Two trials of 40 seconds each were given, the score being the number of rights minus the number of wrongs. Reliability of .91 has been reported. Factor loadings in several studies (see Parker, Reilly, Dillon, Andrews, and Fleishman, 1965; Fleishman, Roberts, and Friedman, 1958) include aiming (.37 to .52), manual dexterity (.28 to .73), spatial orientation (.34 to .35), finger dexterity (.31 to .37), visualization (.32), and auditory perceptual speed (.28).

TEST II B (4): AIMING AN OBJECT AT A TARGET. These tests differ from those presented previously in that the subject does not control the aimed object until it hits the target, but rather propels it toward the target.

Rifle Aiming: A technique has been reported by Spring (1952) which allows the precise recording of errors in rifle aiming through use of a dual optical system. With this apparatus, the experimenter can record the accuracy and steadiness of the rifle's aim by a subject. The system uses a series of lenses and slits to produce a collimated beam which is subsequently reflected through several

stages and eventually produces a dot of light on a moving film. Movement of the rifle produces movement of the dot (1° of rifle movement producing about 8mm. of movement on the film). Such a system is used to record both elevation and azimuth errors. The entire apparatus adds only 2 oz. to the rifle itself, since only a mirror is attached. A schematic view of the device is provided in the above article. Apparently this device, though complex, could be used in modified form in a number of environmental settings. Very fine visual-motor coordination is involved here, and the task could be made to have a high degree of face validity.

Summary: In this section, several tests have been presented which, in common, have an "aiming" component. Many appear almost identical, but factor analytic studies have revealed subtle differences between them. To aid in overall comparison, Table II B 1 presents a summary of factor loading reported in those tests contained in this section.

Fine Manual Manipulation Tests: Many tests of fine manipulation have been produced in industrial settings, primarily as selection or evaluation devices for employees (). Most of these tests have had a single use, or have been used extensively in a single setting. Some, though, have gained a more general usage, and have become relatively standard tests for many industrial settings and, in some cases, for laboratory research in human performance. Only these later types will be described in this section since they probably encompass most of the previously used techniques for measuring fine manipulation, and since they represent the only relatively standardized techniques available.

TABLE II B 1

	TEN TARGETS TEST (CORRECTS)	TEN TARGETS TEST (ERRORS)	ROTARY AIMING	TAPPING TESTS			PURSUIT AIMING		MARKING ACCURACY	SQUARE MARKING
				LARGE	MEDIUM	SMALL	I	II		
Aiming	.31		.22, .38	.33		.36, .54, .57	.63; .68	.63	.37, .40, .52	.30, .31, . .71
Manual Dexterity	.05, .42	.43, .35		.28	-				.28, .32, 38, .53, .73	
Speed of Arm Movement	.50, .66, .72	-.70, -.35, .63	.02, .38, .46, .53	.31, .21	.28					
Wrist-Finger Speed			.36	.75, .43, .74	.77, .74	.42, .52	.52	.48, .54		.29, .46
Finger Dexterity							.27	.28	.31, .36, .37	
Spatial Orientation									.35, .34	
Visualization									.32	
Auditory Perceptual Speed									.28	

Specifically, we are dealing here with tests of visual- or kinesthetic-motor manipulation essentially requiring fine adjustments of small muscles in the hand. We are not referring here to tests of visual-motor precision such as aiming or dial setting. The precision required in the present tests is more directed to sequentially produced motor behaviors where the visual input is auxiliary, although it may or may not be essential. These tests are sometimes called manual dexterity tests, although we would wish to avoid the factor analytic connotation of this term in the general case and look more at the factorial composition of each specific test. Most of the tests to be described are commercially produced, and where this is known, information on cost and availability is given.

TEST II B (5): ASSEMBLY TASKS. A relatively quick and interesting test of fine manipulation can be constructed by simply having the subject assemble or disassemble small objects. If the objects used are similar to real-world objects, such as nuts and bolts, machine parts, or production-line products, then the task can have a great deal of face validity and, in some cases, considerable content validity. In general, the specific task to be used can be anything on which the experimenter can obtain an accurate and meaningful score, either in terms of accuracy or speed or both. However, as with most "home grown" tests, certain problems exist which must be considered.

First of all, in the type of tasks likely to be used in such a test, there is usually considerable learning involved in early trials. The shape of this learning curve is not predictable in any general sense. Depending on the specific task, it may be extremely

steep in the beginning and reach asymptote very early or it may be a positively accelerated curve, or it may be very slight for a considerable time and then "shoot up" rapidly as the subject discovers a new technique for the task. What is worse, all of these may appear at different times in the same complex learning curve. A second problem arises in the differences in experience level of the different subjects with the task being used. Using more common items, such as nuts and bolts, may reduce this problem somewhat, but there are still likely to be wide variations between subjects in initial skill. Problems such as these point up the need to devote an unusually great deal of time and attention to the experimental design when using any of the tests in this category. With such attention, it is possible to use them fruitfully. Without it, the results are worse than useless.

The Pennsylvania Bi-Manual Work Sample: This is a test developed by J. R. Roberts involving both hands and the subject's capacity for performing a relatively simple manipulation. The subject selects a bolt with the thumb and index finger of the right hand, and a nut with the thumb and index finger of the left. He then assembles them, placing the product in a hole of an 8" x 24" board. There are 20 practice combinations and 80 to be done while being timed. Standardization is based on 5790 cases. The subject can also be required to separate all 100 assemblies (saving the experimenter considerable time). In this case, the correlation between parts is only .55, which indicates considerable independence between whatever the parts are measuring. Split half reliability is reported to be .95 (test-

retest reliability is estimated at .80 to .85). Correlations with other dexterity tests are .46 and .40 for the Minnesota Rate of Manipulation Placing and Turning tests respectively. The test takes 10 to 20 minutes to administer, and norms have not been extended below 16 or above 39 years. No factor analytic studies have been reported, but one would assume that the test might measure qualities such as aiming, finger dexterity, speed of arm movement, visual-motor coordination, multi-limb coordination and wrist-finger speed.

This test is produced by the American Guidance Service, Inc. The complete set of board, bolts, nuts, case, 50 test forms and manual is listed at \$32.00; Cat. #C-126.

Bennett Hand-Tool Dexterity Test: This test is reported to measure proficiency in the use of wrenches and screwdrivers. It consists of a wooden frame with an upright at each end. The frame measures about 9" x 9" x 18". In the left hand upright, twelve fastenings are attached through holes. The subject's task is to take the fastenings apart in prescribed sequence using wrenches and screwdrivers. He then reassembles them on the right hand upright. About 7 minutes is usually required for this task (4-12 min). Norms are available for adolescents and adults. The test is manufactured by Psychological Corporation and the set, with manual, is \$44.00, Cat. #3A019. This test is of primary use in industrial settings, and would appear to be appropriate only in extremely specific performance situations (e.g. when questions of this particular work sample are involved).

TEST 11 B (6): FINE MANIPULATION PLACING AND POSITIONING TESTS USING

TOOLS. In this type of test, the subject is required to place or fit an object into a designated position, or he is required to adjust the position of an object. Both of these tasks are to be carried out through use of a tool or device, adding additional dimension to the task. Again, obviously, many such versions of this basic test type are possible. A few have received rather wide usage and will be described here.

O'Connor Tweezer Dexterity Test: This test consists essentially of a board in which there are 100 holes $1/16''$ in diameter. Above the holes is a shallow well which contains a number of pins. The subject uses tweezers to pick up a pin and insert it into one of the holes.

Under "color shock," no significant disturbances were found in this performance (Kline, 1953). This test is manufactured by the Lafayette Instrument Company, and the price is \$23.00 (Cat. #32022). A set of 100 extra pins costs \$2.00 (Cat. #32106).

Crawford Small Parts Dexterity Test: The apparatus for this test is a 10" x 10" board containing three wells for placement of screws, pins, and collars, and two sections of 42 holes. In Part I of the test, the subject is required to use tweezers to insert small pins in close-fitting holes and then to place small collars over the pins. In Part II, the subject places small screws into the threaded holes, and screws them down until they drop through into a dish below. Thus, the subject is required to grasp, aim, position and manipulate the objects precisely in order to achieve a good score. The test can be given in two ways. In the work limit method, the subject is timed until he achieves a given productivity, and time is the score. This method usually takes 9 to 25 minutes (median 15) and percentile norms are available for ten applicant, employee, and student groups, both male and female. In the time-limit method, the number of correctly placed parts in a given time (usually about 10 minutes) is the score. Only tentative norms are available with this method. The test is manufactured by The Psychological Corporation. Cost for the set, with manual and spare parts, is \$43.00 (Cat. #3N010).

The Craik Screw Test: (Contrary to what one might think) the subject's task in this test is to loosen or tighten a line of screws mounted on top of a long wooden box.

The task has been used under the stress of body cooling (thermal stress) (Lockhart, 1968) where it was found that a mean weighted skin temperature of 70° did not affect performance.

TEST II B (7): FINE MANIPULATION POSITIONING AND PLACING TESTS: NOT

USING TOOLS. In the tests to be described below, the subject is required to alter the position of a test object in some way using his hand. The task may be a relatively simple turning of the objects, or it may involve placing the object in a defined place with great precision. In contrast to previous tests in this series, the subject is not required to use tools, nor is he essentially concerned with a bi-manual task.

The O'Connor Finger Dexterity Test: In this test, the subject is required to pick up a number of pins one at a time and insert them into small holes. The test has taken a number of forms since first being introduced by Kimble in 1917 (see Corlett, Salvendy and Seymour, 1971; Hines and O'Connor, 1926; O'Connor, 1928; O'Connor, 1938; Dardenne, 1952). In its present form, it consists of a shallow well below which is a 10 x 10 matrix of holes, each $3/16$ " in diameter and spaced $1/2$ " apart (Lafayette version). The pins to be inserted are 1" long and about $1/16$ " in diameter. Buros (1965) provides 47 references to this test.

The subject's task is to pick up three pins with his preferred hand and insert them into a single hole. As O'Connor and others have used the test, the score is the time required to fill all 100 holes,

and this usually ranges from 8 to 16 minutes. Fleishman has used a 5 minute time limit in which the score is the number of holes filled. With this scoring system, a reliability of .76 was found. Fleishman has also reported factor loadings on finger dexterity (.53, .55, .59, .49), manual dexterity (.25 and .50), and visual feedback (.43) (Fleishman, 1953; Fleishman and Hempel, 1954; Fleishman and Ellison, 1962; Parker and Fleishman, 1959).

This test is currently manufactured by Lafayette Instrument Company, and lists for \$26.00 (Cat. #32021). Sets of 300 extra pins are \$3.50 (Cat. #32105).

Grooved Pegboard: This is a manipulative dexterity test manufactured by Lafayette Instrument Company. It consists of a small board containing 25 holes. The holes will hold special pegs, which consist of a pin with a slot attached so that they are like keys. The holes in the board will accomodate any peg, but the slot holes are randomly positioned so that the subject must rotate the pin to its proper position before inserting. Thus, the test requires somewhat more visual-motor coordination than most pegboards. This test has been used to evaluate lateralized brain damage. However, no extensive statistical information was uncovered. Cost is \$25.00 (Cat. #32025) and 30 extra pegs list at \$14.00 (Cat. #32104).

Minnesota Manual Dexterity Test: This is a widely used test of visual-motor coordination. The test consists of a masonite board with 60 equally spaced holes in a 15 x 4 matrix. The subject is required to pick up wooden blocks, approximately 1" in diameter, and place them in the holes. The blocks are laid out in a set sequence,

and each block is to be placed in a specific hole. No turning or specific positioning of the blocks is required, and the subject is not required to differentiate specific sizes or shapes. The test is manufactured by Lafayette Instrument Company and lists for \$60.00 (Cat. #32023) for 60 blocks, 1 board, carrying case, manual, and record blanks.

Minnesota Rate of Manipulation Test (1969 Edition): In form, this test is almost identical to the Minnesota Manual Dexterity Test described above. The test board contains 60 wooden blocks which the subject must place. However, this version of the test (produced by American Guidance Service) uses several other tasks which the subject must perform on the blocks while placing them. Consequently, there are 5 separate subtests, each requiring 10 minutes or less to administer. These include: The Placing Test, The Turning Test, the Displacing Test, The One-Hand Turning and Placing Test, and The Two-Hand Turning and Placing Test. Internal consistency is estimated to range from .86 to .95. Reference norms are available based on 11,000 employed and unemployed young adults, and on 3,000 older adults. It would appear that for the tests involving larger-object manipulation, this particular version provides more extensive background information and more standardization and flexibility. One may suppose that the test might measure aspects of finger dexterity, wrist-finger speed, speed of arm movement, visual-motor coordination, bi-manual coordination, and several aspects of laterality. List price is \$48.00 for the set, record forms, and manual (Cat. #C-125). The manual separately, listing previous work, is \$2.00 (Cat. #M-125).

Stromberg Dexterity Test: This test is similar to the Minnesota tests except that the biscuit-sized discs have to be sorted before they are placed. In addition, the discs must be placed precisely in order to attain maximum speed. Therefore, the sequence of movements required is not repeated exactly for each placement. Discrimination and placement are determined by color and by sequence, introducing significant elements not included in the Minnesota tests. The range of the test includes adolescents and adults. It is manufactured by The Psychological Corporation and lists for \$56.00 with manual (Cat. #3P010). The manual separately is \$.60 (Cat. #3P408).

Blocks Test (MacQuarrie Test for Mechanical Ability): See the MacQuarrie test description (pp.) located in the section on test batteries.

Santa Ana Finger Dexterity Test: This test, described by Fleishman and Hempel (1954) consists of a board with 48 square holes. Into these are fitted pegs which have rounded tops painted half blue and half yellow. The subject is presented the board with all pegs in place and having the colors all facing in the same direction. He is given two 35-second trials, in each of which his task is to lift each peg out of the hole, rotate it 180°, and return it to the same hole as fast as possible. The square holes, of course, prevent his turning the peg without first lifting it. Thus, a rather difficult sequential task is created without imposing complex memory for directions or other intellectual loads. Reliability of .91 is reported

for this test. Factor loadings have been found on manual dexterity (.28, .38, .38, .45, .47), wrist-finger speed (.33), timing (.17, .33), finger dexterity (.06, .16, .42, .46), and spatial orientation (-.07, .20, .39) (see Parker, Reilly, Dillon, Andrews, and Fleishman, 1965). The test has not been found in commercial listings.

The Purdue Pegboard: The Purdue Pegboard is one of the most widely used tests of its kind. Like the O'Connor Finger Dexterity Test, this represents an evolution from the original matchboard constructed by Kemble (see Corlett, Salvendy, and Seymour, 1971). Buros (1965) provides 41 references, as well as a critical evaluation of this test. Tiffen and Asher (1948) provide norms, as well as reliability and validity data. In addition to its use in a number of experimental situations (other than for personnel selection) the test has been treated in several factor analytic studies (Fleishman and Ellison, 1962; Fleishman and Hempel, 1954; Parker and Fleishman, 1959). Results of these will be summarized below.

Basically the test consists of a board (11 3/4" x 17 1/4") with 25 small holes in each of two rows up the middle. There are four shallow bins at the top of the board which hold pegs, collars, and washers. Administration of the test takes 10 to 20 minutes, and consists of a number of individually timed subtests. In a common mode of presentation, the subject is required to pick up a pin and insert it into one of the holes with one hand, using a predetermined sequence. Two 30-second trials are given for each hand. Another subtest requires the subject to pick up two pins simultaneously, one with each hand, and insert them. Two 30-second trials are

also given in this case. Another subtest requires assembly of the pins, washers, and collars. Reliabilities have been reported for the right hand (.70), left hand (.68), both hands (.70), the assembly task (.74), and the whole test (.90). It is clear, therefore, that the subtests are not particularly reliable, and this fact should certainly be considered by anyone contemplating use of the test. The factor analytic studies mentioned above have revealed loadings of .38 on positioning for the right hand subtest, .32 on manual dexterity for the assembly subtest, and loadings on finger dexterity of .46 for the right hand, .62 for the left hand, .61 for both hands, and .57 for the assembly subtest.

The Purdue Pegboard has been used in a cold environment ($^{\circ}$ mean weighted skin temperature) and showed no decrement (Lockhard, 1968). Vega (1969) has discussed the use of this test as a screening device for organic brain pathology, and such considerations may apply to certain areas of stress research. Walk (1964) used this pegboard with pressure-suited subjects in different conditions and concluded that it was a delicate measure of finger dexterity under these conditions.

On the other hand, the Purdue Test has been criticized from a number of aspects. Buross (1965) provides a comprehensive critique of the test. Corlett, Salvendy, and Seymour (1971) used high speed film of a subject performing on the pegboard. Analysis of the film indicated that the score was critically affected by the method of using the thumb and fingers, and by whether the operator looked at the task or not. In addition to the overall time, the standard devi-

ation and the number of fumbles were also affected by these factors. With respect to speed-skill acquisition, these authors concluded that the Purdue Test is inherently too variable.

The test is manufactured by the Lafayette Instrument Company, and lists for \$24.50 (Cat. #32020) with instruction manual. A replacement set of 50 pegs, 40 washers, and 20 collars, is \$6.00 (Cat. #32103).

The One-Hole Test: Corlett *et al* (1971) found the Purdue and O'Connor tests unsatisfactory in terms of the variability of several of their elements. This group, therefore, set out to establish a test which would reduce these variability problems. They first tried a modification of the Purdue Test in which the distance from pins to hole was the same on each trial. This resulted in less variability in the move element than the original Purdue Test, but still had the random arrangement of the pegs. In view of this, the One-Hole Test was developed. In this test, the pins are all prepositioned in such a way that the distance between the grasp position and the hole is always the same (Salvendy, Seymour, and Corlett, 1970). As used by these authors, each subject performed 15 trials of one minute each, and the score was the number of correctly placed pins on each trial. Reliabilities for the One-Hole Test ranged between .54 and .92 for various groups, which was better than the .21 to .80 reliabilities found on the same groups for the Purdue Test. High speed film analysis indicated that the variable factors and chance effects seen in the Purdue Test did not appear on the One-Hole Test. Validity measures against certain industrial performance criteria indicated

that both the rate of improvement and the final scores derived from the One-Hole Test are more closely associated with the prediction of speed-skill in these performances than measures derived from the Purdue Test.

Apparently, for those situations where the Purdue or O'Connor Tests are appropriate, the One-Hole Test provides an equivalent and, in some cases, preferable alternative. Sources of variability are reduced, and the task would appear to be much more reliable. These factors could allow the experimenter to use a smaller number of subjects in some situations. One should remember that the very power of this test lies in its reduction of the visual-motor component and the standardization of finger-thumb interactions. Thus, it should be used in situations where it is not desirable to tap these skills. In addition, the test is not yet manufactured and, consequently, contact must be made with the author to obtain standardization instructions for fabrication (Dr. Gavriel Salvendy,).

VISUAL MOTOR TESTS OF SPATIAL ASPECTS

In this section are included those tests which require the subject to coordinate visual input and motor output to physically locate a point in two or three dimensional space, or to find and produce a desired path through some field of view. Thus, tracing tests and maze tests where the entire solution is visually before the subject at one time fall into this category. We are not concerned here with tasks which require the subject to visualize the

solution internally (e.g., typical spatial orientation tests such as the Combat Planes Test, p.). These are covered in the section on "Association Processes." Instead, in keeping with the orientation toward motor processes in the present section, we are interested only in those tests which give the subject the entire spatial route or field, and where his primary task is to coordinate this visual input with a motor behavior, even where some element of decision is involved, and where some "conceptual" visualization may precede the actual motor behavior.

TEST II B (8): SPEED OF PRODUCING PATHS AND FORMS. In this class of tests, the subject is required simply to trace a pattern. The pattern can be either already laid out or it can be clearly indicated on the paper or board. There is no real "noise" in the visual field, i.e. the path is not imbedded in other paths nor otherwise made hard to find. It is difficult to determine a priori what a test of this type will measure. Most likely, some aiming and positioning will always be involved, as well as visual-motor coordination. With variations in the pathway to be traced, one could require the subject to make rapid alternations, produce smooth movements, break a well-established "set," et. Speed is obviously the most basic score to be obtained in these tests; however, it would seem possible to obtain accuracy scores, even automatically, if this would ever be desirable. In this case, the task would approximate a primitive tracking task.

Tracing Test: This is a paper and pencil test used by Fleishman. The subject is presented with a printed rectangle divided into a series of columns by vertical lines. Each line is split at

... some point by a $1/16$ " opening. The subject is required to draw lines across the paper, going through the opening in each line. The score is the number of openings that were passed through, minus the number of times the pencil touched any line, in a 50-second trial. Reliability of .85 is reported for this test, and a factor loading of .39 was found on aiming and .27 on positioning (Fleishman and Ellison, 1962; Fleishman and Hempel, 1954).

Copying Test: This test has been used in several forms (see MacQuarrie's Test for Mechanical Ability, section : also French, Edstrom and Price, 1963). In one of its many possible modifications, it consists of a series of items, each of which shows a simple (four line) figure and a matrix of dots separate from the figure. The subject's task is to reproduce the simple figure within the dot matrix. A test of this form is copyrighted by Educational Testing Service. It consists of 32 items, takes three minutes to administer, and is reported to be suitable for grades 6 to 16 (NASA CR). Again, it is difficult to guess what this test will measure. As used in the MacQuarrie Test, it loads .53 on spatial orientation and visualization, and .36 on spatial orientation alone. However, without a great deal of information, or a specialized need, why such a test would be used in stress research is hard to see.

Tracing Subtest: This is a subtest of the MacQuarrie Test for Mechanical Ability (see section , pp.).

Letter and Number Joining Tests: In this class of tests, the subject is required to join a scattered array of letters or numbers in some predetermined sequence. The Letter-Pathways Test has been used by Roweton (1968) in an experiment on the effect of massed ver-

sus distributed practice. The Number Joining Test was used by Tsai and Newbold (1969), who used alternate forms and found a correlation of .71 and almost identical mean scores. They also found correlations of .93 between 4- and 6-minute segments of the test, .33 with a motor test, .47 with a perceptual test, and .58 with a coding test. Apparently then, when the test is used in this form, involving symbolic routes, there is a heavier central loading than is perhaps found when the linear path is laid out for the subject, as in the tracing tests above. In addition, there appears to be a perceptual component which is not obvious in the former tests.

TEST II B (9): MAZES. Human mazes have had rather extensive use (although they certainly cannot compete with animal mazes in this regard). Most mazes have been constructed for and used in the area of learning, and in the assessment of pathology, intelligence, etc. However, a few cases of maze use as a performance measure have been found. In these, the subject is generally given a series of printed maze problems and told to find the path visually or by using a pencil. Clearly, the task is somewhat different under these two conditions, and the experimenter should be aware of the added visual burden if no tracing is allowed. Another significant parameter in this type of task is whether there is any orderliness to the paths given in the various mazes. As the degree of similarity between the pathways increases, there is the introduction of the possibility for a type of concept formation, and the overall test might very well load highly in this area.

Considered generally, mazes are usually well received by the subject. They may be given over long periods of time and, by using some ingenuity, they can be made to have a great deal of face validity (e.g., circuit diagrams). However, scoring can be time consuming and difficult if anything but a simple time score is to be obtained. With the exception of the Porteus Maze Test noted below, there is no great amount of information available on the mazes used in performance measurement, and it might be just as well to construct a maze test for any specialized purpose that might require such a task. Other than the subject acceptability mentioned above, a maze test of performance might possibly be desirable in situations where there is concern that decrements in perceptual speed, closure, or short term planning might occur. However, inferences to such factors from maze performance must obviously be made with extreme caution.

Visual Pursuit Test: A type of maze used by Fleishman (1957) has more objective information available than most other such tests. In this, a series of lines of irregular shape are given to the subject, who visually traces them from beginning to end. Reliability of only .80 has been reported for this test. Factor loadings have been reported on perceptual speed (.38, .46, .46, .28, .50, .35), control precision (.24, .36, .20), spatial orientation (.17, .22, .35), and integration (.33) (see Parker and Fleishman, 1960; Parker, Reilly, Dillon, Andrews and Fleishman, 1965).

Maze Tracing Speed Test: (See NASA CR). This paper and pencil test presents the subject with a series of moderately complex

paper mazes (see French, Ekstrom, and Price, 1963). The test, as produced and copyrighted by Educational Testing Service, takes three minutes, produces four independently scorable units, and is suitable for grades 6-16. It is said to measure spatial scanning.

Choosing a Path: (See NASA CR). This printed test simulates circuit diagrams having a large number of intersecting wires. There are several sets of terminals shown, and the subject is to visually trace out the wires from S (start) terminals to see if there is a complete circuit to a corresponding F (finish) terminal. The scheme on each item has a similarity to other items; consequently, the subject might eventually develop a kind of set for the proper solution rather than relying simply on visual pursuit. This test, therefore, tends toward a heavy emphasis on inference or perceptual-set development which is not present in the previous maze tests. Educational Testing Service produces this test, and it is copyrighted by them (see French, Ekstrom, and Price, 1963). It consists of 15 items, taking 7 minutes and is suitable for grades 6-16.

Pencil Maze Apparatus: The Lafayette Instrument Company produces pencil mazes of two basic types. Although they are primarily designed for learning experiments, some use might be made of these tests in other contexts. One maze (Cat. #20014) uses a fairly complex series of choice points to form the maze, which is cut into an aluminum sheet. Standard $8\frac{1}{2}$ x 11 inch paper is placed under the maze to produce a permanent record of the subject's moves. Cost is \$16.00. An automated version of this maze is available (Cat. #20015; cost

\$48.00) which can be combined with any electrical counter (e.g., Lafayette Cat. #58022; cost \$39.00) to automatically tally the number of times a subject enters the wrong alleys of the maze. The classical sequence of T-type choices is also available from Lafayette in an aluminum maze with a vinyl-coated steel tray (Cat. #20016, cost \$11.00). This apparatus also uses standard 8½" x 11" paper placed under the maze to produce a permanent record. Some flexibility is obtained with this unit, since the maze can be turned over and upside-down to produce a different task. Obviously, in almost all uses of these mazes, the subject is blindfolded.

Porteus Maze: The Porteus Maze Tests are a series of printed mazes which have seen long use as diagnostic tools in clinical settings. Variations of these have also been used as subtests in intelligence testing (e.g., the Arthur Point Scale of Performance Tests). Their use as straight performance tests is somewhat limited, but certain situations are possible where the extensive experience with these mazes may be a highly desirable feature recommending their use.

The various forms of the test, as well as the manual, are published by The Psychological Corporation. The basic set is the 1933 Vineland Revision, which consists of twelve mazes. The tests cover years 3-12, 14, and adult levels (Cat. #6H015, price \$14.50 for 12 pads and a pad of score sheets). Another series, the Porteus Maze Extension, is designed to permit retesting after use of the Vineland series. Each test in this set is slightly more difficult than the corresponding test in the Vineland set in order to compensate for practice effects. It is not recommended for use as an initial test

series. Catalogue number for this set is 6H261 and the cost is \$11.00 for 8 pads and a pad of score sheets. A third series, the Porteus Maze Supplement, has been produced to allow for a third testing of the same subjects. This series is slightly more difficult than the Extension series. (Cat. #6H364, cost \$9.50 for 8 pads). A manual is also available (not supplied with the above sets) which gives directions for administration and scoring of all three series and discusses research covering 50 years of application of the test (Cat. #8Z047, cost \$7.60).

TEST II B (10): MIRROR DRAWING TESTS. A classic way to measure certain aspects of learning or visual-motor readaptation has been a variety of mirror drawing techniques. Classically, this apparatus consists of a board on which is placed a pattern of some sort (frequently a star). Behind the board is an upright mirror which reflects the pattern. The subject's task is to trace the pattern. However, direct vision is blocked in some way, and all he is allowed to see is the reversed and inverted mirror-image of the pattern. He must, therefore, re-adjust his normal visual-motor response pattern. The task is rather difficult at first, although learning is fairly rapid. Lafayette Instrument Company produces a portable "Mirror Tracer" (Cat. #31010, price \$16.50) which has a stainless steel mirror and can be used by right- or left-handed individuals without modification. A pack of 100 star patterns for this instrument costs \$3.50 (Cat. #31110). The same company produces an automatic scoring mirror tracer (Cat. #50024, cost \$134.00) which uses a metal pattern board. A non-conducting star is anodized flush with the surface.

The subject uses a stylus and, by attaching any stop-clock (e.g., Lafayette #58007, price \$68.00), a measure of the subject's total time outside the pattern may be obtained.

Mirror drawing tests have been used in sensory deprivation (Vernon, McGill, Gulick, and Candland, 1959) where significant effects were found after 24 hours. Parker (1969) administered mirror star tracing tasks to subjects at sea in a small boat. He found significantly more errors in subjects who got seasick, and a differential effect of sickness on males and females. Smith (1953) demonstrated a steady rise in muscular tension as the goal was approached in a mirror tracing task. This tension persisted for a time in certain muscle groups after the activity was interrupted. James (1953) used the mirror drawing test to assess the effect of "color shock" on normals and schizophrenics. No changes were found.

TEST 11 B (11): VISUALLY DIRECTED LOCATION OF A POINT IN SPACE.

Beyond simple aiming tests discussed previously, there is sometimes interest in determining the subject's ability to visually determine and point out location of a desired point in space. In this context, the interest is usually in situations where the visual environment does not provide many clues for locating the point. Such situations are encountered, for example, in the subject's ability to judge distances in the air or in his ability to choose a scanning zone where a target would be expected to appear. Three types of such questions are immediately evident. In the first, we wish to evaluate the subject's ability to estimate distances absolutely (i.e., how far away is this target?). In the second, we ask the subject to fractionate a

distance, e.g., bisect a line or an expanse. In the third, we ask the subject to determine an area in, essentially, an empty visual field (e.g., asking the sailor to scan the horizon at sea on a totally dark night). Many techniques for evaluating such questions are obvious and will not be detailed here. These include actual distance estimations by subjects in "open field" situations (Aume, ;), miniature field models (Aume,), and, of course, all the techniques of scaling visual extent used in classical psychophysics (Stevens, 1951; Woodworth and Schlosberg, 1954). An apparatus for bisection of a visual extent bounded by two lines has been described by Nazzaro (1964). Essentially, this consists of two plexiglass plates mounted together and viewed through an artificial pupil. The subject was able to move one plate by means of a meter, thus moving one line in relation to bounding lines engraved on the other plate. With this technique, field luminescence and the separation between the lines affect the error and variability of the settings.

The creation of a homogeneous field enabling measurement of the subject's selection of a point in that field is a somewhat more difficult task than those noted above. One attempt to do this has been reported by Katz (1967) using an apparatus constructed at the U.S. Naval Training Device Center, Port Washington, New York. In this, a 270° curved, flat white projection screen with an internal diameter of 20 feet was constructed of fiberglass bonded to a frame of fiberboard and steel. The subject sat this homogeneously lighted environment with his body, and the floor, covered with a white cloth. Behind him, a movable projector was used to shine a

small target on the screen. The subject's task was to tell the experimenter where to move the target so that it was in the center of the field. This proved to be a feasible task, although the unit is, of course, somewhat cumbersome and expensive. In the above case, no head restraint was used on the subject, introducing a different situation than if such a restraint had been used. Much smaller visual "alleys" or "globes" surrounding the subject's head are obvious possibilities in tests such as these (). But these are more difficult to use because of the subject's head restraint problem, because of the difficulty of getting an accurate reading of exactly where the subject wishes to locate the point, and, in some situations, because of the "white out" phenomenon in which the subject sometimes loses fixation and feels as if he is viewing an infinitely large field ().

TEST II B (12): VISUALLY DIRECTED LOCATION OF A POINT IN SPACE:

DISTORTED VISUAL INPUT: A situation somewhat analogous to that found in mirror drawing tests is present when we wish to expose the subject to a distorted visual input and ask him to locate a point in that field. If, however, we wish him to do this without ever seeing his hand (with the resultant feedback of seeing how far his hand is from the point) the situation is much more complex. Held and Schlank (1959) constructed an apparatus (later used by Weinstein, Sersen and Weinstein, 1964) which allows just such a presentation.

The basic unit is a box divided into upper and lower sections which can be independently lighted. Two mirrors are hinged inside the box in such a way that the subject, looking into the upper chamber through a viewing tube, sees either a virtual image of a target,

or of his own hand. By manipulating these mirrors and the lights, the target or the hand can be optically displaced from its real position, or can be occluded from view completely. Thus, the subject can be asked to place a mark at the target's virtual image without seeing his hand at all, or with some distorted input of hand, target, or both. The Weinstein et al study used this in conjunction with a device which constrained the subject's self-initiated hand movement, thus adding an additional proprioceptive-kinesthetic control to the task.

TEST II B (13): MEASUREMENT OF HANDWRITING AREA AND PRESSURE. Handwriting is a visually directed motor performance which may be linked to a variety of psychological as well as physiological factors. Many scientific and pseudo-scientific methods of "handwriting analysis" have been used, and obviously these are not of interest in the present context. On the other hand, the possibility of developing techniques for objective evaluation of certain parameters of this virtually universal activity is a very attractive one. It is a highly "personal" skill; there is essentially no training necessary; subjects consider it "relevant" to many tasks; and, judging from the number of dedicated graphologists, it would appear to be a highly sensitive measure of the subject's condition. It is, therefore, interesting to find that at least two aspects of this performance can be measured with a great deal of accuracy.

One of the parameters of handwriting most commonly (and easily) measured is total area. One technique for doing this has been described by Fischer, Kappeler, Wisecup, and Thatcher (1970). In this system, the total area of a sample of standard material writ-

ten on standard (unlined, of course) sheets is outlined by a rectangle. The area of this rectangle is calculated as the total writing area. If there are incomplete lines, the large rectangle covers only the complete lines and a small rectangle is formed of the incomplete line and its area is added to that of the large rectangle. Normally, of course, each subject acts as his own control in these evaluations. This technique has been used successfully in evaluating the effects of psilocybin (Fischer and Mead, 1966).

Determination of the pressure used by a subject in handwriting is obviously a much more difficult task. Fischer et al (1970) also provide a method for accomplishing this which appears reliable and relatively easy to construct. The basic apparatus is a small box resembling a "clip-board." An $8\frac{1}{2}$ " x 11" sheet of paper is placed in a standard position on the board, which is actually a pressure transducer (Daytronic). The subject uses a medium-point fountain pen to write a standard 28-word test. While writing, his hand is supported by a sliding plate, so that only the pressure of the pen is affecting the transducer. The proportionate output voltage produced by the transducer is fed to a voltage-to-frequency converter (Hewlett-Packard) and the pulse train produced is fed to a counter, the output of which represents the instantaneous pressure integrated over time. Actual pen-contact time, as well as total writing time, is also determined. The force pattern can be printed out on a strip chart or otherwise treated further to determine usable statistics (i.e., average pressure, variability, total integrated force, etc.). This system has been successfully used by its originators to objectively evaluate the

effects of psilocybin (Fischer, et al., 1970; Thatcher, Kappeler, Wisecup, and Fisher, 1970; ,1971).

It would appear to be a highly productive direction for performance measurement since it is an attempt to quantify an actual performance in meaningful ways. One wonders only what effect the movable hand-plate has on the subject's normal writing style, as well as the obviously contrived test situation. But these are concerns present in any test and should not keep these techniques from being used experimentally in many situations.

TRACKING

Introduction

Stresses, range of sophistication in apparatus, scoring,
and interpretation: Trumbo, 1970; Jünger, 1968.

Design Considerations:

Control element:

- 1) Joystick or lever: see manufacturer's literature
(Co.); Mack-
worth, 19 ; Hammerton and
Tickner, 1969; see 1968;
Jenkins, 1954; Ziegler, 1968;
Singleton.
- 2) Wheels and cranks: Simon, De Crow, Lincoln, and
Smith, 1952; Lamport, 1943; Sur-
willo, 1956; Siddall, 1955;
Lincoln, 1954; Gerall, 1954;
- 3) Large lever: Mackworth, 19 .
- 4) Fingertip or other pointers: Walsh, O'Leary, and
Scheda, 1968; Bonnardel, 1947.

Display:

- 1) Lights: Adelson, 1953; Leslie and
Thompson, 1958; Gendreau et al.,
1968; Knowles, 1967.

- 2) Auditory: Adams, 1962.
- 3) Dials and meters: Payne and Hauty, 1953a,b.
- 4) Continuously moving drum or wheel: see Rotary Pursuit Section; also Lamport, 1943; Mackworth, 19 ; Walsh, O'Leary, and Schena, 1968; Bonnardel, 1947.
- 5) CRT display: Hammerton and Tickner, 1968; Warren, Fontaine, and Clark, 1952.
- 6) Objects: Mackworth, 19 .

Input and Analysis of performance:

Inputs:

- 1) Step function: Slack, 1953; Agarwal and Gottlieb, 1969:
- 2) Continuous forcing function:
 - Systematic: Siddall, 1955.
 - Random: Clark, Fontaine, and Warren, 1953; Dvorak, Filsakova, and Hanousek, 1968.
- 3) Zero input: Zubal, 1969.
- 4) System instability:

Describing functions and parameters of control: Hammer-
 ton and Tickner, 1968; Jex and
 Magdaleno, 1969; Levison, Baron,
 and Kleinman, 1969; Wierenga,
 1969; Wingrove, Edwards, and
 Lopez, 1969; Baty, 1969;
 Wingrove and Edwards, 1968;
 Matheny and Norman, 1969; Taran
 and Kofanov, 1967.

Included display lead, lag, etc.: Ziegler, 1968.

Scoring of performance:

- 1) Time on target: Mortimer, Russell, and Tiffin,
 1964.
- 2) Integrated or average error: see Birmingham, 1955.
- 3) RMS error:
- 4) Difficulty level:
- 5) Other scoring techniques:

Types of Tracking Task - Visual Control

Step tracking and discrete display movement:

One dimensional: Slack, 1953.

Lights: Adelson, 1953.

Using ankle joint muscles: Agarwal and Gottlieb, 1969.

Bisensory (visual and auditory): Adams, 1962; Gerall, 1954; Leslie and Thompson, 1968; see Gendreau, 1968 and Knowles, 1967 for the Control Adjustment Test (loads .46 and .38 on control precision, .29 on reaction time, and .26 on "mechanical experience").

Continuous tracking:

One dimensional, wheel control: Simon, De Crow, Lincoln, and Smith, 1952.

Single axis, rate control: Baty, 1969.

Compensatory pursuit task: Payne and Hauty, 1953a,b; Dvorak, Filsakova, and Hanousek, 1968.

"Drivemobile": Lamport, 1943.

CRT display-effect of target/stick relations: Hammerton and Tickner, 1968; two dimensional apparatus: Warren, Fontaine, and Clark, 1952; Jenkins, 1954.

Heavy pursuit meter test: Mackworth, 19 .

- Random line tracking: Walsh, O'Leary, and Schena,
1968; Bonnardel, 1943.
- Mark II Navy Trainer: Tufts College, 1942.
- Compensatory tracking:
Effect of adaptive training: Wood, 1969.
Zero-input rate control: Zubal, 1969; Siddall, 1955;
McGuire, 1955.
- The rangefinder test: Mackworth, 19 .
- Group tracking task: Umanski, Chernyshev, and
Tarasov, 1969.
- Multiple limb coordination: see Warren, Fontaine, and Clark,
1952; and Jenkins, 1954; above.
- Modified Two-Hand Coordinator: Shephard, 1950.
- Hand-foot coordination test: Drake, 1937.
- The Complex Coordinator: NASA, Langley.
- Tracking of noise: Tombaugh and Tombaugh, 1963.

ROTARY PURSUIT TRACKING

A particular kind of pursuit tracking which has received a great deal of attention is called rotary pursuit tracking. The elements of the task in this situation are similar to any pursuit task, with the exception that in this case the target position is predictable at any point in time because it essentially travels a circular path. Although additional difficulties may be introduced which cause the target to effectively increase or decrease speed during the course of a revolution, the basic rotational speed is usually constant in a given trial and, therefore, the subject would be able to rely on each revolution being like the last.

Physical Parameters

The basic elements of virtually all pursuit rotors are a turntable, or other rotational element, and a stylus with which the subject tries to keep up with the rotation. The target is designated on the turntable and there is some automated system for determining the amount of time, or the number of times, the subject is on or off target. Ammons (1955) has discussed the apparatus variables which can affect pursuit rotor performance, and which must be considered in using this test. Although many of the factors he mentions have been standardized in newer, commercially available equipment, some are still valid considerations and will be mentioned here.

Target Size

The target in pursuit rotor tests is usually a small circle or rectangle. In most cases it is between 1/2" and 1" in diameter. Performance apparently is "increasingly and markedly better" with the larger targets. Eason, Hoke, and White (1963) consider that results obtained with one size target cannot be directly comparable with those from another size, since the degree of neuromuscular control changes considerably from one to the other. For the same reason, Humphries (1961) discussed the technique of using RMS error in pursuit rotor performance in order to partly compensate for size differences (see section on scoring pursuit tasks). Using different size targets, Humphries found differential sensitivity of the task to practice and to a five-minute rest interval. The effect of target size is aggravated in some of the commercial apparatus using light targets and pursuit paths of non-circular design. In these, the target size can vary in the course of one revolution and can even change shape radically if extremely sharp angles are included in the pathway to be tracked. Clearly, therefore, for a given research, the target size must be considered; one must also report size and shape of the target in detail.

Direction of Target Rotation: In most cases, a clockwise rotation has been used in pursuit rotor studies. There appears to be no particular reason for this except that most phonograph motors operate in that direction and these formed the core of early pursuit rotors. Modern commercial apparatus usually can be operated in either direction.

Rate of Target Rotation: Most commonly, again for no apparent objective reason, the rate of rotation used in many studies is around 60 rpm. Ammons reports finding a range of from 32 rpm to 80 rpm in reviewing 28 studies. Additionally, he reports results of Helmick indicating differences in performance level between groups practicing at 50, 60, or 80 rpm. It seems obvious to point out that the rpm level should be calibrated periodically and checked before each session; yet some turntables can show great variability from day to day. This caution cannot be ignored even with the more elaborate commercial pursuit rotors or with supposed "constant speed" motors. In one type of pursuit task, where the target only moves when the subject is in contact with it, the time necessary for the motor to start and stop is particularly important since this can drastically affect the final score.

Height of the Apparatus: It is perhaps most common to place the turntable on an available surface, such as a desk, and to ignore its resultant height in considering the subject's score. But work surface height is an important variable in performance testing and attention should be given to this in planning the experiment. Most often, one desires to locate the turntable at a height such that the average standing subject will feel comfortable during the task. If extreme control is desired, the height could be adjusted proportionally to each subject's shoulder height. But such precision is probably not necessary in most cases, especially since subject's performing on this task tend to adopt different positions, with some preferring to stand to the side, some standing straight, others bending over the turntable, etc.

Other Factors: The choice of a pursuit apparatus, from those described below, will determine to a large extent the range of final scores obtained by the subjects. To some extent also, these decisions will affect such things as learning curves, fatigue effects, and variability. However, no studies of specific effects of apparatus variations were found. Thus, one must be particularly careful in the standardization of his own apparatus, and particularly conscientious in reporting details of the equipment used. Even more important than the probable effects of equipment variation mentioned above is the possibility that certain variations may even change the nature of the skill being measured. In any case, such variation would certainly seem to modify the skills involved, such as one using a wand that was rigid or flexible, straight or angled, or the task being scored as time on target or number of target hits.

Scoring Techniques

As mentioned previously, the common way to score rotary pursuit tasks is simply to determine the amount of time the subject is on or off target. This is a straightforward problem that most modern commercial apparatus can be equipped to handle by adding any one of several clocks. However, Bahrick, Fitts, and Briggs (1957) have shown that for some applications such a score ignores certain aspects of the subject's behavior and can lead to interpretations which are at variance with those which would be obtained using other scoring techniques. In particular, interpretation of time-on-target scores is tenuous when attempts are made to test for interaction effects or to interpret functioned relations over an extended range of task difficulty or over an

extended period of learning." Basically, such a dichotomized score requires the experimenter to define the target precisely, and then to obtain a dichotomized score based on whether the subject is within an "acceptable" distance from the target. If the subject shows great variability within the acceptable area, his score will be the same as if he were always in the exact center of the target. In other words, elements of style and interactions with apparatus and experimental variables may be completely overlooked by the time-on-target score. Obviously, the same arguments can be made if one scores the task in terms of "number of hits," or any other categorical all-or-none method.

Using the above study as a starting point, Humphries (1961) developed a rotary pursuit unit which permits the experimenter to obtain simultaneous time-on-target scores for each of 18 concentric target bands (this type of unit is described more fully in the section on apparatus). With this system, one can determine precisely how much time the subject spent in each portion of the target area, as well as his tendency to move around -- his variability -- within the target. This, then, permits calculation of a number of additional scores, including standard deviations and root mean square error (RMS) scores. Humphries used two techniques of calculating RMS, based on one- and two-dimensional models of the distribution of radial errors, and concluded that the latter was superior. In tests of the model, he found that subjects sometimes performed better than predictions, but in general the overall shape of the performance curve was accurately described.

A further modification of the type of equipment described above yields a single score which represents an integrated value of the subject's performance within the target area (Eason, Hoke, and White, 1963). A bank of 16 concentric rings is used as the target, and each of these is connected to a variable resistor. As the tracking wand moves from one ring to another, voltage variations are produced. These modulate the amplitude of an 1100 hz sine wave signal which is then fed to a pulse-frequency electronic integrator which, in turn, causes an electronic printing counter to count at a rate proportional to the amplitude of the sine wave signal. The total number of counts over a given time period, therefore, reflects the average deviation of the tracking wand from the center of the target. Schematic diagrams of this scoring technique are given in the above article.

Simpler variations of the traditional scoring techniques are possible and for certain purposes serve as well as the more complex scores. Catalano and Berger (1970) obtained simple time-on-target measures for consecutive 15 second periods of a one minute tracking trial. By comparing the last 15 seconds of one trial with the first 15 seconds of the next, they obtained a "reminiscence" score which differentiated between high and low need-achievement subjects. They also obtained a "decrement" score by comparing the fourth with the second period during a trial. Obviously, many variations of this technique are possible and these illustrate the flexibility of scoring available to the experimenter. It should be evident, however, that such flexibility requires the experimenter to exercise maximum care in using a particular method. Since there is so little standardization

in this area, the burden of justifying the choice of a particular method, and of explaining it in detail in the report, is all the heavier on the researcher.

Design Considerations

In using the pursuit-rotor task, one must, of course, devote attention to questions of learning, motivation, previous experience, and the other design considerations normally associated with a complex performance. Scores on the test are subject to "post rest upswing" and "post rest downswing" in accordance with the amount and kind of practice given (Eysenck, Iseler, Star, and Willett, 1969). But which hand is used for practice does not appear to matter (Dunham, 1969). The effects of reinforcement in the task have been studied (Reynolds, Bradley, and Adams, 1953; Miller, Sheldon, and Bjorklund, 1969; Gordon, 1968), and are particularly important in cases where the apparatus itself, or the timing clocks used with it, create a noticeable click or other signal whenever the subject goes on or off target. Such a factor can interact with personality factors, such as need-achievement, to produce different effects on different subjects. Further, such reinforcement may act differentially at different points in the learning curve, so that the amount of practice and absolute level achieved become important controls.

Abilities Measured and Statistical Data

We should emphasize here that, as with many of the widely used tests discussed in this book, most of the objective data on the pursuit-rotor task has come from a single laboratory. These studies used one type of apparatus and, even in this there are variations in

size, etc. Subsequent designs of the test have not been related to the original equipment; therefore, it is somewhat tenuous to assume that the same skills or reliabilities are obtained with all forms of the basic unit. For this reason, the apparatus parameters of the rotary pursuit meter used by Fleishman will be specified here as well as they are known. It is left to the individual researcher to determine how closely the apparatus to be used approximates this one.

The equipment used by Fleishman was based on the Air Force version of the Rotary Pursuit Test described by Melton (1947). In its most extensive test by Fleishman (1960) the turntable was a black Bakelite disk, 10.88" in diameter, which rotated clockwise at 60 rpm. A .75" silver target was placed 3.19" from the center of the disc, and the turntable was located 38" above the floor. The stylus was hinged so that when it was held on the turntable with the handle and rod in a straight line it exerted a downward force of approximately 22 gm. The overall length of the stylus was 11 inches. In this study, a trial consisted of five 20-second periods separated by 15-second pauses, but in other studies different timing was used. Similarly, dimensions were varied slightly in other studies.

Using such an apparatus, reliability of .92 to .97 was found. The test loaded most consistently on speed of arm movement (-.02, .17, .35) and on control precision (.26, .49, .60) (Finley et al, 1969, prime reference; Fleishman, 1954; Fleishman, 1957; Fleishman, 1960; Parker and Fleishman, 1960). In addition, it has been found that the loading on speed of arm movement changes from .28 on trials 1 through 8 to .47 on trials 25 through 30. Similarly, the loading on control

precision moves from .55 in the early trials to .26 later (Fleishman, 1957).

Stresses Used With This Test

The rotary pursuit task has been used with sensory deprivation of 24, 48, and 72 hours duration by Vernon, McGill, Gulick, and Candland (1959). They found that there were small but consistent effects on rotary pursuit after 48 hours of deprivation; but at the 72 hour point, performance had improved and, if subjects were released at 48 hours, the decrement tended to be eliminated 24 hours later. McFarland (1932) reported that with oxygen reduced to 8.87% (equivalent to 24,000 ft.), the resulting anoxemia produced decrements on a pursuit test more quickly than on reaction tests. Telchner and Wehrkamp (1954) found that subjects performed worse when the ambient temperature was above 70°F. and that performance was particularly bad at 100°F.

Types of Pursuit Rotors Available

Since the pursuit rotor has been used for so long and in so many situations, one would expect that a great many variations have been marketed and that the literature will reveal a great many brand and type names which are no longer readily recognizable.-- a supposition which turns out to be true. References are found to a "Pentagon Devices" pursuit rotor (Catalano and Berger, 1970) and to a K_____ apparatus (). Neither of these were referenced, and no further information was revealed through industrial contacts.

Currently marketed units from major sources are limited to one type of traditional pursuit rotor and two light-tracking devices.

The original equipment described by Melton (1947) and used by Fleishman (1960) is now most closely approximated by a system manufactured by Lafayette Instrument Company (Cat. #30010, "Rotary Pursuit Apparatus, price \$139.00). This model has four discrete speeds of 15, 30, 45, and 60 rpm, and an interval timer which provides for automatic 20-second test and rest periods. The revolving surface is of black Formica with the metal target located in approximately the same place as in the Melton equipment. The stylus (Cat. #30100, replacement price \$12.00) is spring loaded to prevent the subject from tapping the target. Contact of stylus and target provides a contact closure which can be used to drive a suitable stop-clock (purchased separately). Variations of this model include the addition of an "on-off" cycle which is continuously variable from 5 to 35 seconds (Cat. #30011, price \$174.00) and a package containing the model #30010 unit, two timers to vary trial periods from 0 to 60 seconds, and rest periods up to five minutes, and a stop-clock to measure performance (Cat. #30012, price \$415.00).

The above constitutes the only known manufacturer of a contact-type rotary pursuit apparatus. Although the unit is theoretically not difficult to construct, there are problems associated with it, and the article by Ammons (1955) should be consulted before attempting it. No case was found of a commercially available unit which incorporates the concentric rings used by Eason, Hoke, and White. (1963), but we know that a version of this apparatus is currently in use at the Langley Research Center, NASA (Dr. Randall Chambers). In view of its advantages, one would certainly think that if a contact-

type apparatus is to be constructed, consideration should be given to using this design.

The newest form of rotary pursuit apparatus uses a photo-sensitive element in the tracking wand. The revolving surface is then slit and placed over a circular neon light. Over this surface a glass can be inserted which is darkened except for a particular design through which the underlying light can show. In its simplest form, the dark glass has a clear circle on it. As the turntable revolves under it, a square of light travels around the circle; this is the target to be tracked. Other patterns typically used are a square and a triangle. One should note that when such patterns are used, the target size and shape vary considerably as it revolves from say, the leg of a triangle to its apex. In addition, because distances from the center of rotation are changing, the target "speeds up" at various parts of its track and, if the glass is not perfectly centered, this speed up is different for different parts of even a symmetrical figure. All this means that the task given the subject with this apparatus is much harder than the "old" style apparatus. Very probably, different skills are measured, and results from this apparatus can not be directly related to previous pursuit-rotor studies.

Photo-sensitive rotary pursuit apparatus are currently manufactured by three known companies. The Lafayette model provides variable target speed from 10 to 100 rpm. in both forward and reverse directions. The model #30013 (price \$285.00) is supplied with three standard patterns -- circle, square, and triangle. The unit measures $14\frac{1}{2}$ " x $14\frac{1}{2}$ " x $8\frac{1}{2}$ "; and features external programming of trial and rest

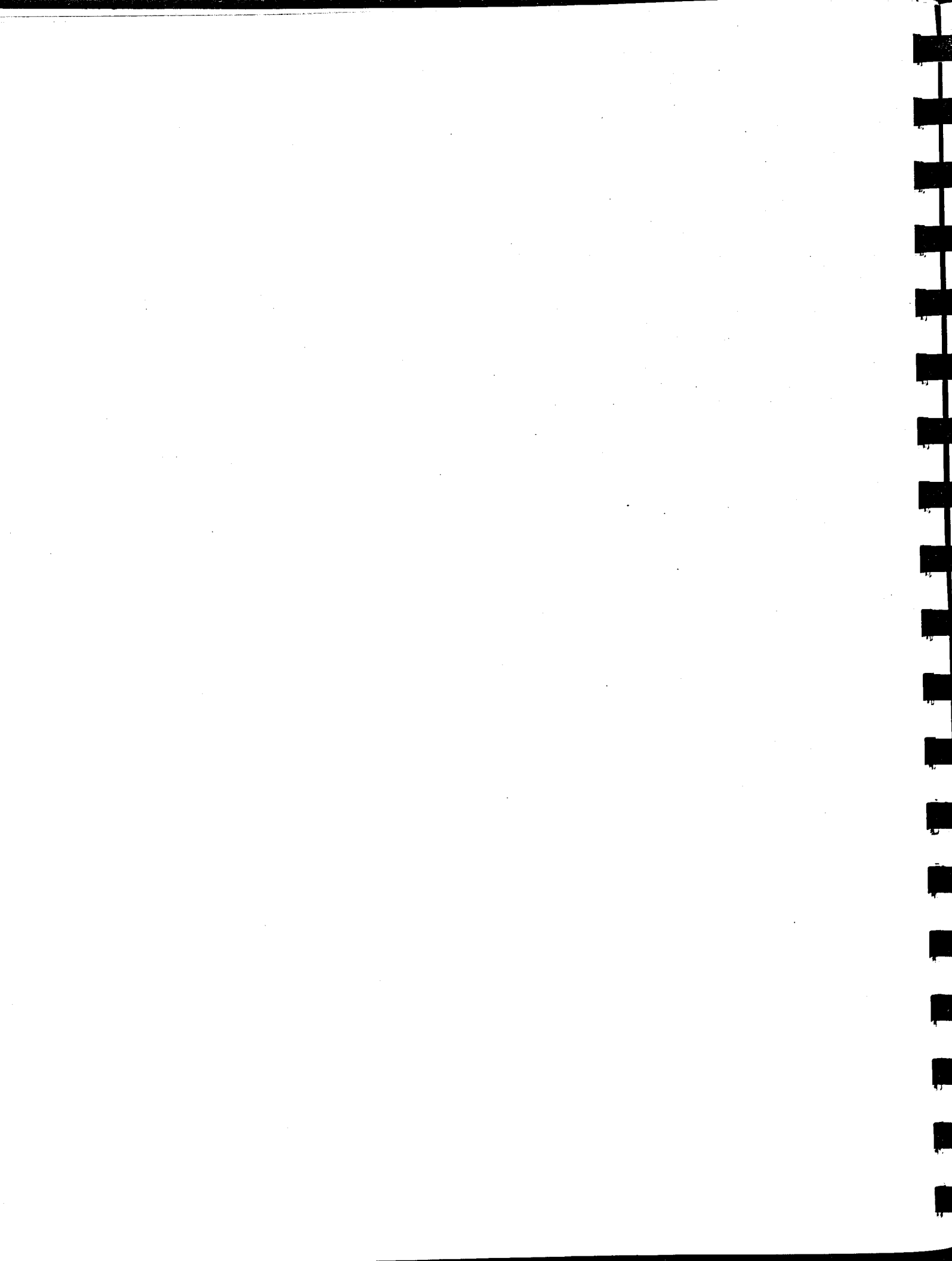
periods and contact closures for recording target hits, total revolutions, and time on or off target. Another model (Cat. #30014, price \$390.00) has an rpm indicator built in.

Research Media, Inc. produces two types of photo sensitive pursuit rotors. The unprogrammed models are available with constant, one-way speeds of 15, 30, and 45 rpm (Model PR-15, price \$240.00), with 10 to 100 rpm variable speed (Model PR-16, price \$320.00), and with 10 to 100 rpm variable speed and reversible (Model PR-16A, price \$350.00). The programmed models are totally self-contained devices which eliminate the need for auxiliary timers and stop-clocks for normal operation. The units contain internal clocks to reflect time on or off target and to permit setting trial lengths from 0 to 5 minutes in 5-second intervals. Number of target hits is also recorded automatically, and target speed is variable from 10 to 100 rpm. Model PR-14 is priced at \$495.00, and Model PR-14A, which allows for reversible target rotation, is \$525.00. Both programmed and unprogrammed units measure 16" x 14" x 10½".

The Stoelting Company manufactures a series of photosensitive rotary pursuit apparatus

TABLE RT-1

DIFFERENCES IN REACTION TIME FOR VARIOUS SENSORY MODALITIES



HISTORICAL BACKGROUND

For over a century, scientists have been attempting to quantify the absolute speed with which a human can react to a signal. This phenomenon was of interest initially for its contribution to basic physiological and philosophical knowledge, and was called "the physiological time" by Hirsch (1861), who was the first, after Helmholtz, to study it. A landmark paper in this field was read by Professor F. C. Donders in 1865 at the meeting of the Royal Netherlands Academy of Sciences. The results presented in this paper were again presented and expanded by Donders in 1868 in an article titled "On the Speed of Mental Processes" (Donders, 1969a) and, in 1873, Exner introduced the term "reaction time."

Donders' equipment (Donders, 1969b) was not remarkably different in concept from some of the apparatus presently being used to measure reaction time. One device called the noematachograph, was to be used "to determine the duration of more or less complex actions of the mind." It consisted of a cylinder which was covered with smoked paper and which moved helically while being turned by hand. The paper was in contact with a tuning fork which vibrated at 250 vibrations per second. This basic instrument could be connected to other devices such as the Scott phonautograph. This instrument translated sound vibrations into mechanical movement which could then also be

recorded on the smoked paper. Thus, two subjects would sit before the instrument, one pronouncing a vowel sound and the other responding as quickly as possible with another sound. The time at which the two sounds were initiated could be differentiated on the paper and, with reference to the vibrations of the tuning fork, the speed of reaction could be calculated. For other experiments using visual or tactile stimuli, more complex electrical equipment could be connected to the noematachograph.

Donders' noematachometer was an instrument used to determine "the shortest possible time for a simple thought." This consisted of a vertical board with a slit through which the subject could look. A complex series of events was initiated by the experimenter burning a thread, which produced an audible sound (from metal and wooden arms snapping together) and a flash of light through the slit (from one or two burning coals falling past it). Since the timing of these two stimuli were controlled by the experimenter, the temporal ordering could be varied until the subject reported that he had established "priority." Donders felt that this was "the time consumed by a single thought." In addition, by alternating the order of presentation of auditory and visual stimuli, "the difference in time of handling the stimuli is also found."

Using such equipment, Donders developed his "Subtraction Method" of reaction time. Basically, this theory stated that the elements of the reaction time response were additive, and that each component of the response begins immediately when, and only when, the preceding component has ended. Thus, "decision" is a component of a

reaction involving choice. When the decision is being made, nothing else is going on and when that process ends, the subject immediately moves into another, perhaps "movement," phase. If this and other assumptions are true, then "decision-time" could be calculated by knowing the total reaction time and subtracting from it the time required for all other components of the response. Using this approach, Donders distinguished between three types of reactions. The "a-reaction" involved a single response to a single, invariant stimulus. This is what is now called the "simple" reaction time. The "b-reaction" involved two stimuli and two responses, with the stimulus-response relationship always constant. This is the most simple form of "choice reaction time" presented. The "c-reaction" also used two stimuli; but in this case only one response was used and that response was to be given to one of the stimuli but not to the other. Consequently, one could calculate "response selection time" by calculating b-c, and "stimulus categorization time" by c-a, and so forth (Smith, 1968).

Donders' methods enjoyed great popularity for some time, being used by Wundt and his students, and then fell out of favor (Kulpe, 1895). The argument was given that not only were the various components of the reaction time task not additive, but they were so interactive that deletion of one component, as was attempted in the subtraction method, was bound to affect all the others in such a way as to make the results meaningless. Primarily on introspective evidence, the assumptions of additivity and independence were attacked, with the result that the entire theory was discredited.

Recently, however, the Donders approach has received significant empirical support, and now forms the basis for several new models of reaction time (Smith, 1968; Sternberg, 1969; Audley, 1960; McGill, 1963; Hohle, 1967). They argue that the assumption for independence has been shown to hold for significant portions of the reaction time sequence, most notably . In addition, the additivity assumptions become defensible if certain changes are made in the nature of assumptions dealing with the shape of distributions underlying reaction time components.

In summary, then, one can see that reaction time as a performance measure continues to be a thriving, evolving, productive task. Researchers in the performance area occasionally appear to adopt either an over-simplistic view of the difficulties of using reaction time, or they forego the measure entirely because of a naive belief that it is not "sensitive" enough for their needs. The first error leads to use of inappropriate, unstandard reaction time tests that, frequently enough, have such intrinsic variability that they fail to show differences or changes when they clearly should. This, of course, leads to convincing more researchers that reaction time as a performance measure is useless, and so the second error is perpetuated. We hope that the information contained in the

following sections will provide a more balanced view of what essentially is an important, sophisticated, and terribly delicate measure of human performance.

GENERAL EXPERIMENTAL CONSIDERATIONS

One reason reaction time has a history of being so badly misused is its apparent simplicity. After all, what could be more straightforward than the definition of reaction time as the interval between a stimulus and a response? However, as one works with this measure more and more, even without entering into some of its more theoretical aspects, it becomes clear that the apparently simple concept actually encompasses a great deal more than appears at first glance. Obviously, there are several kinds of reaction time, depending on the modality of the stimulus, the modality of the response, and the requirement for various amounts of "choice" or "decision" behavior before a response can be made. Not so obviously, but still not requiring a great deal of insight, there are varieties of reaction time which differ along dimensions dependent on such things as whether a warning signal is given or not, the instructions given to the subjects, their motivation, amount of previous experience or practice, and other such factors. Finally, differences in reaction time will appear as a result of experimental conditions which are either much more subtle or, at least, much more uncertain in their outcomes. Under this heading would fall factors such as stimulus or response uncertainty and probability, the so-called "psychological refractory period," stimulus-response compatibility, intersensory facilitation,

and certain stimulus characteristics which are frequently overlooked by the user of RT tests.

Factors such as those mentioned above can affect, if not determine, the results obtained with use of a given reaction time methodology. These are general considerations in that one or more of them must be considered in planning and interpreting any reaction time study. Presumably, these considerations will arise after the decision has been made to use either simple or choice reaction time, and after the modality of stimulus and response, as well as the specific methodological technique, have been determined. These, after all, must ultimately be based on the purposes for which the research is being done and the nature of the questions being asked. Once these decisions have been made, then it is appropriate to consider the questions raised in this section so that the details of procedure can be worked out. These details will answer such questions as how many stimulus presentations will be used, the interval between S-R pairs, the intensity of the stimulus, etc. Under the following subheadings will be found discussion of experimental considerations such as these, along with some indications of the effects which will be introduced as the result of using particular methods.

Stimulus Characteristics

Stimulus Modality: The basic differences in reaction times to be expected as a result of differences in sensory modality are presented in Table RT-1. While this table serves as a most general indication of the approximate RT levels, one must remember that many factors can upset these classical relationships. For instance, when the

over-all reaction measure includes a movement time, then the determinants of the movement time, which may be independent of the simple time to initiate action (Breen, 1969), may tend to mask basic modality differences. However, it does not appear that certain forms of modality "mixing" between stimulus and responses alter the basic relationship. Thus, the "pure" RT to an auditory signal will still be faster than to a visual signal whether the respective response required is verbal or mechanical (Greenwald, 1970). In general, then, and with the reservation that other factors must be considered, the fastest reaction times will be obtained by using auditory or tactile signals, with vision, odor, taste, temperature, rotation, and pain representing an increasing order of response latency. The additional factors to be considered include stimulus duration, frequency, uncertainty, intensity, and discriminability, intersensory facilitation, sensory asymmetry, and stimulus location. These are each discussed below.

Stimulus Intensity: Generally, observations relating RT to stimulus intensity have consistently found shorter RT's as the intensity of the stimulus increases. Chocholle, in 1945, confirmed this over a wide range of 1000 hz (RT 11) tone intensities. He found simple RT's reduced from 400 to 110 milliseconds as the intensity was increased by 10 log units. The simple RT to light was measured over 3 log units by Cattell and Berger in Wundt's laboratory, and found to decrease from 180 to 169 msec. (Woodworth and Schlosberg, 1954). This relationship has been found to hold for a much wider range of intensities (Pollack, 1968; Bartlett, 1954) and also for the luminance

of flashes (Lewis and Mertens, 1962). In addition, summation effects of light intensity, time, and area occur (Grossberg, 1968; Robinson, 1966). The inverse relationship between light intensity and RT holds even when rod functions alone are operating (Hufford, 1964). Measurement of the evoked potential accompanying a simple Reaction Time indicates increased amplitude with higher intensity flashes (Eason, Oden, and White, 1967).

The amount of change in RT that accompanies a given increase or decrease in stimulus intensity appears to differ in some clearly pathological groups, and in some experimental conditions. As such, it might be considered as a measure of "normality" in stressed subjects. Retarded subjects have been shown to profit more than normals from a large increase in auditory intensity under certain presentation conditions (Baumeister, Hawkins, and Kellos, 1965). Psychotic subjects show a greater absolute reduction in RT latency with increases in auditory intensity, although this may be related to their initially long RT's (King, 1962). Costello (1968) reports studies showing a flattening of the curves relating RT's to stimulus light intensity and, in some instances, a paradoxical increase in RT's at high intensities for schizophrenics, subjects with "weak" nervous systems, and subjects to whom caffeine has been administered. This same study, though, reports that these "paradoxical relations" between RT's and stimulus intensity do not occur in subjects classified as "anxious" on the basis of the Taylor Manifest Anxiety Scale. The unusual patterns of RT performance do occur for a brief time when subjects are threatened with shock for poor performance, pos-

sibly indicating an interactive effect between intensity and motivation (see also Murray, 1970). Stimulus intensity also appears to interact with the length of the preparatory interval (King, Baumeister, and Wilcox, 1969) and with the regularity of stimulus presentation, with regular presentation yielding a smaller intensity effect than irregular (Murray, 1970). In addition, the intensity of the preparatory signal itself, whether auditory or visual, was found to vary directly with RT, i.e. longer RT's were found with more intense ready signals (Kohfeld, 1969), and the same direct relationship was found between RT and the intensity of the preceding trial stimulus (Murray, 1970).

Closely allied to the question of stimulus intensity is the determination of whether the stimulus should be delivered to one ear or eye, or to both. As early as 1893, stimuli delivered to both ears were found to produce a shorter RT than the same stimuli confined to one ear. Poffenberger, in 1912, demonstrated that the RT to light was shorter with binocular presentation than with monocular. Although these phenomena might be viewed in terms of the number of receptors stimulated in a given trial, there is some indication that interference from the non-stimulated side might contribute to the increased RT with single-sided presentation. Conticelli and Fujiwara (1964) used differential adaptation levels in both eyes prior to determining the RT to a suprathreshold stimulus. As expected, binocular RT was superior to monocular in all cases. However, with differential adaptation, the difference was enhanced. It was as if the dark-adapted non-viewing eye impaired the perception mediated through the light-adapted eye. In another experiment, if the ear

stimulated corresponded to the direction of the required response, the RT was faster than if the opposite case was true (Simon, 1968; Simon and Small, 1969). Similar response interference was observed on binaural trials using verbal directional commands where the apparent source of the command was manipulated by shifting the interaural phase (Simon, Small, Ziglar, and Craft, 1970). For visual directional RT's, the same result was found (Craft and Simon, 1970). In all these cases, it appeared that the significant effect was due to interference on the trials where the direction of the stimulus and the required response was different, rather than facilitation on trials where they were the same.

Signal Duration: We noted above that interactive effects on RT occur as a result of duration of stimulus presentation. Under normal conditions, this effect operates only within rather narrow limits and within these limits, longer durations tend to produce shorter RT's (Woodworth and Schlosberg, 1954; see also Rabb, Fehrer, and Hershenson, 1961; Rabb and Fehrer, 1962 with respect to simple RT, and Kaswan and Young, 1963; Kaswan and Young, 1965; and Christ, 1970 with respect to choice RT).

In 1949, Chernikoff and Brogden reported that if the subject was allowed to turn off an auditory stimulus by his response, the RT was faster than when the stimulus lasted for a fixed duration of 2000 milliseconds (Chernikoff and Brogden 1949). This result was replicated and extended by Chernikoff, Gregg, and Brogden (1950), who used fixed durations of 100, 200, 400, 800, and 1400 msec. They found a general tendency for the RT to decrease as compared to fixed

times of 200 or 100 msec. Gregg and Brogden (1950a) again confirmed these findings, but suggested that the phenomenon was related strictly to duration of the stimulus since, by turning off the stimulus, the subject was presented with a duration which exactly equaled his RT. They also found that, independent of response termination by the subject, RT increased as the duration of an auditory stimulus increased above 400 msec. (Gregg and Brogden, 1950b). It seems clear, therefore, that with auditory stimuli at least there is an optimum stimulus duration which falls somewhere below 400 msec., and which will produce the minimum RT. Since the response-terminated stimulus procedure appears to approximate this optimum, this technique would be appropriate for consideration for auditory RT experiments where the fastest RT possible is desired.

Location of the Stimulus: The effect on RT of stimulating one ear or eye as opposed to both has been discussed above. In that section we also suggested that there may be an interference effect which facilitates directional RT's if the required response is to the stimulated side. Similar effects are seen when the subject is required simply to respond with the hand opposite to the ear stimulated (Simon, 1969). In both cases, "crossed" responses which required a response in the opposite direction to the source of the stimulus produced longer RT's. If the subject's task is to press a button to his right or left when the button lights up, and if he is simultaneously given a tone in one or the other ear, his reactions will be faster when the tone is presented to the ear on the same side as the required button press (Simon, 1970). Generally, the same relationships can be

expected for visual cues. So we can see that, where directional information about the source of a stimulus is present to the subject, then care must be taken to arrange that the responses required do not introduce unwanted facilitation or inhibition of the response. From a more positive viewpoint, we might consider that if the expected degree of facilitation produced by directional matching of stimulus and response does not occur under certain stresses, the specific nature of the effect of the stress might be apparent.

An interesting effect of signal location on a visual task has been reported by Bevan and Avant (1967). Using change in the intensity of one of five lights arranged horizontally before the subject, they found that the shortest RT's consistently appeared when the signal position corresponded to the mean (center) location, and were significantly longer when the signal appeared at either end position. This phenomenon was not related to the signal frequency in each position, and this tends to indicate that the mean location of the stimulus sequence in an extensive array is a more important determinant of the RT than the statistical shape of the array.

Special consideration must be given to stimulus location when using visual signals which are small enough in area that questions of retinal location arise. Generally, the RT response to such stimuli are best when the fovea is stimulated, and become worse as distance from the fovea increases. In addition, RT is slightly better when the stimulus is delivered to points on the nasal side of the retina as compared to corresponding points on the temporal side (Poffenberger, 1912; Rains, 1964; Payne, 1966). Similar results have been found with

evoked potential studies using visual reaction time. Sinusoidal evoked potentials having a frequency equal to the subject's alpha rhythm were found to have a latency which varied directly with reaction time. Both increased out to 5° , decreased out to 10° - 20° , and then progressively increased (Eason, Oden, and White, 1967). It has been suggested that these differences are due to differences in retinal sensitivity and rod-cone density, and that a physiological summation occurs with such stimuli, assuming non-independence of retinal receptor elements (Hufford, 1964). Payne (1967) found large variations in RT in various half meridians on a circle around the fovea extending 15° from the line of direct vision. These variations were also interpreted as reflecting the distribution of retinal receptors. However, Slater-Hammel (1955) found that the direction of the stimulus from the direct line of vision was not a significant variable. An interaction has been found between hypoxia and peripheralization of a visual stimulus (Kobrick and Dusek, 1970), indicating that effects of hypoxic stress might show up somewhat faster if the RT stimulus was confined to the periphery. Finally, a curious phenomenon has been demonstrated which has interesting theoretical as well as experimental implications. Reaction time to the offset of a visual stimulus is longer than to the onset of the same stimulus in the periphery of the retina. But the opposite is true in the fovea, where RT to the onset are longer than to the offset (Pease and Sticht, 1965). Since the results can be related to the distribution of certain types of retinal cells, changes in this phenomenon under stress could be directly related to effects in such cell populations.

Another special case of stimulus location arises when the stimulus is so constituted as to be delivered to only one side of the brain. This occurs, for instance, in some monocular viewing and in some special arrangements of binocular viewing (see pp.). In a choice RT situation the response was found to be consistently faster when the S-R pathways were ipsilateral rather than when they involved transcommissural connections (Bradshaw and Perriment, 1970). Filbey and Gozzaniga (1969) have estimated that callosal transmission time is 30-40 milliseconds when information received in one hemisphere is required to be acted upon by the other. Such a situation would occur when a verbal response is required to a visual stimulus presented in the right visual field. However, Jeeves and Dixon (1970) found that, for a motor response involving movement by both hands to a visual stimulus, the fastest RT's were obtained when the stimulus went initially to the right hemisphere rather than the left. This was true even when the reaction required transmission along a transcallosal pathway. Using a somewhat more complex task, Diamond (1970) found no significant differences between RT's where the stimulus was initially presented to either left or right hemisphere and a relatively simple response was required. But when two signals were presented simultaneously, the RT's were lowest when they were directed to separate hemispheres through separate eyes. There was an increase in RT when the signals were directed to separate hemispheres through the same eye, and the longest RT's were found when the signals went to the same hemisphere.

Signal Frequency and Probability: One can easily recognize that if a signal, particularly in a simple RT situation, comes with absolute certainty at precisely the same time after the previous signal or warning signal, the reaction time will soon reflect not only a response to the appearance of the signal, but also an evaluation of the subject's capability to estimate time intervals (see Andreassi, 1969). In this case, one would say that the signal probability was extremely high. For this reason, it is elementary to assume that when the goal is to determine the subject's capability to react to the appearance of the stimulus, the interstimulus interval will be varied (see Baumeister and Joubert, 1969, for a discussion of the effect of such variation), and the probability of a stimulus appearing on a given trial will be controlled. However, from this elementary starting point, the questions become quite complex. Manipulation of the signal probability and frequency necessarily affect the amount and rate of information transmission to the subject, and these factors have been shown to be related to the reaction time (Leont'ev and Krinchik, 1962; Klemmer and Muller, 1969; Krinchik, 1969; Sanders, 1970; DeKlerk and Oppe, 1970). Typically, increasing the number of alternatives in a choice RT task, or decreasing the probability of appearance of a given alternative, or increasing the uncertainty of the stimulus in a single choice situation all result in an increase in response latency. However, these relationships are not linear. For example, discrimination RT for a 1023-alternative condition was less than 25 milliseconds longer than in a 31-alternative condition (Seibel, 1963). Clearly, therefore, if the research goal focuses on

on the complexity of the stimulus requiring a response, care must be taken not only in creating a task which looks complex in terms of the number of alternatives, but also is complex in terms of actually putting the subject's response capability under stress. This can best be accomplished by reference to the literature of information theory, and by determination of past RT results using tasks similar to those that will be employed (Kamlet and Boisvert, 1969; Symington, 1971).

In addition to the above questions of stimulus frequency and probability, the effect of stimulus repetition must be considered. We have known for some time that the reaction time to a repeated signal is faster than that to a changed signal -- the so-called "repetition effect" (Hyman, 1953). Further, this effect is not limited strictly to adjacent stimuli. Apparently, there is an "adaptive weighting" that occurs as a result of the occurrence of each stimulus, so that even fifth-order sequential effects can be isolated in properly analyzed data (Remington, 1969). Emtus and Bindra (1970) have found shorter reaction times to repeated trials, not only in choice RT tasks, but also in simple RT tasks and in recognition (or "same-different") tasks. Further, these effects appear to combine with the intertrial interval, and if the time between trials is long enough, the shorter RT on repeated trials (or on "same" trials) actually becomes a longer RT in these cases (also see Eichelman, 1970). For the investigator interested in performance measurement, these few facts should emphasize the need to assure extremely sophisticated randomization of stimulus presentation if reaction capability is the phenomenon to be tested. Otherwise, a haphazard sequen-

cing of stimuli might change the task into one entirely different from what it appears to be. In view of the higher-order effects mentioned above, this caution must be emphasized even when the number of discriminations is extremely large.

The Psychological Refractory Period: Effect of Very Brief

Interstimulus Intervals: If a stimulus is given requiring a reaction type of response, and if another stimulus is presented within a critically short period of time after the first, the reaction time to the second stimulus will be appreciably longer than the RT to the first. This phenomenon has been called the Psychological Refractory Period (Broadbent, 1958) which, although descriptive, cannot be assumed to imply a true physiological refractoriness since the second stimulus is still received and processed. Several theories of this phenomenon have been proposed (see Bertelson, 1966; Reynolds, 1964; Welford, 1959) and lively interest in explaining the phenomenon is still maintained (Herman and Kantowitz, 1970). For the present purposes, one should note that this phenomenon operates over a "critical" period for introduction of the second stimulus of approximately 10 to 200 milliseconds (Herman and Kantowitz, 1970) (see also Vreuls and Schmidt, 1966). In tests of the response to two closely paired visual signals, delays in the second RT persisted for as long as 500 msec between signals (Slater-Hammel, 1958). The suggestion has been made that the magnitude of this refractory effect is dependent on the antagonism between common elements of the response tasks rather than on the unrelatedness or absence of common elements (Way and Gottsdanker, 1968). As the time between the two stimuli increases, the RT to the second stimulus increases (Herman and McCauley, 1969).

Consideration of the refractory period is of particular interest in human performance measurement, although analyses have more often tended to the theoretical rather than to the applied. However, there are many situations in operational practice where one is called upon to respond rapidly to two stimuli arriving in rapid succession, e.g. driving, flying, athletic tasks, and a wide range of other tracking behaviors. Kroll (1969) has suggested that the ability to make consecutive responses with interstimulus intervals of less than .5 second might constitute a new and orthogonal factor in human response characteristics. As such, it certainly deserves a place in the array of performance tests available for use by the researcher, and the methodology of testing this "factor," as well as its relationship to and diagnostic value for real-world performances deserves greater interest (see pp.).

Closely allied to the question of the refractory period is consideration of RT when two tasks must be performed simultaneously. Here, we refer specifically to the continuous performance of two tasks, rather than to individual "trials" requiring a combined or temporally contiguous pair of responses. Diamond (1966) has shown that improved performance on one of two continuously performed tasks of the reaction time type is accompanied by improvement on the other. Four factors contributing to improved performance with practice on a dual task have been identified by Johnson (1970). These include 1) an increase in the number of simultaneous responses, 2) a decrease in response variability, 3) the development of more stable patterns of responding, and 4) a shift in the amount of time allocated to recog-

nition, forward movement, and return movement. Findings such as these provide important clues with respect to the source of performance changes when they are observed in stressful situations. A similar clue to the possible cause of changes which might be observed has come from the work of Rabbitt and Birren (1967). These authors found that older subjects were able to respond more quickly than younger subjects when the signal appeared during repetitive tapping responses (see p.). They interpreted this to indicate that older subjects did not "program" repetitive movements in advance, but rather made each tap a separate response to a given, redundant signal. Apparently then, such a methodology would be appropriate in situations where the interest was in determining whether a given treatment had broken down a subject's ability to make continuous, easy responses over a period of time. Again, as in so many instances, we see that the most appropriate way to test the integrity of a given "skill" is not to measure it directly, but to assess it indirectly by means of a secondary task.

Response Characteristics

The nature of the stimulus, as we have seen, can greatly influence the absolute value of RT's obtained in various conditions, as well as defining the meaning of changes in performance which might be found. No less important a determinant of RT results, but one that is more frequently overlooked, is the nature of the response which must be made to a given stimulus. We have already indicated that the required response, in terms of direction, location, and physiological system involved, can not only affect the RT values found,

but can make a given RT stimulus sensitive to changes in performance capabilities and physiological systems that it previously would not test. Such a situation might occur when a response is constructed so that transcallosal integrity is required for maximum performance.

In this section, the characteristics of the response, per se, insofar as it can be separated from the stimulus, will be examined. Broad outlines of results to be expected with certain response selections will be given, although one can appreciate that in separating given responses from the stimuli with which they were used, the generalizability of these outlines is restricted. Finally, where possible, some indications of desirable response measures for various purposes will be given. However, information of this type in general terms is relatively scarce, and this question alone deserves much greater research interest.

Response Types

The vast array of possible responses to stimuli can easily be appreciated. In the case of responses, we can not deal with a small number of highly generalizable "modalities" as we can in discussing stimuli. Almost any part of the body -- internal or external -- can be used in responding to a stimulus -- tongue, eye, toe, heart, brain, etc. (and all of these have been used). It is appropriate, therefore, to consider only some of the specific response types as representative of the general classes of response the investigator has available. These specific types are spelled out in greater detail in the section on RT tests proper, but the following should place this array of choices in general perspective.

Most commonly, when we think of the "response" side of an RT test, we think of a movement by some body part in response to the stimulus. This movement can signal recognition, can terminate the stimulus, can return a dial to a null position or otherwise alter the stimulus, can initiate a second stimulus, or serve a variety of other functions. Its essential component, however, is that some "point" in the movement is identifiable as the response to the signal. The difference between that "point" and the "point" of stimulus initiation defines the reaction time. Usually, the movement required of the subject involves one or more body parts. Responses by the fingers (Bradshaw, 1970; Hannes, 1968) have been shown to depend on the number of fingers used. Hand responses, already discussed (p.) show complex dominance and directional effects (Diamond, 1970; Simon, 1967; ; Gottsdanker, 1967). When hands and feet are combined (Blyth, 1963; Blyth 1964) a possible confusion occurs between ipsilateral responses in certain choice-reaction situations. A knee-flexion task has been used to test for the differential effect of proprioceptive feedback on pre-motor and motor RT (Santa Maria, 1970). Movement time of the entire leg has been investigated as a dependent variable in an exercise experiment (Smith, 1970). In addition to these more traditional movements, reaction time has been measured for movement of the tongue (Siegman, 1962), the eye (Bartz, 1962; Latour, 1967), and the whole body ().

In using movement as the response in a reaction time experiment, several points, beyond the selection of an appropriate movement and consideration of the factors presented in the next sections, should be kept in mind. Most movement responses involve neuromuscular

transmission over varying distances and along pathways of varying complexity. This fact should be kept in mind, and a response should not be chosen which is so simple as to be insensitive to the expected effects. On the other hand, in combining motor behaviors, such as hand and foot responses, or those involving complex displays, care should be taken not to unintentionally mix responses of a different complexity. Another point requiring attention with respect to movement responses is the laterality and dominance problems (see pp.

). To ignore handedness would be inappropriate in subject selection for an experiment involving reaction by one or both hands. Similarly, in visual-motor responses, one must consider the nature of the neural and neuromuscular transmission in both the design of the experiment and the interpretation of results.

Another common form of response in an RT experiment is that in which the subject gives a verbal response to the stimulus. This can be anything from the simple uttering of a sound, to a verbal report of the result of a highly symbolic transformation which may or may not use traditional words. (Recent examples of the use of such responses can be found in Besiach and Frangini, 1970); Forrin, Kumler, and Morin, 1966; and Greenwald, 1970). An interesting and significant phenomenon associated with verbal response indicates the complexity of processes involved in this simple response. Fraisse (1969) and others have shown that reaction time is longer in naming than in reading. Thus, if a subject is shown a red square under instructions to name the color, he will do so in a longer period of time than if he were asked to read the name "RED." Here the response

is the same, but the stimuli differ in the associative connections which must be made before the response can be given. Therefore, response times differ. Such a distinction is often overlooked by researchers not searching for basic theoretical information, but is crucial if the experiment is to be organized with sufficient precision to answer the questions of interest. In using verbal responses one must also remember the primarily unilateral organization of language in the brain. Where visual stimuli are so organized that information is delivered only to the right hemisphere, verbal responses will tend to be slower due to the necessity for inter-hemispheric transmission (Filbey and Gazzaniga, 1969) (also see pp.). This phenomenon can either be a source of unwanted experimental error in an imprecisely organized visual RT experiment, or can be used to obtain information on the functioning of an otherwise inaccessible neural structure.

Another form of RT response which is used somewhat less frequently than the above types is one which involves a change in status of a physiological system. In this case, the question of interest frequently concerns the speed with which a subject can perceive and/or react to the meaning or impact of a stimulus. Thus, a stimulus is presented, and some physiological process, such as EEG or GSR, or a state such as pupil size or EMG, is monitored for change in activity. This, of course, is to be distinguished from the type of experiment which monitors physiological state while taking RT measures of some other type (e.g. in Andreassi, Rapisardi, and Whalan, 1969). In such cases, interest is primarily in how these measures correlate with an

"independently" measured reaction and so to infer the effect of physiological state on the RT. One can, however, possibly view the response capabilities of these physiological systems for their reactive capability in their own right. Many such studies have used the evoked potential of the EEG as the measure of reaction time, hoping in this way to eliminate major efferent pathways from the system (Barlow, 1964; Eason, Harter, and White, 1969; Wilkinson and Morlock, 1967). Others have used the latency for alpha blocking in the EEG (Cromwell and Held, 1969; Robinson, 1966). The electromyogram reaction speed has been used to isolate the motor component of a reaction (Schmidt and Stull, 1970; Santa Maria, 1970), the level of "spinal excitability" (Requin, 1969), and the effect of "motor conflict" involving approach-avoidance conditions (Hoshiko and Grandstaff, 1967). The GSR, which of course has a rather long latency under all conditions, is not ideally suited for reaction time studies. However, combined with other indices, GSR can sometimes be used to indicate autonomic reactivity to a stimulus, particularly a threatening or startling stimulus (Thackray, 1965).

In general, it would appear that too few RT studies have been done which utilize our present ability to measure physiological state with precision. By careful choice of the system involved, and by calling upon the vast basic literature existing in these areas, one should be able to construct stimulus-response combinations which aid precise interpretation of any alterations found in performance. The EEG evoked potential studies perhaps most clearly illustrate this "fractionation" of the RT response into more meaningful elements, in

this case afferent and efferent. However, it is not difficult to visualize an RT experiment using EEG, EMG, GSR, and/or pupillary response which could define the location of a particular stress-induced effect in terms of fairly precise neural and neuro-muscular systems. Yet outside of the areas of basic research, this potential is largely unrealized.

A final type of RT "response" should be mentioned, even though its use might be somewhat specialized. This is the introspective report. Normally, the RT situation emphasizes speed, and the objective measure involved in the task is in units of time. However, in addition to this measure and, in some cases in place of it, it is frequently valuable to obtain from the subject a report of the events he can describe which took place before, during, and after the RT sequence. Kulpe and his students, and the landmark work done in Wundt's laboratory, utilized this method to its fullest. An unfortunate development is that, in response to some excesses, the technique has largely fallen out of use. Introspection, in this case, can never substitute for objective measurement, but it can add dimensions to the objective evaluations which are inaccessible any other way. Combined with non-parametric statistical techniques for analyzing nominal and ordinal data, this response method can hold great promise for producing valid and reliable information on many aspects of reaction-time performance.

Response Repetition: We pointed out above that the RT to a stimulus which has recently been presented is shorter than to one which has not been presented recently (Bertelson, 1965) (see p.).

A "response-repetition effect" has also been demonstrated. Responses following responses made with the same hand are significantly faster than responses following response made with the opposite hand (Rabbitt, 1965). This effect occurs even when different but equivalent signals are used for the same-hand response, and when a different sequence of muscle movements is required. If, then, the response repetition rate becomes a determinant of the RT score, one must insure that particular response sequences do not occur often enough to bias any set of measurements toward the low end of the scale. In this respect, three types of "transitions" between successive responses have been identified and, when necessary, can be used as categorizing schemes to assure that none of the three are over-represented (Rabbitt, 1968). These are 1) Identical Responses, where the same signal and response are immediately repeated, 2) Equivalent Responses, where the same response is made to a new signal, and 3) New Responses, where neither signal nor response is repeated.

The effect discussed above is not to be confused with a "response-probability" effect. The response-repetition effect refers only to responses which occur immediately after each other. An additional question can be raised concerning the effect of the overall probability of a given response on the reaction time. Put in a different way, we might ask, "Is the facilitating effect of high stimulus probability on reaction time due to a bias on the stimulus side alone, or is it due to the fact that the same response is made to a frequently occurring stimulus?" Early research into this question failed to differentiate between the two probabilities. Responses

were assigned to stimuli in a 1:1 fashion (Hick, 1952; Hyman, 1953). Subsequent research has tended to favor the position that when stimulus probability is held constant, the probability of a given response does not exert a very significant effect on the reaction time (Beiderman and Zachary, 1970; Hawkins, 1970; Orenstein, 1970).

Supporting this view is a result which indicates that RT's are faster when the subject correctly predicts which stimulus will appear, but are not faster on an incorrectly predicted stimulus having the same response as the predicted stimulus (Hinrichs and Krainz, 1970).

Thus, with respect to response probability, it is perhaps less important than controlling the stimulus probability although, as will be seen in subsequent sections, the interaction between stimulus and response taken together must be considered carefully.

Special Characteristics of RT Tests

In this section, we will consider a number of selected topics dealing with reaction time testing which are too general to be related specifically to the stimulus or response. These topics will be "selected" because they either have special bearing on the use of RT as a performance test, or because they represent relatively new considerations in the RT literature which are not readily available to the non-specialist in reaction time testing. We need to re-emphasize that many topics of great theoretical interest, some bearing rather heavily on the use of reaction time in performance situations, are omitted from this discussion (e.g. theoretical models, information-theory formulations, etc.). Many of these are implied in what is discussed, but the emphasis here has necessarily had to be

limited to questions which deal with the "hard" (i.e., concrete) questions of how to set up a particular test. Thus, general questions dealing with the warning signal, error analyses, intersensory facilitation, motivation and instructions, components of the RT score, onset vs. offset RT, practice, sex differences, and S-R compatibility will be discussed. In addition, a short section will discuss the relatively little known transit-signal technique for measuring reaction time.

Use of a Warning Signal: Simple introspection by anyone who has been a subject in a reaction time experiment reveals that once the signal to respond is given, a great deal of activity is initiated without any conscious experience of planning or initiating. The subject can report relatively little "thought" occurring between the stimulus and response. He does report a great deal of thought occurring during the preparatory interval, however, while he is waiting for the stimulus to occur. If this is the case, then one would expect that manipulation of this interval would have dramatic effects on RT, and this has in fact proven to be the case.

Woodworth and Schlosberg (1954) report that for most applications, a foreperiod of about two seconds is "about right" if it is slightly varied from trial to trial to prevent the subject from anticipating the stimulus. Most studies, in fact, find that warning periods between one and two seconds produce minimal RT's. We know that muscular tension begins about 200 to 400 milliseconds after the ready signal is given and reaches a maximum in one to two seconds, with the shortest RT's occurring at the point of higher tension. Changes in the

EEG which occur during the preparatory interval appear to be much more complex, being dependent on the subject's age, and do not correlate in a detectable way with RT variations (Thompson and Botwinick, 1968). The effect of the warning signal itself seems to be dependent on age. Generally, reactions given when warning signals are used are faster than when no warning information is presented, but this result is not always found with aged subjects (Talland, 1964; Rabbitt, 1964).

When the length of the preparatory interval is kept constant from trial to trial, the subject is able to "anticipate" the approximate intertrial length, and thus to get ready for the stimulus in his (subjectively) most appropriate way. As expected, such conditions produce shorter RT's than with variable foreperiods or with no warning (Woodworth and Schlosberg, 1954; Nickerson, 1968). Nevertheless, even in this optimal condition, the absolute length of the foreperiod makes a difference. Optimal warning still appears to be two to four seconds, since the subject cannot seem to prepare in much under two seconds nor to maintain it for much over four seconds. In experiments where the warning signal is varied from trial to trial, the same overall relative priorities hold. Up to about 225 milliseconds between warning and stimulus, RT tends to get shorter (Nickerson, 1968), but beyond this no clear pattern of optimum trials emerges as a function of the warning period length. Response times are generally slow with these longer periods relative to the same period length when the intervals are constant from trial to trial.

The warning period or "preparatory interval" apparently constitutes a time of considerable activity for the subject. It would

not be inconceivable that much of the response to be given when the stimulus occurred were "programmed" during this period. If this should be true, then one would expect that the length of the preparatory interval would interact with other important determinants of the RT. Such interactions have, in fact, been found; it is clear that varying the length of the interval significantly changes the nature of the task which the subject must perform. For instance, when the warning signal was an auditory or visual stimulation, RT increased with an increase in the intensity of the warning (Kohfeld, 1969). Kellas, Baumeister, and Wilcox (1969) have pointed out that the preparatory interval may interact with the intensity of the stimulus which follows it, and that the functions describing these interactive effects may be different in different experimental designs. These authors suggest that subjects develop an ability to discriminate different preparatory intervals and form a response strategy based on their successive probabilities of occurrence (see also Baumeister and Joubert, 1969).

For performance test purposes, it would seem desirable to present the subject with a task which is most likely to call upon the type of skill of interest to the experimenter. In the case of warning periods in reaction time tests, this would take several forms. Since several "avenues" of adequate performance are open to the subject where the warning period is constant and of the duration of two to four seconds (e.g. time estimation, muscular tension, etc.), one might predict that this design will produce the most resistance to decrement in performance. On the other hand, if extremely long and

highly variable warning periods are used -- or none at all -- the experimenter may obtain a "purer" measure of the subject's true "reaction capability." However, he will often achieve this at a cost of increased variability in the data. Depending on his circumstances, and remembering the interactions found with varied time periods, the experimenter might choose to use a shorter but still highly variable foreperiod, or to use more subjects, or fewer but more highly practiced subjects. Each of these decisions represents a tradeoff which must be made consciously and with some literature familiarity.

Analysis of Errors: In the typical reaction time experiment, where the interest is traditionally on speed, an error rate below 10% is usually the goal, even in complex, choice reaction times. If rates much higher than this are tolerated, then the task becomes one which is heavily loaded on the perceptual-decision side, and the motor-speed component begins to account for less and less of the total variance. Given such low error rates, it is no wonder that error analysis in RT experiments has always been somewhat problematical. Frequently, in simple RT or on easy choice RT experiments, there are just not enough errors made to make analysis profitable. Even when such error analyses have been done, they typically include only the mean numbers of errors for each group during the entire experiment, perhaps with a measure of variability between subjects.

Although such analyses have been disappointing with respect to most "performance" research on stressors, some theoretical attention has been given to the errors made in an RT experiment, and interesting analytical possibilities are beginning to emerge (Flitts,

Peterson, and Wolpe, 1963). However, in the common type of RT test the situation still appears to rely on gross statistical evaluation (which might or might not duplicate information contained in the RT score itself) and on the perceptive, insightful analyses by the experimenter of individual subjects' errors.

For one type of RT task, there appears to be an analysis technique which offers more promise (Schouten and Bekker, 1967; Rabbitt and Vyas, 1970). In a serial, self-paced choice RT, one can determine the "error probability" for a given subject at each of many different response speeds. Thus, where each response the subject makes is scored correct or incorrect, and where stimulus-response times are derived for each response, one can construct a frequency distribution showing per cent errors as a function of the total number of responses within each speed window. Such a plot is called a "T-function," and is illustrated in figure RT-1.

Even simple analysis of a particular T-function will indicate a speed "window" which, if exceeded, produces a dramatic increase in errors but which appears to represent a true optimum since an increase in RT is not accompanied by a decrease in errors. Other analyses are possible, such as determining the median of a theoretically "optimal distribution" and calculating the subject's strategy in terms of "risky" and "cautious" responses (Rabbitt and Vyas, 1970). Such techniques offer some encouragement to the stress researcher

in opening up possibilities of seeing subtle effects on strategy as a result of experimental treatments. However, one should note that this particular technique does not provide a valid means of distinguishing between performance in different tasks. It does offer the possibility of analyzing within specific tasks, though. In line with this, a preliminary taxonomy of error types has been developed by Rabbitt and Vyas (1970) for the serial, self-paced RT tasks. This includes errors due to 1) motor set, 2) motor programming, 3) motor confusion, and 4) perceptual analysis. One would hope that this direction will be continued with respect to many kinds of RT tests, perhaps allowing eventually for objective indication of response strategy and source of errors as well as delays in the speed reaction.

Intersensory Facilitation: We have noted that the reaction time to binocular stimuli is shorter than to monocular (p.). The question was raised early in the history of RT experiments whether the reaction to combined stimuli in different modalities is faster than in either modality alone (MacDougall, 1903; Todd, 1912). Woodworth and Schlosberg (1954) dismiss the question by positing that the subject is unable to respond to the stimulus in a modality for which the RT is slower than the modality of the accompanying stimulus. Thus, if given a tone and a light together, he will respond to the tone no matter what his instructions and, consequently, his RT will be that of a simple RT to tone. Early experiments seemed to bear out this supposition, since when light and tones were combined, the RT was the same as to the tone alone.

Recently, though, there has been a renewed interest in this

question -- at least with respect to light and sound stimuli. In 1954, Teichner concluded that "simultaneous stimulation of more than one sense modality produces faster RT's than stimulation of just one!" (Teichner, 1954). Thershenson (1962) showed that when light and sound are presented singly and in combination, RT's were faster to the combination than to either alone. In addition, maximum facilitation occurred at or just beyond the point at which the stimulus asynchrony was equal to the difference in RT to the single stimuli. Other experimenters have confirmed and extended these basic results (Simon and Craft, 1970; Morrell, 1968; Morrell, 1967; John, 1964; Davis and Green, 1969; Bertelson, 1967; Nickerson, 1970). Although many unanswered questions still exist and research into these areas is still being carried out, it is reasonable to suggest that those interested in performance should consider the following points when using RT experiments where simultaneous sensory stimuli may be present: 1) Light and sound stimuli occurring in close temporal proximity may interact to produce a faster RT than if either had been presented alone; 2) the magnitude of this effect can be influenced by the amount of time separating the light and sound stimuli; 3) the intensity of each stimulus may affect the magnitude of the change in RT; and 4) the effect frequently changes from facilitory to inhibitory when the two stimuli are presented in the same modality (see "Psychological Refractory Period" pp.). Typically, intersensory facilitation is greatest in those cases where the RT is to a visual stimulus and where "irrelevant" stimulus is a tone of fairly high intensity occurring from 0 to 200 milliseconds

ahead of the visual signal. However, the literature in this area makes it clear that these effects are highly interactive with other experimental conditions, and so it is necessary to refer to results obtained in conditions similar to those being used before anticipated effects can be determined.

Separation of RT into Components: The classic attempts by Donders (1969) to separate reaction time into component parts (see pp.) represented one of the first attempts to probe more deeply into the total RT response. Many subsequent attempts to do this have been made, with varying success and, in some cases, Donders' techniques are still being used successfully (see Taylor, 1966). Unfortunately, though, most researchers in the applied fields have not attempted such fractionation of reaction time, being content to use summary statistical treatments of the total RT or, at best, obtaining several measures of RT, such as simple and choice RT's.

Such simplistic treatments may be uneconomical in terms of potentially informative data being wasted, and in terms of specific decrements being masked in the overall response and, therefore, missed. Although no universal system has evolved for RT fractionation, several interesting general trends are apparent in the literature. The most obvious of these techniques involves simply designing the apparatus so that separate times are calculated for various movements in an RT experiment. This may be an elementary system where, for a simple RT experiment, the subject keeps his hand on a switch until the stimulus appears. The time from stimulus onset until his first move off the switch may be considered a "simple reaction time." Then the time from leaving the switch to reaching the response button may be called the

"movement time." In this way, the total reaction time has been divided into two component parts, each of which may be orthogonal to the other (see next section on "Movement Time!");

A more complex version of the above system has been constructed (see figure RT-2). In this system, the subject responds to a light by removing his hand from a lap switch, moves to a response device, manipulates it, and returns to the lap switch. Times are automatically calculated for his initial response time, travel time to the response device, manipulation time of the device, and return to the switch. Since combinations of these times are possible, analysis of the data rapidly gets to the point of requiring computer assistance. However, for purposes of stress analysis and human engineering, such a system provides detailed information on task components which are lacking in an overall RT score.

One of the more frequently used breakdowns of the simple reaction time is into "premotor" and "motor" components (see Botwinick and Thompson, 1966; Yensen, 1966; Weiss, 1965). This is usually defined to mean breakdown into the period between stimulus onset and the appearance of electromyographic changes (the "premotor" period) and the period between these changes and the actual, completed response. It appears that changes in RT due to such things as set, motivation, practice, age, etc. may have significant loading in the premotor component. Extension of such analyses may permit interesting hypotheses concerning the locus of any stress effects seen in RT and, in conjunction with other techniques, may lead to definitive information on the nature of RT differences.

Statistical treatment can often effect component analysis of the RT score. Such treatments have taken the form of factor analytic studies. (Botwinick and Brinley, 1962) or of inferring component latencies from statistical distributions of total RT's (Hohle, 1967). A more sophisticated treatment has used signal-detectability theory to evolve the "central component of simple reaction time" (Emerson, 1970).

A pioneering effort at separation of RT components on a physiological level was made by Haider, Ganzlberger, and Groll-Knapp (1969). Using patients during stereotaxic surgery, these authors were able to demonstrate a prominent thalamic potential during virtually the whole stimulus-response interval in reaction time. One prominent thalamic potential change precedes the beginning of the cortical slow negative potential shift, and another follows its termination. It is suggested that the first wave activates the process related to the preparation for movement, and the second initiates the motor response. If these results are confirmed, then important basic determinants of RT components will be isolated. If, then, these components which are accessible to the performance researcher are found to decrement under certain stress conditions, meaningful interpretations are possible.

Stimulus-Response Compatability: In a choice-reaction situation, one might expect that the degree of similarity or compatability between the stimulus and the response would influence the reaction time. It should, for instance, take longer to respond "no" when the stimulus is the printed word "yes" than to respond by saying "yes." Such an effect has, in fact, been found and confirmed in a number of

studies (Fitts and Deininger, 1954; Conrad, 1962; Alluisi, Strain, and Thurmond, 1964; Smith, 1968). Generally, the more "naturally" a stimulus and response go together, the faster the RT will be. Examples of such naturalness include hitting a button which is the same color as the stimulus light, moving to the right-hand switch in response to a light on the right side, and even using nonsense syllables which have high association value where the response is to read the syllable.

There are several categories of compatability which will affect the subject's reaction time (Fitts, 1959). From the viewpoint of performance research, however, an important theoretical issue has been raised concerning the effect of S-R compatability on the nature of the way the subject handles the task. The task may, with extremely high S-R compatability, become independent of the number of alternatives presented (Sanders, 1967). Thus, when S-R compatability is this high, the task may fail to measure information handling in the subject, and may be a relatively simple reaction time task even though it might look like an extremely complex task measuring a great deal of capacity. The suggestion has also been made that when S-R compatability is high, the subject uses a "parallel" processing mode for information, and thus may be able to handle higher workloads (Smith, 1967). If the facilitating effect of high S-R compatability were not considered in the interpretation of such studies, erroneous extrapolations concerning subject's capabilities in other task situations might be made. One should note, however, that the above considerations are grossly oversimplified with respect to their mathematical bases, and definitive interpretations based on such preliminary results should not be made.

But they should influence the design of experiments so as to avoid problems of interpretation.

Movement Time: We noted in the section on RT fractionation that one of the most elementary ways to break the reaction response into components is to measure the initial time to respond to the stimulus and the time occupied in moving to the response keys. This latter time, which can assume many forms depending on the experimental setup, will be referred to as "movement time."

The question arises as to whether the movement component of an RT task measures anything different than the total RT score of which it is a part. More precisely, does movement time performance require processes different from those involved in getting the initial response started after the appearance of the stimulus? Many studies have attempted to determine this, and based on correlational and factor-analytic results, the general consensus is that movement time is independent of the initial speed of reaction (Slater-Hammel, 1952; Teichner, 1954; Fleishman, 1958; Henry, 1961; Fitts and Peterson, 1964; Breck, Dellaemer, and Poock, 1969; but see Pierson and Rasch, 1960, where "a low but statistically significant" correlation was found between movement time and reaction time). In females, movement time has been shown to improve with age up to age 15, remain constant to 19, and then become a pattern different from that found for reaction time (Hodgkins, 1962). Movement time appears to be affected by such response variables as the size of the target and the amplitude of the response required to hit it, whereas the "pure" reaction time is relatively unaffected by these factors (Fitts and

Peterson, 1964). Such evidence has been interpreted as indicating the serial and independent nature of perceptual and motor processes. On the other hand, Kantowitz (1969) used both single and double stimulation conditions and concluded that RT and movement time reflect additive rather than independent stages of information processing. One would, therefore, think it desirable to avoid over-generalizations regarding the nature of the processes underlying these RT components, although for most applications both would be worth obtaining and analyzing.

The Transit-Signal Method: The questions discussed so far in this section have assumed a particular method of studying reaction time -- the "signal method." This method involves response to the onset or offset of a particular signal which may have any nature. This method has been by far the most frequently used in the field of reaction time. There is, though, a different method which has as long, if not as extensive, a history as the signal method. This is the "transit method" and was discussed by the original reaction time researchers, the astronomers. In this method, the subject's task is to respond when a moving target crosses a reference line.

The transit method has not been used extensively in reaction time testing, in spite of its obvious face validity for many types of common tasks. One reason is that the subject has available to him a movement clue which may allow him to synchronize his response with the transit rather than to respond to the crossing event per se. Although "catch" trials effectively prevent such behavior for the overall series (Slater-Hammel, 1960), questions still remain about the mean-

ing of the reaction time derived with this method. For instance, what role does the factor of "rate control" found by Fleishman () play in an individual reaction score? In addition, the method is probably limited to simple visual reactions ("a-reactions") and is difficult to manipulate experimentally. On the other hand, passable test-retest reliabilities have been demonstrated, performance with and without knowledge of results has been shown to be free of systematic bias, and a small threshold refractory period has been found (Slater-Hammel, 1960). The method should be considered, therefore, for use in certain specific applied problems and, when appropriate, should be used with great caution.

A combination of the transit and signal methods would appear to offer the possibility of overcoming many of the problems posed by each alone. Gottsdanker (1970a) has proposed a display system which consists of a rotating disc in which a sector of variable arc has been defined, either by painting it or removing the sector. A reference line stands before the disc, and the subject is informed that the stimulus will only occur when the reference line and the sector are aligned. Thus, the subject's timekeeping role in the signal method is changed drastically by clearly defining the time during which the signal can occur; on the other hand, the subject's ability to depend on absolute movement rate to synchronize his response is reduced. Gottsdanker points out several other advantages of this method, as well as certain limitations. It has been used to test factors related to the subject's reaction to time uncertainty (Gottsdanker, 1970b) and the fact that it minimizes many of the timing and foreperiod problems

of the signal method, as well as its freedom of time-memory effects, recommends its use in a variety of applications.

Miscellaneous Experimental Considerations: Obviously, in the space of a summary introduction to reaction time tests, one can not list all the factors which might cause variance in experimental results between laboratories using apparently the same test, or even within a laboratory on different occasions. Just as obviously, even those factors which have been discussed have had to be treated superficially. No attention has been given to such vital experimental considerations as the effect of instructions, knowledge of results, motivation, or the sex of the subject on the final RT scores. To treat these, and a variety of other RT subjects, in detail would require separate volumes. Yet, as will be indicated below, any of these factors can influence the RT's found in a given experiment and, worse, can influence the presence, absence, and/or nature of any changes in RT as a result of experimental treatment.

For example, the instructions in an RT experiment would seem, on first glance, to be one of the more straightforward aspects of the test. The subject is told to respond as fast as he can. Yet, it has been shown that instructions can severely affect the RT scores, both absolutely and in interaction with other factors such as amount of practice (Noble, Alcock, and Frye, 1959). However, this effect does not occur in all conditions (Sidowski, Morgan, and Eckstrand, 1958; Kushner, 1963). If the effect of motivation is also considered (as can happen in a stress experiment or one in which a blind design is not used) the picture is even more complex. Even on the physiologi-

cal level, it has been shown that in high motivational states the contingent negative variations in the scalp EEG have significantly greater amplitude than in low motivation (Waszak and Obrist, 1969). This was accompanied by shorter RT's. Thus, failure to find RT changes in cases where the stress would be expected to produce such changes can sometimes be blamed purely on experimental designs which allow for such sources of variation.

Intensive study of the problem will sometimes reveal ways to circumvent such problems. For example, we frequently find that with increased length of the test, the subject's performance tends to degrade. This "work" effect could be bothersome in many designs. On the other hand, McCormack, Binding, and Chylinski (1962) have shown that if the subject is given knowledge of results during the experiment, performance remains invariant with respect to time on the task. As a minimum, such a result could be used for the time period they studied (35 minutes) to "design around" the time problem. If giving knowledge of results introduces problems, it might be some help to know that performance will improve even when subjects are given false knowledge of results on a random basis (Peretti, 1970). Thus, one does not even have to inform the subject of the true outcome of the experiment (provided other considerations do not require it).

In general, then, the experimenter cannot, it is clear, simply decide to use "reaction time" as one of his measures and then just pick one of the test techniques mentioned in this handbook. Every test, and every decision to use the test in a particular way, introduces effects which may change the experimental results and which certainly

alter the interpretation and generalizability of those results. On the other hand, it is unrealistic to expect every experimenter to be so familiar with the literature that he will know the implications and generalization limits of every test he might use. To some extent, one hopes that a handbook such as this will help to reduce the magnitude of this problem. The preceding discussions, in addition to pointing out specific areas of concern which are relatively new, should also serve to "sensitize" the test user to the problems of reaction time testing so that he will raise his own questions of test meaning and interpretation. Then, through use of the several general bibliographies available (see Kamlet and Boisvert, 1969; Symington, 1970), more detailed information on the questions of interest can be obtained. Certainly such a procedure is necessary prior to establishing a final experimental protocol. Whenever a particular test technique implies some especially noteworthy effect, an attempt has been made to point this out in the test portion of this handbook. However, in no case can it be assumed that all such necessary cautions could be included in a particular test, and the test user still retains ultimate responsibility for avoiding improper utilization or interpretation of a given test.

GENERAL VARIETIES OF REACTION TIME TESTS

Introduction

There are two general methods of reaction time measurement, and all of the varieties of tests which have been used can be subsumed under these methods or under a combination of the two. Between the two, the signal method has been used the most frequently and is most familiar to the general population. In this, the subject is instructed to respond to the appearance, disappearance, or change in a designated signal which occurs at discrete time periods. Thus, the subject is faced with a discrete task where the condition of the stimulus at any given moment signals either a "go" or a "no go" situation. Once the stimulus signals "go," the subject's task is to respond as quickly as possible according to the previously given instructions. These instructions specify the signal-response "mapping" which the subject is to perform. They may specify a single possible response to a single invariant signal. This is a 1:1 mapping which is classically called the Donders "a-reaction" or the "simple reaction time" (Donders, 1969). Or the instructions may specify a "many:many" mapping, where several signals are used and these are matched to several responses. In this case, the mapping situation is a Donders "b-reaction," or a straightforward case of the choice RT situation. Variations in these mapping conditions are possible (see e.g. Donders "c-

reaction," pp.) but for the present purposes, these are probably best subsumed under the terms "simple" or "choice" reaction time. The important point to remember is that the mapping requirements of the task define a great deal of the subject's workload and, therefore, are a major source of variance in the RT situation. Consequently, they should be planned with extreme care. Characteristics of the mapping task, primarily in the choice RT but even in as elementary a task as the simple RT, can define the absolute RT's obtained, the interaction between stimulus, response, and subject variables, and perhaps most importantly other physiological and psychological systems which the test measures.

The signal reaction method, because of its extensive usage, will constitute the great bulk of this entire section. It will be divided generally into a section on "simple" RT and one on "choice" RT. Under these headings will be presented specific types of stimulus-response combinations which have been used. Unlike other sections of the handbook, the information on each test will usually not contain extensive descriptions of the apparatus, statistical data, or other information appropriate to more standardized procedures. This is done, of course, because reaction time tests, perhaps more than any others, have been "home-grown" by individual researchers and, unfortunately, there is no such thing as a "standard" RT apparatus. Because of this, a separate section on commercial or other well-defined instruments will be included and cross-referenced to the present section.

The second general type of RT method is the transit method. This technique has had remarkably little use, for reasons mentioned

previously (see p.). However, it does constitute an entirely different task than that represented by the signal method, and thus must be discussed separately in spite of its brevity. In this technique, derived from the astronomers, the subject's task is to respond when a moving target passes a pre-determined line or point. Since the subject is able to view the target moving toward the line, the task takes on a much different form from the totally discrete signal method.

Few direct uses of the transit method have been made. But current interest in pursuit tracking, and in studies where the task is to respond rapidly in order to keep a moving target within previously defined boundaries, begins to blur the distinction between tracking and reaction time (i.e. the definition of 1 in the critical instability tracking task as a reaction --- p.). For these reasons, the transit method, as well as the newer transit-signal method, will be discussed.

The Signal Method

The signal method of measuring reaction time has certain advantages which have resulted in its use by most RT researchers. Certainly it is the more flexible of the two RT techniques. Reaction speed using from very simple to very complex signals can be measured with this method. More importantly, this technique appears to be the only one which can measure what people generally mean by "reaction time," i.e. the fastest speed with which a given response can be made to the discrete occurrence of a signal. So the signal method is what naturally occurs to a researcher who wishes to study reaction time. It

is probably true that the signal method measures pure "reaction time" only under extremely rare conditions of stimulus timing and stimulus-response mapping as, for example, when a simple RT is used with complex, variable interstimulus intervals, high S-R compatibility, etc. On the other hand, it is also true that the signal method is capable of probing much more than "pure" RT and, with proper selection of stimuli and response in a "choice" RT situation, can yield data on such inaccessible factors as interhemispheric transfer time, information processing, retinal sensitivity, as well as a variety of other factors. In the test listing which follows, suggestions will be made on how some of these might be accomplished.

Simple Reaction Time (Signal): By definition, a simple RT can contain one signal and one response and there is always a 1:1 mapping between them. The only addition to this scheme which is allowed is the occurrence of "catch" trials, usually in situations where the foreperiod is constant. At the time a stimulus is normally given, it is withheld and no response time is obtained. Although this might seem unnecessary in a simple RT experiment, it is a desirable feature in order to prevent the subject from "timekeeping" and responding in part to the synchronous nature of the signal (see Gottsdanker, 1970a). Thus, if the experimental purpose would be better served by eliminating "timekeeping" from the subject's score, catch trials should be included. Another obvious way to frustrate the subject's timekeeping tendency is to use varied foreperiods. However, even this technique is not as effective as it might first appear. Any distribution of foreperiods, whether systematic or random, suffers from the

fault that, as time goes on after the warning signal or the start of a trial, the probability is .2 that a signal will occur in any second of a five-second foreperiod, then if it has not occurred by the fourth second the probability is 1.0 that it will occur in the next second. This can severely influence the interpretation that a given change in RT, or lack of it, will be given under stress conditions. A solution to this dilemma has been proposed. Nickerson and Burnham (1969) proposed a technique of "nonaging" foreperiods in which the probability of signal occurrence remains constant over time. This technique has distinct advantages in reducing the subject's timekeeping tendency, but does not eliminate the problem entirely. Perhaps the best technique, if this question is of genuine import to the experiment, is a combination of the nonaging foreperiod technique and the use of catch trials. If this is not sufficient, then consideration should be given to the use of the transit-signal method described below (see also pp.).

Simple Reaction Time (Transit and Transit-Signal Methods):

These methods have been discussed previously (pp.).

Choice Reaction Time: Whenever there is uncertainty introduced into the mapping of stimulus and response, a choice or decision situation exists. Consequently, whenever the S-R mapping is not 1:1, the task should properly be considered a "choice" reaction task, even though there still may be only one response (i.e. a many:1 mapping). This introduction of uncertainty (over and above timing uncertainty) changes the reaction task completely from what it is in the 1:1 mapping

condition. The nature of processes underlying the subject's response becomes more complex in most choice RT situations, involving such factors as scanning, memory, association, and/or probability generation, which are either absent or minimized in the simple RT situation. Even in view of this, however, the researcher should not lose sight of the fact that there is a virtual continuum between the "extreme" simple and choice situations. Thus, even in a relatively simple RT situation such as responding to a light with a finger movement, there are elementary aspects of scanning, attention, S-R associations, and even timekeeping and/or probability-function generation of signal timing. This obvious point is often forgotten in choosing an RT test, and researchers look on a fairly involved "simple RT" as if it were a physiologically elementary reflex, or on uncomplicated "choice RT's" as if they required magnificent feats of associative mental agility. There is, between the electrophysiological reflex and the totally symbolic operation, enough of a variety of reaction time test (in terms of stimulus, response, and mapping) to approximate any need.

Many models of the subject's behavior in a choice RT situation have been developed (see, e.g., Christie and Luce, 1956; Stone, 1960; Audley and Pike, 1965; Edwards, 1965; DeKlerk and Oppem 1970). For the present purposes, though, these statistical treatments are much too detailed. The researcher is usually interested primarily in choosing an S-R situation that will 1) maximize the chance of finding a performance decrement if it exists, and 2) interpreting it if it is found. For these purposes, the subject's typical way of responding to the task may represent only a starting point. We must

also consider such questions as the alternatives open to him for performance when this typical channel is blocked. It is this consideration which is frequently overlooked in choice RT research. Since the task is becoming more complex (relating to the simple RT) it would be expected that more alternative performance channels are opened up. Similarly, one might expect that the further one gets from the "reflex" RT, the more the overall response will be affected by motivation, attitude, boredom, knowledge of results, practice, and a multitude of other factors which, in a good experiment, must be controlled by the experimenter. All of this is in no way meant to discourage the use of choice RT. It is simply to indicate that the measurement of more "complex" processes is not achieved without some cost in terms of planning and, in some cases, interpretability.

Self-Paced vs Forced-Pace RT's: Once an appropriate stimulus-response pairing is determined, one must next decide on the method of stimulus sequencing. Broadly, there are two general categories of stimulus sequence, self-paced and forced-pace. The intended difference between these two revolves around whether the occurrence of a new signal is timed from the subject's response (self-paced) or from the last stimulus (forced-pace). Within each of these categories, the sequencing has been further classified into discrete or serial, depending on the amount of time involved between stimuli. Thus, four types of RT sequencing are possible:

- 1) Self-paced, serial: In this, when the subject makes a response, the next signal comes on immediately or almost immediately.

- 2) Self-paced, discrete: Here the subject's response initiates an intertrial interval (which may be constant or varied) so that

there is always an appreciable period of time between one response and the next stimulus.

3) Forced pace, serial: The occurrence of a signal is dependent on the time since the last stimulus. The timing, however, is arranged in such a way that signals occur in rather rapid succession and there is often a possibility, or even a probability, that the subject will not be able to "keep up" with the task and may actually see two signals at once.

4) Forced-pace, discrete: The signal is again timed from the previous signal. This time, though, ample time is given between signals so that the subject will certainly respond between signals, or will be considered to have missed the signal altogether. In this latter case, the signal is typically removed and the score on that trial is treated as some arbitrary maximum, or ignored.

In those cases where both forced and self-paced techniques are applicable, the differences in RT between them are not as great as one might expect; they seem highly dependent on additional experimental factors. Self-paced discrete reactions have been found to be more accurate but slower than self-paced serial reactions (Brainard, Irby, Fitts, and Alluisi, 1962), but the differences were small. Shaffer (1967) found that subjects were both slower and made less use of advance information with self-paced than with discrete pacing. From an information-processing viewpoint, Klemmer and Muller (1969) concluded that self-paced tests can result in as high transmission as forced pace tests.

From a practical viewpoint, the use of self-paced, serial techniques tends to avoid many problems dealing with the optimum interstimulus interval (pp.), since the interstimulus interval is always very close to the subject's reaction time. However, it does tend to "work" the subject, since he never gets a rest period. Thus, fatigue might become a problem. The technique, of course, is appropriate only for choice RT tests, since it rapidly would become a test of tapping ability in a simple RT situation with 1:1 mapping (unless catch trials are used extensively).

The most commonly used technique is probably the self-paced, discrete sequence. This is appropriate for simple RT; and can probably be set up to avoid problems of the serial method while retaining most of the advantages. However, with this technique, new questions of foreperiod emerge, as well as the question of whether or not to use a warning signal. In a similar situation, Foley and Duvis (1960) found that the task with a warning signal does not differ from the task where the subject's response serves as a warning signal. However, this finding is obviously related to the length of the interval, and if long intervals are to be used, a warning signal would become a necessity if the task was not intended to become a timekeeping or vigilance task. The question of foreperiod length and distribution is more complex, and has been discussed separately.

The forced-pace, serial task deserves special consideration. Its unique advantage is in opening up the possibility of having two stimuli appear at the same time. There are certainly circumstances where this might be a desirable feature (e.g. to simulate emergency

situations where things happen at once, or to establish response preferences or perceptual tendencies), but the use of this technique certainly adds additional factors to the reaction situation. If the subject knows that the stimuli are independent of his response, he has the added burden of searching for a new signal during his response to the first. This never happens in any of the other techniques of sequencing. The added stress of this alone is great. There is also the fact of "psychological refractory period" (pp.) which is not only a factor on those trials when stimuli occur together, but may affect all other trials as well. Finally, there is the problem of scoring. On an elementary level, what is to be done with trials which occurred very close in time? Should the refractory period's effect on RT be considered? But, on a more sophisticated level, how do you "fractionate" a response where two whole responses were occurring at once? These problems can certainly be overcome if the question being asked warrants such an elaborate plan, but they must be faced in the planning stage, and not come as surprises in the conduct of the experiment and embarrassments in its interpretation.

The forced-pace, discrete technique, in practice, doesn't often differ from the self-paced, discrete. This is so because the time for most RT's is so short it will hardly be noticed in a long interstimulus interval. Theoretically, some might argue that the forced-pace technique is better at avoiding accurate timekeeping by the subject since he is occupied with his response during part of the interstimulus interval. However, one doubts that this would affect the results much in the typical applied experiment.

STIMULUS-RESPONSE COMBINATIONS

The modality through which the signal will be delivered to the subject presumably will be determined by the nature of the question to be answered, the limits or characteristics of the stress environment to be used, the absolute and relative speeds of the responses one wishes to test, or a combination of these factors. In many cases, then, this constitutes the most basic question to be asked. In these cases, other questions of stimulus frequency, duration, and sequencing, as well as questions about response characteristics, follow on the selection of a modality to be tested. For this reason, this section will be organized around the modality of stimulus input (e.g. vision) and specific subcategories within a modality will reflect the variety of ways information can be presented to that modality (e.g., lights, words, pictures, etc.). Different forms of RT test within the same modality will be segregated sequentially (e.g, on and off, RT to movement) but will not be placed under separate subheadings. Responses to the various stimuli will be mentioned initially, and exotic response forms will be stressed separately, but a separate listing will not be given for every possible response to every possible stimulus, i.e. stimulus-response combinations will not simply be permuted to multiply the number of test listings. The reader is expected to appreciate those responses that are appropriate for certain stimuli, even where they are not pointed out.

Visual Signal

A. Single light signal. Much simple RT research involves the use of a single light stimulus which comes on well above threshold at prede-

terminated times. It should be obvious that the light signal, as well as the switch initiating it, must be silent if RT to the light alone is desired, since auditory RT is faster than visual. Intensity of the light is a significant factor (see pp.) and wavelength can influence the absolute reaction time obtained (pp.). In the fovea, RT to onset or offset of the light has been reported to be the same at some intensities but not at others and, in the periphery, onset of the light gives a faster response (Pease and Sticht, 1965; Bartlett, Sticht, and Pease, 1968; Goldstone, 1968). The reaction time is faster if the entire retinal surface is illuminated by the light (Elliott, 1968); one study found a lengthening of the reaction time which was different for red and blue lights but which corresponded to the rod-cone density function (Eason, Oden, and White, 1967).

TEST RT-1: SINGLE LIGHT, SINGLE RESPONSE RT. Under this heading is included all simple RT tests (Donders' "a-reaction") where a single light, well above threshold, is presented to the subject in a constant retinal position. When the light goes on, or off, the subject responds with a predetermined single response. There is no "decision" except to respond or not to respond since mapping is 1:1. Movement may or may not be included in the response and the interstimulus interval may be constant or varied. The sequencing may be either self-paced, discrete or forced-pace, serial or discrete, although interpretation of this task may be quite different under the forced-pace serial sequencing (see pp.). Intensity and wavelength of the light affect the absolute RT (see pp.).

Literally thousands of experiments have been done using some form of this test and dating from the time of Donders. Response to the light can be anything yielding a reasonably stable "point" of time. In addition to obvious responses such as finger, hand, arm, and leg movements, vocal responses have been used (Birch, 1967). Most commercial apparatus which is designed to test reaction time can be adapted to obtain this type of measure, but it is probably true that individual experimenters most often construct their own instruments.

Variations of the single light signal: Clearly, the simplest presentation of the single light signal involves placing the light some distance from the subject and having him respond to it when it comes on. For special purposes, however, variations of this procedure are sometimes used.

One stimulus manipulation which has been used successfully involves constructing the unit in such a way that the single light signal is delivered only to one cerebral hemisphere. This can be done because of the semi-crossed nature of each retina. Since the fibers from the nasal half of each retina go to the opposite side, and those from the temporal half go to the corresponding side, one can limit the visual stimulus viewing to the nasal half of one eye and the temporal half of the other. Several techniques for doing this are available (see Filberg and Gazzanusa, 1969; Jeeves and Dixon, 1970), and the technique allows for evaluation of hemispheric changes in response to stress, as well as the functional integrity of interhemispheric processes.

TEST RT-2: SINGLE LIGHT - SINGLE RESPONSE.

Stimuli directed to various retinal locations: For some applications, one desires to know the absolute reaction capability to a particular light stimulus which will appear at a constant retinal position, usually other than the vovea centralis. In such a case, the subject should be required to maintain a fixation point such that the light stimulus will occur in the desired retinal location. As a general rule, other factors being constant, RT becomes longer as distance from the periphery is increased.

The particular problems associated with this technique revolve around the difficulty of insuring constant retinal location. The fixation point introduces an additional element which could, under certain conditions, be facilitating or masking. The RT is generally considered to vary with the rod-cone density function in various retinal locations and, therefore, characteristics of the stimulus light become crucial in this type of test. Finally, there will be differences in the absolute RT depending on whether onset or offset of the light is used as a signal (see).

One should note that this test is similar to one to be described later (Test RT-11: Multiple lights-single response) which might be considered in lieu of this. Generally, the present test presents a closer approximation to a "pure" RT since stimulus uncertainty is less. Consideration should be given to use of both tests in order to assess the effects of the added uncertainty.

TEST RT-3: SINGLE STIMULUS - SINGLE RESPONSE RT: EFFECT OF A BORDER.

Another variation of the single stimulus involves the use of a border in the visual field (Versteeg, 1970). In this, the visual field can be divided into two contiguous regions of black and white, or various colors. The stimulus light can then be presented in various positions in either field, and the effect of the border and mixed field can be assessed. Such a setup affects both onset and offset RT's. In situations where this question is of interest, or related ones dealing with multiple or irregular borders, the experimenter might consider such a field superimposition on the subject.

TEST RT-4: OFFSET OF THE STIMULUS LIGHT. In some applications, it might be of interest to measure the subject's ability to respond to the offset of a stimulus light. This may be of interest in its own right (to evaluate the status of certain retinal receptors or because of specific "real-world" applications) or one may wish to do this in conjunction with measuring onset RT in order to probe for differences in the relation between the two.

Offset RT's can obviously be measured in ways which are analogous to almost any of the onset techniques. A continuously burning signal may simply be turned off to obtain a completely "simple" response. Analogous to the flashing of a light, a continuously burning signal may simply be interrupted or pulsed for some period of time well above threshold (Sticht, 1969). The onset of the light can be used as a warning signal.

TEST RT-5: UNEXPECTED CHANGES IN THE STIMULUS. For some applications, one might wish to assess the effect of unexpected but irrelevant changes in a stimulus on the subject's simple RT. This can be done in a number of ways (size, duration, location, etc.). The prime requirement being that the changes in stimulus parameters be, in themselves, truly irrelevant. Thus, if the size of the stimulus light is to be varied, then it must be certain that all sizes used are above the threshold for size-intensity or size-area effects. One study has used a colored light as a stimulus and measured GSR to presentation of a different color (Grim and White, 1965). In this case, they were careful to equate intensity between the two light colors. In general, use of such techniques to introduce stimulus changes would appear to be an extremely delicate operation, and one which should be done with great care.

TEST RT-6: SINGLE STIMULUS - SINGLE RESPONSE RT: USE OF MOVING VISUAL STIMULI: RT to the appearance of a light which is or seems to be moving might be of interest in some real-world applications. Fairbank (1969) had subjects view a moving mirror in the dark. At a specific time, a light went on and its reflected image in the mirror caused the subject to perceive the light as moving. His response to seeing the light was to release a microswitch. The authors also produced apparent movement by stroboscopically flashing five lights in succession. Results of this experiment revealed no difference in reaction time between real movements, apparent movement, and a stationary flash of the same duration (50 milliseconds). Latour (1967) has measured reaction time to horizontal changes in the

position of a fixation light and this technique would appear to have some advantages when EEG is to be measured simultaneously with the RT.

TEST RT-7: SINGLE STIMULUS-SINGLE RESPONSE RT: USE OF A FLASH: If a flash is to be used to measure single RT, one should remember that RT has been shown to be faster with higher intensity flashes in the range from 7.9 to 15,850 millilumens (Lewis and Mertens, 1967). But flash duration from 2 to 1024 milliseconds had no clear effect. Interstimulus interval effects are still important, with shorter intervals producing faster RT's (Morrell, 1968). The suggestion has been made that a flash produces, in some individuals at least, an extremely short latency increase in voltage between two fingertip electrodes passing a 2 microamp direct current (Levonian, 1967). If validated, this would constitute a unique response phenomenon which should be explored in conjunction with flash stimuli for its possible usefulness in stress research.

TEST RT-8: SINGLE STIMULUS-SINGLE RESPONSE; THE TRANSIT METHOD. The transit method of reaction time measurement has been discussed previously as an alternative to the more commonly used signal method (see pp.). In this method a target, usually visual and typically a single light, moves across the subject's visual field. At some point in the field, the target reaches a reference line and the subject is to give his response at this time. One of the problems with this task has been the difficulty in obtaining exact crossing, or "transit," times from which to gauge the subject's reaction time. This difficulty can largely be overcome now with the use of CRT's and

electronic circuitry. In addition, the method appears to have passable test-retest reliability (.95 to .84) (Slater-Hammel, 1960).

However, for a number of reasons, this technique should be limited to those cases where its unique advantages are absolutely required to answer the question of interest. Even in those cases, one would think that the newer transit-signal method discussed below might be more desirable.

TEST RT-9: SINGLE STIMULUS-SINGLE RESPONSE: THE TRANSIT-SIGNAL METHOD. In this procedure (Gottsdanker, 1970a, b), the subject views a disc which rotates at a constant predetermined speed. A sector is designated in the disc, and the subject is informed that the stimulus will only occur when that sector coincides with a reference line placed in front of the disc. At one of a predetermined set of points of coincidence between the sector and the reference line, a light flashes and the subject responds.

The advantages of this method lie mainly in its reduction of the subject's timekeeping task without giving him the absolute movement cues afforded by the transit method. Its disadvantages lie mainly in its limitation to the simple RT design and the difficulty of using it in any but the visual mode.

B. Multiple Light Stimuli. Whenever there is more than one signal to which the subject has to respond differentially, a choice reaction situation exists. In the case of lights, the situation can be as simple as two lights differentially requiring one of two responses (Donders' "b-reaction") or two lights requiring a response to one

and no response to the other (Donders' "c-reaction"). One exception to this general rule exists; that is the case where any of a number of lights signal the initiation of a single response (see Test RT-10 below). Beginning with these elementary cases, the task can increase in complexity until there are a large number of lights which can appear in any combination, each combination requiring a different response.

TEST RT-10: MULTIPLE LIGHTS-SINGLE RESPONSE. Under this heading are classified those kinds of tests where the interest is in determining how rapidly the subject can respond by pressing a single key or otherwise making a single response when any or all of a number of lights act as signals. This test is actually very similar to the single light situation where the stimulus is presented in various parts of the retina (Test RT-2, p.). But in that case, the mapping always appears 1:1 and the subject knows where the stimulus will appear. Here, there is often an element of uncertainty introduced, since there is more than one light and the subject is uncertain which one will occur. However, the mapping situation here is still many:1 and there is no response uncertainty for the subject. The test may be administered from the viewpoint of retinal sensitivity, where the subject is given a fixation point and RT's to points along the visual field are determined. In this case, it should produce results comparable to Test RT-2, with any differences being due to the stimulus uncertainty. Or the test might be used in a scanning mode, which would make it quite different from a simple RT test. Finally, this technique has been used as a secondary "monitoring" technique along with another task. This last use is perhaps the most justified of the

three, since it could be argued that this task resembles the monitoring of warning signals (each requiring the same response) while operating a system. No standardized systems for tests of this type are known, but any system such as that to be described under the next heading might be adapted to this use.

Kobrick and Dusek (1970) used 48 stimulus lights distributed systematically throughout the visual field and flashed randomly during 3.5 hour exposures to hypoxic conditions. The subject in this case was required to press a response button held in his preferred hand whenever a flash was seen. They found systematic increases in response time and variability due to both hypoxia and stimulus peripheralization, as well as an interaction between the two.

TEST RT-11: MULTIPLE LIGHTS-MULTIPLE RESPONSE: MOVEMENT RESPONSE TOWARD THE STIMULUS. In this category are placed all choice RT tests where the subject's response to the appearance (or offset) of one of many stimulus lights is to move toward the stimulus, and perform some manipulation (pressing, turning, switching, etc.) which registers his total RT. Such arrangements vary in complexity from a two-choice situation where the light appears either in or near a response key, to a light array of many potential stimuli spread throughout the visual field where the subject must reach for the light, perform some complex manipulation and return to a starting point. Clearly, movement response can be of many types and of varying degrees of complexity, and each such variation introduces new elements into the measurement situation. Although these are some cases where the overall RT in such

a complex situation might be of interest, it would seem highly desirable in most cases to obtain separate scores for initial reaction and movement time, as a minimum, and for other potentially orthogonal factors such as manipulation time and return time where these are justified.

Sharp () has developed a technique which uses a variable system of stimulus light arrangement and which allows the experimenter to vary position, distance, intensity, size, and other stimulus parameters throughout the whole range of potential "workspaces." Using such an arrangement, one can evolve maps showing isobaric contours of equal RT areas. These maps are especially useful in human engineering applications, where they communicate rapidly the tradeoff in terms of reaction time which can be expected by placement of switches and dials in any location throughout a defined workspace (see fig. RT-3; also see pp. for discussion of fractionation of RT using this system). This apparatus configuration has been used in studies involving hypoxia (Heinig,), various response-switch designs (), and the effect of secondary workload (). It is, apparently, one of the most elaborate and potentially productive techniques for exploring reaction time (in extremely detailed and fractionated ways). Its cost, while not extremely low, is reasonable for a moderately large laboratory, and it can be designed to perform adequately in a variety of stress environments. As mentioned previously, the sheer volume of information which can be collected with this system rapidly leads to the requirement for computer analyses, but this is not an absolute require-

ment, and the system can be used profitably even with modest analyses.

TEST RT-12: MULTIPLE LIGHTS-MULTIPLE RESPONSES; DIFFERENTIAL RESPONSE NOT INVOLVING MOVEMENT TO THE STIMULUS. In many choice RT situations using multiple lights, the response signaled by a particular light will involve pressing a key, moving a lever, turning a dial, etc., according to some pre-established code. In this case, we wish to exclude the previously-described tests in which the code was simply to move to the stimulus. The light in this case may signal the subject to make any of a number of responses. For instance, it may signal a directional message (e.g. hit the right key) which may or may not correspond to the direction of the light relative to the subject (see p. for the effect of such directional cues). Two lights have also been used where the subject's task is to move a lever toward or away from himself depending on which light went on (Gottsdanker, Broadbent, and Van Sant, 1963). In addition to the position information which can be given to the subject by two lights, different colors of a single light may be used as signals, or clearly different intensities of the same light. Donders' "c-reaction" involved two lights, and the subject was signaled whether to perform a single response or not depending on which one was on. It has even been required that the subject draw straight or wavy lines in response to one of two light signals (Chorayan, 1969) where interest was not in the RT itself, but in the subject's ability to inhibit a response once started when signaled to do so. See the following section (pp.) on special responses for some additional specific responses which can be paired with multiple light stimuli. In general, the lights can be used to signal any differential

response to the subject. Extreme care must be taken in pairing such signals with responses (see "S-R Compatibility," pp.) because of the varied and frequently unexpected interactions which can appear (see the first part of this RT section for examples of these). Furthermore, the addition of apparent complexity to the situation does not always result in a linear increase in RT with information transmitted. When ten stimulus lights were used, and signals consisted of all possible patterns of lights (1023 alternatives matched to the same number of alternatives in a ten-figure keyboard) the reaction time was only 25 milliseconds longer than when there were only 31 alternatives (Seibel, 1963). One can clearly see, from the above considerations, that exotic S-R pairings cannot be used without extreme care.

TEST RT-13: MULTIPLE LIGHTS-MULTIPLE RESPONSES: USE OF CHANGING MAPPING CONDITIONS. The choice reaction situation can be given additional dimensions by the inclusion of a variable mapping condition. Thus, the subject may be instructed that a particular set of responses are to be made at one time, and another set at a different time.

(19) gave an external signal () to inform the subject which of two response mappings to use. In this condition, the error scores become especially important in terms of missed or misinterpreted signals, response perseveration, rigidity, etc. One would assume that if such a strategy were chosen, it would be precisely because of its ability to probe into such features as these, and the RT itself was of only secondary interest. Consequently, adequate treatment of errors becomes essential.

Another form of this technique involves changing stimuli along one or several dimensions during the course of the experiment. The dimensions may be relevant or irrelevant, with the subject told to change his responses (for a relevant change) or to ignore the irrelevant change. Thus, a change in the color of an array of lights might signal the subject to make a different set of responses to the position of the lights (e.g., the top light in a display now requires the verbal response "3" rather than "1"). Or the colors may be a relevant cue, and the lights may appear in any of a number of positions (irrelevant). In both cases, the subject's mapping is not as stable as in other RT situations, and an additional element of uncertainty is introduced into his response.

C. Visual Signals Other Than Lights. The use of lights to evaluate visual reaction time has been a most popular technique for a number of reasons, partly related to the supposed physiological simplicity of the circuits involved, and partly to the flexibility of a light in terms of the meaning that can be attached to it. With some noteworthy exceptions, it is generally true that in the visual mode almost any other stimulus will tend to have associations and preferences attached to it which will affect its reaction time. Precisely because of this characteristic, and because of the great variety of visual stimuli which can be presented, a great deal of RT research has used visual stimuli other than lights. Again, to attempt an exhaustive description of specific tests of this nature would be useless, and only a general categorization will be given with one or two specific examples of each type presented.

TEST RT-14: RT TO ALPHA-NUMERIC VISUAL SIGNALS: IDENTIFICATION

RESPONSE. A simple form of visual signal is the presentation of numerals or letters to the subject. The response in this case can be to react in some differential manner to the stimulus. This response can be as simple as naming the letter or number, making a verbal response of another letter, number or word, pressing a response key, or any other differential response. Stimulus presentation is accomplished either through a tachistoscope or some other mechanical device which permits exact marking of the point of stimulus presentation.

Clearly, this technique affords a great deal of variety and many degrees of task difficulty. Since responses can be anything from the extremely overlearned "naming," to the interference of saying a different letter or number, to an extremely complex set of logical or mathematical transformations, the task difficulty can be selected with some precision and with specific functions in mind. Further, alpha-numeric characters, more than any other pictorial presentation, probably have fewer natural associations to set up competing responses.

TEST RT-15: RT TO ALPHA-NUMERIC VISUAL SIGNALS: SAME-DIFFERENT

RESPONSE. In this case, the same alpha-numeric characters are used, but the subject's task is to indicate in some way whether pairs of the characters presented together or sequentially are the "same" or "different." The stimuli can be pairs of single letters or numbers, or they can be strung together in quite complex arrays (see Corballis, Lieberman, and Bindra, 1968). The subject, again, may give a verbal response, or he may in some other way indicate his decision. We can, therefore, see that this technique also offers a great deal of flexibility, and probably probes much different processes than the recognition response technique above.

TEST RT-16: RT TO PATTERNS. Two or more geometrical patterns of various complexity can be presented to the subject, either simultaneously or sequentially, and the required response is "same" or "different". In this case also there is a great latitude for variations in complexity, and although the response options are limited, the technique offers some options which will be discussed below.

One caution must be given. The skill involved in making a "same-different" comparison on an extremely complex design is not at all clear. To some extent, though, it may involve a component of figure-ground separation. That is, the different subjects may separate a dominant "figure" from the design and base the bulk of their decisions on that, or at least scan that aspect first. To the extent that crucial differences are limited to what these subjects see as figure, they will have an advantage in the test, and changes that may be seen may be more related to such characteristics of the individual, introducing uncontrolled variation. One should also note that if this is the case, then the same factors might better be measured by a test specifically geared to evaluate figure-ground relationships (e.g., see the Rod and Frame Test, pp. , and the Embedded Figures Test, pp.).

In spite of the above, this technique does open up the possibility for other variations on the standard technique. Instead of presenting two patterns for comparison, and (19) presented a verbal description followed by a pattern, with the subject responding to whether they were the same or different. RT's between the pattern-pattern comparison and the description-pattern comparison

diverged as the patterns became more complex (the description taking longer) and as the interstimulus interval increased (the two patterns taking longer). In some cases, the subjects may have converted the description into a visual code before responding.

Another possibility which is opened up by this technique is the study of eye movements in making such a match. It would represent a somewhat exotic form of RT "fractionation" to break the total response time into several types of eye movement (e.g., large sweep vs. small detail; various positions, etc.). One could study response strategies in this way, and isolate changes in strategy as a result of "stress" perhaps before they even affected the overall reaction time.

TEST RT-17: RT TO WORDS: IDENTIFICATION RESPONSE. This test is just like Test RT-14 (p.) except that words are used instead of alphanumeric characters. Although the same options are available with this test as are available there, the distinction is important. Words have a much greater frequency of association, meaning, preference, and emotion than do letters or numbers; for this reason, the association value of words used should always be known (see Woodworth and Schlosberg, 1954). The introduction of such a factor complicates the test enormously, but used wisely can add increased dimensions to the testing situation.

Another factor can add further to the problem of using words in an RT test. Fraisse (1969) has presented an extensive discussion of why the response of reading should be faster than that for naming, e.g.

reading the word "red" is faster than naming it. Apparently, these differences go deep into the nature of the two types of response, and stimulus or response characteristics alone cannot account for it. The researcher, then, must be particularly careful in his selection of words as the stimulus, and should at least be aware that very specific processes may be tested by such techniques.

A special case of this test, which uses competing responses to assess the subject's ability to free himself from the past associations of the stimulus, is called the Stroop Color Word Test. Since this test has attained some independent existence apart from its RT aspect, it is covered separately (pp.).

TEST RT-18: RT TO WORDS: SAME-DIFFERENT RESPONSE. The simultaneous presentation of two words for "same-different" comparison is a reading test and, as such, is not justified in many performance contexts. But a variation of this technique has been used successfully. Seymour (1969) presented subjects with the printed words "ABOVE" or "BELOW." Along with these, a rectangular shape was presented with another, smaller figure either above or below it. Subjects responded "yes" if the word and picture were congruent, and "no" if they were opposites. Even in this case, the "ABOVE/above" pair was reacted to more quickly than any other combination. In addition, if the word was fixated first, response times were faster. These findings indicate that variations of this technique might reveal early changes in response style or preference as a result of an experimental treatment.

TEST RT-19: RT TO PICTURES: IDENTIFICATION RESPONSE. The use of pictures as a visual stimulus introduces a great number of problems into the "simple" RT testing situation. However, it also opens up a number of new possibilities. There is no easy way to avoid subject involvement with the picture. It has been shown that even in a simple RT test, where the subject's task is to respond when any picture appears (regardless of content), the RT's are longer to those pictures which are selected to produce more "involvement" (Bokander, 1962). Thus, in any situation using pictures as a stimulus, some care must be taken to control for such factors as "involvement" and "emotional reaction" in the subject. This is not an easy condition, since there are no objective evaluations of great numbers of pictures available such as those which exist for words.

Given these problems, however, there are a number of techniques which can be used with pictures, as well as a number of responses to which the stimuli can be linked. Classically, recognition of aircraft silhouettes has been tested using tachistoscopically presented pictures and timing the accurate verbal response. Recognition responses to test the speed of a subject's identification of an object appears, in fact, to be the most frequent use of this technique. However, in a number of other contexts, one can visualize that the subject's instructions would be to make any of a wide array of responses to the picture. For example, analogous to the Donders "c-reaction," the subject may be shown pictures of people tachistoscopically, one of whom has been previously identified as the "criminal." He is to "shoot at" the criminal but not at the others. His errors, latency, and accuracy may be measured.

Briggs and Blaha (1969) have used pictures to differentially test memory load and display load. Subjects viewed a picture containing various numbers of items and determined whether a previously memorized item was present. Subjects showed an exhaustive serial comparison process with display rechecking prior to a negative response.

Because of the fact that pictures appear to add an element of face validity to a study involving particular applications, they are often used in situations where more abstract stimuli might also be used. So, when using paper and pencil, cards, or pictorial projection, the subject is often presented with an object (a man, airplane, car, etc.) in some position and asked to choose from a set of alternatives the position of the object after some set of transformations has been performed. Or, for example, a subject may be asked to look at a picture of a man in various positions and decide whether an object in his hand (p.) is on the right or left side (see Dennison, Ledwith, and Poulton, 1966). Such situations can also be used with abstract or geometric forms. There are certainly advantages to these techniques in terms of probing "symbolic representation and manipulation" in the subject while minimizing motor skill components. However, one rapidly leaves the area commonly encompassed by the term "reaction time" and becomes involved in extremely complex performance "factors." For instance, tests such as this commonly load very little on a "reaction time" factor and even load on different factors depending on whether the picture stimulus is a real object or geometric form (Fleishman,). Again, therefore, extreme caution must be recommended in using what, on the surface, appears to be a fairly straightforward

test. One cannot simply use a picture instead of a light because it has greater face validity, unless careful consideration is given to the changes this introduces in the factors measured.

TEST RT-20: RT TO PICTURES: SAME-DIFFERENT RESPONSE: This form of test is similar to that presented in test RT-16 (pp.) except that pictures are used for comparison instead of patterns. The distinction is significant in terms of the "meaning" attached to the pictures by the subject, and in terms of the greater tendency by the subject to view the picture as a "whole" and to disregard parts of it. Such factors can drastically change the results obtained with this technique in comparison with the use of patterns. The use of eye movement analysis is also desirable with this technique and would afford interesting information on subject strategy in the task.

D. Miscellaneous Techniques of Visual Reaction Time Testing. In addition to the relatively standard stimulus configurations discussed above, there are many techniques which either cut across all visual presentations, involve different presentation techniques, or are only indirectly related to reaction time per se although they use the RT as a measure. These techniques, in general, differ from the classic view of reaction time where the stimulus is a relatively discrete signal introduced by the experimenter for the subject's discrete response. They frequently involve self-pacing by the subjects, simultaneous performance on a number of tasks, and/or use of a complete series of reactions to obtain a total score for task completion rather than a reaction

time per se. These techniques have, in many cases, been described elsewhere when the thrust of the task is clearly different from its reaction time components (e.g. mental arithmetic, tracking, etc.). On the other hand, a few specific instances of these techniques overlap the "pure" reaction time area enough to deserve special mention here.

One form of such a task involves the sorting of cards, or objects, into discrete categories. This is a variation of the "same-different" response technique, where the decision "same" is required on each trial, and the subject's task is to find the categories to which the stimulus belongs. The stimuli here may be abstract symbols, patterns, colors, words, objects, etc. -- anything which can be categorized. Use of particular stimulus materials opens up all the problems associated with that material which have been discussed previously. With respect to reaction time, the total time to sort a series is usually taken as the score, and the RT is considered to be the average time per item. In some cases, though, and with special timing equipment, one can obtain a separate score for each item. Such a scoring would be facilitated by the use of any of the commercial apparatus which are capable of presenting the "card" to the subject either mechanically or by projection. The subject's response is then to press one of a number of "category" buttons to indicate the classification of the stimulus. Obviously, use of this system changes the nature of the task somewhat, but the gain in information may be worth it in specific cases.

Another type of RT response can be obtained whenever the subject is required to correct his own errors. This has been done in both

choice reaction situations and in visual pursuit tracking. Rabbit (1966, 1968) and Rabbit and Phillips (1967) have explored reaction time for error correction in various choice-response tasks. They found that 1) responses correcting errors were made faster than equivalent correct responses; 2) the first correct response following error correction was slower than other, equivalent correct responses; 3) subjects can accurately correct errors in four-choice task, by making the response they should have made, even though they are not informed an error has been made; and 4) no after-effect upon response rate of committing an error was found beyond two responses following error correction. In the pursuit tracking situation, Angel and Higgins (1969) and Higgins and Angel (1970) have found that subjects can correct errors (in many cases) in less than the estimated minimum time necessary to process visual feedback. Further, using a subject's proprioceptive reaction times as a comparison, they found the mean error correction time to be less in every case than a comparable arm movement. Thus, a central mechanism can be postulated to account for error correction in this task, and the possibility is raised that this form of reaction time may probe skills which are not touched by other tests. Apparatus capable of detecting such errors and their correction in a pursuit task is described in the section on pursuit tracking (pp.).

AUDITORY SIGNAL

For virtually every visual RT test there is an analogous type of auditory technique. Further, there is a positive correlation

between visual and auditory RT (Teichner, 1954). However, in many cases, the apparent comparability between the two is extremely misleading and tends to lure the experimenter into believing that the two types of test are interchangeable in every situation. While this is certainly true for many applications (e.g., basic information theory and some other basic applications), one must remember that, ultimately, different systems are involved and that even in the simple reaction response there are absolute differences in favor of the auditory system (see pp.) in the speed which can be attained through the two modalities. For this reason, as well as to permit a more coherent organization, the auditory tests are presented here separately.

A. Single Auditory Tone. The use of a single tone as a stimulus in auditory RT research is perhaps even more common relative to more complex auditory methods than its analogy, the use of a single light in visual research. The case in auditory RT research is most often that the primary interest is a "simple" reaction time. When a "choice" RT is required, the experimenters generally appear to prefer a visual test if there is any option. No doubt this stems largely from the relative ease of presenting a great many lights which are easily differentiated in a relatively small space. However, even in the single-tone mode, there are important considerations which can influence the reaction times obtained and the meaning of variations that are seen. The intensity of the auditory stimulus is an important determinant of the absolute reaction time, but in a way which appears to be more complex than the intensity effect in vision (Reason, 1968). Generally, the more intense the stimulus, at least up to the point where the tone becomes loud, the faster the reaction time (Woodworth and Schlosberg,

1954). However, there may be an interaction with the rise time of the tone such that for fast rise times, intensity may not affect the speed of reactions (Grier, 1966). In the above study, rise time had a simple effect on RT independent of its intensity interaction; the longer the rise time, the slower the response. This occurred to a degree not explainable by the fact that slower rising tones take longer to reach threshold. Obviously, then, tone rise time must be considered carefully in using an auditory RT signal. On the other hand, pitch has not shown large, significant effects on RT (John, 1967) and so is not as crucial a determinant as intensity and rise time.

The ear to which a tone is presented appears to affect the reaction time (Simon, 1967). When subjects were unaware of the ear in which the stimulus would appear, they responded faster to right-ear stimulation than to left. This difference was erased when the subjects knew on which side the stimulus would appear. Binaural presentation of the stimulus results in somewhat faster RT's than monaural except possibly in old age.

One technique which is sometimes used results in altered RT's to tones and may eventually prove to be worth standardizing for performance testing. However, as yet it is still used primarily for theoretical purposes. This is the technique of adapting the subject to a particular intensity or pitch prior to giving the RT test. In line with adaptation level theory, there is apparently a shift in the RT as a function of the prevailing adaptation which can last for at least 24 hours (e.g., see Kohfeld, 1968). This phenomenon would appear to be worth investigating further to determine its significant parameters and its possible sensitivity to experimental intervention.

TEST RT-21: SINGLE TONE-SINGLE RESPONSE: MOVEMENT RESPONSE TO ONSET

OF TONE. This is the classical "simple" auditory RT involving a rapid response of some type to a tone well above threshold. One assumes that rise time and other significant tone parameters are controlled and that laterality effects are considered. Either relatively "pure" tones or white noise can be used, although the absolute RT will vary somewhat depending on this factor.(). There is no reason to expect large, significant effects on RT dependent on whether sine waves or "chopped" square or pulsed waves are used. A more important consideration is the surrounding noise environment of the test. Masking of tones which are not well above the intensity of the surround is entirely possible and to whatever extent the two sounds are not entirely separate, the task is no longer an RT task, but becomes a test of differential threshold.

Responses to tone onset typically involve some form of switch depression or other movement. Thus, the classic setup involves a subject in a quiet room or wearing high quality earphones receiving a clearly audible signal to which he responds by pressing a button or signaling his response with some other minimal movement. Variations on this technique involve having the subject turn off the tone by his response (Chernikoff and Brogden, 1949; Chernikoff, Gregg, and Brogden, 1950; see also pp.) or requiring a response of the limb such as a foot-pedal depression or even a knee movement. One study (Siegenthaler, 1965) has even used the reaction time of the tongue as the response to an auditory stimulus.

TEST RT-22; SINGLE TONE-SINGLE RESPONSE; RT TO OFFSET OF TONE. The use of the offset of a tone as the stimulus in RT studies appears beset with some problems not encountered in visual research and not found with onset stimulation. Both Woodworth and Schlosberg (1954) and Teichner (1954) indicated that RT's to onset and offset of a tone were approximately equal. However, Grier (1966) used a 1000 hz tone embedded in white noise and found that the offset RT was significantly shorter. Goldstone (1968) found no difference using rapid rise and decay sounds. Finally, Warm and Foulke (1970) measured onset and offset reactions as a function of signal rise and decay times (from .5 to 250 milliseconds). They found that offset RT was longer only at the 250 msec. time interval. Below that time, there were no differences apparent. These authors suggest that perceived tone intensity may lag behind a decrease in physical intensity, and that this lag may be amplified by extensions of the physical decay time of the signal. In view of this problem, it would seem preferable to use stimulus onset where the function of the research is not specifically aimed at elucidating offset mechanisms. On the other hand, if there is interest in these offset characteristics (since they may represent very specific physiological structures), then the investigator might capitalize on the interaction of the offset RT with the decay time of the tone. If, in fact, there is a genuine "lag" in the perceptual decay of a tone, then proper manipulation of decay times in various groups may reveal changes in the curve of RT to the decay times which are dependent on the experimental treatment.

TEST RT-24: SINGLE TONE OR VOCAL STIMULUS: VOCAL RESPONSE. If one wishes to test the simple RT of the subject where spinal influences, large muscle influences, etc., are to be minimized, the test of choice could require a vocal response. Other responses, of course, could be used (autonomic reactivity or other physiological measures), but the vocal response requires somewhat less sophisticated instrumentation and is perhaps more suited as a "workhorse" standard test than the more sophisticated types. Their administration is straightforward, but the same cautions pointed out for any simple RT must be considered. Generally, the experimenter initiates a tone, or makes a sound, or says a word (although effects due to word meaning must then be considered). The subject responds by uttering a predetermined sound or saying a predetermined word. The mapping should be 1:1 or, in rare cases, many:1, but the subject's task must always contain no decision or choice element or the task then assumes a different nature (see Test RT-).

TEST RT-24: SINGLE TONE-SINGLE RESPONSE; USE OF BACKGROUND NOISE.

If, for a particular reason, there is interest in reaction time to a tone against a background of other noise (e.g., a warning signal in an aircraft cockpit), the experimenter is faced with a complex situation. Auditory masking is a difficult phenomenon to control (see Licklider, 1951), and experiments in which precise knowledge about the physical parameters of the sounds is necessary require extremely sophisticated instrumentation.

Fortunately, in many cases, one does not have to specify the physical characteristics in such detail. Using bursts of noise (ΔI) added to ongoing noise (I), Rabb (1965) was able to determine that

Reaction time to a noise burst was directly related to ΔI and inversely related to I . For constant values of $\Delta I/I$, the reaction time generally decreased as I was decreased. In most cases, one can determine this kind of relationship by knowing the frequency of the stimulus and using white noise as a background. Again, though, if specific questions about particular backgrounds are important, then only the use of the actual system or painstaking recreation of the environment are adequate.

TEST RT-25: SINGLE TONE-SINGLE RESPONSE: VERY LOUD (STARTLE) TONES.

There are many potential cases where an experimenter might wish to know a subject's reaction time to a sudden "emergency" type of situation. Because of operational considerations, the question is often raised with respect to the effect of slow acting and insidious stressors such as fatigue or anoxia. It is reasoned that even though performance on a routine task may show no decrement as a result of such treatments, there is a "latent" effect which would make the subject less able to respond in some difficult, or emergency situation.

Because of the particularly alerting nature of loud sounds, they would appear to be very good instruments for simulating emergencies in the laboratory in order to probe the subject's response time. A loud, unexpected stimulus would appear to afford an ideal approximation to such a situation, and the coupling of an appropriately complex response to it would provide information on several aspects of subject function.

In view of the above, it is remarkable that few studies have used this technique. Steinbach (1960) exposed subjects to a sudden,

high intensity tone and obtained their response time for pressing a button. Thackray (1965) used an initial 120 db startle tone followed by fifty lower intensity tones and another 120 db tone. He found initial differences in RT to the startle which were correlated with autonomic reactivity. The final high intensity stimulus produced a reaction time which did not differ significantly from the RT on the final lower intensity trials. Thus, startle responses by subjects seemed relatively stable under normal conditions. Apparently, such a situation recommends the use of this technique under various stressor conditions to determine whether or not it is sensitive to such experimental treatments.

TEST RT-26: SINGLE TONE; PHYSIOLOGICAL RESPONSE. As discussed previously (pp.), it is possible to obtain certain electrophysiological responses as reactions to virtually any stimulus. Visual stimuli are frequently used, particularly in obtaining evoked potentials to flashes. However, auditory stimuli have some advantages over visual which make them attractive for use with physiological responses. For instance, it is hard for a subject to avoid at least sensing an auditory stimulus, although they may not respond to it. In vision, the subject may have his eyes closed, be blinking, or simply looking the other way. Also, in using vision, there is an added problem if one wishes the subject to have a high amount of EEG "alpha." In the "eyes-open" condition, alpha is diminished. Auditory stimuli allow this "standardizing" condition to be maximized. For reasons such as these, physiological responses to stimuli will be discussed here, although one should remember that such responses, with adequate precautions, can be used with a number of stimulus types.

The most common use of the electromyogram (EMG) in RT research is to detect a "pre-motor" and "motor" component in the total RT response. Thus, EMG electrodes are typically placed on the belly of a muscle which is strongly involved in the RT response to be made (e.g., the biceps in a lever-pulling task). The EMG interference pattern is monitored and, from the point of view of stimulus presentation, the time is calculated up to a predefined point of increase in EMG activity. This is considered to reflect the time for the subject to receive and to initiate motor movement (the "pre-motor" RT). The difference between this time and the total reaction time is the "motor" RT. Systems such as this have been used with auditory stimuli by Costa, Vaughan, and Gelden (1965) and by Botwinick and Thompson (1966).

An additional technique was used by Luschei, Saslow, and Glickstein (1967). Starting with the same general system described above, these authors also used computer averaging to isolate small but consistent aspects of the signal. They found an expected potential which corresponded to the response component of the RT task (about 80 milliseconds for auditory stimulus and 125 milliseconds for visual) but they may also have discovered another, unexpected component. This consisted of early EMG activity appearing with latencies as brief as 25 to 50 msec. Such activity was seen in the human subject only with intramuscular electrodes, but appeared in every case when monkeys were tested. If such a response is valid, it adds another dimension to the RT score, since it would appear to be more related to the appearance of the stimulus than to the response.

The electroencephalogram (EEG) has been used extensively in auditory RT research. A particular phenomenon has been isolated to the occurrence of the auditory warning signal in an RT experiment. This is a surface negative potential shift which appears between the warning signal and the stimulus. Since the magnitude of the shift depends on the contingent association between the warning and the stimulus, it has been called the contingent negative variation (CNV) (Hillyard and Galambos, 1967). The CNV amplitude appears to be negatively correlated to the RT, and to increase and decrease with "subjective expectancy." In addition, this slow wave has been related to the subjective report of "alertness" and appears to vary systematically with cardiac rate events which have been theoretically associated with "attention" and "activation" (Connor and Lang, 1969). Finally, using patients during surgery, a prominent thalamic potential has been found to precede this slow wave potential and another has been shown to follow it (Haider, Ganglberger, and Groll-Knapp, 1969). Since its appearance, the CNV has received a great deal of attention, and it would appear to be a worthwhile experimental technique for assessing certain subjective conditions.

The evoked potential has also been used extensively with auditory stimuli (Vaughan, Costa, Gilden, and Schimmel, 1965). In this case, one can isolate the "cortical-motor potential" which occurs in an RT situation by comparing responses evoked by stimulation alone with those obtained during the RT task. The form of this potential is independent of stimulus modality and intensity, and it precedes the response-correlated phase of the EMG activity. The nature of these differences has been spelled out in greater detail by Wilkinson and

Morlock (1967) who also found great intra-subject consistency from day to day, but no correlation between auditory reaction time and either amplitude or latency of the evoked potential components.

Cardiac changes in response to a very loud stimulus have been considered by Sternbach (1960) and Thackray (1965). However, like the GSR response, cardiac changes are relatively slow in occurring and so have limited utility for "pure" RT research. However, components of the cardiac response may have value in indicating attention, expectancy, and activation in response to the warning signal in an RT experiment (see Connor and Lang, 1969; also see the work of Lacy and Lacy).

B. Multiple Auditory Stimuli. It is not nearly as easy to do choice reaction time measures with tones and noise as it is with visual signals. The range of options open to the researcher is not as great in terms of visual geometric forms and abstract symbols. But once the verbal stimulus is opened up, a new array of tests becomes possible. The meaning of simultaneous presentation (same-different) comparisons may be more restricted in auditory presentation, but certain advantages are gained. Sentences are presented verbally, and the experimenter is aware at each moment "where the subject is" in the sentence. This, of course, is possible but not easily done with visual presentation. In this section, we will consider the categories of option open for doing choice RT using auditory signals.

TEST RT-27: DIFFERENTIAL RESPONSE TO VARIATIONS IN AUDITORY FREQUENCY, INTENSITY, OR PITCH. Clearly, one can deliver several easily distinguishable tones to the subject and require him to respond differentially to these tones. The parameters on which the tones differ may be any of those on which perception of an auditory stimulus is based. However, except in rare cases involving very specific questions (e.g.,

whether a particular system employing such parameters induces decrement under stress), it is difficult to see why such a test would be used, at least as an RT test. The number of possible stimuli are much more limited and difficult to control than comparable visual stimuli, and the requirement to make such differential auditory responses is not very often in practice. When necessary, the instrumentation of such a task is rather straightforward, but obviously must be done with sufficient precision and with care that the stimuli are truly well beyond the threshold of discriminability (see pp. on "Stimulus Discriminability").

One should note that if an auditory test of this sort ever involves a same-different decision on the part of the subject, it is no longer testing reaction time per se, but is testing differential thresholds. The reaction time may or may not be used as an "index of certainty" (a very valid use) but it is not measuring the subject's "speed of response" capability, and cannot be inferred to do so. This distinction (like a similar one in "vigilance" research) sometimes becomes important in a practical sense. A researcher may find a change in differential threshold as a result of some treatment or stress. In a particular system, such a change may be unimportant since the system always operates at suprathreshold values. But if the change is reported as a reaction-time change, then serious consequences (and a great deal of wasted effort) may result. A small change in reaction time may be intolerable in the system, and expensive changes may be made or, worse, unnecessarily prohibitive restrictions may be imposed. It is an unending source of wonder that such errors, based on misnaming of what a test measures, continue to appear in the literature, especially where emotion-laden stressors such as air pollution are concerned.

TEST RT-28: DIRECTIONAL RESPONSE TO THE LOCATION AND/OR MEANING OF
AN AUDITORY STIMULUS.

One can assess the functioning of some performance characteristics by presenting the subject with a click, or tone, or word, which signals him to make a directional response. These may be presented binaurally or monaurally although, again, there is a clear cut need to keep the task from becoming a spatial location problem if one wishes to truly measure reaction time. Thus, a word, click, tone, or noise burst is presented in such a way that the subject is able to easily tell if it comes from the right or left. In response to this, the subject makes a directional move (right-left, up-down, move-no move, etc.) either for the move itself (e.g., to move a joy-stick or lever) or to activate a switch. Simon (1968) has used this technique to study the optimum mode of auditory presentation to increase the speed of processing directional commands. He found that the fastest simple auditory RT was obtained when monaural pure tones were presented in the ear corresponding to the desired movement. This RT was faster than when verbal commands were presented to the corresponding ear, and when binaural commands were given. Murphy and Venables (1970) found that with this technique there was no difference in simple RT between the ears stimulated (i.e., a 1:1 stimulus). On the other hand, if a choice RT was used, then RT was significantly faster to stimuli presented to the left ear than to the right. One should note that these authors used a variation of the above technique in that they presented the subject with white noise in one ear while the signals, which were clicks, were presented in the other ear.

Other studies have shown that when the ear stimulated is opposite to the required direction of movement, the reaction time is significantly slowed (Simon, Small, Ziglar, and Craft, 1970). More complex designs calling for crossed-arm responses to monaural tonal commands, both in corresponding and non corresponding ears, have revealed the expected lengthening of RT as a result of the increased S-R incompatibility (Simon, Hinricks, and Craft, 1970).

It should be clear from the above that there are really two aspects of the stimulus being used if the experimenter decides to use words presented from different locations as the cue. The words themselves are apparently processed in different systems than the "meaning" conveyed by a spatially significant signal. There is a potent natural tendency in humans to react toward the source of stimulation (Simon, Small, Ziglar, and Craft, 1970) and such a tendency can either be used by the experimenter (e.g., by measuring the subject's ability to block this tendency) or it can cause great problems for him (e.g., by biasing critical measurements in a poorly randomized design). If, on top of this, words are used as the signal, even more complication is introduced. For these reasons, words as directional signals should be used with great care, and only when directly applicable to the questions of interest.

TEST RT-29: MEANINGFUL AUDITORY STIMULUS; VERBAL RESPONSE. This class contains those tests which require the subject to give a verbal response as quickly as possible to the spoken word or syllable or to some other meaningful sound. It is not simply a reaction of sound to sound (see Test RT-23), nor is it a single vocal response to a single stimulus. The differentiating characteristic here is that the subject receive and, to some extent, process the sound. Thus, it can be an

identification task, where familiar sounds are presented (e.g., truck, train, car, etc.) and the subject verbally identifies the sound. Or it can be a word or syllable where the subject gives a differential verbal response or, most simply, repeats the word or syllable (see Davis, Moray, and Triesman, 1961). In any case, this technique has particular advantages where it is used along with a continuous task requiring, for example, vision and muscular control, such as tracking. In such a case, the simple RT as a function of "workload" might be assessed without involving such variables as visual scanning or competing or shared motor responses. On the other hand, since a genuine choice RT is involved, the task cannot be repetitively carried out without this fact being apparent in the score.

TEST RT-30: VERBAL COMMANDS REQUIRING MOTOR RESPONSE. It is desirable at times to test the subject's ability to react to verbal commands which are somewhat more complex than simple directions or identifications. One might wish to know if a particular stressor (say a slow acting gas at low levels) affects the subject's desire or ability to make a rapid change in the status of a system on command. Such an experiment involves a great deal of difficulty from the viewpoint of standardization, since verbal commands are subject to such a variety of interpretations and reactions on connotative bases alone. It is essential, for instance, that the tone (the "emergency" content) of the message be equated or controlled. Thus, recorded commands should be the norm. One should also assure that the command is not subject to misinterpretation and that its emotional content will be reacted to in a standard way. These, of course, are difficult parameters to con-

trol, and the experimenter should take great care in using this technique. Unlike other techniques which are beset with difficulties, however, this one is extremely valuable, and its use cannot be discouraged lightly.

Attempts to control the above factors have involved either severely limiting the number of possible commands, or the use of a single class of commands tied to mathematically defined spatial locations. For instance, subjects can be instructed to make a response movement continuously in one direction (e.g., tracing a circle). The experimenter may then use the words "continue" or "reverse," or some other symbolic form such as a number, as a stimulus to the subject (see Baddeley, de Figueredo, Hawkswell-Curtis, and Williams, 1968). Here, the subject is aware that only one of two commands can be given, and the task is very close to an elementary form of the choice RT to sound. A more complex form of this task would be to have the subject monitor a moving disc and respond to commands to speed it up, slow it down, reverse direction, etc. with appropriate motor behavior. The task here is only slightly different from a multi-choice RT task, but it involves some verbal processing (at least in the early trials) and can be made to involve more by manipulation of the content of the commands.

Another approach to involving more complex verbal processing is to define the basic task quite clearly (e.g., turn out one of a hundred lights) and to force the subject to choose a particular sub-aspect of the task (e.g., find the light by use of mathematical coordinates). In such a situation, the difficulty of the task can be

manipulated quite accurately, and yet there is little danger of subjective factors influencing the task unduly (see Siegel and Birren, 1967). By means of tasks such as this, a great deal of complex processing can be achieved. But the experimenter must be aware of several problems. First, by removing much of the subjective variability from the verbal content, we frequently remove much of the subject's interest. We may see the task as a complex mental process, and may feel this should be interesting to the subject, but he may still see it as "turning off the lights." This can certainly affect results. Next, it should be obvious that with a great many trials tasks such as this can change their nature rapidly. The "verbal command" to which the subject responds at first may soon become just a series of "different sounds" linked to specific responses. Thus, it is wise to consider shifting the meaning of the sound occasionally if this aspect is undesirable. Finally, the experimenter must be aware that these tasks are difficult to relate in any obvious way to real world tasks. The presentation of an array of lights such as those described above can be made to look like an airplane cockpit warning system as much as we like, but this will not mean it can predict performance in such a system. Unfortunately, such a jump is not easy to make, but it is precisely in tests such as this, where the stimuli begin to "look like" the real world, that researchers frequently make the unjustified connection.

TOUCH SIGNAL

Of all the sense modalities, it is easiest to get direct, separate reaction times on vision, hearing, and touch. The other

modalities all require extensive instrumentation to deliver adequate stimulation and still it is difficult to insure against giving the subject some unplanned stimulation in another modality. Within the three mentioned above, touch is without doubt the most difficult to use. The receptors for this sense are less well known, are distributed more unpredictably over the body, and respond to stimuli in somewhat peculiar ways, showing great specificity (or great generality; free nerve endings). Because of this and other factors such as the apparent lack of sensitivity in this modality, the number of studies and techniques for studying RT to touch is not large. However, some information has been gained, and in view of current concepts of using unusual channels as input sources for information, it is likely that continued interest will be shown in the testing of reactions to touch.

Along with hearing, the general reaction time to touch, at least in the most sensitive areas, is about 140 milliseconds (Woodworth and Schlosberg, 1954). This is faster than that to vision, although the differences have little practical significance. Skin areas near the brain yield a faster reaction time than those far away. There is some question with respect to the equivalence of either onset (applying pressure) or offset (releasing pressure) on the skin. Some authors feel that the subjective effect is the same. But onset stimulation apparently has a faster RT (Sticht, 1964) and a smaller differential threshold (Grindley, 1936).

The number of techniques for studying reaction to touch is large, but not as voluminous as those used in vision or hearing. Thus, although general categories of tests will again be used, and although

the examples of these categories are still to be considered illustrative rather than definitive, these examples will generally be spelled out in somewhat more detail. One should still note, though, that if a researcher plans to use any of these techniques, the original sources must be consulted.

Mechanical Stimulation of the Skin

Touch, pressure, or movement of the skin all are adequate stimuli for sensation of touch. Since the earliest days of RT testing to touch, mechanical methods of producing such stimuli have been used. One must remember the elementary point that the techniques to be described are rather gross in terms of the physiological mechanisms involved. Even where a small needle is used for stimulation, the resultant skin depression is probably stimulating many receptors (and many types of receptors).

Under this heading, we wish to include all those techniques where the stimulation is produced by a mechanical deformation or movement of the subject's skin. Tests of this type attempt to stimulate the skin by contacting it with an object either once or in a repeated, vibratory fashion. The stimulating object may be quite small, such as a needle, where the attempt is to keep fairly precise control of the area being stimulated. Or the stimulus may be a vibrating bar which is in relatively random contact with the whole finger. In either case, some control must be maintained over the pressure with which the stimulus contacts the skin, since this parameter is analogous to the intensity dimension in other modalities, and could affect the RT.

In such an arrangement, some aspect of the subject's skin surface (frequently the fingertip) is either rested on a bar which is capable of vibrating, or placed in close proximity to an object which can be caused to move into contact with the skin. The instructions are either to report when any activity is felt on the skin, or to decide as quickly as possible after a signal whether the object is vibrating. The subject's response may be verbal or mechanical.

TEST RT-31: TOUCH RT TO DROPPING OR REMOVING AN OBJECT. The simplest way to stimulate touch in a reasonably controlled way is to drop a light, above-threshold object on the skin or, conversely, to remove the object from the skin. Given reasonable care and accurate calculations, fairly accurate stimulus parameters can be maintained with this method and, for an overall estimate of tactile sensitivity, this technique may be quite adequate. Its difficulties are fairly obvious. Care must be taken to avoid cues from other senses, particularly from the auditory sense. The object size should produce a touch sensation, but not be heavy enough to involve deep pressure. Unless there is some reason to study it separately, shear-type movement should be minimized in the falling stimulus, and, of course, timing must be carefully done since even a small difference in the relative location of stimulus and skin could give erroneous stimulus times.

TEST RT-32: RT TO PLUNGER-TYPE MECHANICAL STIMULATION OF THE SKIN.

An example of a "plunger" type stimulator is that used by Sticht (1964). In this, a stainless steel needle, .5 mm. in diameter, was adjusted above the subject's finger. The finger was held rigidly in a plastic cube, mounted on an arm rest, and only a small area of skin protruded

through a hole in the cube. Using a micrometer, the needle was positioned above the subject's finger in such a way that activation of a solenoid plunged the stimulus .02 mm. into the finger with calibrated pressure. This apparatus was used to produce both onset and offset stimulation. For use in the offset mode, the stimulus was plunged into the subject's finger and allowed to remain there until adaptation occurred. When offset stimulation was to occur, the needle was rapidly removed. This technique has the advantage of stimulating a very small area of the skin with pressure which can be calibrated fairly well, at least within a subject. It produces a clear-cut reaction time, although the subject's instructions to report "whenever they felt any activity on their finger" are somewhat vague and might require practiced subjects to yield consistent results. A distinctive characteristic of this type of stimulus is its independence of the "following" characteristics of the skin. If a vibratory stimulus is used (as noted in the next test) the skin may be deformed and released at such a rapid rate that it cannot "follow" the stimulus. A complex pattern of stimulation can then be set up, and although it was thought for some time that this had no effect on sensory processes, Sticht and Sitterley (1965) showed that this might, indeed, attenuate the touch sensation. Therefore, if the researcher is truly concerned with obtaining a "pure" RT to touch, the present technique might be more desirable than use of a vibrotactile stimulus.

TEST RT-33: RT TO A VIBROTACTILE STIMULUS. One can construct an apparatus such that a vibratory stimulus is delivered to the subject's skin at a given frequency, displacement, and wave-shape. For simple

RT measurement, the stimulus is switched on at a given time, with an amplitude and frequency well above threshold. The subject responds with any prearranged signal. In practice, such a system is difficult to use if a "pure" RT to touch is desired since one wishes to adjust the stimulus intensity to a level which will stimulate the skin, but will not cause vibration in the bone and/or deep receptors under the skin. Such additional stimulation, while affecting senses which have slower RT's than touch, may confound the overall RT and produce results which are, at the very least, difficult to interpret. For this reason, and others to be mentioned, this technique is not recommended for simple RT work.

A particular type of RT study which comes close to being a threshold study can be done particularly well with this type of stimulus. If the subject, on each trial, is given a stimulus signal other than vibrotactile, and his task is to decide as quickly as possible whether a vibrotactile signal is or is not being delivered to his skin at a given point, various parameters of the vibration can be studied. The reaction times in this case are actually being used as indices of the subject's certainty (see pp. on "Stimulus Discriminability"). On the other hand, they could be of value in the area of helping to define particular stimulus parameters which produce a given detection frequency above threshold. Thus, the psychological method of constant stimuli (see Woodworth and Schlosberg, 1954) is combined with reaction time measurement to define a performance level for each subject. Systems such as this have been used by Gescheider, Wright, and Evans (1968) and by Gescheider, Wright, Wever, Kirchner, and Milligan (1969).

Choice reaction times are readily determined using vibrotactile stimuli. Leonard (1959) constructed a vertical array of five relays, and the subject rested his fingers on the armatures of the relays. Application of 30 volt, 50 cycle A.C. to a particular coil caused the armature to vibrate, and simultaneously activated a timer. The subject responded by depressing the armature with the stimulated finger, thus stopping the timer. Errors in responding were indicated by a light. With this arrangement, various combinations of stimulus presentation are possible and the system appears to be free from many of the problems inherent in simple RT work with vibrotactile stimuli. A similar apparatus is described by Broadbent and Gregory (1965).

One should hope, as mentioned previously, that vibratory stimuli may introduce problems in measuring RT due to the fact that at higher frequencies the skin cannot "follow" the vibrating stimulus. Thus, the pattern of skin deformation might be different from that which is planned, and may become quite complex even when a simple sinusoidal input is used. If such considerations are important to the purpose of the research, then other tactile stimuli should be used (see Test RT-32, pp. .).

Electrical Stimulation of the Skin

We have seen that the use of electrocutaneous stimulation to transmit information is both possible and practical (Gilmer, 1961). One may, therefore, expect that questions regarding this type of stimulation will be raised in the future. Several attempts to measure the reaction time to electrocutaneous stimulation have been made using

various parameters of stimulation. However, many body areas and parameters remain. A sample of techniques which have been used will be described here, but the interested reader is referred to other sources for additional areas and techniques of potential value (Foulke, Coates, and Alluisi, 1966; Sheridan, Foulke, and Alluisi, 1966; Brown, Galloway, and Gildersleeve, 1965; Alluisi, Morgan, and Hawkes, 1965).

TEST RT-34: RT TO ELECTRO CUTANEOUS STIMULATION. D.C. pulses have been used to determine the simple reaction time to electrocutaneous stimuli and the effect of various inter-signal intervals (Hoffman, 1967). In this system, electrodes 8 mm. in diameter were attached to the lateral sides of the right hand or foot. Continuous D.C. pulses, .4 to .5 milliseconds in duration, were delivered at a rate of 25 per second and an intensity of .32 milliamperes. Inter-electrode distance was 5 mm. and electrode pressure was regulated with foam rubber backing. The positive-charge electrode was always toward the extremity. Subjects were exposed to auditory white noise in order to mask apparatus noises. The response was to activate a microswitch which stopped the timer and also terminated the stimulus.

Swink (1966) studied the electrocutaneous RT by using square wave pulses delivered to the palm of the non-preferred hand. The pulse in this case was delivered by a Grass Instrument Stimulator with a frequency of 200 pulses per second and a duration of 1.5 ms. at from 40-80 volts. Responses were made with the index finger of the preferred hand. He found that RT to this stimulus was faster than that to a light or buzzer in the same subjects. Further, when this electrosignal was combined with the light and buzzer, RT's were faster than to either

alone. Based on this, Swink recommends further exploration of the square-wave pulse as a potential signal vehicle.

A unique use of the electrocutaneous signal was employed by Behar and Warm (1967). These authors used an A.C. signal delivered between the subject's finger and heel of the non-preferred hand as a ready signal for a visual response stimulus. Peak-to-peak current was about 4.0 milliamperes, a level reported to be uncomfortable but not painful. The ready signal was given by either raising the level from a near-zero intertrial level, or decreasing it to near-zero from a relatively high intertrial level. Either signal equivalently informed the subject of the imminent visual response signal. Although the exact procedure used here does not produce an RT to electrocutaneous stimulation, the basic technique would appear to be capable of refinement into a method for studying choice RT. A clear-cut change in electrocutaneous stimulation level (or in some other detectable parameter) could be responded to differentially by the subject, thus yielding the classic two-choice RT. Such a technique may prove valuable if electro-communication does, in fact, become a reality.

OTHER SENSE MODALITIES

We have already noted that it is extremely difficult to obtain good reaction times from any sense modality except vision, hearing, and touch. In the cases of olfaction, taste, thermal sensation, and rotation, one needs special procedures to stimulate the sense (with any precision) and not also stimulate some other receptors, principally those of touch. Thus, other than for basic interest in the sense modality itself, it is generally not practical to attempt RT measurements on these senses. Apparently, this is particularly true of taste and olfaction. It is difficult to conceive of a situation where a researcher in an applied setting, or one attempting to assess some environmental impact, would choose to measure the subject's RT to taste or smell. Both would require extremely elaborate instrumentation, highly contrived conditions, and sophisticated subjects. Even if these were feasible and available, there are other questions dealing with the functioning of these senses (e.g., absolute and differential thresholds) which would yield more information than the RT. For these reasons, these senses will not be treated separately here. For specific information the reader is referred to Stevens' (1951) chapters and .

There could, however, be some interest in RT's to temperature and to rotation. Thermal stress is becoming a real consideration in aircraft and space systems, and rapid reactions to rotational inputs are essential at times in some systems. Thus, even though techniques for measuring RT to these inputs are not extensive, some suggestions will be presented.

Thermal Stimuli.

With most contact techniques, it is difficult if not impossible to get a consistent simple reaction time from an unpracticed subject. This is because he must learn to ignore the sense of touch and report only when the thermal sensation is felt. At best, this introduces an additional element of decision to the subject's task, and at worst it introduces intolerable unreliability into the measures. Determination of choice RT using these simple methods is somewhat easier, since at least the subject must wait for some thermal sensation before he can reliably make a determination. However, the question still arises as to whether the superimposition of the touch sensation had an effect on the absolute value of even the choice RT.

Where either simple or choice RT is to be determined and where other factors do not contraindicate it, a radiated heat technique is probably better. One apparatus for producing such a stimulus will be described.

TEST RT-35: RT TO THERMAL STIMULI; CONTACT METHOD. A typical contact technique for applying a thermal stimulus is described by Lela and Sinclair (1955) and will be used here as a model. These authors used a 12.5 mm. copper cylinder which was brought to the selected temperature by electrical heating or by placing it in contact with ice. Thermocouple measurement insured proper temperature. As in all work

with the thermal sense, the temperature of the skin must be taken continuously; this was done using a freely suspended thermoelectric junction of copper-constantan wire. In this study, the cylinder was freely laid against the skin, but other, more standard applications are of course recommended. At the moment of contact with the skin, the heated or cooled cylinder also contacted a single strand of wire stretched across the skin just outside of the test site. This closed a circuit which started a timer. When the subject was able to tell whether the stimulus was warm, cool, or neutral, he pressed a key which stopped the timer. With this technique (and throwing out wrong answers and responses which the subject reported to have been improper) reaction times well over .5 second were found in most cases, even when the stimulus was as much as 18°C . above or below skin temperature. Further, the thermal threshold for a given subject varied from day to day (and even during a test session), so that these authors state that it is essential to measure thermal stimuli from the subject's skin temperature rather than from some absolute temperature scale.

We have mentioned that the contact method of thermal stimulation is not desirable in many respects. Yet, in some cases, this is the only technique available. Clearly, it is easier to use this technique for studying RT to cold stimuli. Furthermore, there are significant differences in the results obtained with the two techniques. For instance, if small areas of skin are to be tested (less than about 700 sq.mm.), contact stimuli must be used since no warmth at all will be sensed using radiant stimulation in areas this small (until the

stimulus is strong enough to cause pain). In addition, the summation effect of using more than one stimulus appears very significant with radiant energy (an area will be reported as "warmer" if a nearby area is also being stimulated). In contact stimulation, this effect is minimal, or even negative (Jenkins, 1951). This has led some authors to suggest that there may be two "warm" senses, a point of theory which underlines the need for caution in interpreting the results obtained with different methods.

TEST RT-36: RT TO THERMAL STIMULI: RADIANT HEAT METHOD. The above section has indicated some of the problems encountered with the use of both contact and radiant stimuli. On balance, it would still appear that in those cases where both techniques are applicable, the radiant heat method will provide the better estimate of "pure" reaction time. This is not to minimize the interpretation problems involved with radiant stimuli, but unless a complex procedure such as that used by Corson and Crannell (1970) is employed to separate the RT to touch, it is difficult to see how the contact method can produce a genuine thermal RT with certainty.

The most basic method for delivering a radiant stimulus involves an energy source, a condensing lens to concentrate and/or equilibrate energy over an area, and an aperture to control the size of the area stimulated. Oppel and Hardy (1937) used non-penetrating, infra-red radiation of longer wavelength than 3μ obtained from a 250 W hotplate. For visible and penetrating infra-red, they used a 1,000 W tungsten filament flood light. In the penetrating infra-red mode, they filtered the visible and longwave infra-red with a Corning heat transmitting glass. They considered it important that the spectral

distribution of the heat source be measured precisely since they report differential sensitivity of the skin to the various types of radiation. The strength of the stimulus was determined by the distance of the light from the subject.

A more recent example of a radiant heat apparatus is that developed by Hardy, Wolff, and Goodell. (1952) and used in a large number of experiments dealing primarily with the threshold of pain (see Dillon, 1968; Zegers and Cahill, 1965). Use as a reaction time apparatus would require some alterations to the manufactured version of this instrument ("The Hardy-Wolff-Goodell Dolerimeter," Williamson Development Company) in which the heat source is a 100 W projection lamp, controlled by a regulated power supply and timer. A gun-like device houses the lamp in the "handle" and a reflector and lens in the "barrel." The front of the barrel is placed against the skin surface and the light is focused at a point 4" behind. In the standard configuration, the subject initiates the stimulus by depressing a button switch in the handle, but this aspect could easily be modified for RT tests. Adjustments to alter the area of skin stimulated would also be necessary, but should be feasible. The unit requires frequent calibration by means such as a thermopile. In use, it has proven to be a durable and highly reliable piece of equipment.

Rotation

Measurement of a subject's reaction capability to rotation or angular acceleration is obviously quite difficult in any "basic" sense. If one has to eliminate the possible contributions of other senses entirely, the task is virtually impossible. In any attempt to achieve

vestibular activation, one will almost certainly stimulate touch, proprioceptive, kinesthetic, or gravity dependent structures, most of which probably have a faster RT than the vestibular system. Elaborate systems may be devised if the question is of crucial concern (e.g., use of zero-gravity aircraft and sophisticated apparatus for inducing the rotation). But it is difficult to conceive of a situation where there would be that much need to study the pure RT to rotation where evaluation of particular functions is at issue; other tests are more defensible (e.g., caloric nystagmus, ocular counter-rolling, etc.).

On the other hand, a much simpler and more approachable problem is more likely to arise in practice. That is, what is the subject's reaction time when he is slowly (or rapidly) rotated? This question may specify the presence or absence of visual stimuli, or other experimental constraints peculiar to a given system. But seldom is the system so constraining that the interest is solely in the vestibular apparatus. Given this leeway, one can provide a reasonable experimental procedure.

TEST RT-37: RT TO ROTATION. Rotation in only one axis will be discussed since production of rotation in the other axes requires extremely bulky equipment not commercially available nor readily accessible to the average researcher (but see the Human Disorientation Device, NAMI, Pensacola NAS, Florida, and the Dynamic Environment Simulator, Wright-Patterson AFB, Ohio). The type of rotation to be discussed involves movement about the x-axis with the center of rotation located approximately in the region between the two semicircular canals. Such rotation is produced in the seated subject by

the classical Bárány chair. For use as a reaction time device, the subject must be seated and restrained, with as many other constraints placed on him as the question of interest dictates (e.g., he may be blindfolded, may be made to fix his head location with a "bite bar," etc.). Rotational onset can be adjusted (over threshold) to any level of operational interest, and the response can be any response which is neither facilitated nor inhibited by the rapid movement. We must emphasize, of course, that there are a wealth of cues given to the subject with such stimulations and so it is hard to specify just what his reaction time is. However, the task itself is of such interest that the existence of such an apparatus cannot be overlooked in a detailed listing.

SPECIALIZED RT TECHNIQUES AND STIMULI

This section includes some relatively unusual techniques for measuring reaction time. Since these have specialized utility, they will not be treated in detail, and the interested reader will need to consult the original sources listed for more detailed discussions.

TEST RT-38: RT TO THE NULL STIMULUS. One can obtain an apparently valid reaction time to a nonappearing or "null" stimulus (Cowan and Monroe, 1970). In this case, the subject is obviously responding to something, but the timing for his response is not locked to a discrete presentation of a physical event. A "countdown" procedure is used to produce the null stimulus (S_0). A string of warning signals is given, followed either by S_0 or a "non-null" stimulus (S_1) which appears in rhythm with the warning signals. The subject has to respond "as

quickly as possible" to the presentation of either S_0 or S_1 , and the authors speculate that the subject uses the estimated time interval as a stimulus, and that he begins to "sample" for this time interval not from the last warning signal, but at a point somewhere just prior to the normal appearance of S_1 . If this is true, then this task is perhaps a very sophisticated form of time estimation task, and its use would provide much more information about the subject's status than either an RT or a time estimate alone. The procedure deserves further investigation.

TEST RT-39: RT BY MEANS OF THE PERCEPTION OF TEMPORAL ORDER (PTO).

One of the earliest techniques used by Donders involved having a subject judge which of two stimulus events in two modalities occurred first (see pp. , the noematachometer, Donders, 1969b). Theoretically, by varying the temporal separation between the stimuli, the speed of response to each stimulus could be calculated. Several recent studies have used this technique and, while it has not proven to be a good index of more classically determined reaction times, the procedure may have utility in its own right.

Rutschman and Link (1964) used auditory (10 ms. burst of white noise) and visual (increase in luminance of a foveal central light) stimuli presented to the subject both alone and in various temporal orders. The temporal order judgments were obtained by the method of constant stimuli (see Woodworth and Schlosberg, 1954). Five values of delay between stimulus onset were used. A most interesting reversal was found in this study. Although, when presented alone the auditory stimulus clearly had a shorter RT than the visual, the exact opposite

result was obtained when the stimuli were presented in a PTO format, i.e., the clock had to precede the flash by about 43 ms. to be judged "equal" 50% of the time. This reversal clearly indicates that the PTO and RT techniques cannot be measuring exactly the same thing.

Another study has used stimuli from three modalities (vision, hearing, and touch) presented in close temporal order (Dinnerstein and Zlotogura, 1968). Again, the method of constant stimuli was used, and stimuli were either synchronous, or one preceded or followed the other by 50 ms. or 150 ms. The stimuli continued "on" for three seconds after the start of the first stimulus. Comparisons of these PTO results were made to serial reaction time scores in each modality alone. Again, little relationship was found between PTO and RT scores, although the relationship in this case was opposite to that found in the Rutschmann study. An interesting and potentially useful exception to the above was found however. Among those subjects 39 years of age and older, there were relatively high correlations between PTO scores and various forms of the standard-RT's, and also between PTO and reading and pegboard scores. Since all these correlations were essentially zero among younger subjects, the possibility of using PTO and other tests in a correlation matrix to reveal a decrease in "channel capacity" becomes a real consideration.

SPECIAL RESPONSE CHARACTERISTICS

The response in a reaction time experiment can range from a necessary evil, used only to pinpoint the end of a process, to a complex procedure constituting the result and principle interest of the experimental manipulation. In the first case, we would like to have

an automatic signal response which simply clicks on when the processing signal reaches it. In the second case, we would like to see the response completely broken into simple components so that we can obtain the greatest amount of information about it. Both goals are probably unrealistic since the simplest responses (e.g., EEG and EMG evoked potentials) are quite complex, and since complex responses show such rich interactions among their elements. Thus, the typical reaction time experiment uses response requirements which are compromises at best.

Probably the most frequently used response is that in which the subject presses or, less frequently, releases a response key. Consequently, the combination of stimulus and response seen most often in simple visual RT experiments is a single light which goes on and signals to the subject to make a rapid depression of a key. This arrangement and minor variations of it have been used in countless reaction studies and, because of its popularity and ubiquity, should probably be considered first as an S-R choice where simple visual RT is required and special requirements do not dictate that other responses be used.

On the other hand, other responses have frequently been used in conjunction with either standard or exotic stimulus forms. These should always be justified by the purpose of the research but this has not always been the case. They have sometimes contributed nothing but confusion to the interpretation of the study. Too often, too little thought has been given to the effect of using, say, a verbal response when the primary interest was in the motor system. More often, difficulties introduced by using a particular response (physiological path-

ways, handedness, directional preferences by the subject, etc.) have not been considered either in the choice of a response or in the interpretation of results. Some considerations regarding both common and unusual responses are presented below.

Finger Responses

It is common, especially with simple RT's, to require the subject to place his finger directly over the response button and to simply depress it when the signal occurs. As early as 1920, it was shown that there are measurable differences between the reactions of the several fingers, with the dominant hand fingers tending to be faster and, where more than one finger is used, complex interactions determining the speed of a given finger's reaction (Gatewood, 1920). The same study also showed that two-finger reactions are faster than single-finger reactions (but see Hannes, 1968 for differential effects of alteration and repetition on this), two-hand combinations give faster responses than when the two fingers are on the same hand, and practice can reduce but not eliminate differences in RT between fingers. More recently, Bradshaw and Perriment (1970) have studied the relationship between the finger used in a response and certain known interhemispheric phenomena.

Squeezing Responses

A particularly appropriate response technique for use with recorded EMG has been used by Schmidt and Stull (1970). In this technique, the subject is asked to squeeze a hand-grip to some level of submaximal tension prior to the appearance of the signal. The response is to squeeze as quickly and forcefully as possible. The unique advan-

tage of this technique is the control it allows over presignal muscular tension. Under variations in this parameter, the study above found significant shifts in the relationship between premotor and motor RT's. Apparently, such a technique might have wide applicability in stress research.

A similar technique of response with controlled amounts of muscular stretch has been used by Santa Maria (1970). In this case, a knee flexion task was used, and the amount of stretch in the hamstring muscles was used as the independent variable. Although this requires somewhat more exotic equipment than the grip procedure above, it may have application in answering specific system questions.

Tongue Response

Basic questions concerning vocal feedback mechanisms as well as applied interest in the mechanism of speech led to the development of an apparatus to test the response time of the tongue (Siegenthaler and Hochberg, 1965). The apparatus for this purpose is described by these authors, and consists essentially of a bite bar through which a plunger extends 3 mm. into the subject's mouth. Upon stimulation (in the above case auditory and tactual) the subject pushes his tongue forward and a resulting plunger movement of 1 mm. breaks switch contact. The instrument can be used with any number of stimuli, appears relatively inexpensive to construct, and would seem to be adequate for the purpose intended.

Eyeblink Response

The eyeblink response as a voluntary response to a discrete stimulus would seem at first glance to provide the experimenter with

an extremely simple response. It is rapid and involves relatively few, but well trained, muscles. Direct pathways involve only cranial nerves and the subject can be asked to execute the response while otherwise occupied or constrained. On the other hand, recording techniques are rather sophisticated and cumbersome, and require some degree of care.

Bixler, Bartlett, and Lansing (1967) recorded response time of eyeblink in the various intensities of auditory and visual stimuli. They used two independent systems which yielded somewhat different RT's. Their first system was a mechanical one which employed an optical system with a selenium photocell. This was attached to a bracket shaped to the subject's head in such a way that the shadow of the moving eyelash altered the output of the photocell. In the visual stimulus mode, the photocell also recorded the onset of the light. This system proved reliable and produced RT's which were consistently longer than those obtained with the second technique.

The other system used direct recording of the "muscle action potentials" of the orbicularis oculi muscle. In this, two electrodes, each 2 mm. in diameter, were applied to the upper lid. Care must be taken in doing this to insure that the latency of the eyelid response is not changed, and that the obtained signal is free from the electroretinogram. Standard amplification and recording of these potentials is then carried out. The response is defined in terms of some discreet point of deviation from baseline. Using this system, RT's between about 70 ms. and 125 ms. were found for visual signals, and between about 38 ms. and 58 ms. for auditory. The mechanical system produced RT's which were consistently 20 ms. to 30 ms. longer.

SECTION II C
PHYSIOLOGICAL RESPONSES

Introduction

Galvanic Skin Response

Introduction and history: Darrow, 1931 and 1935.

Design considerations:

Basal level vs. GSR's; AC and DC vs. potential:
Grings, 1953.

Relation to performance; reliability: Adams, 1969;
Shnidman, 1969.

Effect of skin temperature: Surwillo, 1967.

Effect of task difficulty: Freeman, 1940.

Sleep GSR's: Johnson and Karpan, 1968.

In sensory deprivation: Zuckerman, Levine, and
Biase, 1964.

Subject's ability to control: Stern and Lewis, 1968.

Subject-to-subject variability: Goldstein and Adams,
1967.

Data reduction and interpretation:

GSR methods:

Simple Palmer Sweat, using crystals: McCleary, 1953a,b.

GSR apparatus descriptions: Haggard, 1947; Silkett, 1950; Stewart, 1955; Flanders, 1953; Mays, 1953; Forbes, 1937; Lacey, 1948.

Method of separating total signal into basal level and responses: McGraw, Kleinman, Brown, and Korol, 1969.

Group GSR: Gladstone, 1953.

Commercial GSR apparatus:

Pupillary Responses

Introduction and history:

Design considerations: Bradshaw, 1868; Elshtain and Schaefer, 1968; Schaefer, Ferguson, Klein, and Rawson, 1968; Vacchiano, Strauss, Ryan, and Hochman, 1968.

Variability:

With mental activity: Payne, Perry, and Harasymiw, 1968.

With decisions: Simpson and Hale, 1969; Simpson, 1969.

Affective responses:

Apparatus: Mackworth and Millikan, 1967; Kumick, 1960; and commercial manufacturers.

Ocular Responses

The Electrooculogram (EOG):

Technique and uses: Monnier, 1952.

Eye motions: Higgins and Stultz, 1953.

Muscle Tone

The Electromyogram (EMG):

Technique and uses: Davis, 1959; Conen and Tonnies,
1936; Van Liere, 1953.

Cardiac Measures

Heart Rate - including electrode locations, cardiometer
parameters, limitations, and past uses.

EKG - brief discussion of requirements.

Blood pressure measures:

Limitations, requirements, uses, etc.:

The Cold Pressor Test: Lenox and Lange, 1969.

The Electroencephalogram (EEG)

General discussion of surface EEG use and interpretation.

Includes variability, artifacts, EMG interference, cyclic
effects, and other design considerations.

Section on data reduction by hand scoring, zero-crossing
analysis, derivative analysis, and auto-correlation.

Section on Contingent Negative Variation (CNV):

see RT section and Low and
McSherry, 1968.

SECTION III A

EVALUATION OF ASSOCIATIONAL PROCESSES

Introduction

Definition of section contents -- use of "mental"

Difficulty of classifying these topics and rationale used.

Problem and cautions in inferring internal processes.

Learning, insight, "sets," etc.

The problem of motivation in testing internal processes
(e.g. in tests of "production," and in long, boring
tasks such as mental arithmetic).

Intrasubject variability in overall abilities.

CLASSIFICATION, DEFINITION, AND PRODUCTION

Introduction (Summary)

These tests require the subject to mentally place an external or internal representation into a "set" of representations before performing a required action on it. Generally, requirements for internally manipulating, visualizing, or changing the representation are minimal. The subject's task is simply to "perceive" an external representation (word, symbol, etc.) or to "produce" an internal representation (Image, word, sentence, etc.). He may then be required

to further work with the symbol (as for example, in simple syllogistic reasoning) or to identify the representation as belonging or not belonging to a class. In any case, the operation is symbolic, but it has low requirements for symbolic retention, manipulation; or creative organization.

Letter Cancellation Tests (Summary)

In these tasks, the subject is required to visually scan a series of letters, numbers, or other symbols, in order to find previously defined symbols. Typically, the task is to circle, cross out, or otherwise identify the "target" symbols. Although this task appears very simple, several important design considerations must be kept in mind.

1) The familiarity of the symbols will affect the absolute results and, more importantly, the interactions between the task and other factors in the experiment (Kaplan, Carvellos, and Metlay, 1966).

2) The number of different "targets" which make up a set of target symbols (Neisser, Novick, and Lazar, 1963).

3) The number of non-targets which appear between targets may have a greater effect than the number of targets to be searched (Shurtleff and Harsetta, 1968).

Consequently, in choosing a particular task of the cancellation type, one must be aware that these sources of variation may influence results. Typically, experimenters choose a section of newspaper, a telephone directory, or the like, and have the subject search for a common letter or a digit. One should be aware that the task may change not only with the type of material used (e.g. physical

size of the type and intrinsic interest the material holds), but also with the "commonness" of the symbol chosen (e.g. the letter "e" is more common than "x"). Some authors have used randomly generated characters (Neisser, Novick and Lazar, 1963). See also Colquhan and Corcoran (1964) for relationship to extroversion and time of day; Srivastava, et al., (1968); Miller, (1953) for use under the stress of parachute training; U.S. Dept. of the Army, AGO, PRB (1953). Among standardized cancellation tests are the following:

The Bourdon-Wierama Test: (Rey and Rey, 1963): This is a complex letter cancellation test involving multiple criteria for determining which letter is to be cancelled. For instance, the subject is to cancel consonants which come two letters after the letter "z." The effects of different types of fluorescent lighting on a mechanized version of this test were compared in the above study.

The Finding A's Test (French, Ekstrom, and Price, 1963): This is a copyrighted test (Educational Testing Service) adapted from Thurstone's test. The subject checks columns of 41 words and attempts to find five words in each column having the letter "a." In all, there are 1,025 words, and a two-minute time limit is given. The test is reported to be suitable for grades 6 to 16 (NASA CR).

Tests of Internal Production: In these tests, the subject is required to develop certain internal representations according to a rule or system of rules. Since these must be communicated in some way, the tests all involve verbal representation at some point. Again, many investigators have used their own techniques for measuring these skills, but some standardized tests have been used.

Copying Tests: On the surface, one would think that copying should be considered a simple motor skill involving little more than the ability to make the appropriately controlled muscular response. Nevertheless, it has been found that the copying test contained in the MacQuarries Test for Mechanical Ability (Boros, 1949; Anderson, Fruchter, Manuel, and Worchel, 1954) loads .53 on spatial orientation and visualization, and .36 on spatial orientation alone (NASA CR).

A digit copying test was used by Baddeley, de Figueredo, Hawkswell-Curtis, and Williams (1968), and a copying task was used by Pallack and Kiesler (1968), in conjunction with an investigation of incidental learning under conditions of high and low dissonance.

Tests Involving Production of Similar Things: A series of tests are described by French, Ekstrom, and Price (1963) which involve requiring the subject to write or name things which are alike or identical in certain ways. Most of these are copyrighted by Educational Testing Service. Additional information is given in NASA-CR. These include:

- Word Beginnings Test
- Word Endings Test
- Word Beginnings and Endings Test
- Word Arrangements Test
- Controlled Associations Test
- Object Naming (copyright J.P. Guilford).

In addition, Kaplan, Carvellos, and Matlay (1969) required subjects to list all the four-letter words they could make up from a set of five to ten letters. The time course of word production with differing sets of letters was studied in this experiment.

A somewhat different technique -- perhaps requiring a different skill -- the Theme Test, was adopted from a test by Cattell (French, Ekstrom, and Price, 1963; NASA-CR). In this, the subject must write as much as possible about a given topic in four minutes. The score is simply the number of words written. This test is copyrighted by Educational Testing Service.

Tests Involving Production of Different Things: Tests in which the subject's task is to produce as many different things as possible have also been described by French, Ekstrom, and Price (1963). These are similar to the above tests, except that the element of flexibility within a given conceptual direction is required. For instance, in the Utility Test (French, Ekstrom, and Price; NASA-CR) the subject is required to list different uses for a given object. His score is the number of times he changes the class of use in five minutes (Copyright, Sheridan Supply Co.). In the Simile Interpretations Test (see the previous reference) the subject is required to complete a sentence fragment ending with "because" with as many different explanations as possible. In both of these, therefore, an element of ideational flexibility is needed. This class of tests may measure the same thing as the previous class, but there is probably an additional factor involved.

Tests of Concept Formation and Use

This category contains tests which require the subject to induce an overall concept from a series of representative examples. In addition, aspects of the subject's use of the concept (such as inability to shift to another concept) can be measured by such tests as these.

A series of tests, all copyrighted by Educational Testing Service, have been adapted from Thurstone (French, Ekstrom, and Price, 1963; NASA-CR). These all require the subject to discover a general rule and to apply it to a specific example. In the Letter Sets Test, five sets of four letters each are given and the subject is to find the rule which relates sets and to indicate the exception. In the Locations Test, the subject must discover the rule by which specific areas in a row of five places are marked. He then marks an additional row according to the rule. In the Figure Classification Test, the rule joining three geometrical figures must be determined and used. All of these tests take six to eight minutes to administer and they are reported to be suitable for grades 8 to 16.

The Wisconsin Card Sorting Test: Berg (1948) described a concept test which has gained wide use in a variety of situations. Subjects were given cards to "sort" without instructions. Figures on the cards differed in color, form, and number of objects. The experimenter called each sort either correct or incorrect according to an arbitrary criterion of one of the above differences. After the subject made five correct responses, the criterion was shifted to one of the other categories, and the subject had to discover the new basis. This was done until nine categories of response were completed. Scoring was in terms of the number of cards it took for the subject to successfully "shift" categories. Three groups of subjects were identified; 1) those who could discover and name the shifts, 2) those who could succeed without being able to name the shifts, and 3) those who failed to master the nine categories.

A different version of this test has been described by Hovland (1953). This version uses four different dimensions. Another type of card sorting test has been described under the title of NYU Card Sorting (Phelan and Gustafson, 1968). Morton (1969) presented an analysis of card sorting by number of symbols, and developed a functional model in which different types of interference between stimuli are enumerated.

Tests of Logic and Reasoning

There are many tests designed to evaluate subjects' relative abilities in reasoning and inference (e.g. Miller Analogies Test, etc.). However, these are primarily ability tests and are not specifically designed to measure short-term performance. Similarly, a series of tests described by French, Ekstrom, and Price (1963) from Guilford and Thurstone, attempt to evaluate syllogistic reasoning in much the same way. The Inference Test, the Nonsense Syllogisms Test (both copyrighted by Educational Testing Service), and the Logical Reasoning Test (copyrighted by Sheridan Supply Co.) take from four to ten minutes and require the subject to solve syllogistic-type statements in one form or another,

The Logical Inference Tester (LOGIT): This apparatus consists of a series of lights which are activated when the subject presses buttons. The task is to determine which of many "concepts" (sequences of button presses) will "solve the problem" and cause the lights to be activated in proper order. The task has been used by Parker (1968) under the stress of a flashing light and no decrement was found.

The RATER is a similar form of test (see above reference) which uses geometric forms as stimuli.

A concept-formation type of task is included in the Neptune Battery under the title Reactor Control Task (McKenzie, White, and Hartman, 1969). In this, the subject presses each of four buttons in a row and lights indicate certain relationships that exist in a problem set. Using this information, he must then press two or three buttons to identify the problem set.

Pattern Conceptualization

See Vince (1955): the subject traces a circular pattern through a slit so that he sees only one segment at a time. He must visualize the pattern, and determine optimum strategies for tracing it.

The Grassi Block Substitution Test (Grassi, 1953). In this test the subject reconstructs designs using four blocks. Patterns represent simple concrete, complex concrete, simple abstract, and complex abstract performances (see also the Kohs Blocks Test). These tests are designed to diagnose organic brain damage, both early and late.

Other Tests of Classification

Counting Accuracy (Mullins, 19): Subject counts dots in a series of squares. Measures "carefulness."

Sentence Comprehension Tests: Baddeley, de Figueredo, Hawkswell-Curtis, and Williams, 1968.

Picture Gestalt: French, Ekstrom, and Price, 1963; NASA-CR. Subject determines utility of objects (Copyright, J. P. Guilford).

SECTION III B

MEMORY AND INTERNAL COMPARISON

Introduction

In this section, we are concerned with tests of associational processes which require the subject to retain something internally for a relatively short period of time, or which call on the subject to compare an external event (such as time or distance) to some previously established criterion or representation. We will not consider long-term memory per se, nor will we be concerned specifically with the "learning" process itself. But in many cases it is obvious that tests of short-term memory must involve learning to some extent. In these cases, the volume of learned material should be relatively small, and the subject should clearly perceive the task as a short-term task (i.e., he should not feel he will be required to remember the material for days, or even hours). With respect to the comparisons, the criterion is that the subject must produce a great deal of at least one side of the comparison internally. Consequently, estimating which of two dots is closer to a line would not constitute internal comparison since both dots are present to the subject externally. Time estimation, where the subject is comparing the passage of external time with some internal criterion, is specifically the task contained here. Even if the subject counts internally, keeps track of his heart beat, produces muscle tension, or

taps his foot, it will still be considered an internal comparison.

Short Term Memory (STM)

What is being measured in STM?

Physiological evidence:

Experimental studies: see Underwood, 1969 for theoretic review.

Stresses used with STM: Phillips, Griswold, and Pace, 1963.

Parameters affecting results in this area:

Material used:

Words, digits, syllables, sentences, etc. The association value of these differ, even among words or syllables:

see Underwood and Richardson, 1956; Witmer, 19 .

These form the basis for the classification of tests below, but may not be intrinsically more important than other parameters.

Duration of the retention interval:

The presentation rate:

Activity intervening between exposure to material and reproduction.

The "Peterson distractor technique" is a standard method of filling the interval: Peterson and Peterson, 1959.

The unit size and total quantity of material, etc.

STM for letters and syllables:

The use of symbols which are as devoid of meaning as possible while still retaining some association value has been an attractive technique in learning and memory research.

Letters:

8-letter task, studying effect of presentation rate, modality of presentation, and intrusion of errors:

Laughery and Harris, 1969; also
see Laughery and Fell, 1969; and
Laughery, Harris, and Ulbricht,
1967.

Effect of stimulus length, trials, repetition, interpolated activity, recall interval, and intertrial interval:

Using consonants: Azerrad and Kennedy, 1969.

Length of list: Merikle, 1969.

Vowels vs. consonants: Sales, Cole, and Haber, 1969.

Letter Span Test, and Letter Span Test II (auditory):

Letter Span Test I (visual):

These tests (NASA-CR) involve presentation of varying numbers of letters by the different modalities: see Brandt and Hollien; French, Ekstrom, and Price, 1963.

The auditory tests load .33 on rote memory and .64 on span memory. The visual test loads .66 on span memory.

Syllables and Trigrams (CCC or CVC): Loess and McBurney, 1965; Laughery and Pinkus, 1968.

Compared words vs. abbreviations vs. CVC's: Ellis and Dugas, 1968; Tarpy and Marshall, 1969; Cermak, 1969; Cimbalo and Mahoney, 1969; Grant and McCormack, 1969; Leeming (1968) studied effect of the intertrial interval; see also Cimbalo and Mahoney, 1970; and Grant and McCormack, 1969; Montague, Hillix, Kiess, and Harris, 1969; Schumsky, Grasha, Trinder, and Richman, 1969; Bruce and Cofer, 1965.

Memory for Syllables, Test I and Memory for Syllables,

Test II: These are noted in NASA-CR and in Brandt and Hollien.

Subject learns pairs of nonsense syllables.

The tests load .34 and .41 on rote memory and .35 and .58 on doublet-nonsense syllable paired associates.

Recognition Test I:

Syllables:

STM for words:

The Underwood-Richardson norms: Underwood and Richardson, 1956; also see Hudson, 1969 on tendency to categorize; also see Thompson and Poling, 1969.

Providing signal detection measures: Donaldson, Wayne,
and Glathe, 1969.

The Brown-Peterson STM tasks: Crowder, 1967.

Effect of connotative content of word triads: Turvey,
Fertig, and Kravetz, 1969;

With numbers: Epstein, 1969.

Effect of position in a sequence: Fuchs, 1969; see also
De Rosa, 1969.

Effect of word length: Lacher and Goggin, 1969.

Auditory and visual input: Craik, 1969; Murdock and
Walker, 1969.

Effect of reading aloud: Gumenik, 1965.

Time for retrieval as a function of short-term vs. long-
term memory: Waugh, 1970.

Effect of Intervening activity: (Peterson technique) on
words and consonants: Loess and McBurney, 1965.

Compared to picture recall: Sampson, 1969.

Recognition Test II (Words): NASA-CR; Brandt and
Hollien.

Memory for Words Test I (Unrelated words): see NASA-
CR; and Brandt and Hollien paired
associates learning of one syl-
lable, unrelated nouns. Loads
.19 on verbal comprehension, .64
on rote memory, and .25 on
visual memory.

Memory for Words Test II (Related words): see NASA-CR;

and Brandt and Hollien paired associates technique; loads .36 on rote memory and .43 on immediate meaningful memory.

STM for sentences and ideas:

Sentence Completion Test:

The subject learns a group of unrelated sentences.

The sentences are then presented with one word missing and he fills in the missing word: NASA-CR; Brandt and Hollien. Loads .53 on immediate meaningful memory.

Sentence Span Test:

The subject repeats sentences ranging from 18 to 33 syllables after hearing them: NASA-CR; Brandt and Hollien. Loads .38 on verbal comprehension, .24 on span memory, and .28 on auditory memory.

- 1) Memory for Limericks Test: see previous reference;
- 2) Memory for Instructions Test: " " "
- 3) Memory for Ideas Test: " " "

In 1) the subject learns a limerick and later reproduces the idea and key words. Loads .26 on numerical facility, .22 on perceptual speed, .39 on visualization, and .28 on visual memory. In 2) the subject must follow up to five verbal instructions. Loads

.41 on span memory. In 3) the subject reproduces the key ideas of a story. Loads .33 on immediate meaningful memory and .54 on auditory memory: see also Meaningful Memory paragraph: NASA-CR; Brandt and Hollien.

Memory for Relations Test:

Subject learns matrices consisting of letters, numbers, etc. and fills in missing cells later. Loads .26 on numerical facility, .22 on perceptual speed, .39 on visualization, and .28 on visual memory.

Film-retention and GSR: Levonian, 1968.

Effect of message structure, length, and presentation rate: Gerver, 1969.

STM for numbers:

Age and norms for 10-digit numbers: Broddin, 1953.

Correlation with syllogistic reasoning: Whumbey and Ryan, 1969.

Effect of presentation rate, 18-digits: Mayzner, and Schoenberg, 1965.

Use of constant repetition of digits: Dalrymple, 1967.

Visual vs. auditory: Dornic and Halmiova, 1968.

Digits vs. words: Epstein, 1969.

Effect of quinary vs. decimal numbers: Slak, 1969.

Kelley's Digit Span: NASA-CR; French, Ekstrom, and Price, 1963; Kelley, 1964.

Cards containing single digits are shown at one per second. (Copyright, Educational Testing Service).

Hibb's procedure: Chorayan, 1968.

Memory for numbers test:

Subject is given words and associated numbers. He must produce the number on hearing the word: NASA-CR; Brandt and Hollien. Loads .53 on rote memory and .21 on visual memory. See also Object-Number Test: French, Ekstrom, and Price, 1963.

Picture-number test: NASA-CR; French, Ekstrom, and Price, 1963.

Number span test I (Auditory):

Four to twelve digits are presented: NASA-CR; Brandt and Hollien. Loads .27 on rote memory, .57 on span memory, and .21 on visual memory.

Probe stimulus technique: Jahnke and Erlick, 1968.

Number span test II (Visual):

Four to twelve digits. Flash cards are presented on a display stand: NASA-CR; Brandt and Hollien. Loads .26 on rote memory and .59 on span memory.

WAIS Digit Span Test: See the Wechsler Adult Intelligence Scale. Loads .34 on nonverbal reasoning, .37 on fluency, and .52 on unique and error factors;

Cronback, 1960.

Has been used under the stress of anxiety-producing verbal remarks and showed decrement: Moldawsky and

Moldawsky, 1952.

In confinement: Ormiston and Finkelstein, 1961.

In parachute training: Miller, 1953.

Also used in astronaut section: Wilson, 1959.

See also Meaningful memory with numbers: NASA-CR;

Brandt and Hollien.

STM for forms, diagrams, and figures:

Line drawings vs. words: Sampson, 1969.

Reproduction of visual designs test: NASA-CR; Brandt and

Hollien. Loads .22 on perceptual speed, .43 on visualization, and .55 on visual memory.

Tachistoscopic exposure of forms: Hyman, 1954.

Involving 2 and 3 dimensional figures: Wallach,

O'Connell, and Neisser, 1953.

Recognition Test III (Figures):

Subject studies geometric figures, then indicates whether figures in test group were among those studied.

Loads .21 on immediate meaningful memory, .28 on visualization, and .26 on visual memory: NASA-CR; Brandt

and Hollien.

Map Memory Tests (I, Reproduction; II, Verbal Recall; III, Recognition):

The subject studies various types of maps and then either reproduces them, answers questions, or identifies correct representations. Load .35 and .21 on "perceptual speed", .46 and .25 on "visualization", and .24 on "visual memory": NASA-CR; Brandt and Hollien, 19 .

Meaningful Memory: Picture:

Subject answers questions about the sketch of a particular scene. Loads .22 on "immediate meaningful memory": NASA-CR; Brandt and Hollien, 19 .

STM of other material:

Force:

Subject attempts to reproduce a criterion force during recall: Pepper and Herman, 1969.

Flash rate, brightness, loudness, pitch and duration:

A 25-location rhombic-shaped display matrix is used, and the subject attempts to recall locations within the matrix: Cherry, 1969.

Time Estimation

The underlying bases for the tests to be described here are primarily the concept of the "internal clock", and the measurement of the internal time sense as mediated by the various senses. The "internal clock" hypothesis assumes an intrinsic rhythmicity which is speeded up or slowed down much as a real clock. It has had a

long history (Carlson and Feinberg, 1968; Ross, 1969, discusses M. Treisman's model). However, there has never been a great deal of success in relating such a clock to either actual internal mechanisms, or to other behaviors in the real world. The relationship to real clock time is very complex (Richards, 1964). Use of this type of test to evaluate sensory-cognitive interactions is a very delicate operation, and it is not certain that all the significant parameters have been identified.

Effect of subject and experimenter expectations on a tone-length comparison task: Zoble and Lehman, 1969.

Clock speed and other external pacers: Rotler, 1969; Craik and Sarbin, 1963.

Effect of frequency of occurrence on judgements of recency: Peterson, Johnson and Coatney, 1969.

Methods used to indicate time; e.g. estimation, production, reproduction, filled interval, empty interval, successive comparison, etc.: Siegman, 1962; Bell and Provins, 1963; Carlson and Feinberg, 1968; Goldfarb and Goldstone, 1963; Hornstein and Rotter, 1969; Aitken and Gedye, 1968; Warm, Smith and Caldwell, 1967; see Coburn, 1967; Fox, 1952; Simonds, 1967; Conticelli and Gloria, 1967; Essman, 1960.

The absolute time interval estimated:

may range from less than 1 sec: Lichtenstein, White and Harter, 1963;

up to several hours' estimate over many weeks: Jirka and Valousek, 1967;

Color of the environment in which the subject estimates time:

red stimuli produce shorter estimates: Smets, 1969.

Subject's perception of the task: Bakan, 1956.

The elapsed time between standard and comparison in successive comparisons: Sixtl, 1963.

Effect of age: Tejmar, 1962.

Effect of stimulus intensity: Zelkind and Ulehla, 1968;

Oleron, 1952 (increases in sound intensity leads to over-estimation of its duration).

Effect of auditory vs. visual vs. tactile comparison signal:

Goldstone and Goldfarb, 1964; Lhamon, Edelberg and

Goldstone, 1962, showed auditory durations were judged

longer than visual; see also Goldstone, 1968. Goldstone

and Goldfarb, 1964 discusses anchors, durations and

interactions in auditory and visual time estimates.

Gridley, 1932, studied both vision and touch estimates.

Stresses used with time estimation:

Illumination: Ross, 1969, used steady illumination,

darkness, and intermittent photic stimulation with

10-second estimates.

Failure and pacing: Greenberg and Kurz, 1968, studied

this in both men and women.

Sensory isolation: Sugimoto, Kida, Teranishi and Yamamoto,

1969; Kato and Saito, 1964.

Heat: Bell and Provins, 1963.

Carbon monoxide: Beard and Wertheim, 1967; Beard and

Grandstaff, 1970; O'Donnell, Mikulka, Heinig and

Theodore, 1970; O'Donnell, Chikos, and Theodore, 1971.

Apparatus and techniques:

Use of arm movements to indicate passage of time

intervals: Danziger and Du Prezz, 1963.

"Time-Sense Apparatus": an apparatus which is "quite free from any noises, and can easily give any short stimulus-time and time-intervals from 10 sec to 1/1000 sec by mere rotation of its dial": Mizusawa, 1952.

The Seashore phonograph record for the measurement of the 'sense of time'; see Gridley, 1932.

SECTION III C

MANIPULATION OF ABSTRACTIONS

In this section, we are concerned with the subject's ability to perform some fairly complex internal manipulation on a representation or symbol. In a sense, this represents the most "mental" of all tests listed since it requires not only retention, representation and reproduction of symbols but also the internal process of changing these figures to produce a new symbol or a new representation of the old symbol. For convenience, we classify these tests into three sub-categories. The first is those dealing with spatial manipulations, where the subject uses a "system", either verbal or otherwise, to internally visualize positions in two or three dimensional space. Thus, he may have to visualize where an object will be after it had moved, or he may be required to visualize what the object would look like after it had changed in some way. The second category involves verbal manipulations. These may be "problem-solving" tests in some sense, as long as the interval representation can be expressed solely in words or alphabet letters. The third category is numerical. This is separated from the others not so much because it is different from verbal representation, but to allow for separate consideration of the various forms of mental arithmetic tests.

SPATIAL MANIPULATIONSStatic Visualization of Changed Objects

In these tests, an object is changed in some way, and the subject

must describe or identify what it would look like after the change.

There is no requirement to visualize the movement or change in the object per se, but simply to picture it in a "before" and "after" way.

Surface Development Test. This has been adopted from Thurstone (see NASA-CR; French, Ekstrom and Price, 1963). The subject views a drawing of a solid form and another drawing representing what a sheet of paper which had been folded to make the form might look like when opened up. One section of this latter drawing is marked with boundaries corresponding to a side of the solid form. The subject is to identify the side marked. The test takes about six minutes, and has five items (copyright Educational Testing Service).

Paper Folding Test (also adapted from Thurstone). Drawings indicate how a paper might be folded two or three times, and the final drawing shows the folded paper with a hole punched in it. The subject must indicate which of five drawings show how the paper would look when opened (copyright Educational Testing Service). See NASA-CR and French, Ekstrom and Price, 1963.

Minnesota Paper Form Board Test (copyright Educational Testing Service). This printed test shows five shaded figures. The subject is to determine which of the five figures, when fitted together, will form a given outline. Some or all of the figures can be used. The test requires eight minutes for 24 items. (NASA-CR and French, Ekstrom and Price, 1963).

See also Crawford (1941);
Barratt, 1953, gives a factor analysis of spatial orientation abilities; and Reynolds (1960) for the "Thurstone test of the space factor". See also the Card Rotations Test and the Cube Comparisons Test (NASA-CR and French, Ekstrom and Price, 1963).

Dyanmic Visualization--Moving Objects.

In this class of tests, the subject must not only visualize a static change in the object, but must also move the object from one position in space to another. He can do this under the direction of rules or cues which may be verbal or may consist of some other informational symbol.

Tests Using Symbols to Give Directions.

Complex Movements Test. In this, the subject is presented with two lines (one vertical and one horizontal) each having a circle and dot associated with it. The subject must use a grid pattern and, starting from a given location, indicate the direction which would have to be taken in order to "move" both dots into their circles (Parker and Fleishman (1959) (1960); Fleishman and Hempel (1954); NASA-CR). Reliability of .85 is reported for this test. It has shown loadings of .32 and .34 on "spatial visualization" and .30 and .40 on "spatial integration".

Forced Landings Test. In this test, the subject is presented with a printed representation of an aircraft and several landing fields. Arrows show wind direction and direction of drafts. The subject must select the best landing field (NASA-CR; Parker and Fleishman, 1960). Reliabilities from .88 to .91 have been reported, and the test loads .36 on "response orientation", .35 on "mechanical experience" and .29 on "spatial orientation".

Coordinate Movements Test. A dot and circle are shown, along with a series of arrows whose curvature and thickness indicate direction and distance. The subject selects the arrow which would "move" the dot into the circle (NASA-CR; Parker and Fleishman, 1959, 1960; and Fleishman and Hempel, 1954). Reliability is .85, and loadings have

been found of .34 and .38 on "spatial orientation", .27 on "response orientation", .28 and .30 on "integration", and .34 on "visualization".

Instrument Comprehension. Subject interprets aircraft instruments (Fleishman, 1957; Parker and Fleishman, 1960; Parker, Reilly, Dillon, Andrews and Fleishman, 1965; NASA-CR).

Tests Using Verbal Rules.

Combat Planes. The subject sees pictures of planes in combat. He must use previously given rules to determine which planes will attack (NASA-CR; Guilford, 1947).

Flight Formation Test. Pictures of aircraft in formation are shown, and moves by each plane are presented verbally. Subject indicates the formation after all moves have been made (NASA-CR; Guilford, 1947).

Guilford-Zimmerman Aptitude Survey (Spatial Orientation and Spatial Visualization Tests). See Buros, 1965; also Buros (4th and 6th yearbooks).

Planning Air Maneuvers. Subject selects best paths for "skywriting" certain letters while following rules. Copyright J.P. Guilford (NASA-CR; French, Ekstrom and Price, 1963).

Ship Destination Test. The subject must use wind direction, ocean current, and ship's heading to compute the distance a ship will travel in getting to a port. Developed by Christensen and Guilford and copyrighted by Sheridan Supply Co. Takes 15 minutes to administer.

Other Tests. See for test of manipulating geometric figures and playing "the game of 5". See also "Signal Interpretation III" (NASA-CR) and Guilford, 1947.

Tests of Verbal Manipulation

These tests involve directly working with verbal material, usually

in the context of verbal directions. One would expect to find a great many such tests, but this is not the case. Although the field of learning and aptitude testing uses many tests of this type, not many are specifically appropriate as performance tests. Those that are can be roughly grouped into two classes.

Following Directions and Interpreting Complex Commands. In these tests, the subject is given a set of rules, either verbally or in writing, and is required to perform actions in order to indicate understanding of those rules. An example of such a test is the "Following Directions Test" (NASA-CR; Parker and Fleishman, 1960, 1959). The subject sees two aircraft panels and is given a set of printed instructions. The instructions contain complex directions telling him to underline particular words depending on relations between instruments shown in the aircraft displays. Reliability of this particular test is .75, and it has shown factor loadings of .31 on "perceptual speed", .27 on "spatial orientation", and .27 on "integration".

No other tests of this nature were isolated, however, it should be pointed out that the characteristics of this test are frequently incorporated into other tests where the actual output is more related to another form of test. For instance, in a reaction-time test with complex mapping, the verbal manipulations required may be as complex as in any other test, but the test would still be described under reaction times.

Code Tests. This category includes those tests which involve transforming verbal symbols or alphabet letters in some way in order to produce a meaningful solution. Thus, things such as crossword puzzles might be placed here, although they might more appropriately be

considered under the heading of "definitions". Codes involving digits, or some other numerical component, are considered in the next section in order to retain the distinction between verbal and numerical manipulations. See Olshavsky and Gregg (1969) for a code test involving the alphabet.

The most common and most extensively studied test of this type is the Anagram. These word games have recently received considerable theoretical attention (Warren and Thomson, 1969), and a model of anagram solution has been suggested which consists of two processes: word-association emission and initial bigram rearrangement coupled with word emission. Rules for a Standard Anagram Task have been developed (see Reid, Van Nuys, Davies and Ammons, 1963). Ammons (1960) has described a standard anagram task designed to be used in studying problem solving. Parameters affecting performance in anagram tasks include reinforcement and task solvability (Tombaugh and Tombaugh, 1963), the transitional probability of the anagram letter order (Stachnik, 1963), instructions and anagram class (Maltzman and Morrisett, 1953a and b), field dependence (Boersma, Muir, Wilton and Barham, 1969) (these authors also discuss eye movements in anagram solution) and male-female differences in scanning (Strauss, 1969). Other studies using anagrams include: Schwartz and Olson, 1968; Dominowski, 1967; Olson and Schwartz, 1967; DiVesta and Walls, 1968; Harris and Loess, 1968; and Juola and Hergenhahn, 1968.

Another code-type test was described by Harmon (1944) as the "H-D Code Aptitude Test". It is a 25 minute test in which the subject "compares signals and records his decisions on a mimeographed sheet." Reliability of .80 is reported.

The "alphabet maze" was used by Cowen, Wiener and Hess (1953) as a parallel to the Luchins water-jar technique to investigate problem solving rigidity.

TESTS OF NUMERICAL MANIPULATION

These tests are essentially the same as those presented in the previous section, except that numbers are used instead of words. Placing them separately is not meant to infer that differing functions are measured by the two types (although this is certainly not an impossibility). It is done simply for ease of acquisition.

There are perhaps more varieties of numerical manipulation tests than of verbal. This may be because of the relative "meaninglessness" of numbers, or it may be due to their flexibility. In any case, several varieties of numerical manipulation tests are available to the researcher, and these are outlined below.

Numerical Code Tests

These tests involve using numbers to stand for some other symbol, or in some way making a connection between a number and another representation. They are analogous to the code tests presented in the section on verbal manipulation.

The WAIS Digit-Symbol Test. This test is part of the Wechsler Adult Intelligence Scale, and involves assigning numbers to geometric symbols according to a code. It has been used under the stresses of verbal failure (Westrope, 1953; and Stopol, 1954), noise distraction (Stopol, 1954), and parachute training (Miller, 1953). It was also used with subjects of differing heart rate (Burgess and Hokanson, 1968). It has shown factor loadings of .52 on "numerical speed", .37 on "perceptual speed", .30 on "fluency", and loads .61 on unique and error

variance.

Other investigators studying digit-symbol performance have studied the effects of arousal (Burgess and Hokanson, 1964), difficulty, and anxiety (Johnston and Cross, 1962). A similar test has also been used at altitude (Ledwith, 1968). A three-phase code transformation task has been used by Alluisi and Coates (1969), using various approaches to the solution. Many measures of performance were factor-analyzed, and five factors were identified. Another code transformation test has been used by Dempsey and Morgan (1969) to assess the effects of various workload stresses. This "Digital Readout Code Transformation Test (DR-COTRAN)" was sensitive to the effects of two levels of work-load stress.

Mental Arithmetic

When the subject is required to incorporate some numerical information directly, and then to perform a process on the information in order to produce an answer, it will be defined here as "mental arithmetic." The information may be given visually or in some other way, but it must always be precise quantitative information, and not given as an approximation or a qualitative judgement (e.g., we are not concerned here with the subject estimating numerosity or making judgements about the quantitative aspects of some stimulus). Similarly, the process carried out may be extremely simple (adding two numbers) or a very complex series of mathematical procedures, but the end result should be fairly precise (i.e., the "answer" must be correct within a very narrow band). Within these basic definitions a large number of tests have been used. Most of these, by far, have been "home grown" and have never been standardized. As a matter of fact, it is difficult

to standardize such a test in a very specific sense because any arithmetic test using the same numbers would soon become well-known and the test would thus be compromised. The closest approach to a standard test would be to standardize the operations required. This raises unique questions which must be considered in using the tests. The categories listed below give some idea of the variety of arithmetic operations which have been tested.

Simple Arithmetic Operations. It is necessary to remember that in using simple arithmetic problems, an extremely overlearned response is being tested in most cases. This factor must be considered carefully in interpreting results, since the structures and functions being tested by such responses may be different from those tested with relatively "new" material. It must also be remembered that since these operations are so "simple", they tend to become rather boring rather fast. Mech (1953), using addition tasks under various "sets", found that frequent reinforcements were necessary to maintain superior performance. Thus, it should be remembered that if one uses these tests and, as most researchers have done, requires the subject to perform the task for an extended period of time, one is not testing a simple "numerical ability". There may be strong elements of boredom, suggestability, anger, and, worst of all, motivational changes which affect the results. Interpretations should always point this out.

Addition Tests. Usually, the subject is given a long series of one or two digit numbers to add. It is perhaps better to provide only three or four numbers in the series so that errors can be isolated to more specific points. Educational Testing Service copyrights such an "Addition Test"

(French, Ekstrom and Price, 1963). See also Mech (1953). Sampson (1962) tested the effect of digit presentation rate and monocular vs. binocular viewing on serial addition. Similarly, Corballis and Sampson (1963) used a Paced Serial Addition Task (PSAT) and compared it to measures of its component operations.

Subtraction Tests. Not tested very often. See French, Ekstrom and Price (1963) for the Subtraction and Multiplication Test (copyright ETS).

Multiplication Tests. Kurz (1964) used pacing, shock, and distraction with a multiplication test. Pacing was the only stress producing an effect. See French, Ekstrom and Price (1963) for the Subtraction and Multiplication Test (copyright ETS).

Division Tests. See French, Ekstrom and Price (1963) for the Division Test (copyright ETS). Burch, Childers, and Edwards (19) used division tests with 98 and 108 db noise and found no decrement on either easy or hard problems.

Combination Tests. The Numerical Operations Test (Brandt and Hollien, 19) gives problems in addition, subtraction, multiplication and division. It loads .67 on "numerical facility" and .26 on "perceptual speed". The Arithmetic Reasoning, Test 1 gives problems verbally, many in aviation terminology. It loads .25 on "verbal comprehension", .54 on "numerical facility", .28 on "visualization", .36 on "kinesthetic-spatial-reasoning", and .28 on "visual memory".

More Complex Arithmetic Operations. These tests involve something

more than the simple process of receiving numbers, processing them with a single operation, and giving the answer. In the present case, the subjects must either remember a complex series of directions, must perform quite complex operations on the numbers, or must use memory to a great extent. Obviously, many such tests have been used, and only a few representative examples can be given here.

The Digit Test. A moving tape presents black and red digits which the subject is to add and subtract differentially (Iseliani, 1968). The task has been used with 5-7 G acceleration, reduced atmospheric pressure, and under vibration. All stressors affected performance adversely.

Number Comparison Test. Restle (1969) presented subjects with two numbers to be added, and with another number. The subjects were to indicate whether the sum was larger or smaller than the third number.

A simple form of this was used by Moyer and Landauer (1967). In that, two 1-digit numbers were simply presented, and the subject threw a switch to indicate his answer.

Verbal-Numerical Test of the Officer Qualification Test. (See Glickman and Vallance, 1954).

Resourceful Arithmetic. The subject is given 20 problems, and he can increase his total score by taking short-cuts in their solution (Frederiksen, 1966). This test loads .69 on "cognitive flexibility-rigidity"; and has a reliability of .86.

Sign Changes. This is a one minute test of standard arithmetic problems. However, the subject must reverse the meaning of all the signs attached to the numbers. The test loads .73 on "cognitive flexibility" and the reliability is .85.

Broadbent's Mental Arithmetic Task. This is a subtraction task with strong memory requirements. The subject is presented a six digit number which he must study until he is sure he can remember it. He then presses a button, the number disappears, and a four digit number appears. He must mentally subtract the four digits from the six and report when he has the answer. Broadbent (1958) showed effects of noise on this task, and Sommers and Harris (1972) showed interactive effects of vibration, noise and time of day.

Tests of Numerical Judgement

This category of tests may or may not require numerical manipulation, but it at least requires a quantitative sophistication which places it somewhat differently than a simple sensory integration task. The essential element of these tests is that the numerical information is not being handled in a precise way, but is being "estimated" or "judged".

Number-Judgement Tests. Miller and Baker (1968) used a set of slides which contained 14, 23, 37, 60, and 98 objects at four levels of heterogeneity. The objects were circles and triangles of different size. Subjects estimated the number of objects. Results showed subjects underestimated the number of large objects and overestimated the number of small objects. Instructions, heterogeneity, and shape had no effect. Weiss (1963) studied the effect of the judgement scale used and differences between open-ended and fixed-category judgements. Fujji (1967) examined the effect of spatial arrangement of objects. Lieblick and Lieblick (1969) studied various difficulty levels, feedback, and decision time on a forced-choice estimation task.

Implicit Calculations. Weiss (1963) used a technique in which subjects had to remember several classification categories while briefly

looking at a list to be categorized. They then estimated the number of members in the list which belonged to each category.

Estimates of the mean number of objects can be obtained from subjects after exposure to several groupings. A similar technique was used by Edwards (1963), and it was found that the number of signals to be integrated, and their pattern affected absolute accuracy of the judgement. It is difficult to know what is being measured in this type of test, and interpretations should be made with extreme caution. However, it provides an interesting possibility for probing a type of "judgement" which, on the surface appears to be used quite frequently in real-world tasks.

Tests of Other "Association" Functions

Abel's Concentration Progress Test. (See Birke and Kühne, 1967).

Audiovisual Conflict. (See Frankenhaeuser, et al, 1968).

REFERENCES

- Abramovich, C. A., and Pichugina, E. N. On the influence of general physical fatigue upon the associative reflex. Novoe v refleksologii i fiziologii nervnoi sistemy. Reflexological and Neurophysiological News, 1926, 2, 180-195.
- Abric, Jean C.; Faucheux, Claude; Moscovici, Serge, & Plon, Michel. Role of the image of the partner on cooperation in a game situation. Psychologie Francaise, 1967, 12(4), 267-275.
- Adams, Jack A. Multiple versus single problem training in human problem solving. Journal of Experimental Psychology, 1954, 48, 15-18.
- Adams, J. A. A source of decrement in psychomotor performance. Journal of Experimental Psychology, 1955, 49, 390-394.
- Adams, O. S., & Chiles, W. D. Human performance as a function of the work-rest ratio during prolonged confinement. Tech. Rpt. 61-720, Contract Nos. AF 33(616)-7607, Behavioral Science Lab., Aerospace Med. Lab., ASD, USAF, WPAFB, Ohio, Nov., 1961.
- Adams, O. S., and Chiles, W. D. Human performance as a function of the work-rest cycle. WADD Tech. Rpt. 60-248, Contract No. AF 33(616)6050, March, 1960.
- Adams, O. S.; Fitts, P. M.; Rappaport, M., & Weinstein, M. Relations among some measures of pattern discriminability. Journal of Experimental Psychology, 1954, 48, 81-88.
- Adams, O. S.; Levine, R. B., and Chiles, W. D. Research to investigate factors affecting multiple-task psychomotor performance. WADC Tech. Rpt. 59-120, WPAFB, Ohio, Mar., 1959.
- Adamson, Robert. A drum for tachistoscopic presentation. American Journal of Psychology, 1955, 68, 473-474.
- Adelson, Marvin. A method for studying human tracking behavior. USAF Hum. Resour. Cent. Res. Bull., 1953.
- Adevai, G., & McGough, W. E. Retest reliability of rod-and-frame scores during early adulthood. Perceptual & Motor Skills, 1968, 26(3, Pt. 2), 1306.
- Adevai, Greta; Silverman, Albert J., & McGough, W. Edward. Perceptual correlates of the Rod-and-Frame Test. Perceptual & Motor Skills, 1968, 26(3, Pt. 2), 1055-1064.

- Aftanas, Harion, & Zubek, John P. Long-term after-effects following isolation of a circumscribed area of the skin. Perceptual & Motor Skills, 1963, 17(3), 867-870.
- Aftanas, M., & Zubek, J. P. Effects of prolonged isolation of the skin on cutaneous sensitivity. Perceptual & Motor Skills, 1963, 16(2), 565-571.
- Agarwal, Gyan C., & Gottlieb, Gerald L. Analysis of step tracking in normal human subjects. IEEE Transactions on Man-Machine Systems, 1969, MMS-10(4, Pt. 1), 132-137.
- Ahearn, Thomas R.; Beussee, Mary P., & Hammes, John A. Effects of austere group confinement on measures of intelligence, personality, and psychomotor factors. Psychology, 1969, 6(4), 73-77.
- Aiken, L. R., & William, E. N. Three variables related to reaction time to compare single-digit numbers. Perceptual & Motor Skills, 1968, 27, 199-206.
- Aitken, R. C., & Gedy, J. L. A study of two factors which affect arousal level and the apparent duration of a ten-minute interval. British Journal of Psychology, 1968, 59(3), 253-263.
- Alajouanine, Theophile; Scherrer, Jean; Barbizet, Jacques; LeHenaff, Maryvonne, & Buser, Pierre. Concept of the temporal interval of sensory discrimination. C. R. Acad. Sci. Paris, 1953, 236, 1995-1997.
- Albe, D., & Fessard, A. A new apparatus for the measurement of visual accommodation time. Annee Psychol., 1942, 40, 135-151.
- Allas, Y., & Jauhiainen, T. Discrimination in electric taste. Acta Oto-Laryngologica, 1968, 65(4), 420-425.
- Alluisi, Earl A. Methodology in the use of synthetic tasks to assess complex performance. Human Factors, 1967, 9, 375-384.
- Alluisi, Earl A., & Coates, Glynn D. Parameters and factor structure of a three-phase code transformation task (3P-COTRAN). Perceptual & Motor Skills, 1969, 29(1), 155-166.
- Alluisi, Earl A., & Harker, George S. The stereoptometer--a simple haploscopic instrument for the study of binocular space perception. Science, 1953, 117, 682-683.
- Alluisi, E. A.; Morgan, B. B., & Hawkes, G. R. Masking of cutaneous sensations in multiple stimulus presentations. Perceptual & Motor Skills, 1965, 20, 39-45.
- Alluisi, E. A.; Chiles, W. D.; Hall, T. J.; & Hawkes, G. R. Human group performance during confinement. Tech. Doc. Rep. No. AMRL-TDR-63-87, Project No. 1710, Task No. 171002, 6570 AMRL, WPAFB, Ohio, Nov., 1963. AD 426-661.

Iluisi, Earl A.; Hall, Thomas J., & Chiles, W. Dean. Group performance during four-hour periods of confinement. USAF MRL Tech. Doc. Rep., 1962, No. 62-70; iv, 37.

Iluisi, E. A.; Strain, G. S., & Thurmond, J. B. Stimulus-response compatibility and the rate of gain of information. Psychonomic Science, 1964, 1, 11-112.

Ipern, Mathew. Relation of visual latency to intensity. A.M.A. Arch. ophthalmol., 1954, 51, 369-374.

Ipern, Mathew, & Faris, John J. Note on the electrical response of the human eye during dark adaptation. Journal Opt. Soc. Amer., 1954, 44, 74-79.

Itman, I., & Haythorn, W. W. The effects of social isolation and group composition on performance. Human Relations, 1967, 20, 313-340.

Iano, T., & Komatsu, H. The size comparison of spatial structures by visual stimulation. Jap. Journal of Psychology, 1932, 7, 735-754.

Ibler, R. K., & Guedry, F. E. The validity of a brief vestibular disorientation test in screening pilot trainees. USN AMI Rept. 122, Oct., 1965.

Ibler, Rosalie K., & Guedry, Fred E., Jr. Cross-validation of a Brief Vestibular Disorientation Test administered by a variety of personnel. USN Army-Navy Joint Report, 1967, No. 1009, ii, 6.

Irons, C. H., & Ammons, R. B. Motor skills bibliography: XCIV. Psychological Abstracts, 1967, Vol. 41, Fourth Quarter. Perceptual & Motor Skills, 1968, 27, 47-50.

Irons, C. H., & Ammons, R. B. Perception bibliography: LXI. Psychological Abstracts, 1941, Vol. 15, Second Half. Perceptual & Motor Skills, 1968, 27, 5-318.

Irons, R. B., & Ammons, C. H. Perception bibliography: LXII. Psychological Abstracts, 1942, Vol. 16. Perceptual & Motor Skills, 1968, 27, 607-610.

Irons, R. B. Rotary pursuit apparatus: I. Survey of variables. Psychol. Monographs, 1955, 52, 69-76.

Irons, R. B., Alprin, S. I., & Ammons, Carol H. Rotary pursuit performance related to sex and age of pre-adult subjects. Journal of Experimental Psychology, 1955, 49, 127-133.

Irons, R. B.; Ammons, C. H., & Morgan, R. L. Subskills in rotary pursuit affected by rate and accuracy requirements and by distribution of practice. Journal of Gen. Psychology, 1958, 58, 259-279.

Irons, R. B., & Ammons, C. H. A standard task. Psychol. Rep. 1959, 5, 656.

Ancona, Leonardo. Contribution to the study of the visual discrimination of points. Cont. Lab. Psicol., Univ. Sacro Cuore, Milano, 1952, Ser. 15, 37-73.

Anderson, G. V.; Fruchter, B.; Manuel, H. T., and Worchel, P. Survey of research on spatial factors. San Antonio, Tex.: AF Pers. & Trig. Rsch. Center, Lockland AFB, Res. Bul. AFPTRC TR-54-84, 1954. AD 62 109.

Anderson, Norman H.; Grant, David A., & Nystrom, Charles O. Performance on a repetitive key pressing task as a function of the spatial positioning of the stimulus and response components. USAF, WADC Tech. Rep., 1954, No. 54-76, iv, 15.

Anderson, Norman H.; Grant, David A., & Nystrom, Charles O. The influence of the spatial positioning of stimulus and response components on performance of a repetitive key-pressing task. Journal of Applied Psychology, 1956, 40, 137-141.

Andreas, B. G.; Green, R. F., & Spragg, S. D. S. Transfer effects between performance on a following tracking task (modified SAM two-hand coordination test) and a compensatory tracking task (modified SAM two-hand pursuit test). Journal of Psychology, 1954, 37, 173-183.

Andreas, B. G.; Green, R. F., & Spragg, S. D. S. Transfer effects in following tracking (modified SAM two-hand coordination test) as a function of reversal of the display-control relationships on alternate blocks of trials. Journal of Psychology, 1954, 37, 185-197.

Andreassi, John L. Effects of induced muscle tension and auditory stimulation on tachistoscopic perfection. Perceptual & Motor Skills, 1965, 20(3, Pt. 1), 829-841.

Andreassi, J. L.; Rapisardi, S. C., & Whalen, P. M. Autonomic responsivity and reaction time under fixed and variable signal schedules. Psychophysiology, 1969, 6, 58-59.

Angel, R. W., & Higgins, J. R. Correction of false moves in pursuit tracking. Journal of Experimental Psychology, 1969, 82, 185-187.

Angel, Ronald W., & Higgins, Joseph R. Correction of false moves in pursuit tracking. Journal of Experimental Psychology, 1969, 82(1, Pt. 1), 185-187.

Arakawa, Yasuhiro. Quantitative measurements of visual fields for colors with a direct-current method. American Journal Ophthal., 1953, 36, 1594-1601.

Arakawa, Yasuhiro, & Oikawa, Toshihiko. Chromaticity diagrams and retinal color processes. Tohoku Journal Exp. Med., 1952, 56, 291-297.

Ariel, G. The effect of knee-joint angle on Harvard Step-Test performance. Ergonomics, 1969, 12(1), 33-37.

- Armington, John C. Electrical responses of the light-adapted eye. Journal of the Optical Society of America, 1953, 43, 450-456.
- Arner, Robert S. Some visual problems of flight. American Journal of Optometry, 1957, 34, 233-240.
- Ashdown, A. J. The Ashdown rotoscope. Journal of Scientific Instruments, 1925, 3, 15-20.
- Askren, William B., & Regulinski, Thaddeus L. Mathematical modeling of human performance errors for reliability analysis of systems. USAF AMRL Technical Report, 1969, No. 68-93, 30.
- Atkinson, Chester J. Adaptation to delayed side-tone. Journal of Speech and Hearing Disorders, 1953, 18, 386-391.
- Atkinson, M. A simple quantitative method of testing vestibular function. Archives Otolaryngology, 1939, 30, 916-921.
- Audley, R. J., & Pike, A. R. Some alternative stochastic models of choice. British Journal of Mathematical & Statistical Psychology, 1965, 18, 207-225.
- Audley, R. J. A stochastic model for individual choice behavior. Psychology Review, 1960, 67, 1-15.
- Austin, T. R., & Sleight, R. B. Factors related to speed and accuracy of tactual discrimination. Journal of Experimental Psychology, 1952, 44, 283-287.
- Azerrad, Jacob, & Kennedy, Wallace A. Short-term recall of CVC trigrams. Psychological Reports, 1969, 24(3), 698.
- Baddeley, A. D.; de Figueredo, J. W.; Hawkswell Curtis, J. W., & Williams, A. N. Nitrogen narcosis and performance under water. Ergonomics, 1968, 11(2), 157-164.
- Bahrack, H. P.; Noble, M., & Fitts, P. M. Extra-task performance as a measure of learning a primary task. Journal of Experimental Psychology, 1954, 48, 298-302.
- Bahrack, H. P.; Fitts, P. M., & Briggs, G. E. Learning curves--facts or artifacts. Psychological Bulletin, 1957, 54, 256-268.
- Bahrack, Harry; Rankin, Robert E., & Fitts, Paul M. The effect of motivation upon peripheral perception during the performance of a central psychomotor task. USAF Human Resources Research Center, Research Bulletin 52-14, 1952, 7.
- Baird, J. C. Retinal and assumed size cues as determinants of size and distance perception. Journal of Experimental Psychology, 1963, 66(2), 155-162.

- Bakan, P. Effect of set and work speed on time estimation. Perceptual & Motor Skills, 1955, 5, 147-148.
- Baker, E. Jo, & Payne, M. Carr, Jr. Pattern recognition by audition and vision. Perceptual & Motor Skills, 1969, 29(1), 129-130.
- Baker, Lawrence M., & Csapo, Geza A. An improved device for recording changes in skin temperature. American Journal of Psychology, 1955, 68, 474-475.
- Baker, Lawrence M., & Taylor, William M. An apparatus for recording changes in skin temperature. American Journal of Psychology, 1953, 66, 124-125.
- Bald, L.; Berrien, F. K.; Price, J. B., & Sprague, R. O. Errors in perceiving the temporal order of auditory and visual stimuli. Journal of Applied Psychology, 1942, 26, 382-388.
- Baldwin, Alan W. Development of the optical imaging oscilloscope (optimascope). USN Research Laboratory Report, 1954, No. 4436, 1, 5.
- Ballou, Susan R., & Corah, Norman L. The phenomenal vertical and perception of change in spatial orientation. Perceptual & Motor Skills, 1965, 20(3, Pt. 2), 1200.
- Barlow, J. S. Evoked responses in relation to visual perception and oculomotor reaction times in man. Annals of the New York Academy of Science, 1964, 112, 432-467.
- Barnes, James D., & O'Connell, Daniel C. Perception of horizontality as a function of age and stimulus setting. Perceptual & Motor Skills, 1967, 25(1), 70-72.
- Barnette, W. L. Readings in psychological tests and measurements (rev. ed.). Homewood, Ill. Dorsey Press, 1968, 393.
- Baron, P. The objective method of measuring noise. Revue d'Acoustique, 1933, 2, 441-471.
- Barratt, Ernest S. An analysis of verbal reports of solving spatial problems as an aid in defining spatial factors. Journal of Psychology, 1953, 36, 17-25.
- Barrett, Gerald V.; Cabe, Patrick A., & Thornton, Carl L. Relation between hidden figures test and Rod and Frame Test measures of perceptual style. Educational & Psychological Measurement, 1968, 28(2), 551-554.
- Barrett, Gerald V., & Thornton, Carl L. Perceptual style and speed judgments. Perceptual & Motor Skills, 1969, 29(1), 75-77.
- Barry, H., & Bousfield, W. A. An apparatus for measuring knee-jerk. American Journal of Psychology, 1931, 43, 643-644.

Bartlett, N. R. The discrimination of two simultaneously presented brightnesses. Journal of Experimental Psychology, 1942, 31, 380.

Bartlett, N. R., & MacLeod, S. Effect of flash and field luminance upon human reaction time. Journal of the Optical Society of America, 1954, 44, 306-311.

Bartlett, N. R.; Sticht, T. G., & Pease, V. P. Effects of wavelength and retinal locus on the reaction time to onset and offset stimulation. Journal of Experimental Psychology, 1968, 78, 699-701.

Bartlett, N. R., & MacLeod, S. Effect of flash and field luminance upon human reaction time. Journal of the Optical Society of America, 1954, 44, 306-311.

Bartley, S. Howard. The perception of size or distance based on tactile and kinesthetic data. Journal of Psychology, 1953, 36, 401-408.

Bartley, S. Howard. Conditions intended to manipulate accommodation as factors in performance with a visual acuity target. Journal of Psychology, 1953, 36, 409-415.

Bartley, S. Howard, & Wilkinson, Frank R. Certain factors in producing complexity of response to a single pulse of light. Journal of Psychology, 1953, 35, 299-306.

Bartz, A. E. Eye-movement latency, duration, and response time as a function of angular displacement. Journal of Experimental Psychology, 1962, 64, 18-324.

Barty, Daniel L. Effects of display gain on human operator information processing rate in a rate control tracking task. IEEE Transactions on Man-Machine Systems, 1969, MMS-10(4, Pt. 1), 123-131.

Baumister, A. A.; Hawkins, W. F., & Kellas, G. The interactive effects of stimulus intensity and intelligence upon reaction time. American Journal of Mental Deficiency, 1965, 69, 526-530.

Baumister, A. A. & Joubert, C. E. Interactive effects on reaction time of preparatory interval length and preparatory interval frequency. Journal of Experimental Psychology, 1969, 82, 393-395.

Baumgardt, M. E. Area and threshold brightness in extra-foveal vision. C. R. Academy of Science, Paris, 1947, 225, 259.

Baumgarten, F., & Ehinger, G. Apparatus or paper tests of visual judgment? Psychotechn. Zsch., 1931, 6, 33-40.

Bachtoldt, Harold P., & Mager, R. F. Stimulus presentation devices for use in studies of discrimination abilities. USAF Human Resources Research Center Research Bulletin, 1953, No. 53-23, 35.

- Beck, Charles, & Rosner, Burton S. Magnitude scales and somatic evoked potentials to percutaneous electrical stimulation. Physiology & Behavior, 1968, 3(6), 947-953.
- Beck, Jacob, & Shaw, William A. Single estimates of pitch magnitude. Journal of the Acoustical Society of America, 1963, 35(11), 1722-1724.
- Beck, L. H. Conditioning and the coordination of movements. Journal of General Psychology, 1939, 20, 375-397.
- Becker, Paul W.; Mussina, Carolyn M., & Persons, Roy W. Intertrial interval, delay of knowledge of results, and motor performance. Perceptual & Motor Skills, 1963, 17(2), 559-563.
- Bee, Helen L. Cognitive style and performance under distraction: A partial replication. Perceptual & Motor Skills, 1968, 26(3, Pt. 1), 863-867.
- Behar, Isaac, & Warm, Joel S. Effects of electrocutaneous ready-signal variation on visual reaction time. Perception & Psychophysics, 1967, 2(11), 489-490.
- Bekesy, Georg V. A new audiometer. Acta Oto-Laryngologica, Stockholm, 1947, 35, 411-422.
- Belisle, James J. Accuracy, reliability and refractoriness in a coincidence-anticipation task. Research Quarterly of the American Association for Health, Physical Education, and Recreation, 1963, 34(3), 271-281.
- Bell, C. R., & Provins, K. A. Relations between physiological responses to environmental heat and time judgments. Journal of Experimental Psychology, 1963, 66(6), 572-579.
- Bellefleur, Philip A. A device for recording speech on audiograms. Journal of Speech & Hearing Disorders, 1968, 33(2), 117-120.
- Bensel, Carolyn K.; Dzendole, E., & Meiselman, H. L. Body sway during long-term standing and as affected by pure tones. Perception & Psychophysics, 1968, 4(3), 171-174.
- Berg, Esta A. A simple objective technique for measuring flexibility in thinking. Journal of General Psychology, 1948, 39, 15-22.
- Berger, Curt, & Mahneke, Axel. Fatigue in two simple visual tasks. American Journal of Psychology, 1954, 67, 509-512.
- Berger, Curt; Mahneke, Axel, & Mortensen, Otto. Electronic flicker apparatus with automatic frequency variation. Journal of the Optical Society of America, 1955, 45, 307-308.
- Bergum, Fruce O., & Lehr, Donald J. End spurt in vigilance. Journal of Experimental Psychology, 1963, 66(4), 383-385.

- Berliner, C.; Angell, D., & Shearer, J. W. Behaviors, measures, and instruments for performance evaluation in simulated environments. Paper presented at the Symposium and Workshop on the Quantification of Human Performance, Albuquerque, Aug., 1964, 17-19.
- Berman, A. An inexpensive, variable multiple-choice maze. American Journal of Psychology, 1939, 52, 113-114.
- Bertelson, P. The time course of preparation. Quarterly Journal of Experimental Psychology, 1967, 19, 272-279.
- Bertelson, P. Central intermittency twenty years later. Quarterly Journal of Experimental Psychology, 1966, 18, 153-163.
- Bertelson, P. Serial choice reaction-time as a function of response versus signal-and-response repetition. Nature, 1965, 206, 217-218.
- Bertrand, Gerard. Visual differential trichromatic colorimeter designed to measure near-white specimens. Revue d'Optique Theorique et Instrumentale, 1957, 36, 509-530.
- Bevan, W. & Avant, L. Serial reaction-time and the changing location of successive signals. Technical Report No. 52, Johns Hopkins University, Aug., 1967.
- Bevan, William, & Dukes, William F. Color as a variable in the judgment of size. American Journal of Psychology, 1953, 66, 283-288.
- Bezák, Jozef, & Dornic, Stanislav. Effect of a sensorimotor activity on the estimation of movement velocity. Studia Psychologica, 1968, 10(1), 73-74.
- Biase, D. V., & Zuckerman, M. Sex differences in stress responses to total and partial sensory deprivation. Psychosomatic Medicine, 1967, 29(4), 380-390.
- Bice, Raymond C. Apparent movement in vibrotactile displays. Perceptual & Motor Skills, 1969, 29(2), 575-578.
- Bickford, R. G. An automatic electrode combination selector switch. EEG Clinical Neurophysiology, 1949, 1, 109-110.
- Biederman, I., & Zachary, R. A. Stimulus versus response probability effects in choice reaction time. Perception & Psychophysics, 1970, 7, 189-192.
- Bieri, James. Category width as a measure of discrimination. Journal of Personality, 1969, 37(4), 513-521.
- Biersdorf, W. R.; Ohwaki, Sonoko, & Kozil, D. J. The effect of instructions and oculomotor adjustments on apparent size. American Journal of Psychology, 1963, 76(1), 1-17.

- Bilger, Robert C., & Melnick, William. Shifts in masking with time. Journal of the Acoustical Society of America, 1968, 44(4), 941-944.
- Bilodeau, Edward A. Performance decrement in a simple motor task before and after a single rest. Journal of Experimental Psychology, 1952, 43, 381-390.
- Bilodeau, Edward A. Decrements and recovery from decrements in a simple work task with variation in force requirements at different stages of practice. Journal of Experimental Psychology, 1952, 44, 96-100.
- Bilodeau, Edward A. Massing and spacing phenomena as a function of prolonged and extended practice. Journal of Experimental Psychology, 1952, 44, 108-113.
- Bilodeau, Edward A. Some effects of various degrees of supplemental information given at two levels of practice upon the acquisition of a complex motor skill. USAF, Human Resources Research Center, Research Bulletin, 1952, 52-15, vi, 18.
- Bilodeau, Edward A. The effects of force variations before rest on rate of responding after rest. USAF, Human Resources Research Center, Research Bulletin, 1953, No. 53-26, iv, 13.
- Bilodeau, E. A., & Rosenquist, H. S. A simple skills device for research on learning and memory. Perceptual & Motor Skills, 1963, 16(2), 521-524.
- Birke, Werner, & Kohne, Harald. A critique of Abel's KVT. Diagnostica: Zeitschrift fur Psychologische Diagnostik, 1967, 13(3), 130-133.
- Birmingham, Henry P. A device for use in studying the pattern of hand movements. USNRL Report, 1948, No. R-3298, vi, 7.
- Birmingham, Henry P. An electronic error integrator. USNRL Report, 1948, No. R-3297, v, 6.
- Birren, J. E.; Fisher, M. B.; Vollmer, E., & King, B. G. Effects of anoxia on performance at several simulated altitudes. Journal of Experimental Psychology, 1946, 36, 35-49.
- Bishop, George H. A simple electronic stimulator suitable for peripheral nerve and skin sensory testing. EEG Clinical Neurophysiology, 1935, 5, 105-106.
- Bisiach, E., & Frangini, G. The influence of conditioned reactions on verbal reaction time in a picture naming task. Cortex, 1970, 6, 97-101.
- Bjorkman, Mats. Individual performances in a single-cue probability learning task. Scandinavian Journal of Psychology, 1969, 10(2), 113-123.
- Black, John W. An application of side-tone in subjective tests of microphones and headsets. U. S. Naval Aviation Medical Research Report, 1954, Project No. NM 001 064.01.20, 5.

acker, K. H.; Jones, R. T.; Stone, G. C., & Pfefferbaum, Dolf. Chronic
 effects of LSD: The "acidheads." American Journal of Psychiatry, 1968, 125,
 1-351.

ackwell, H. R. Contrast thresholds of the human eye. Journal of the
 Optical Society of America, 1946, 36, 624-643.

ackwell, H. Richard; Pritchard, Benjamin S., & Ohmart, James G. Automatic
 apparatus for stimulus presentation and recording in visual threshold experi-
 ments. Journal of the Optical Society of America, 1954, 44, 322-326.

ick, Katharine I. Decision and decay processes in the short-term memory
 length. Journal of Experimental Psychology, 1969, 82(2), 224-230.

imenfeld, Walter. The precision of the "black thread method" and Weber's
 function. Acta Psychol., 1953, 9, 201-218.

th, K. W. Ipsilateral confusion in 2-choice and 4-choice responses with
 hands and feet. Nature, 1963, 199, 1312.

th, K. W. Errors in a further 4-choice reaction task with the hands and
 feet. Nature, 1964, 201, 641-642.

rdman, William K., & Gunter, R. C., Jr. A flexible four-field tachisto-
 scope. American Journal of Psychology, 1963, 76(3), 503-505.

rdijk, A. H. Instrument for the direct measurement of angles in the
 field of view of the naked eye. Rev. Sci. Instrum., 1955, 26, 382-383.

rsma, Frederic J. Test-retest reliability of the Cf-1 Hidden Figures
 test. Educational & Psychological Measurement, 1968, 28(2), 555-559.

rsma, Frederic J.; Muir, Walter; Wilton, Keri, & Barham, Richard. Eye
 movement during anagram tasks. Perceptual & Motor Skills, 1969, 29(2),
 374.

rs, David H., & Simon, J. Richard. Differential effect of noise on tasks
 of varying complexity. Journal of Applied Psychology, 1968, 52(2), 148-153.

nder, Ingvar. Objective indicators of perception. Scandinavian Journal
 of Psychology, 1962, 3(4), 192-195.

nt, Robert F., & Ellis, Douglas S. Voluntary rest pause behavior in a
 key-turning task as a function of wrist-cuff weight. Journal of Experimental
 Psychology, 1954, 47, 84-88.

nt, W. R. A motor-driven make-break stimulus selector. Science, 1932, 76,
 147.

orev, E. V.; Egorov, V. A., & Kuznetsov, V. The estimation of the degree
 of strain in motor activity under conditions of hypoxia and when breathing
 oxygen under pressure. Voprosy Psikhologii, 1968, 14(4), 151-156.

- Bongard, M. M. Visual colorimetry by the method of replacement. Biofizika, 1957, 2, 119-123.
- Bonnardel, R. Double pursuit test. Travail Hum., 1946, 9, 212-218.
- Booth, R. F., & Berkshire, J. R. Factor analysis of aviation training measures and post-training performance evaluations. USN AMI, 1968, No. 1050, 7.
- Boring, Randolph O. The effect of visual stimulus variables upon the perception of the visual vertical. U. S. Naval School of Aviation Medical Research Report, 1952, Project No. NM 001 063.01.28, (Joint Report No. 28), 6.
- Borozdina, L. V., & Gippenreiter, Y. B. The function of eye movements in the visual judgment of extent. Voprosy Psikhologii, 1969, 15(3), 46-55.
- Bosco, James; Travers, Robert M., & Wilkins, Thomas. Visual recognition under conditions of high and low discrimination redundancy. Perception & Psychophysics, 1968, 4(2), 69-70.
- Bose, S. K., & Kanji, N. L. Perception of form by passive touch. Indian Journal of Psychology, 1926, 1, 93-101.
- Botwinick, J., & Brinley, J. F. An analysis of set in relation to reaction time. Journal of Experimental Psychology, 1962, 63, 568-574.
- Botwinick, J., & Thompson, L. W. Premotor and motor components of reaction time. Journal of Experimental Psychology, 1966, 71, 9-15.
- Bourne, Lyle E., Jr.; Kepros, Peter G., & Bier, Ernst G. Effect of post-inspection delay upon kinesthetic figural aftereffects. Journal of General Psychology, 1963, 68(1), 37-42.
- Bowen, H. M. Driver performance and the effects of cold. Human Factors, 1968, 10, 445-463.
- Boyle, Daniel J., & Hagin, William V. The light plane as a pre-primary selection and training device: 1: Analysis of operational data. USAF Human Resources Research Center Technical Report, 1953, No. 53-33, vi, 61.
- Bradley, James V. Direction-of-knob-turn stereo-types. USAF WADC Technical Report, 1957, No. 57-388, iii, 11.
- Bradshaw, J. L. & Perriment, A. D. Laterality effects and choice reaction time in an unimanual two-finger task. Perception & Psychophysics, 1970, 7, 185-188.
- Bradshaw, J. L. Pupillary changes and reaction time with varied stimulus uncertainty. Psycho. Science, 1968, 13, 69-70.
- Bragg, Vernon C. Cumulative effects of repeated exposure to high-intensity tones upon recovery of auditory sensitivity. USN SAM Research Report, 1963, Project MR005.13-2005, Subtask 3, Report No. 1, 13.

- Bragg, W. An instrument for measuring small amplitudes of vibrations. Journal of Scientific Instruments, 1929, 6, 196-197.
- Brainard, R. W.; Irby, T. S.; Fitts, P. M., & Alluisi, E. A. Some variables influencing the rate of gain of information. Journal of Experimental Psychology, 1962, 63, 105-110.
- Brandt, John F., & Hollien, Harry. Underwater hearing thresholds in man. Journal of the Acoustical Society of America, 1967, 42(5), 966-971.
- Brandt, John F., & Hollien, Harry. Underwater speech reception thresholds and discrimination.
- Brebner, John. Continuing and reversing the direction of responding movements: Some exceptions to the so-called "psychological refractory period." Journal of Experimental Psychology, 1968, 78(1), 120-127.
- Breen, W. W.; De Haemer, M. J., & Poock, G. K. Comparison of the effect of auditory versus visual stimulation on information capacity of discrete motor responses. Journal of Experimental Psychology, 1969, 82(2), 395-397.
- Bregelmann, Johannes C. The building up of memory from degrees of generalizations. Z. Exp. Angewand. Psychol., 1953, 1, 65-101.
- Breternitz, W. The Tourtual illusion. Zsch. f. Sinnesphysiol., 1934, 65, 146-165.
- Brewer, W. Lyle. Fundamental response functions and binocular color matching. Journal of the Optical Society of America, 1954, 44, 207-212.
- Bricker, P. D.; Johnson, S. C., & Mattke, C. F. Apparatus for auditory stimulus sorting. Behavior Research Methods & Instrumentation, 1969, 1(4), 148-149.
- Briggs, G. E., & Blaha, J. Memory retrieval and central comparison times in information processing. Journal of Experimental Psychology, 1969, 79, 395-402.
- Brinton, George, & Rouleau, Robert A. Automating the hidden and embedded figures tests. Perceptual & Motor Skills, 1969, 29(2), 401-402.
- Broadbent, D. E. Immediate memory and simultaneous stimuli. Quarterly Journal of Experimental Psychology, 1957, 9, 1-11.
- Broadbent, D. E. Perception and Communication. New York: Pergamon Press, 1958.
- Broadbent, D. E. The twenty dials and twenty lights test under noise conditions. Medical Research Council, A. P. U. Report 160/51, Oct., 1951, 8.

- Broadbent, D. E. The twenty dials test under quiet conditions. Cambridge, Eng.: Medical Research Council, Applied Psychology Research Unit, 1950. 12 p. Mimeo.
- Broadbent, D. E., & Gregory, M. On the interaction of S-R compatibility with other variables affecting reaction time. British Journal of Psychology, 1965, 56, 61-67.
- Broddin, M. J. A test of auditory numerical memory. Ergologie, 1953, 1, 185-189.
- Brousek, J. Automatic flicker. Ceskoslovenska Psychoslogie, 1963, 7(4), 377-382.
- Brozek, J.; Simonson, Ernst, & Taylor, Henry L. Changes in flicker fusion frequency under stress. Journal of Applied Physiology, 1953, 5, 330-334.
- Brown, A. E. Measurement of auditory thresholds. Journal of the Acoustical Society of America, 1965, 38(1), 86-92.
- Brown, C. C., & Whitman, J. R. Apparatus for measuring restricted ranges of linear movement. American Journal of Psychology, 1963, 76(1), 138-139.
- Brown, C. W. A simple apparatus for measuring recovery from glare stimulation. Journal of General Psychology, 1941, 25, 421-428.
- Brown, G. G. Perception of depth with disoriented vision. British Journal of Psychology, 1928, 19, 117-146.
- Brown, Howard Steven. A comparative study of motor fitness tests. Research Quarterly of the American Association for Health, Physical Education, and Recreation, 1954, 25, 8-19.
- Brown, I. D. An asymmetrical transfer effect in research on knowledge of performance. Journal of Applied Psychology, 1966, 50, 118-120.
- Brown, I. D., & Poulton, E. C. Measuring the spare "mental capacity" of car drivers by a subsidiary task. Ergonomics, 1961, 4, 35-40.
- Brown, I. D.; Simmonds, D. C., & Tickner, A. H. Measurement of control skills, vigilance, and performance on a subsidiary task during 12 hours of car driving. Ergonomics, 1967, 10(6), 665-673.
- Brown, James W. An adaptable three-dimensional graph model. Science, 1947, 105, 439.
- Brown, John Lott. Effect of different preadapting luminances on the resolution of visual detail during dark adaptation. Journal of the Optical Society of America, 1953, 44, 48-55.
- Brown, Judson S.; Knauff, E. B., & Rosenbaum, G. The accuracy of positioning reactions as a function of their direction and extent. American Journal of Psychology, 1948, 61, 167-182.

rown, Kenneth T. Factors affecting differences in apparent size between opposite halves of a visual meridian. Journal of the Optical Society of America, 1953, 43, 464-472.

rown, R. L.; Galloway, W. D., & Geldersleeve, K. R. Effects of intense noise on processing of cutaneous information of varying complexity. Perceptual & Motor Skills, 1965, 20, 749-754.

rozek, J., & Keys, A. Flicker-fusion frequency as a test of fatigue. Journal of Industrial Hygiene, 1944, 26, 169-174.

rozek, Josef; Simonson, Ernst, & Taylor, Henry O. Changes in flicker fusion frequency under stress. USAF School of Aviation Medical Research Report, 1953, Project No. 21-32-004, Report No. 3, II, 5.

rozek, Josef; Simonson, Ernst, & Keys, Ancel. A work test for quantitative study of visual performance and fatigue. Journal of Applied Psychology, 1947, 32, 519-532.

rozek, Josef, & Taylor, Henry O. Tests of motor functions in laboratory investigations on fitness. Project No. 21-32-004, Report No. 4, Contract AF (038)-2194, USAF SAM, Randolph Field, Tex. Laboratory of Physiological Hygiene, University of Minnesota, Minneapolis, May, 1954. AD 54 726.

ruce, Darryl, & Cofer, Charles N. A comparison of recognition and recall in short-term memory. Proceedings of the 73rd Annual Convention of the American Psychological Association, 1965, 81-82.

unt, M., & Goetzinger, C. P. A study of three tests of central function with normal hearing subjects. Cortex, 1968, 4, 288-297.

chanan, William, & Weiss, Robert F. A simple timing shutter for stimulus-presentation devices. Behavior Research Methods & Instrumentation, 1970, 2(1), 28.

ckhout, Robert. A bibliography on aircrew proficiency measurement. USAF Technical Document Report, 1962, No. 62-49, iv, 25.

el, J. A stylus punch board maze with automatic differential and cumulative response indicators. Journal of Genetic Psychology, 1939, 55, 221-228.

las, R. A new method of measuring fatigue. Lijecn. Vjesn., 1935, 7, 1-4.

rch, Neil R.; Childers, Harold E., & Edwards, Robert J. Automatic GSR analyzer. USAF SAM Technical Document Report No. 63-74, 31.

rdick, J. A. The color pyramid test: a critical evaluation. Journal of Psychology, 1968, 70, 93-97.

rgess, Michael, & Hokanson, Jack E. Effects of increased heart rate on intellectual performance. Journal of Abnormal & Social Psychology, 1964, 68(1), 85-91.

- Burgess, Michael M., & Hokanson, Jack E. Effects of autonomic arousal level, sex, and frustration on performance. Perceptual & Motor Skills, 1968, 26(3, Pt. 1), 919-930.
- Burnham, Robert W. A colorimeter for research in color perception. American Journal of Psychology, 1952, 65, 603-608.
- Burnham, Robert W., & Clark, Joyce R. A test of hue memory. Journal of Applied Psychology, 1955, 39, 164-172.
- Burnham, Robert W., & Newhall, Sidney M. Color perception in small test fields. Journal of the Optical Society of America, 1953, 43, 899-902.
- Buros, O. K. (Ed.). The Nineteen Forty Mental Measurements Yearbook, Highland Park, N. J.: Gryphon Press, 1941.
- Buros, O. K. (Ed.). The Third Mental Measurement Yearbook, Highland Park, N. J.: Gryphon Press, 1949.
- Buros, O. K. (Ed.). The Sixth Mental Measurement Yearbook, Highland Park, N. J.: Gryphon Press, 1965.
- Burrows, David, & Murdock, Bennet B., Jr. Effects of extended practice on high-speed scanning. Journal of Experimental Psychology, 1969, 82(2), 231-237.
- Burt, H. E. Inexpensive apparatus for continuous choice reaction. Journal of General Psychology, 1931, 5, 286-288.
- Butov, V. I., & Chartorizhskii, D. N. Electronic tachistoscope for the presentation of numbers. Voprosy Psikhologii, 1964, 3, 155-157.
- Byer, Vincent W. Two methods of measuring recovery following short-duration fatigue. Journal of the Acoustical Society of America, 1963, 35(5), 662-667.
- Byers, Joe L.; Collins, Carter C., & Toughborough, Baldrige. An apparatus for concept attainment research. Psychological Reports, 1964, 14(3), 759-773.
- Cabe, Patrick A. Note on response sets on the Rod-and-Frame Test. Perceptual & Motor Skills, 1968, 26(1), 94.
- Cabe, Patrick A. The relation between the Rod-and-Frame Test and Witkin's Embedded Figures Test. Educational & Psychological Measurement, 1968, 28(4), 1243-1245.
- Calabresi, R. Observations on the tactile-kinetic evaluation of angles. Atti del 21° Congresso Internazionale di Psicologia, 1964, XXI Riunione Suntuale della Commissione Internazionale di Psicologia, 124-125.
- Caldwell, L. S., & Herbert, H. J. The judgment of angular positions in the horizontal plane on the basis of kinesthetic cues. U. S. Army Medical Research Report, 1956, No. 216, ii, 18.

- Campbell, N. R., & Gardiner, H. W. B. Photo-electric colour-matching. Journal of Scientific Instruments, 1925, 2, 177-187.
- Cappon, Daniel; Banks, Robin, & Ramsey, Craig. Improvement of recognition on a multi-modal pattern discrimination test. Perceptual & Motor Skills, 1968, 26(2), 431-441.
- Carlson, Jean B. Effect of amount and distribution of inspection time and length of decay interval on kinesthetic aftereffect. Journal of Experimental Psychology, 1963, 66(4), 377-382.
- Carlson, V. R. The generality of negative aftereffect following adaptation to curvature. Scandinavian Journal of Psychology, 1963, 4(3), 129-133.
- Carlson, V. R., & Feinberg, I. Individual variations in time judgment and the concept of an internal clock. Journal of Experimental Psychology, 1968, 77(4), 631-640.
- Carmon, Amiram. Stimulus contrast in tactile resolution. Perception & Psychophysics, 1968, 3(4-A), 241-245.
- Carnes, Edwin H. Kinesthesia in flying. Contact, Pensacola, 1947, 6, 201-207.
- Carpenter, A., & Conrad R. An apparatus providing signals at "random" intervals. Quarterly Journal of Experimental Psychology, 1953, 5, 87-88.
- Carver, R. P., & Winsmann, F. R. Analysis of the army physical proficiency test in terms of the Fleishman Basic Fitness Tests. Perceptual & Motor Skills, 1968, 26(1), 203-208.
- Carver, R. P., & Winsmann, F. R. Effect of high elevation upon physical proficiency, cognitive functioning, and subjective symptomatology. Perceptual & Motor Skills, 1968, 26(1), 223-230.
- Catalano, John F., & Berger, David F. The effect of need for achievement and normative information on rotary pursuit performance. Psychonomic Science, 1970, 18(2), 69-71.
- Causse, R., & Chavasse, P. Researches on "auditory fatigue." Bulletin Biol., 1943, 137, 654-656.
- Cavonius, C. R., & Hilz, R. Visual performance after preadaptation to colored lights. Journal of Experimental Psychology, 1970, 83(3, Pt. 1), 359-365.
- Cermak, Laird, S. Repetition and encoding in short-term memory. Journal of Experimental Psychology, 1969, 82(2), 321-326.
- Chalmers, E. Laurence, Jr. The role of brightness in primary size-distance perception. American Journal of Psychology, 1953, 66, 584-592.

- Chalupa, B., & Cizkova, J. Psychologicke studium cinnosti operatora pri vyhledavacich ukolech. (Psychological study of operators' activity in search tasks.) Ceskoslovenska Psychologie, 1967, 11, 598-601.
- Channell, R. C. Fatigue and hours of service of interstate truck drivers. III. Driving and glare tests. Public Health Bulletin, Washington, D. C., 1941, No. 265, 179-194.
- Chant, S. N. F. Psychology as applied in the Royal Canadian Air Force. Bulletin of the Canadian Psychological Association, 1943, 3, 34-37.
- Chapanis, Alphonse. Studies of manual rotary positioning movements: I. The precision of setting an indicator knob to various angular positions. Journal of Psychology, 1951, 31, 51-64.
- Chapanis, Alphonse. Studies of manual rotary positioning movements: II. The accuracy of estimating the position of an indicator knob. Journal of Psychology, 1951, 31, 65-71.
- Chapanis, Alphonse, & Halsey, Rita M. Luminance of equally bright colors. Journal of the Optical Society of America, 1955, 45, 1-6.
- Chapanis, A., & Mankin, D. A. Tests of ten control-display linkages. Human Factors, 1967, 9, 119-126.
- Charlip, Walter S., & Burk, Kenneth W. Effects of noise on selected speech parameters. Journal of Communication Disorders, 1969, 2(3), 212-219.
- Chatterjea, Ram G. Time gap in the estimation of long duration. Perceptual & Motor Skills, 1963, 17(1), 143-149.
- Cheesman, G. H., & Mayne, Stella. The influence of adaptation on absolute threshold measurements for olfactory stimuli. Quarterly Journal of Experimental Psychology, 1953, 5, 22-30.
- Cheng, Mei-Fang. Tactile-kinesthetic perception of length. American Journal of Psychology, 1968, 81(1), 74-82.
- Chernikoff, R., & Brogden, W. J. The effect of response termination of the stimulus upon reaction time. Journal of Comparative and Physiological Psychology, 1949, 42, 357-364.
- Chernikoff, R.; Gregg, L. W., & Brogden, W. J. The effect of fixed duration stimulus magnitude upon reaction time to a response terminated stimulus. Journal of Comparative and Physiological Psychology, 1950, 43, 123-128.
- Chernikoff, R., and Taylor, F.V. Reaction time to kinesthetic stimulation resulting from sudden arm displacement. Journal of Experimental Psychology, 1952, 43, 1-8.
- Cherry, Eugene S. Effects of rehearsal and methods of retrieval on performance in a visual short-term memory task. Journal of Experimental Psychology, 1970, 83(1, Pt. 1), 141-146.

- Chiles, W. D. Methodology in the assessment of complex performance: Introduction. Human Factors, 1967, 9, 325-327.
- Chiles, W. D. Methodology in the assessment of complex performance: Discussion and conclusions. Human Factors, 1967, 9, 385-392.
- Chiles, W. D. Assessment of the performance effects of the stresses of space flight. AMRL-TR-66-192, AMRL, WPAFB, Ohio, December, 1966. AD 649 881.
- Chiles, W. Dean; Fox, Richard E.; Rush, Joseph H., & Stilson, Donald W. Effects of ionized air on decision making and vigilance performance. USAF MRL Technical Document Report, 1962, No. 62-51, iii, 10.
- Ching Chi-Cheng; Peng Jui-Hseung, & Fang Yun-Chiu. The effect of distance and posture of observer on the perception of size. Acta Psychologica Sinica, 1963, 22(1), 20-30.
- Ching Chi-Cheng; Peng Jui-Hseung; Fang Yun-Chiu, & Lin Chung-Hsien. Size judgments of an object in elevation and in descent. Acta Psychologica Sinica, 1963, 24(3), 175-185.
- Chorayan, O. G. The psychological mechanism of short-term memory. Voprosy Psikhologii, 1968, 14(1), 27-30.
- Chou, S. K. A multiple groove board for testing motor skill. Journal of Experimental Psychology, 1929, 12, 249-253.
- Chou, S. K. A universal finger maze: the pattern box; maze pattern and maze construction. Journal of General Psychology, 1929, 2, 527-532.
- Christ, R. E. Some effects of stimulus-exposure time on choice-reaction time. American Journal of Psychology, 1970, 83, 264-271.
- Christensen, J. M., & Mills, R. E. What does the operator do in complex systems. Human Factors, 1967, 9, 329-340.
- Christie, L. S., & Luce, R. D. Decision structure and time relations in simple choice behavior. Bulletin of Mathematical Biophysics, 1956, 18, 89-111.
- Christman, R. J. Figural aftereffects utilizing apparent movement as inspection-figure. American Journal of Psychology, 1953, 66, 66-72.
- Cibis, Paul A.; Gerathewohl, Siegfried J., & Rubinstein, David. Depth perception in monocular and binocular vision. USAF School of Aviation Medicine, Special Report, 1953, 12.
- Cimbalo, Richard S., & Mahoney, Margaret S. Short-term memory: Effects of type of trigram and isolated and position of isolation. Psychonomic Science, 1970, 18(2), 77-78.

- Clark, B., & Stewart, J. D. Magnitude estimates of rotational velocity during and following prolonged, increasing, constant, and zero angular acceleration. Journal of Experimental Psychology, 1968, 78, 329-339.
- Clark, Brant, & Graybiel, Ashton. A device to manipulate and to indicate the position of remote test objects in studies of visual space perception. U.S. Naval School of Aviation Medicine, 1951, Project No. NM 001 059.01.26, 2.
- Clark, L. D., & Nakashima, E. N. Experimental studies of marihuana. American Journal of Psychiatry, 1968, 125, 379-384.
- Clark, J. R.; Fontaine, A. B., & Warren, C. E. The generation of a continuous random signal for use in human tracking studies. USAF Human Resources Research Center Research Bulletin, 1953, No. 53-40, iv, 23.
- Clegg, W. C., & Dunfield, N. M. Non-visual perception of the postural vertical: I. Sagittal plane. Canadian Journal of Psychology, 1954, 8, 1-8.
- Cleghorn, T. E., & Darcus, H. D. The sensibility to passive movement of the human elbow joint. Quarterly Journal of Experimental Psychology, 1952, 4, 66-77.
- Coburn, K. R. The effects of stress produced by confinement in small groups. In Part II of: A report of the physiological, psychological, and bacteriological aspects of 20 days in full pressure suits, 20 days at 27,000 feet on 100 per cent O₂, and 34 days of confinement. NASA CR-708, U.S. Naval Air Engineering Center, Philadelphia, Pa., Feb., 1967.
- Coe, L. A. Some notes on the reactions of aircraft pilots to zero gravity. Journal of the British Interplanetary Society, 1954, 13, 244.
- Cohen, Gillian. Pattern recognition: Differences between matching patterns to patterns and matching descriptions to patterns. Journal of Experimental Psychology, 1969, 82(3), 427-434.
- Collins, William E., & Capps, Mary Jayne. Effects of several mental tasks on auditory fatigue. Journal of the Acoustical Society of America, 1965, 37(5), 793-796.
- Colquhoun, W. P., & Corcoran, D. W. J. The effects of time of day and social isolation on the relationship between temperament and performance. British Journal of Social & Clinical Psychology, 1964, 3(3), 226-231.
- Coltheart, Max, & Curthoys, Ian. Short-term recognition memory for pitch: Effect of a priori probability on response times and error rates. Perception & Psychophysics, 1968, 4(2), 85-89.
- Conen, M., & Tonnies, J. Measurement of muscle tone under forced movement. Journal of Psychol. Neurol., Lpz., 1936, 47, 40-48.
- Conklin, J. E.; Baldwin, A., & Brown, R. H. Apparatus for measuring the threshold for visual discrimination of direction of movement. American Journal of Psychology, 1953, 66, 289-294.

- Connor, W. H., & Lang, P. J. Cortical slow-wave and cardiac rate responses in stimulus orientation and reaction time conditions. Journal of Experimental Psychology, 1969, 82, 310-320.
- Conover, Donald W., & Kraft, Conrad L. The use of color in coding displays. USAF WADC Technical Report, 1958, No. 55-471, v, 16.
- Conrad, R. Practice, familiarity, and reading rate and nonsense syllables. Quarterly Journal of Experimental Psychology, 1962, 14, 71-76.
- Conrad, R. Some effects on performance of changes in perceptual load. Journal of Experimental Psychology, 1955, 49, 313-322.
- Conrad, R. Speed and load stress in a sensori-motor skill. British Journal of Industrial Medicine, 1951, 8, 1-7.
- Conticelli, M., & Fujiwara, S. Visuo-motor reaction time under differential binocular adaptation. Atti della Fondazione Giorgio Ronchi, 1964, 19, 177-188.
- Conticelli, Mario, & Gloria, Ercole M. - Temporal numerosity in various environmental conditions. Studi e Ricerche di Psicologia, 1967, 10, 9.
- Conticelli, Mario, & Gloria, Ercole M. Visual performance in the empty field and in partially structured fields: III. Task involving vernier acuity. Studi e Ricerche di Psicologia, 1967, 10, 10.
- Corballis, M. C.; Lieberman, W., & Bindra, D. Discriminability and central intermittency in same-different judgments. Quarterly Journal of Experimental Psychology, 1968, 20, 51-61.
- Corballis, Michael C.; Lieberman, William, & Bindra, Dalbir. Discriminability and central intermittency in same-different judgments. Quarterly Journal of Experimental Psychology, 1968, 20(1), 51-61.
- Corballis, M. C., & Sampson, H. Scanning and immediate memory in serial adding. Australian Journal of Psychology, 1963, 15(2), 99-107.
- Corbin, H. H. The perception of grouping and apparent movement in visual depth. Arch. Psychol., New York, 1942, No. 273.
- Corlett, E. N.; Salvendy, G., & Seymour, W. D. Selecting operators for fine manual tasks: A study of the O'Connor Finder Dexterity test and the Purdue Pegboard. Occupational Psychology, 1971, 45, 56-65.
- Corso, John F. Evaluation of operating conditions on a Beksy-type audiometer. Arch. Otolaryng., Chicago, 1955, 61, 649-653.
- Corson, J. H., & Crannell, C. W. Simple reaction time to cutaneous temperature stimuli. Canadian Journal of Psychology, 1970, 24, 305-310.

- Costa, L. D.; Vaughan, H. G. Jr., & Gilden, L. Comparison of electromyographic and microswitch measures of auditory reaction time. Perceptual & Motor Skills, 1965, 20, 771-772.
- Costello, C. G. The effects of anxiety on the relation between reaction time and stimulus light intensity. British Journal of Psychology, 1968, 59, 437-442.
- Costello, C. G., & Stephen, James. The tape-recorder as an instrument for measuring time. American Journal of Psychology, 1963, 76(2), 324-325.
- Cowan, T. M., & Monroe, B. D. Choice reactions with a null stimulus event. Perception & Psychophysics, 1970, 7, 267-270.
- Cowen, Emory L.; Wiener, Morton, & Hess, Judith. Generalization of problem-solving rigidity. Journal Consult. Psychol., 1953, 17, 100-103.
- Craft, J. L., & Simon, J. R. Processing symbolic information from a visual display: Interference from an irrelevant directional cue. Journal of Experimental Psychology, 1970, 83, 415-420.
- Craig, James C., & Sherrick, Carl E. The role of skin coupling in the determination of vibrotactile spatial summation. Perception & Psychophysics, 1969, 6(2), 97-101.
- Craik, Fergus I. Modality effects in short-term storage. Journal of Verbal Learning & Verbal Behavior, 1969, 8(5), 658-664.
- Craik, K. H., & Sarbin, T. R. Effect of covert alterations of clock rate upon time estimations and personal tempo. Perceptual & Motor Skills, 1963, 16(2), 597-610.
- Craik, K. J. W. Specifications for Clark-adaptation tests. British Medical Journal, 1943, 1, 632.
- Crandell, John M.; Hammill, Donald D.; Witkowski, Fasimar, & Barkovich, Fred. Measuring form-discrimination in blind individuals. International Journal for the Education of the Blind, 1968, 18(3), 65-68.
- Crawford, J. E. A test for tridimensional structural-visualization. Journal of Applied Psychology, 1940, 24, 482-494.
- Creelman, C. Douglas, & Donaldson, Wayne. ROC curves for discrimination of linear extent. Journal of Experimental Psychology, 1968, 77(3, Pt. 1), 514-516.
- Crider, B. A battery of tests for the dominant eye. Journal of General Psychology, 1944, 31, 179-190.
- Crites, C. D., & Ammons, R. B. A simple stylus-target linear pursuit device. Motor Skills Research Exchange, 1950, 2, 6-8.

romwell, R. L., & Held, J. M. Alpha blocking latency and reaction time in schizophrenics and normals. Perceptual & Motor Skills, 1969, 29, 195-201.

ronbach, L. J. Essentials of Psychological Testing (2nd Ed.). New York: Harper & Row, 1960.

ronbach, L. J., & Gleser, G. C. Psychological Tests and Personal Decisions. University of Illinois Press, Urbana, 1957.

ronholm, Borje, & Schalling, D. Cognitive test performances in cerebrally alsied adults without mental retardation. Acta Psychiatrica Scandinavica, 1968, 44, 37-50.

rook, M. N.; Harker, G. S.; Hoffman, A. C., & Kennedy, J. L. Effect of mplitude of apparent vibration, brightness, and type size on numeral reading. Dayton, Ohio: U.S. Air Force, Air Materiel Command, Wright-Patterson Air Force ase, 1950. AF Technical Report No. 6246, 54.

rowder, Robert G. Short-term memory for words with a perceptual-motor nterpolated activity. Journal of Verbal Learning and Verbal Behavior, 1967, (5), 753-761.

rozier, W. J., & Holway, A. H. Theory and measurement of visual mechanisms. A visual discriminometer. Journal of General Physiology, 1939, 22, 351.

rumley, Lloyd M., & Atkinson, William. Human engineering investigation of e exterior lighting of naval aircraft. Part I--A study of the effect of lash rate and on/off ratio on the detectability of flashing lights. U.S. Naval Air Exp. Sta. Aeronaut. Med. Equip. Lab. Report, 1954, No. TED NAM EL 2003, Part I, 16.

rtis, Dwight W. Magnitude estimations and category judgments of brightness id brightness intervals: A two-stage interpretation. Journal of Experimental ychology, 1970, 83(2, Pt. 1), 201-208.

shle, Arthur J.; Hume, W. Garrett, & Haspiel, George S. Comparison of speech késey tracings with selected clinical auditory measures. Journal of Auditory earch, 1968, 8(2), 125-128.

shmen, O. The augmenting effect of recresal on visual apprehension. Indus. ychotechnn., 1930, 7, 271-278.

lrymple, Alford E. Repetition and immediate memory. British Journal of ychology, 1967, 58(1-2), 63-67.

mmers, B. G.; van der Knapp, P. D., & Uitjens, A. G. W. The electrical cording of diagrams with a calibrated system of coordinates. Philips chnical Review, 1951, 12, 283-292.

nziger, K., & Du Preez, P. D. Reliability of time estimation by the method reproduction. Perceptual & Motor Skills, 1963, 16(3), 879-884.

- Danziger, K., & Hart, Jennifer R. Two kinds of variability in a flicker-fusion discrimination task. Journal of General Psychology, 1965, 73(1), 37-42.
- Dardenne, Robert. Le 'O'Connor Finger Dexterity Test.' Ergologie, 1952, 1, 103-108.
- Darrow, C. W. Continuous quantitative records in standard units by the Wheatstone bridge method. Journal of General Psychology, 1930, 4, 418-420.
- Darrow, C. W. An efficient photo-recording galvanometer. Journal of General Psychology, 1934, 11, 452-453.
- Davenport, W. G. Vibrotactile vigilance: The effects of costs and values on signals. Perception & Psychophysics, 1964, 5, 25-28.
- Daves, W. F.; Keinbofer, Maria, & Holland, C. L. Visual autokinesis as a function of the amount of "possible" movement. Psychonomic Science, 1969, 17(4), 219-220.
- Davies, D. R.; Hockey, G. R., & Taylor, Ann. Varied auditory stimulation, temperament differences, and vigilance performance. British Journal of Psychology, 1969, 60(4), 453-457.
- Davis, Hallowell, & Niemoeller, Arthur F. A system for clinical evoked response audiometry. Journal of Speech & Hearing Disorders, 1968, 33(1), 33-37.
- Davis, R. C., & Geldard, F. A. An oscillator and synchronous motor for obtaining exact variable speeds. Science, 1931, 73, 369-370.
- Davis, R.; Moray, N., & Treisman, A. Imitative responses and the rate of gain of information. Quarterly Journal of Experimental Psychology, 1961, 13, 78-89.
- Day, R. H. The effect on a difficult co-ordination task of the frequency of signals. Quarterly Journal of Experimental Psychology, 1953, 5, 159-165.
- Day, R. H., & Wade, N. J. Involvement of neck proprioceptive system in visual aftereffect from prolonged head tilt. Quarterly Journal of Experimental Psychology, 1968, 20, 290-293.
- Dearnaley, E. J. Estimates of endurance under risky conditions. Journal of General Psychology, 1963, 68(2), 243-250.
- Debecker, J., & Desmedt, John E. Maximum capacity for sequential one-bit auditory decisions. Journal of Experimental Psychology, 1970, 83(3, Pt. 1), 366-372.
- de Bonis, M. The Stroop test in the study of some mechanisms of motivation and of stress. (Le test de Stroop son utilisation dans l'étude de quelques processus motivationnels et du stress.) Revue de Psychologie Appliquée, 1968, 18, 93-107.

- DeFazio, V. J., & Moroney, W. F. Performance characteristics of field dependent and independent individuals on an auditory signal detection task. Journal of Psychology, 1969, 71, 77-82.
- de Groot, Sybil G.; Dodge, Jane M., & Smith, Jo Ann. Factors in night vision sensitivity: The effect of brightness. U. S. N. Submarine Medical Research Laboratory, 1952, 11(11), Report No. 194, 17.
- De Klerk, L. F. W., & Oppe, S. Subjective probability and choice reaction time. Acta Psychologica, 1970, 33, 243-251.
- De Klerk, L. F. W., & Oppe, S. Notes on the influence of individual response strategies on choice-reaction time. Report No. E 025-70, Psychological Institute, University of Leyden, The Netherlands, 1970.
- Della Casa, F., & Birkhauser, R. On the official introduction of the dark-adaptation test in traffic. Ophthalmologica, 1946, 111, 315-320.
- Dempsey, Thomas K., & Morgan, Ben B., Jr. Effects of time-sharing stress on skilled performance of a digital-readout COTRAN task. Proceedings of the 77th Annual Convention of the American Psychological Association, 1969, 4(Pt. 2), 755-756.
- Denison, D. M.; Ledwith, F., & Poulton, E. C. Complex reaction times at simulated cabin altitudes of 5,000 feet and 8,000 feet. Aerospace Medicine, 1966, 37, 1010-1013.
- Denner, Bruce; Wapner, Seymour; McFarland, Joseph H., & Werner, Heinz. Rhythmic activity and the perception of time. American Journal of Psychology, 1963, 76(2), 287-292.
- De Rosa, Donald V. Transformations on sets in short-term memory: Set size reduction by deletion. Journal of Experimental Psychology, 1969, 82(3), 415-426.
- De Sisto, Michael J., & McLaughlin, Samuel C. Changes in judgment of direction of gage after autokinetic perception. Psychonomic Science, 1968, 10(6), 221-222.
- Deupree, R. H., & Simon, J. R. Reaction time and movement time as a function of age, stimulus duration, and task difficulty. Ergonomics, 1963, 6, 403-411.
- De Wolfe, Ruthanne K. S., & Duncan, Carl P. Time estimation as a function of level of behavior of successive tasks. Journal of Experimental Psychology, Aug., 1959, 58, 153-158.
- Dick, A. O. Relations between the sensory register and short-term storage in tachistoscopic recognition. Journal of Experimental Psychology, 1969, 82(2), 279-284.
- Dickinson, J. The role of two factors in a gross motor aiming task. British Journal of Psychology, 1969, 60(4), 465-470.

- Dietz, C. A study of a test for eye-sight. Rev. de la Sci. du Trav., 1929, 1, 524-538.
- Dillon, D. J. Stimulus intensity, site of stimulation, and individual re-activity as determinants of the energy threshold for pricking pain. Journal of Experimental Psychology, 1968, 4, 559-566.
- Dimmick, Forrest L., & Rudolph, Leon M. Checkerboard visual acuity targets: An experimental validation. New London, Conn.: Naval Medical Research Laboratory, Report No. 1, Project NM-002-008 (X-423), 1948, 14 p.
- Dimond, S. J. Facilitation of performance through the use of the timing system. Journal of Experimental Psychology, 1966, 71, 181-183.
- Dimond, S. Reaction times and response competition between the right and left hands. Quarterly Journal of Experimental Psychology, 1970, 22, 513-520.
- Dimond, S. J. Hemispheric refractoriness and control of reaction time. Quarterly Journal of Experimental Psychology, 1970, 22, 610-617.
- Dixon, James Cannon. Effect of exposure-time on perception of grouped digits. American Journal of Psychology, 1948, 61, 396-399.
- Dixon, N. F. Apparatus for continuous recording of the visual threshold by the method of "closed loop control." Quarterly Journal of Experimental Psychology, 1958, 10, 62-63.
- Di Vesta, Francis J., & Walls, Richard T. Multiple- versus single-problem training and variation of solution rules in the formation of learning sets. Journal of Educational Psychology, 1968, 59(3), 191-196.
- Dockeray, F. C., & Taylor, J. H. A pressure-recording stylus. Journal of General Psychology, 1934, 11, 215.
- Doerries, Lee E., & Harcum, E. Rae. Long-term traces of tachistoscopic word perception. Perceptual & Motor Skills, 1967, 25(1), 25-35.
- D'Oliveira Esteves, J. V. Place of pilot in formation flights. Rev. Med. Lat.-Amer., 1939, 24, 1232-1235.
- D'Oliveira Esteves, J. V. Psychochronometry in examining and checking aptitude of aviation pilots. Rev. Med. Lat.-Amer., 1940, 25, 530-544.
- Dominowski, Roger L. Anagram solving as a function of bigram rank and word frequency. Journal of Experimental Psychology, 1967, 75(3), 299-306.
- Donaldson, Wayne, & Glathe, Herta. Recognition memory for item and order formation. Journal of Experimental Psychology, 1969, 82(3), 557-560.
- Donovan, Robert J., & Ross, John. The dimensionality of judgments of heaviness. Perception & Psychophysics, 1969, 6(4), 247-249.

- Dornic, Stanislaw, & Halmiova, Olga. Recognition of visual and auditory stimuli in short-term memory. Studia Psychologica, 1968, 10(1), 42-45.
- Doorne, H. V., & Sanders, A. F. PSARP, a programmable signal and response processor. Behavior Research Methods & Instrumentation, 1968, 1, 29-32.
- Dougherty, J. E. Effects of increased flying time on aviation instructors. War Med., Chicago, 1943, 3, 297-302.
- Drake, C. A. Spot the best by test. Fact. Mgmt. Mainten., 1937, 95, 60-62.
- Dratz, M. Apparatus for the study of night vision. Travail Hum., 1946, 9, 207-208.
- Drury, M. B. Progressive changes in non-foveal perception of line patterns. American Journal of Psychology, 1933, 45, 628-646.
- Duane, T. D., Emrich, R. J., & Shepler, H. G. Lens system designed for water-to-air vision in the submerged human eye. AMA Arch. Ophthalmol., 1959, 61, 561-567.
- Dunham, Paul, Jr. Effects of serial versus sequence practice on performance level. Perceptual & Motor Skills, 1969, 29(2), 554.
- Dvorak, Beatrice J. The new USES General Aptitude Test Battery. Journal of Applied Psychology, 1947, 31, 372-376.
- Dvorak, J.; Filsakova, B., & Hanousek, J. Pursuit test with sinusoidal and random signals. Activitas Nervosa Superior, 1968, 10(2), 160-164.
- Dzidzichvili, H. H. On the intensity of the excitation of one eye upon the sensitivity of the other. Prob. Fiziol. Opt., 1941, 1, 43-46.
- Eagles, J. B. (Army Oper. Res., W. Byfleet, Surrey, Eng.); Halliday, A. M., & Redfearn, J. W. T. The effects of fatigue on tremor. In Floyd & Welford, Symposium on Fatigue, (see 28:5511), 41-58.
- Earhart, R. H., & Dallenbach, K. M. The response of warm spots under successive stimulation. American Journal of Psychology, 1933, 45, 722-729.
- Eason, R. G., & Branks, J. Effect of level of activation on the quality and efficiency of performance of verbal and motor tasks. Perceptual & Motor Skills, 1963, 16(2), 525-543.
- Eason, R. G.; Harter, M. R., & White, C. T. Effects of attention and arousal on visually evoked cortical potentials and reaction time in man. Physiology and Behavior, 1969, 4, 283-289.
- Eason, R. G.; Hoke, J., & White, C. T. Apparatus for measuring neuromuscular control during rotary tracking. Perceptual & Motor Skills, 1963, 17(3), 823-830.

- Eason, R. G.; Oden, D., & White, C. T. Visually evoked cortical potentials and reaction time in relation to site of retinal stimulation. Electroencephalography and Clinical Neurophysiology, 1967, 22, 313-324.
- Eason, R. G., & White, C. T. Muscular tension, effort, and tracking difficulty: Studies of parameters which affect tension level and performance during rotary pursuit. Perceptual & Motor Skills, 1961, 12, 331-372.
- Ebenholtz, Sheldon M. Perception of the vertical with body tilt in the median plane. Journal of Experimental Psychology, 1970, 83(1, Pt. 1), 1-6.
- Edgington, Eugene S. Kinesthetically guided movements of head and arm. Journal of Psychology, 1953, 36, 51-57.
- Edmonds, Ed M., & Mueller, Marvin R. Concept formation and utilization in the presence of irrelevant visual stimulation. Psychonomic Science, 1970, 18(2), 109-110.
- Edwards, A. S. The relation of light intensity to accuracy of depth perception. Journal of Applied Psychology, 1953, 37, 300-301.
- Edwards, E. The integration of spaced signals. Ergonomics, 1963, 6(2), 143-152.
- Edwards, W. Optimal strategies for seeking information: Models for statistics, choice reaction times, and human information processing. Journal of Mathematical Psychology, 1965, 2, 312-329.
- Edwards, Ward, & Crutchfield, Richard S. Differential reduction of autokinetic movement by a fixated figure. Journal of Experimental Psychology, 1951, 42, 25-31.
- Effron, Robert. The minimum duration of a perception. Neuropsychologia, 1970, 8(1), 57-63.
- Efron, Robert. The relationship between the duration of a stimulus and the duration of a perception. Neuropsychologia, 1970, 8(1), 37-55.
- Egan, James P., & Meyer, Donald R. Changes in pitch of tones of low frequency as a function of the pattern of excitation produced by a band of noise. Journal of the Acoustical Society of America, 1950, 22, 827-833.
- Eichelman, W. H. Stimulus and response repetition effects for naming letters at two response-stimulus intervals. Perception & Psychophysics, 1970, 7, 94-96.
- Elithorn, Alick; Piercy, Malcolm F., & Crosskey, Margaret A. Tactile localization. Quarterly Journal of Experimental Psychology, 1953, 5, 171-182.
- El'kin, D. G. The perception of duration and the temporal characteristics of sensorimotor response. Voprosy Psikhologii, 1968, 14(3), 56-61.
- Elliott, R. Simple visual and simple auditory reaction time: A comparison. Psychonomic Science, 1968, 10, 335-336.

- Ellis, Norman R., & Dugas, Jeanne. The serial position effect in short-term memory under E- and S-paced conditions. Psychonomic Science, 1968, 12(2), 55-56.
- Elsberg, C. A., & Levy, I. The sense of smell: A new and simple method of quantitative olfactometry. Bulletin of the Neurological Institute of New York, 1935, 4, 5-19.
- Elshtain, E. L., & Schaefer, T. Effects of storage load and word frequency on pupillary responses during short-term memory. Psychonomic Science, 1968, 12, 143-144.
- Elwood, David L. Automation of Psychological testing. American Psychologist, 1969, 24(3), 287-289.
- Emerson, P. L. Simple reaction time with Markovian evolution of Gaussian discriminial processes. Psychometrika, 1970, 35, 99-109.
- Entus, A., & Bindra, D. Common features of the "repetition" and "same-different" effects in reaction time experiments. Perception & Psychophysics, 1970, 7, 143-148.
- Epstein, William. Attitudes of judgment and the size-distance invariance hypothesis. Journal of Experimental Psychology, 1963, 66(1), 78-83.
- Epstein, William. Poststimulus output specification and differential retrieval from short-term memory. Journal of Experimental Psychology, 1969, 82(1, Pt. 1), 168-174.
- Epstein, William, & Landauer, Ali A. Size and distance judgments under reduced conditions of viewing. Perception & Psychophysics, 1969, 6(5), 269-272.
- Eriksen, Charles W. Multidimensional stimulus differences and accuracy of discrimination. USAF, WADC Technical Report, 1954, No. 54-165, iv, 11.
- Eriksen, Charles W. Object location in a complex perceptual field. Journal of Experimental Psychology, 1953, 45, 126-132.
- Eriksen, Charles W., & Collins, James F. Sensory traces versus the psychological moment in the temporal organization of form. Journal of Experimental Psychology, 1968, 77(3, Pt. 1), 376-382.
- Erulkar, S. D. Comparative aspects of spatial localization of sound. Physiological Reviews, 1972, 52, 238-360.
- Eskildsen, Paul R. An apparatus for studies of brightness which controls variations of intensity with time. American Journal of Psychology, 1963, 76(2), 321-323.
- Eskildsen, P.; Morris, Ailene; Carter, C., & Bach-y-Rita, P. Simultaneous and successive cutaneous two-point thresholds for vibration. Psychonomic Science, 1969, 14, 146-147.

Esper, E. A. The bradyscope: an apparatus for the automatic presentation of visual stimuli at a constant slow rate. Journal of Experimental Psychology, 1926, 9, 56-59.

Essman, W. B. Temporal discrimination in problem solving. Perceptual & Motor Skills, 1958, 8, 314.

Evans, Frederick J. Effects of practice on the validity of a group-administered Embedded Figures Test. Acta Psychologica, Amsterdam, 1969, 29(2), 172-180.

Evans, Wayne O. A titration schedule on a treadmill. Journal of Exp. Anal. Behav., 1963, 6(2), 219-221.

Evans, Wayne O., & Consolagio, C. Frank. Effects of high altitude on performance of three different types of work. Perceptual & Motor Skills, 1967, 25(1), 41-50.

Eysenck, H. J.; Iseler, A.; Star, K., & Willett, R. A. Post-rest upswing and downswing in pursuit rotor learning after distributed practice as a function of length of practice. British Journal of Psychology, 1969, 60(3), 373-384.

Farnsworth, D. The Farnsworth-Munsell 100-Hue and Dichotomous Tests for Color Vision. Journal of the Optical Society of America, 1943, 33, 568-578.

Farnsworth, D., & Reed, J. D. A Survey of Methods Used in Administering Pseudo-Isochromatic Test Plates for Color Vision, Medical Research Laboratory, New London, Conn., Color Vision Report No. 3, Nov. 6, 1943.

Farrimond, Thomas. A flexible instrument for presenting visual stimuli tachistoscopically. Perceptual & Motor Skills, 1968, 26(3, Pt. 2), 1236-1238.

Faulke, E.; Coates, G. D., and Alluisi, E. A. Decoding of electrocutaneous signals: Effects of dimensionality on rates of information transmission. Perceptual & Motor Skills, 1966, 23, 295-302.

Fauville, A. Peripheral vision and motor reaction. Miscellanea Psychologica Albert Michotte, (see 23:4008), 323-340.

Feldman, Alan S.; Zeldner, Iris B., & Grimes, Charles T. A modification of the Bing Test utilizing Békésy audiometry. Journal of Speech & Hearing Disorders, 1967, 32(3), 263-267.

Fernberger, S. W. On absolute and relative judgments in lifted weight experiments. American Journal of Psychology, 1931, 43, 560-578.

Ferree, C. E., & Rand, G. Pilot fitness, a safety factor in aviation. British Journal of Ophthalmology, 1940, 24, 581-597.

Ferree, C. E., & Rand, G. Perimetry: Variable factors influencing the breadth of the color fields. American Journal of Ophthalmology, 1922, 5, 886-894.

- Ferree, C. E., & Rand, G. A glareless illuminated holder for visual-acuity test charts with variable intensity of light. American Journal of Ophthalmology, 1939, 22, 399-406.
- Ferree, C. E., & Rand, G. Higher visibility in a roentgenogram illuminator. Arch. Ophthalmol., Chicago, 1939, 21, 70-75.
- Ferree, C. E., & Rand, G. Human factor in airplane crashes. Arch. Ophthalmol., Chicago, 1937, 18, 789,795.
- Ferree, C. E., & Rand, G. A. Multiple-exposure tachistoscope. Journal of Experimental Psychology, 1937, 21, 240-259.
- Ferree, C. E., & Rand, G. Size of objects in relation to their visibility and to the rating of vision. Arch. Ophthalmol., 1930, 4, 37-72.
- Ferree, C. E., & Rand, G. Testing fitness for night flying. Speed of change of adjustment of the eyes for intensity of light and distance of object. American Journal of Ophthalmology, 1939, 22, 655-661.
- Fessard, A. A note on the comparison of different modes of tactile excitation. C. R. Soc. Biol., 1929, 101, 1111-1113.
- Filbey, R. A., & Gazzaniga, M. S. Splitting the normal brain with reaction time. Psychonomic Science, 1969, 17(6), 335-336.
- Finan, J. L.; Finan, Sarah C., & Hartson, L. D. A review of representative tests used for the quantitative measurements of behavior-decrement under conditions related to aircraft flight. USAF TR No. 5830, WPAFB, Ohio, July, 1949.
- Fischer, R.; Kappeler, B. S.; Wisecup, P., & Thatcher, K. Personality trait dependent performance under psilocybin. Diseases of the Nervous System, 1970, 31, 91-101.
- Fischer, R., and Mead, E. L. Time contraction and psychomotor performance produced by 'psilocybin.' Nature, 1966, 209, 433-434.
- Fitts, P. M. Human information handling in speeded tasks. Research Report RC-109, 1959, IBM, New York.
- Fitts, P. M., & Deininger, R. L. S-R compatibility: Correspondence among paired elements within stimulus and response codes. Journal of Experimental Psychology, 1954, 48, 483-492.
- Fitts, Paul M.; Marlowe, Edward, & Noble, Merrill E. The interrelations of task variables in continuous pursuit tasks: 1. Visual-display scale, arm-control scale, and target frequency in pursuit tracking. USAF Human Resources Research Center, Research Bulletin, 1953, No. 53-34, v, 66.
- Fitts, P. M., & Peterson, J. R. Information capacity of discrete motor responses. Journal of Experimental Psychology, 1964, 67, 103-112.

- Fitts, P. M.; Peterson, J. R., and Wolpe, G. Cognitive aspects of information processing: II. Adjustments to stimulus redundancy. Journal of Experimental Psychology, 1963, 65, 423-432.
- Flanders, Ned A. A circuit for the continuous measurement of palmar resistance. American Journal of Psychology, 1953, 66, 295-299.
- Fleishman, E. A. A comparative study of aptitude patterns in unskilled and skilled psychomotor performances. Journal of Applied Psychology, 1957, 41, 263-272.
- Fleishman, E. A. Dimensional analysis of movement reactions. Journal of Experimental Psychology, 1958, 55, 438-453.
- Fleishman, Edwin A. Testing for psychomotor abilities by means of apparatus tests. Psychol. Bull., 1953, 50, 241-262.
- Fleishman, Edwin A. Testing for psychomotor abilities by means of apparatus tests. USAF Human Resources Research Center, Research Bulletin, 1953, No. 53-54, 22. Reprinted from Psychol. Bull., 1953, 50, 241-262 (see 28:2163).
- Fleishman, Edwin A. A modified administration procedure for the O'Connor Finger Dexterity Test. USAF Human Resources Research Center, Research Bulletin, 1953, No. 53-53, 4. Reprinted from Journal of Applied Psychology, 1953, 37, 191-194 (see 28:3349).
- Fleishman, Edwin A. The influence of fixed versus free head position on the perception of body position. USAF Human Resources Research Center, Research Bulletin, 1953, No. 53-37, iii, 16.
- Fleishman, Edwin A. Perception of body position in the absence of visual cues. Journal of Experimental Psychology, 1953, 46, 261-270.
- Fleishman, Edwin A., & Hempel, Walter E., Jr. Changes in factor structure of a complex psychomotor test as a function of practice. USAF Human Resources Research Center, Research Bulletin, 1953, No. 53-68, iv, 18.
- Fleishman, E. A., & Hempel, W. E. A factor analysis of dexterity tests. Personnel Psychology, 1954, 7, 15-32.
- Fleishman, E. A., & Ellison, G. D. A factor analysis of five manipulative tests. Journal of Applied Psychology, 1962, 46, 96-105.
- Fleishman, Edwin A. The perception of body position--effect of speed, magnitude, and direction of displacement on accuracy of adjustment to an upright position. USAF Human Resources Research Center, Research Bulletin, 1953, No. 53-1, v, 17.
- Fleishman, Edwin A. Performance assessment based on an empirically derived task taxonomy. Human Factors, 1967, 9, 349-366.
- Fleishman, E. A. The Structure and Measurement of Physical Fitness. Englewood Cliffs, N. J.: Prentice-Hall, 1964.

- Fleishman, E. A., & Hempel, W. E. Factorial analysis of complex psychomotor performance. USAF Personnel and Training Research Center, Research Bulletin, 1954, No. 54-12. AD 34 411.
- Fleishman, E. A.; Roberts, M. M., & Friedman, M. P. A factor analysis of aptitude and proficiency measures in radio-telegraphy. Journal of Applied Psychology, 1958, 42, 129-135.
- Flock, Howard R. Selective registration of information in visual judgment of surface slant. Perceptual & Motor Skills, 1963, 17(2), 537-538.
- Floyd, W. F., & Welford, A. T. Symposium on fatigue. London: H. K. Lewis & Co., 1953, viii, 196 p. 24 s.
- Foley, P. J., & Dewis, E. V. T. Pacing rate and warning signal in serial simple reaction time. Canadian Journal of Psychology, 1960, 14, 7-12.
- Foley, P. J., & Scott, D. M. Legibility of Leroy digits as function of size, distance, angle of view, and illumination level. Toronto, Can.: Defence Research Board, Department of National Defence, 1957. DRML Report No. 76-3, vii, 7.
- Forbes, S. M.; Taylor, M. M., & Lindsay, P. H. Cue timing in a multi-dimensional detection task. Perceptual & Motor Skills, 1967, 25(1), 113-120.
- Forbes, T. W. Auditory signals for instrument flying. Journal of Aero. Science, 1946, 13, 255-258.
- Forbes, T. W., & Hunt, W. A. Inexpensive apparatus for class demonstration of the resistance response of the skin. American Journal of Psychology, 1936, 48, 663-664.
- Forney, Robert B.; Hughes, Francis W., & Greatbatch, William H. Measurement of attentive motor performance after alcohol. Perceptual & Motor Skills, 1964, 19(1), 151-154.
- Forrin, B.; Kumler, M., & Morin, R. E. The effects of response code and signal probability in a numeral-naming task. Canadian Journal of Psychology, 1966, 20, 115-124.
- Förster, N. The reciprocity between vision and touch in space perception. Psychol. Forsch., 1929, 13, 64-78.
- Fox, Gerald. The effects of interval and duration of visual stimuli upon the time error. Psychol. Newsletter, 1952, No. 45, 1-17.
- Fox, W. F. Human performance in the cold. Human Factors, 1967, 9, 203-220.
- Fraisse, P. Why is naming longer than reading? Acta Psychologica, 1969, 30, 96-103.

Frankenhaeuser, Marianne, & Myrsten, Anna L. Performance decrement after intake of meprobamate as a function of task difficulty and learning level. Perceptual & Motor Skills, 1968, 27, 839-843.

Frankenhaeuser, Marianne, et al. Catecholamine excretion as related to cognitive and emotional reaction patterns. Psychosomatic Medicine, 1968, 30(1), 109-119.

Franks, C. M., & Withers, W. C. R. Photoelectric recording of eyelid movements. American Journal of Psychology, 1955, 68, 467-471.

Franz, S. I., & Watson, T. A. Apparatus for perception of force of movement. Journal of General Psychology, 1929, 2, 513-515.

Franzen, Ove. The dependence of vibrotactile threshold and magnitude functions on stimulation frequency and signal level: A perceptual and neural comparison. Scandinavian Journal of Psychology, 1969, 10(4), 289-298.

Franzen, Ove. On spatial summation in the tactual sense: A psychophysical and neurophysiological study. Scandinavian Journal of Psychology, 1969, 10(3), 193-208.

Fraser, D. C. The relation of an environmental variable to performance in a prolonged visual task. Quarterly Journal of Experimental Psychology, 1953, 5, 31-32.

Frederiksen, J. R. The role of cognitive factors in the recognition of ambiguous visual stimuli. ETS RD 65-23 and ONR Technical Report, Office of Naval Research Contract Nonr 1858-(15), Project Designation NR 150-088, and National Science Foundation Grant G-22889. Princeton University, Princeton, N. J., July, 1965. AD 473 580.

Frederiksen, J. R. A study of perceptual recognition in two sense modalities. RB-66-32, ONR Contracts Nonr/1858-(15) and Nonr 2214-(00) and USPHS Research Grant 1 P01 HD 01762-01. ETS, Princeton, N. J., June, 1966. (Author at Brandeis University, Waltham, Mass.)

Frederiksen, Norman. Factors in in-basket performance. Psychological Monographs: General & Applied, 1962, 76(22, Whole No. 541).

Freedle, Roy O.; Zavala, Albert, & Fleishman, Edwin A. Studies of component-total task relations: Order of component-total task practice and total task predictability. Human Factors, 1968, 10(3), 283-296.

Freedle, Roy O.; Zavala, Albert, & Fleishman, Edwin A. Studies of component-total task relations: Order of component-total task practice and total task predictability. American Institutes for Research, Technical Report, 1967, No. R67-4, 42.

Freeman, E. An anomaly of foveal color perception. American Journal of Psychology, 1929, 41, 643-645.

- Freeman, G. L., & Giese, W. J. The relationship between task difficulty and palmar skin resistance. Journal of General Psychology, 1940, 23, 217-220.
- French, J. W.; Ekstrom, R. B., & Price, L. A. Manual for kit of reference tests for cognitive factors (revised 1963). ONR Contract Nonr-2214(00), Project Designation NR 151-174, Princeton, N. J.: Educat. Testing Service, June, 1963. AD 410-915.
- French, Robert S. The accuracy of discrimination of dot patterns as a function of angular orientation of the stimuli. USAF Human Resources Research Center, Research Bulletin, 1953, No. 53-3, vi, 17.
- French, Robert Stanton. The discrimination of dot patterns as a function of number and average separation of dots. Journal of Experimental Psychology, 1953, 46, 1-9.
- French, Robert Stanton. Identification of dot patterns from memory as a function of complexity. Journal of Experimental Psychology, 1954, 47, 22-26.
- French, Robert Stanton. Pattern recognition in the presence of visual noise. Journal of Experimental Psychology, 1954, 47, 27-31.
- Fritze, Curtis, & Simonson, Ernst. A new electronic apparatus for the measurement of the fusion frequency of flicker. Science, 1951, 113, 547-549.
- Frumkes, Thomas E., & Sturr, Joseph F. Spatial and luminance factors determining visual excitability. Journal of the Optical Society of America, 1968, 58(12), 1657-1662.
- Fuchs, Alfred H. Recall for order and content of serial word lists in short-term memory. Journal of Experimental Psychology, 1969, 82(1, Pt. 1), 14-21.
- Fujita, Ben, & Spitzer, Stephan P. A chair-stabilometer. American Journal of Psychology, 1964, 77(2), 304-306.
- Fujji, Minoru. Experimental investigations on the instantaneous judging of the number of objects: II. Japanese Journal of Psychology, 1967, 38(2), 83-93.
- Furieux, W. D. An apparatus for measuring bodily sway. American Journal of Psychology, 1951, 64, 271-273.
- Gagne, R. M., & Fleishman, E. A. Psychology and human performance: An introduction to psychology. New York: Holt, Rinehart, & Winston, 1959.
- Gallagher, J. R.; Gallagher, C. D., & Sloane, A. E. A brief method of testing color vision with pseudo-isochromatic plates. American Journal of Ophthalmology, 1943, 26, 178-182.
- Ganguli, M. A report on the time-adjustment of the Hippchronoscope. Indian Journal of Psychology, 1930, 5, 25-36.

- Gardner, R. A. Multiple-choice decision-behavior. American Journal of Psychology, 1958, 71, 710-717.
- Garmize, L. M., & Marcuse, F. L. Some parameters of body sway. International Journal of Clinical & Experimental Hypnosis, 1969, 17(3), 189-194.
- Garner, W. R., & Creelman, C. D. Effect of redundancy and duration on absolute judgments of visual stimuli. Journal of Experimental Psychology, 1964, 67(2), 168-172.
- Garvey, W. D., & Knowles, W. B. Pointing accuracy of a joy stick without visual feedback. Journal of Applied Psychology, 1954, 38, 191-194.
- Gassowski, L. N., & Nikolskaya, N. A. Movements of the eye in the course of the fixation of a point. Prob. Fixiol. Opt., 1941, 1, 173-180.
- Gatewood, E. L. Individual differences in finger reactions. Psychological Monographs, 1920, (Whole No. 126).
- Gatti, Jennie. Reports of research in the field of engineering psychology. USAF, WADC Technical Report, 1954, No. 54-220, iii, 31.
- Geblewiczowa, Maria. Influence of the number of warning signals and of the intervals between them on simple reaction time. Acta Psychol., Amsterdam, 1963, 21(1), 40-48.
- Geiger, P. H., & Firestone, F. A. The estimation of fractional loudness. Journal of the Acoustical Society of America, 1933, 5, 25-30.
- Geldreich, E. W. The use of a calibrated potentiometer in the measurement of the galvanic skin response. American Journal of Psychology, 1935, 47, 491-493.
- Gendreau, P. E. et al. Perceptual deprivation and perceptual skills: Some methodological considerations. Perceptual & Motor Skills, 1968, 27, 57-58.
- Gerall, A. A.; Sampson, P. B., & Spragg, S. D. S. An electronic apparatus for studying tracking performance. American Journal of Psychology, 1955, 68, 297-305.
- Gerall, A. A.; Sampson, P. B., & Spragg, S. D. S. Method for studying performance on a simple tracking task as function of radius and loading of control cranks. U.S. Army Medical Research Laboratory Report, 1954, No. 144, ii, 18.
- Gerard, R. Investigations on binocular and monocular size perception. Z. Sinnesphysiol., 1936, 67, 80-90.
- Gerathewohl, S. J., & Cibis, P. A. The space between distinct contours. American Journal of Psychology, 1953, 66, 436-448.

- Gerathewohl, S. J.; Strughold, H., & Stallings, H. D. Sensomotor performance during weightlessness, eye-hand coordination. Journal of Aviation Medicine, 1957, 27, 7-12.
- Gerathewohl, S. J., & Taylor, W. F. Effect of intermittent light on the readability of printed matter under conditions of decreasing contrast. Journal of Experimental Psychology, 1953, 46, 278-282.
- Gerathewohl, S. J., & Taylor, W. F. The effect of intermittent light on vision. USAF School of Aviation Medicine, Project No. 21-1205-0014, 1953, Report No. 1, iii, 6.
- Gerben, Martin J., & House, Joyce L. Hypoxia and self-paced work. Perceptual & Motor Skills, 1969, 28(3), 995-1002.
- Germain, Jose. Universal tremometer. Rev. Psicol. Gen. Apl., Madrid, 1946, 1, 215-217.
- Gerver, D. Effects of grammaticalness, presentation rate, and message length on auditory short-term memory. Quarterly Journal of Experimental Psychology, 1969, 21(3), 203-208.
- Gescheider, G. A.; Wright, J. H., & Evans, M. B. Reaction time in the detection of vibrotactile signals. Journal of Experimental Psychology, 1968, 77, 501-504.
- Gescheider, G. A.; Wright, J. H.; Wever, B. J.; Kirchner, B. M., & Milligan, E. A. Reaction time as a function of the intensity and probability of occurrence of vibrotactile signals. Perception & Psychophysics, 1969, 5, 18-20.
- Gibbs, C. G. The continuous regulation of skilled response by kinesthetic feedback. British Journal of Psychology, 1954, 45, 24-39.
- Gibson, Eleanor J. A survey of research on improvement in perceptual judgments as a function of controlled practice and training. USAF Human Resources Research Center, Research Bulletin, 1953, No. 53-45, iii, 66.
- Gibson, G. L., & Neubrech, D. A. Automatic photoelectric colorimeter for direct reading of Munsell coordinates. Journal of the Optical Society of America, 1954, 44, 703-712.
- Gifford, R. N., & Lyman, J. Tracking performance with advanced and delayed visual displays. Human Factors, 1967, 9, 127-132.
- Gilinsky, Alberta S. Perception of size of objects at various distances. USAF Personnel Training Research Center, Research Bulletin, 1954, No. AFPTRC-TR-54-92, iv, 22.
- Gilmer, B. H. Toward cutaneous electro-pulse communication. Journal of Psychology, 1961, 52, 211-222.
- Gilzen, A. R., & Bakan, P. Influence of task and subject variables in the Squares Test of leveling-sharpening. Perceptual & Motor Skills, 1968, 27, 211-218.

- Gladstone, Roy. A group test of palmar sweat. Journal of General Psychology, 1953, 48, 29-49.
- Glees, M. A simple adaptometer. Klin. Mbl. Augenheilk., 1939, 103, 226.
- Goedel, R. A home-made plug-in audiometer. Arch. Ohr.-, Nas.- u. Kehlkheilk., 1938, 145, 440-446.
- Goff, K. W. An analog electronic correlator for acoustic measurements. Journal of the Acoustical Society of America, 1955, 27, 223-236.
- Gogel, Walter C. The effect of object familiarity on the perception of size and distance. Quarterly Journal of Experimental Psychology, 1969, 21(3), 239-247.
- Gogel, W. C., & Harker, G. S. The effectiveness of size cues to relative depth as a function of the lateral separation of objects. U.S. Army Medical Research Laboratory, Report, 1953, No. 125, ii, 17.
- Gogel, W. C., & Mertens, H. W. Perceived depth between familiar objects. Journal of Experimental Psychology, 1968, 77(2), 206-211.
- Gogel, W. C., & Mertens, H. W. Perceived depth between familiar objects. Psychonomic Bulletin, 1967, 1(2), 3.
- Gogel, W. C.; Wist, E. K., & Harker, G. S. A test of the invariance of the ratio of perceived size to perceived distance. American Journal of Psychology, 1963, 76(4), 537-553.
- Gold, Cecille, & Rosner, B. S. Facilitatory spatial interaction with percutaneous electrical stimuli. Perception & Psychophysics, 1969, 6(2), 118-120.
- Goldfarb, J. L., & Goldstone, S. Time judgment: A comparison of filled and unfilled durations. Perceptual & Motor Skills, 1963, 16(2), 376.
- Goldstein, M. J., & Adams, J. N. Coping style and behavior response to stress. Journal of Experimental Research in Personality, 1967, 2(4), 239-251.
- Goldstone, S. Reaction time to onset and termination of lights and sounds. Perceptual and Motor Skills, 1968, 27, 1023-1029.
- Goldstone, S. Production and reproduction of duration: Intersensory comparisons. Perceptual & Motor Skills, 1968, 26(3, Pt. 1), 755-760.
- Goldstone, S., & Goldfarb, J. L. Auditory and visual time judgment. Journal of General Psychology, 1964, 70(2), 369-387.
- Goldstone, S., & Goldfarb, J. L. Direct comparisons of auditory and visual durations. Journal of Experimental Psychology, 1964, 67(5), 483-485.
- Goldstone, S. Reaction time to onset and termination of lights and sounds. Perceptual & Motor Skills, 1968, 27(3, Pt. 2), 1023-1029.

- Goodman, C. H. The MacQuarrie Test for Mechanical Ability: I. Selecting radio assembly operators. Journal of Applied Psychology, 1946, 30, 586-595.
- Goodman, C. H. The MacQuarrie Test for Mechanical Ability: II. Factor analysis. Journal of Applied Psychology, 1947, 31, 150-154.
- Gorbov, F. D.; Miasnikov, V. I., & Iazdovskii, V. I. Strain and fatigue under conditions of sensory deprivation. Zhurnal Vysshei Nervnoi Deiatel'nosti, 1963, 13(4), 585-592.
- Gordon, Donald A. The reaction between the thresholds of form, motion, and displacement in parafoveal and peripheral vision at a scotopic level of illumination. American Journal of Psychology, 1947, 60, 202-225.
- Gordon, N. B. Guidance versus augmented feedback and motor skill. Journal of Experimental Psychology, 1968, 77(1), 24-30.
- Gottsdanker, R. Choice reaction time and the nature of the choice response. Psychonomic Bulletin, 1967, 1(2), 6.
- Gottsdanker, R.; Broadbent, L., & Van Sant, C. Reaction time to single and to first signals. Journal of Experimental Psychology, 1963, 66(2), 163-167.
- Gould, J. D., & Dill, Amanda B. Eye-movement parameters and pattern discrimination. Perception & Psychophysics, 1969, 6(5), 311-320.
- Gräf, A. The symmetrical setting of distances by touch and kinesthesia. Zsch. J. Sinnesphysiol., 1934, 64, 283-309.
- Granit, R., & Hammond, E. L. Comparative studies on the peripheral and central retina. V. The sensation-time curve and the time course of the fusion frequency of intermittent stimulation. American Journal of Physiology, 1931, 98, 654-663.
- Grant, D. A., & Schiller, J. J. Generalization of the conditioned galvanic skin response to visual stimuli, Journal of Experimental Psychology, 1953, 46, 309-313.
- Grant, K. W., & McCormack, P. D. Auditory and visual short-term memory with successive syllable presentation in both modalities. Psychonomic Science, 1969, 17(6), 341-342.
- Grant, W. T. The Romberg test; a graphic method of recording disturbances of equilibrium. Bulletin of the Los Angeles Neurological Society, 1943, 8, 25-30.
- Grassi, Joseph R. The Grassi Block Substitution Test for measuring organic brain pathology. Springfield, Ill.: Charles C. Thomas, 1953, ix, 75.
- Gray, J. S.; Sustare, G., & Thompson, A. An apparatus for measuring operational hand steadiness. Journal of Applied Psychology, 1953, 37, 57-58.

- Greenberg, Gordon A. Frequency-selective detection at three signal amplitudes. Perception & Psychophysics, 1969, 6(5), 297-301.
- Greenberg, R. P., & Kurz, R. B. Influence of type of stressor and sex of subject on time estimation. Perceptual & Motor Skills, 1968, 26(3, Pt. 1), 899-903.
- Greenwald, A. G. A choice reaction time test of ideomotor theory. Journal of Experimental Psychology, 1970, 86, 20-25.
- Greenwald, D. U. An apparatus for measuring the electrodermal response. American Journal of Psychology, 1935, 47, 682-685.
- Gregg, L. W., & Brogden, W. J. The relation between duration and reaction time difference to fixed duration and response terminated stimuli. Journal of Comparative and Physiological Psychology, 1950, 43, 329-337.
- Gregg, E. C., Jr. Absolute measurement of the vibratory threshold. A.M.A. Arch. Neurol. Psychiat., Chicago, 1951, 66, 403-411.
- Gregg, L. W., & Brogden, W. J. The relation between reaction time and the duration of the auditory stimulus. Journal of Comparative and Physiological Psychology, 1950, 43, 389-395.
- Gregory, R. L. Apparatus for investigating visual perception. American Psychologist, 1969, 24(3), 219-225.
- Grether, W. F. The School of Aviation Medicine Steadiness Test, Form B. AAF School of Aviation Medicine, 1942, Publ. Bd., No. 15514. Washington, D. C.: U.S. Dept. of Commerce, 1946, p.6.
- Gridley, P. F. The discrimination of short intervals of time by finger-tip and by ear. American Journal of Psychology, 1932, 44, 18-43.
- Grier, J. B. Reaction time to "tone-off." Psychonomic Science, 1966, 5, 385-386.
- Grier, J. B. Auditory reaction time as function of stimulus intensity and rise time. Psychonomic Science, 1966, 6, 307-308.
- Griffith, C. R. A flexible form of the Carr slot-maze. American Journal of Psychology, 1931, 43, 283-285.
- Grim, P. F., & White, S. H. Effects of stimulus change upon the GSR and reaction time. Journal of Experimental Psychology, 1965, 69, 276-281.
- Grindley, G. C., & Wilkinson, R. T. The aftereffect of seen movement on a plain field. Quarterly Journal of Experimental Psychology, 1953, 5, 183-184.
- Grindley, G. C. The variation of sensory thresholds with the rate of application of the stimulus. 1. The differential threshold for pressure. British Journal of Psychology, 1936, 27, 86-95.

- Grings, William W. Methodological considerations underlying electrodermal measurement. Journal of Psychology, 1953, 35, 271-282.
- Groden, G. A micro-switch method for measuring finger oscillation speed. Perceptual & Motor Skills, 1968, 26(1), 106.
- Grodsky, M. A. The use of full scale mission simulation for the assessment of complex operator performance. Human Factors, 1967, 9, 341-348.
- Grossberg, M. The latency of response in relation to Bloch's law at threshold. Perception & Psychophysics, 1968, 4, 229-232.
- Grossmann, E. E. The relation of the eye to antiaircraft gunnery. Milit. Surg., 1943, 92, 383-393.
- Guedry, F. E., & Graybell, A. Rotation Devices, Other Than Centrifuges and Motion Simulators. National Academy of Sciences, National Research Council, Publication 902, Washington, D. C., 1961.
- Guelke, R., & Helm, H. The anomalous behavior of the threshold of hearing in relation to the equal-loudness contours. Journal of the Acoustical Society of America, 1952, 24, 317-322.
- Guilford, J. P. (Ed.). Printed Classification Tests. AAF Aviation Psychology Program Research Report No. 5, 1947. Washington, D. C. U.S. Government Printing Office.
- Gulian, Edith. Effects of noise on an auditory vigilance task. Revue Roumaine des Sciences Sociales: Serie de Psychologie, 1966, 10(2), 175-186.
- Gulian, Edith. Effects of noise on reaction time and induced muscle tension in an auditory vigilance task. Revue Roumaine des Sciences Sociales: Serie de Psychologie, 1967, 11(1), 33-45.
- Gumenik, William E. Effects of articulatory activity and auditory, visual, and semantic similarity on the short-term memory of visually presented paired associates. Journal of Experimental Psychology, 1969, 82(1, Pt. 1), 70-74.
- Gundlach, R., & Bentley, M. The dependence of tonal attributes upon phase. American Journal of Psychology, 1930, 43, 519-543.
- Gurnee, H. Measuring the steadiness of manual movement. American Journal of Psychology, 1939, 52, 274-276.
- Hackman, J. R. Tests, questionnaires, and tasks of the Group Effectiveness Research Laboratory: 1951-1964. TR No. 24, ONR Contract NR 177-472, Nonr 1834(36). Group Effectiveness Research Laboratory, Department of Psychology, University of Illinois, Urbana, Ill., July, 1965. AD 623 312.
- Hagbarth, K. E., & Eklund, G. The effects of muscle vibration in spasticity, rigidity, and cerebellar disorders. Journal of Neurological Neurosurg. & Psychiat., 1968, 31, 207-213.

- Haggard, E. A. An apparatus for the measurement of continuous changes in palmar skin resistance. Journal of Experimental Psychology, 1947, 37, 92-98.
- Hall, R. J.; Karsh, R., & Wilsoncroft, W. E. The production and fading of entopic images. Behavior Research Methods & Instrumentation, 1970, 2(1), 22-23.
- Hallett, W. N. A psychophysical study of visual Gestalten. American Journal of Psychology, 1933, 45, 691-700.
- Halpern, J., & Lantz, Alma E. Nonstationary probability processes, event runs, and the development of patterned response habits. Psychonomic Science, 1969, 17(2), 75-76.
- Hama, H. The effect of prior exposure to conflict on post-conflict performance. Japanese Journal of Psychology, 1965, 36(1), 1-9.
- Hammerton, M., & Tickner, A. H. An investigation into the effect of exercising particular limb-segments upon performance in a tracking task. Ergonomics, 1969, 12(1), 47-49.
- Hammerton, M., & Tickner, A. H. Some factors affecting learning and transfer of training in visual-motor skills. British Journal of Psychology, 1969, 60(3), 369-371.
- Hammerton, M., & Tickner, A. H. Comparison of operator performance on a tracking task using discretely and continuously variable controls. Journal of Applied Psychology, 1968, 52(4), 319-320.
- Hammerton, M., & Tickner, A. H. Physical fitness and skilled work after exercise. Ergonomics, 1968, 11(1), 41-45.
- Handel, S., & Buffardi, L. Using several modalities to perceive one temporal pattern. Quarterly Journal of Experimental Psychology, 1969, 21(3), 256-266.
- Hannes, M. The effect of stimulus repetitions and alternations on one-finger and two-finger responding in two-choice reaction time. Journal of Psychology, 1968, 69(2), 161-164.
- Hansel, C. E. M. Apparent movement and eye movements. British Journal of Psychology, 1953, 44, 145-155.
- Hansel, H. On the flicker-fusion-frequency curve during rest periods. Psychol. Beitr., 1953, 1, 146-148.
- Harbert, F.; Young, I. H., & Wenner, C. H. Auditory flutter fusion and envelope of signal. Journal of the Acoustical Society of America, 1968, 44(3), 803-806.
- Harcum, E. R. Two possible mechanisms of differential set in tachistoscopic perception of multiple targets. Perceptual & Motor Skills, 1967, 25(1), 289-304.

- Hardesty, D.; Trumbo, D., & Bevan, W. Influence of knowledge of results on performance in a monitoring task. Perceptual & Motor Skills, 1963, 16(3), 629-634.
- Hardy, J. D.; Wolff, H. G., & Goodell, Helen. Pain Sensations and Reactions. Baltimore, Williams & Wilkins, 1952.
- Hardy, J. D.; Wolff, H. G., & Goodell, Helen. Studies on pain: Measurements of aching pain threshold and discrimination of differences in intensity of aching pain. Journal of Applied Physiology, 1952, 5(6), 247-255.
- Hardy, L. Single judgment test for red-green discrimination. Journal of the Optical Society of America, 1943, 33, 152-154.
- Harker, G. E., & Brune, R. L. The stereoptometer--an instrument for the study of binocular vision. U.S. Army Medical Research Laboratory, Report, 1952, No. 106, i, 9.
- Harmon, F. L., & Dimichael, S. The development of the H-D Code Aptitude Test: A preliminary report. Psychol. Bulletin, 1943, 40, 601-604.
- Harper, R. S. The perceptual modification of colored figures. American Journal of Psychology, 1953, 66, 86-89.
- Harris, C. S. The effects of high intensity noise on human performance. USAF AMRL Technical Report, 1968, No. 67-119, iii, 17.
- Harris, J. D. Some suggestions for speech reception testing. New London, Conn.: Naval Medical Research Laboratory, 1948. Report No. 2, Project NM-003-021, 23.
- Harris, J. D. The roles of sensation level and of sound pressure in producing reversible auditory fatigue. USN Submarine Medical Research Laboratory, Report, 1954, 13(5), Report No. 244, 11 p. Reprinted from Laryngoscope, 1954, 64(2), 89-97.
- Harris, J. D. Pitch-discrimination under masking. American Journal of Psychology, 1948, 61, 194-204.
- Harris, J. D., & Myers, Cecil K. The emergence of a tonal sensation. Journal of Experimental Psychology, 1949, 39, 228-337.
- Harris, J. D.; Haines, H. L., & Myers, C. K. A helmet-held bone conduction vibrator. Laryngoscope, 1953, 63, 998-1007.
- Harris, Richard, & Loess, Henry. Anagram solution times as a function of individual differences in stored digram frequencies. Journal of Experimental Psychology, 1968, 77(3, Pt. 1), 508-511.
- Harris, S., & Smith, K. U. Dimensional analysis of motion: V. An analytic test of psychomotor ability. Journal of Applied Psychology, 1953, 37, 136-141.

- Harter, M. R., & White, C. T. Periodicity within reaction time distributions and electromyograms. Quarterly Journal of Experimental Psychology, 1968, 20(2), 157-166.
- Hartman, B. O., & Page, R. E. Performance with light-weight grenades as a function of weight and distance. U.S. Army Medical Research Laboratory Report, 1955, No. 176, ii, 20.
- Hartridge, H. Some fatigue effects on the human retina produced by using coloured lights. Nature, London, 1947, 160, 538-539.
- Hartridge, H. Dependence of anomaloscope matching on viewing distance or field size. Nature, London, 1947, 160, 831-832.
- Harvard University, Psycho-Acoustic Laboratory. The masking of signals by noise. OSRD Report No. 5387, 1945; Publ. Bd. No. L68916. Washington, D.C.: U.S. Department of Commerce, 1947, p. 35.
- Hasbrook, A. H., & Young, P. E. Pilot response to peripheral vision cues during instrument flying tasks. FAA Office of Aviation Medicine Report, 1968, No. 68-11, 19.
- Hatfield, J. L., & Loeb, M. Sense mode and coupling in a vigilance task. Perception & Psychophysics, 1968, 4(1), 29-36.
- Hawkins, H. L.; Thomas, G. B., & Drury, K. B. Perceptual versus response bias in discrete choice reaction time. Journal of Experimental Psychology, 1970, 84, 514-517.
- Hayashi, T. Olfaction and Taste, 11. New York, Pergamon Press, 1967.
- Hazlewood, Valerie, & Singer, G. Kinesthetic orientation judgments during lateral head, body, and trunk tilt. Perception & Psychophysics, 1969, 5(3), 141-142.
- Heath, S. R., Jr. The military use of the rail-walking test as an index of locomotor coordination. Psychological Bulletin, 1943, 40, 282-284.
- Heath, S. R., Jr. Clinical significance of motor defect, with military implications. American Journal of Psychology, 1944, 57, 482-499.
- Hecht, Selig; Ross, Sherman, & Mueller, Conrad G. The visibility of lines and squares at high brightness. Journal of the Optical Society of America, 1947, 37, 500-507.
- Hecht, S.; Shlaer, S., & Pirenne, M. H. Energy, quanta, and vision. Journal of General Physiology, 1942, 25, 819-840.
- Hector, H. The "form" detection test. American Journal of Psychology, 1964, 77(1), 135-136.

- Heilbrun, A. B., Jr. The effects of various shock-stress conditions upon a complex perceptual-motor task. J. Pers., Sep., 1959, 27, 285-299.
- Heirmann, H. Some observations suggesting preservation of skilled motor acts despite drug-induced stress. Psychopharmacologia, 1968, 13, 287-298.
- Heinsius, E. Night vision testing with the nyctoscope. v. Graefes Arch. Ophthal., 1948, 148, 741-751.
- Heinze, Helmut. Adaptability of the psycho-galvanic skin reflex for the objective measurement of fatigue. Psychol. Beitr., 1955, 2, 98-127.
- Held, R., & Schlank, M. Adaptation to disarranged eye-hand coordination in the distance-dimension. American Journal of Psychology, 1959, 72, 603-605.
- Hellman, R. P., & Zwislocki, J. J. Loudness determination at low sound frequencies. Journal of the Acoustical Society of America, 1968, 43(1), 60-64.
- Henry, F. M. Reaction time-movement time correlations. Perceptual and Motor Skills, 1961, 12, 63-66.
- Henry, F. J. Dynamic kinesthetic perception and adjustment. Research Quarterly of the American Association for Health, Physical Education, and Recreation, 1953, 24, 176-187.
- Herman, L. M., & Kantowitz, B. H. The psychological refractory period effect: Only half the double stimulation story? Psychological Bulletin, 1970, 73, 74-88.
- Herrick, R. M.; Adler, H. E.; Coulson, J. E., & Howett, G. L. The detection of separations between adjacent signals on a simulated PPI radar scope. USAF WADC Technical Report, 1955, No. 55-424, v, 22.
- Hershberger, M. L. An experimental study of image motion compensation tracking for earth reconnaissance from space. Human Factors, 1967, 9, 105-118.
- Hershenson, M. Reaction time as a measure of intersensory facilitation. Journal of Experimental Psychology, 1962, 63, 289-293.
- Hertel, K., & Monje, M. On the influence of the time factor on spatial perception. Pflug. Arch. Ges. Physiol., 1947, 249, 295-306.
- Heym, H. Measurements by touch using both hands. Zsch. f. Sinnesphysiol., 1934, 65, 166-188.
- Hick, W. E. On the rate of gain of information. Quarterly Journal of Experimental Psychology, 1952, 4, 11-26.
- Hickey, T. L., & Bartley, S. H. Foveal critical flicker frequency as influenced by intermittent stimulation of the opposite eye at various locations. Journal of Psychology, 1969, 73(2), 147-157.

- Higbee, K. L., & Streufert, S. Perceived control and riskiness. Psychonomic Science, 1969, 17(2), 105-106.
- Higgins, E. A. et al. Effects of two antihistamine-containing compounds upon performance at three altitudes. Office of Aviation Medicine Report, 1968, No. 68-15.
- Higgins, G. C., & Stultz, K. F. Frequency and amplitude of ocular tremor. Journal of the Optical Society of America, 1953, 43, 1136-1140.
- Higgins, J. R., & Angel, R. W. Correction of tracking errors without sensory feedback. Journal of Experimental Psychology, 1970, 84, 412-416.
- Higginson, G. D. A mirror-drawing apparatus for the instructional laboratory. Journal of Psychology, 1938, 6, 335-337.
- Hilgard, E. R. Methods and procedures in the study of learning. In S. S. Stevens (Ed.), Handbook of Experimental Psychology. New York: Wiley, 1951. 517-567.
- Hill, R. J. A note on inconsistency in paired comparison judgments. American Sociol. Rev., 1953, 18, 564-566.
- Hillyard, S. A., & Galambos, R. Effects of stimulus and response contingencies on a surface negative slow potential shift in man. Electroencephalography and Clinical Neurophysiology, 1967, 22, 297-304.
- Hines, M., & O'Connor, J. A measure of finger dexterity. Personnel Journal, 1926, 4, 379-382.
- Hinrichs, J. R. Ability correlates in learning a psychomotor task. Journal of Applied Psychology, 1970, 54(1, Pt. 1), 56-64.
- Hinrichs, J. V., & Krainz, P. L. Expectancy in choice reaction time: Anticipation of stimulus or response? Journal of Experimental Psychology, 1970, 85, 330-334.
- Hirsh, I. J. Binaural summation and interaural inhibition as a function of the level of masking noise. American Journal of Psychology, 1948, 61, 205-231.
- Hirsch, M. J., & Weymouth, F. W. Distance discrimination: VI. The relationship of visual acuity to distance discrimination. Journal of Aviation Medicine, 1948, 19, 56-58.
- Hirsch, M. J., & Weymouth, F. W. Distance discrimination. V. Effect of motion and distance targets on monocular and binocular distance discrimination. Journal of Aviation Medicine, 1947, 18, 594-600.
- Hockman, S. H. The effects of stress on Stroop color-word performance. Psychonomic Science, 1967, 9(8), 475-476.

- Hock, H. S., & Egeth, H. Verbal interference with encoding in a perceptual classification task. Journal of Experimental Psychology, 1970, 83(2, Pt. 1), 299-303.
- Hodge, R. W., & Diespecker, D. D. A two-channel signalling unit for vibro-tactile experiments. Australian Journal of Psychology, 1968, 20(1), 25-26.
- Hodgkins, J. Influence of age on the speed of reaction and movement in females. Journal of Gerontology, 1962, 17, 385-389.
- Hofffield, D. R., & Kent, Carolyn. Decision time and information use in a choice situation. Psychol. Rep., 1963, 12(1), 68-70.
- Hoffman, D. T. Sex differences in preferred finger tapping rates. Perceptual & Motor Skills, 1969, 29(2), 676.
- Hoffman, H. E. Effects of stress on scanning. Perceptual & Motor Skills, 1968, 27, 891-900.
- Hofmann, M. Response times to electrocutaneous stimulation. Perceptual & Motor Skills, 1967, 25, 509-513.
- Hohle, R. H. Component process latencies in reaction times of children and adults. In Advances in Child Development and Behavior. Vol. 3. New York: Academic Press Inc., 1967, 225-261.
- Holland, C. L. Performance effects of long-term random vertical vibration. Human Factors, 1967, 9, 93-104.
- Holland, M. K., & Lockhead, G. R. Sequential effects in absolute judgments of loudness. Perception & Psychophysics, 3(6), 409-414.
- Holmberg, L., & Holmberg, Ingrid. The perception of the area of rectangles as a function of the ratio between height and width. Psychological Research Bulletin, 1969, 9(3), 6.
- Holmberg, L. The distribution and reliability of certain color vision data as measured by the Pickford-Nicholson anomaloscope. Psychological Research Bulletin, 1963, 3(4), 7.
- Horai, Joann; Tedeschi, J. T.; Gahagan, J., & Lesnick, S. The effects of contingent threats upon target's behavior. Journal of Social Psychology, 1969, 78(2), 293-294.
- Horner, R. G., & Purslow, E. T. Dependence of anomaloscope matching on viewing distance or field size. Nature, London, 1947, 160, 23-24.
- Hormann, H., & Zahn, H. E. The influence of airplane noise on the organization of thought content. F. Merz (Ed.). Report of the 25th Congress of the German Psychological Association, Munster, 1966, 363-369.
- Hornstein, A. D., & Rotter, G. S. Research methodology in temporal perception. Journal of Experimental Psychology, 1969, 79, 561-564.

- Hornstra, L. Fatigue, I. Mens en Onderzinking, 1955, 2, 160-177.
- Hornstra, L. The function of perception in aviators. Schweiz. Z. Psychol. Anwend., 1955, 14, 46-60.
- Horst, P. A technique for the development of a differential prediction battery. Psychol. Monogr., 1954, 68, No. 9 (Whole No. 380).
- Hoshiko, M. S., & Grandstaff, H. L. An electromyographic investigation of motor conflict. Psychonomic Science, 1967, 9, 87-88.
- House, Joyce L., & Jorg, R. J. Performance of simulated military tasks at high altitude. Perceptual & Motor Skills, 1968, 27, 471-481.
- Houston, B. K. Noise, task difficulty, and Stroop color-word performance. Journal of Experimental Psychology, 1969, 82(2), 403-404.
- Houston, B. K. Noise, negative transfer learning, and Stroop color-word performance. Proceedings of the 77th Annual Convention of the American Psychological Association, 1969, 4(Pt. 1), 31-32.
- Hovland, Carl I. A set of flower designs for experiments in concept-formation. American Journal of Psychology, 1953, 66, 140-142.
- Howard, I. P., & Evans, J. A. A new split-beam tachistoscope giving an exact color-match. American Journal of Psychology, 1964, 77(2), 311-312.
- Howland, Daniel, & Noble, Merrill E. The effect of physical constants of a control on tracking performance. Journal of Experimental Psychology, 1953, 46, 353-360.
- Hsiao, H. H., & Cheng, P. L. An experimental study of the reaction of quick discrimination. Educ. Res. Nat. Cent. Univ. (Chinese), 1935, 3, No. 1, 33-57.
- Hudson, R. L. Category clustering for immediate and delayed recall as a function of recall cue information and response dominance variability. Journal of Experimental Psychology, 1969, 82(3), 575-577.
- Hufford, L. E. Reaction time and the retinal area-stimulus intensity relationship. Journal of the Optical Society of America, 1964, 54, 1368-1373.
- Hughes, J. W. The upper frequency limit for the binaural localization of a pure tone by phase difference. Proc. Roy. Soc., 1940, B'28, 293-305.
- Hulpieu, H. R. A simplified all-purpose gravity writing lever. Science, 1943, 98, 116.
- Humes, J. F. The effect of practice upon the upper limen for tonal discrimination. American Journal of Psychology, 1930, 42, 1-16.

- Humphrey, G. A simple apparatus for the class demonstration of the conditioned response. Journal of Educ. Psychol., 1929, 19, 61-63.
- Humphreys, L. G.; Buxton, C. E., & Taylor, H. R. Steadiness and rifle marksmanship. Journal of Applied Psychology, 1936, 20, 680-688.
- Humphries, M. A method of estimating "R.M.S. Error" in pursuit rotor performance. Perceptual & Motor Skills, 1961, 13, 211-225.
- Humphries, M., & McIntyre, J. An attempt to find a locus of temporary work decrement in pursuit rotor performance. Perceptual & Motor Skills, 1963, 17(2), 397-398.
- Hunt, R. W. G. The effects of daylight and tungsten light-adaptation on color perception. Journal of the Optical Society of America, 1950, 40, 362-371.
- Huppert, Felicia, & Singer, G. An aftereffect in judgment of auditory duration. Perception & Psychophysics, 1967, 2(11), 544-546.
- Hurvich, Leo M., & Jameson, Dorothea. A psychophysical study of white. I. Neutral adaptation. Journal of the Optical Society of America, 1951, 41, 521-527.
- Hurvich, Leo M., & Jameson, Dorothea. Spectral sensitivity of the fovea. III. Heterochromatic brightness and chromatic adaptation. Journal of the Optical Society of America, 1954, 44, 213-222.
- Hutt, S. J.; Jackson, P. M.; Belsham, A., & Higgins, G. Perceptual-motor behavior in relation to blood phenobarbitone level: A preliminary report. Developmental Medicine & Child Neurology, 1968, 10, 626-632.
- Hüttner, H. Psychotechnics of signalling. Identifiability of signs against a varied background. Industr. Psychotech., 1940, 17, 34-39.
- Hyman, R. Stimulus information as a determinant of reaction time. Journal of Experimental Psychology, 1953, 45, 188-196.
- Hyman, R., & Hake, H. W. Form recognition as a function of the number of forms which can be presented for recognition. USAF, WADC Technical Report, 1954, No. 54-164, iv, 19.
- Ichikawa, Noriyoshi. The measurement of the figure-effect in the third dimension by the light threshold method: On the front and the rear spaces of the stimulus figure of two parallel lines. Japanese Journal of Psychology, 1967, 38(5), 274-283.
- Idestrom, C. M., & Cadenius, B. Time relations of the effects of alcohol compared to placebo: Dose-response curves for psychomotor and perceptual test performances and blood and urine levels of alcohol. Psychopharmacologia, 1968, 13, 189-200.

Imber, Burton M.; Stern, Irwin D., & Vanderplas, James M. Visual field restriction and apparent size of distant objects. USAF WADC, Technical Report, 1954, No. 54-23, iii, 12.

Imus, H. A. Manual for the adjustment and operation of the projection eikonometer. OSRD, 1943; Publ. Bd., No. 27302. Washington, D.C.: U.S. Department of Commerce, 1946, p. 8.

Ioseliani, K. K. Effectiveness of mental activity as a function of its rate. Voprosy Psikhologii, 1968, 14(1), 12-20.

Ireland, F. H. An electronic flicker apparatus for monocular and binocular stimulation. Journal of Psychology, 1950, 29, 183-193.

Isley, Robert N., & Caro, Paul W., Jr. Use of time-lapse photography in flight performance evaluation. Journal of Applied Psychology, 1970, 54(1, Pt. 1), 72-76.

Ittelson, William H. A note on "Familiar size and the perception of depth." Journal of Psychology, 1953, 35, 235-240.

Jahnke, J. C., & Erlick, D. E. Delayed recognition and the serial organization of short-term memory. Journal of Experimental Psychology, 1968, 77(4), 641-647.

James, W. E.; Mefferd, R. B., & Wieland, Betty A. Repetitive psychometric measures: Handedness and performance. Perceptual & Motor Skills, 1967, 25(1), 209-212.

Jameson, Dorothea, & Hurvich, L. M. A psychophysical study of white. II. Neutral adaptation. Area and duration as variants. Journal of the Optical Society of America, 1951, 41, 528-536.

Jaukiaiian, T.; Allas, Y., & Aho, J. Subjective scale of electric taste. Acta Otolaryngologica, 1967, 63, 462.

Jeanneret, P. R., & Webb, W. B. Strength of grip on arousal from full night's sleep. Perceptual & Motor Skills, 1963, 17(3), 759-761.

Jeeves, M. A., & Dixon, N. F. Hemisphere differences in response rates to visual stimuli. Psychonomic Science, 1970, 20, 249-251.

Jeffress, L. A. A direct-reading frequency-difference meter. American Journal of Psychology, 1948, 61, 405-409.

Jeffress, L. A. An electronic switching circuit. American Journal of Psychology, 1950, 63, 257-259.

Jenkins, W. L. Somesthesia. In S. S. Stevens (Ed.) Handbook of Experimental Psychology. Wiley: New York, 1951.

- Jenkins, W. L., & Karr, A. C. The use of a joy stick in making settings on a simulated scope face. USAF, WADC Technical Report, 1954, No. 53-430, 7.
- Jenkins, W. O. The discrimination and reproduction of motor adjustments with various types of aircraft controls. American Journal of Psychology, 1947, 60, 397-406.
- Jensen, A. R., & Rohwer, W. D. The Stroop color-word test: A review. Acta Psychologica, 1966, 25, 36-93.
- Jerger, J. F. Influence of stimulus duration on the pure-tone threshold during recovery from auditory fatigue. Journal of the Acoustical Society of America, 1955, 27, 121-124.
- Jerison, H. J., & Arginteanu, J. Time judgments, acoustic noise, and judgment drift. USAF WADC Technical Report, 1958, No. 57-454, v, 29.
- Jerison, H. J.; Crannell, Clarke W., & Pownall, Dorothy. Acoustic noise and repeated time judgments in a visual movement projection task. USAF WADC Technical Report, 1957, No. 57-54, v, 26.
- Jerison, H. J., & Wing, S. Effects of noise and fatigue on a complex vigilance task. USAF WADC Technical Report, 1957, No. 57-14, v, 15.
- Jex, H. R., & Magdaleno, R. E. Corroborative data on normalization of human operator remnant. IEEE Transactions on Man-Machine Systems, 1969, MMS-10 (4, Pt. 1), 137-140.
- Jirka, Z., & Valousek, C. Time estimation during prolonged stay underground. Studia Psychologica, 1967, 9(3), 176-193.
- Johannsen, D. E. A quantitative study of binocular color vision. Journal of General Psychology, 1930, 4, 282-308.
- Johansson, B.; Kylin, B., & Langfy, M. Acoustic reflex as a test of individual susceptibility to noise: A preliminary report. Acta Oto-Laryngologica, 1967, 64(3), 256-262.
- John, I. D. The role of extraneous stimuli in responsiveness to signals: Refractoriness or facilitation? Australian Journal of Psychology, 1964, 16, 87-96.
- Johnson, E. M. Effects of extended practice on dual-task performance. Proceedings, 78th Annual Convention, American Psychological Association, 1970.
- Johnson, E. P. The electrical response of the human retina during dark-adaptation. Journal of Experimental Psychology, 1949, 39, 597-609.
- Johnson, L. C., & Karpan, W. E. Autonomic correlates of the spontaneous K-complex. Psychophysiology, 1968, 4(4), 444-452.

- Johnston, R. A., & Cross, H. J. A further investigation of the relation between anxiety and digit symbol performance.. Journal of Consult. Psychol., 1962, 26(4), 390.
- Jones, F. N. A test of the validity of the Elsberg method of olfactometry. American Journal of Psychology, 1953, 66, 81-85.
- Jones, F. P.; Gray, Florence E.; Hanson, J. A., & O'Connell, D. N. An experimental study of the effect of head balance on patterns of posture and movement in man. Journal of Psychology, 1959, 47, 247-258.
- Jones, M. B. Intertrial correlations under variations in effect. Ergonomics, 1968, 11(2), 175-181.
- Jones, R. E.; Milton, J. L., & Fitts, P. M. Eye fixations of aircraft pilots: I. A review of prior eye-movement studies and a description of a technique for recording the frequency duration, and sequences of eye fixations during instrument flight. USAF: TR 5837, Sept., 1949.
- Jongkees, L. B. W., & Groen, J. J. The stability of man. Acta Otolaryng., Stockholm, 1947, 35, 327-351.
- Juler, F. A. A projection scotometer. British Journal of Ophthalmology, 1939, 23, 239-242.
- Julesz, Bela. Experiment in perception. Psychology Today, 1968 2(2), 16-23.
- Junger, Josef. Tracking process in operator's work. Studia Psychologica, 1968, 10(1), 46-53.
- Juola, J. F., & Hergenhahn, B. R. Effects of training level, type of training, and awareness on the establishment of mental set in anagram solving. Journal of Psychology, 1968, 69(2), 155-159.
- Kaiser, P. K. Color names of very small fields varying in duration and luminance. Journal of the Optical Society of America, 1968, 58(6), 849-852.
- Kanarick, A. F. Probability and payoff as factors influencing two-choice reaction-time. Journal of Engineering Psychology, 1966, 5(2), 37-46.
- Kantowitz, B. H. Double stimulation with varying response information. Journal of Experimental Psychology, 1969, 82, 347-352.
- Kaplan, I. T.; Carvellas, Thomas, & Metlay, William. Searching for words in letter sets of varying size. Journal of Experimental Psychology, 1969, 82(2), 377-380.
- Kappauf, W. E., & Brogden, W. J. An instrument for the measurement of inter-pupillary distance. OSRD, 1943; Publ. Bd., No. 27303. Washington, D. C.: U. S. Department of Commerce, 1946.

- Kappauf, W. E. The design and use of instruments. In NRC, Human Factors in Undersea Warfare, (see 25:4021), 77-99.
- Karlin, J. E., & Others. Auditory tests of the ability to hear speech in noise. OSRD, 1944; Publ. Bd., No. 22847. Washington, D.C.: U.S. Department of Commerce, 1946, p. 78.
- Karlin, Lawrence. The New York University tachistoscope. American Journal of Psychology, 1955, 68, 462-466.
- Karlovich, R. S., & Graham, J. T. Visually and auditorily paced key tapping performance during synchronous, decreased, and delayed auditory and visual feedback. Journal of Speech & Hearing Research, 1967, 10(4), 865-875.
- Karlovich, R. S., & Graham, J. T. Visually paced key tapping performance during synchronous, decreased, and delayed pure tone auditory feedback. Journal of Auditory Research, 1968, 8(1), 1-13.
- Karlovich, R. S., & Graham, J. T. Auditorily paced key tapping performance during synchronous, decreased, and delayed visual feedback. Perceptual & Motor Skills, 1968, 26(3, Pt. 1), 731-743.
- Kaswan, J., & Young, S. Effect of luminance, exposure duration, and task complexity on reaction time. Journal of Experimental Psychology, 1965, 69, 393-400.
- Kato, T., & Saito, S. Studies on sensory deprivation: II. Experiments on the time perception: 5. Tohoku Psychologica Folia, 1964, 22(3-4), 79-85.
- Keele, S. W., & Posner, M. I. Processing of visual feedback in rapid movements. Journal of Experimental Psychology, 1968, 77(1), 155-158.
- Keenan, J. J. Some effects of rhythmic distraction upon rhythmic sensorimotor performance. Journal of Experimental Psychology, 1968, 77(3, Pt. 1), 440-446.
- Keighley, G. An instrument for measurement of vibration sensation in man. Milbank Memorial Fund Quarterly, 1946, 24, 36-48.
- Kellas, G.; Baumeister, A. A., & Wilcox, S. J. Interactive effects of preparatory intervals, stimulus intensity, and experimental design on reaction time. Journal of Experimental Psychology, 1969, 80, 311-316.
- Kellaway, P., & Brighthouse, G. A simplified oscillator suitable for auditory research and audiometry. Journal of Experimental Psychology, 1943, 33, 514-516.
- Kelley, H. P. Memory abilities: A factor analysis. Psychometric Monographs, No. 11, 1964.
- Kelvin, R. P. Discrimination of size by sight and touch. Quarterly Journal of Experimental Psychology, 1954, 6, 23-34.

- Kennedy, R. S. A sixty-minute vigilance task with 100 scoreable responses. USN AMI, 1968, No. 1045, 10.
- Kenshalo, D. R.; Homes, C. E., & Wood, Paul B. Warm and cool thresholds as a function of rate of stimulus temperature change. Perception & Psychophysics, 1968, 3(2-A), 81-84.
- Kephart, N. C., & Revesman, S. Measuring difference in speed of performance. Optom. Wkly., 1953, 44, 1965-1967.
- Kharkevich, V. K. A digital kinesthesiometer. Voprosy Psikhologii, 1968, 14(3), 168-169.
- Kidd, J. S., & Micocci, A. Maintenance of vigilance in an auditory monitoring task. Journal of Applied Psychology, 1964, 48(1), 13-15.
- Kientzle, M. J. Properties of learning curves under varied distributions of practice. Journal of Experimental Psychology, 1946, 36, 187-211.
- Kientzle, M. J. Ability patterns under distributed practice. Journal of Psychology, 1949, 39, 532-537.
- Kientzle, M. J. Individual differences under distribution of practice. American Psychologist, 1949, 4, 386.
- King, H. E. Reaction-time as a function of stimulus intensity among normal and psychotic subjects. Journal of Psychology, 1962, 54, 299-307.
- King, H. E. The retention of sensory experience: IV. Short-delay versus long-delay intervals. Journal of Psychology, 1965, 60(1), 103-115.
- Kinney, Jo A., & Cooper, Jane C. Adaptation to a homochromatic visual world. U.S. Naval Submarine Medical Center Report, 1967, No. 499, 7.
- Kipnis, D., & Wagner, C. Effects of motivation to strive on personality-performance relationships. Journal of Experimental Research in Personality, 1965, 1, 138-143.
- Kleinman, K. M., & Stern, J. A. Task complexity, electrodermal activity and reaction time. Psychophysiology, 1968, 5(1), 51-60.
- Klemmer, E. T., & Muller, P. F., Jr. The rate of handling information: Key pressing responses to light patterns. Journal of Motor Behavior, 1969, 1, 135-147.
- Kline, Milton V. A visual imagery technique for the induction of hypnosis in certain refractory subjects. Journal of Psychology, 1953, 35, 227-228.
- Klippel, A. G., & Scelfo, L. M. Performance decrements during a continuous discrimination task. Perceptual & Motor Skills, 1969, 29(1), 43-49.

- Klopfer, F. D. A semiautomatic bright-field tachistoscope. American Journal of Psychology, 1953, 66, 105-109.
- Klughardt, A., & Reuther, R. Measuring perception of simultaneous contrast of uncolored brightness. Veroff. Wiss. Photo-Lab. Agfa, 1951, 7, 162-168.
- Knehr, C. A. Individual differences in subjective color. Journal of Psychology, 1953, 36, 289-294.
- Knoll, H. A.; Tousey, R., & Julburt, E. O. Visual thresholds of steady point sources of light in fields of brightness from dark to daylight. Journal of the Optical Society of America, 1946, 36, 480-482.
- Knoll, H. A. Research tilting haploscope. Journal of the Optical Society of America, 1959, 49, 1176-1179.
- Knowles, W. B. Aerospace simulation and human performance research. Human Factors, 1967, 9, 149-159.
- Knox, G. W. Some psychological factors in flicker and fusion. American Journal of Optometry, April, 1951.
- Knox, G. W. Some effects of auditory stimuli on the perception of visual flicker. American Journal of Optometry, 1953, 30, 520-526.
- Kobrick, J. L., & Dusek, E. R. Effects of hypoxia on voluntary response time to peripherally located visual stimuli. Journal of Applied Physiology, 1970, 29, 444-448.
- Kobrick, J. L. Effects of viewing distance, low ambient temperature, and wind exposure on binocular depth discrimination. Perceptual & Motor Skills, 1969, 28(2), 647-656.
- Koch, E. A new testing apparatus for depth perception. Luftfahrtmedizin, 1941, 5, 317-321.
- Kohfeld, D. L. Stimulus intensity and adaptation level as determinants of simple reaction time. Journal of Experimental Psychology, 1968, 76, 468-473.
- Kohfeld, D. L. Effects of the intensity of auditory and visual ready signals on simple reaction time. Journal of Experimental Psychology, 1969, 82, 89-95.
- Kohn, M., & Clynes, M. Color dynamics of the pupil. Annals of the New York Academy of Sciences, 1969, 156(2), 931-950.
- Kopell, B. S., & Wittner, W. K. The effects of chlorpromazine and methamphetamine on visual signal-from-noise detection. Journal of Nerv. & Mental Disease, 1968, 147, 418-424.
- Kostandov, E. A. Influence of changes in the functional state of the cortex and of the activating system of the brain stem on the detection of weak acoustic signals. Zhurnal Vysshei Nervnoi Deyatel'nosti, 1967, 17(4), 634-642.

- Kozłowski, S. Experiments on the physiological mechanism of "active rest." Acta Physiol. Polon., 1952, 3(1), 85-92.
- Kransman, D. Liquid level detector with automatic refill and depletion indicator. Behavior Research Methods & Instrumentation, 1969, 1(5), 182-183.
- Kravkov, S. V. Critical frequency of flicker and indirect stimuli. C. R. Acad. Sci., U.R.S.S., 1939, 22, 64-66.
- Krinchik, E. P. The probability of a signal as a determinant of reaction time. Acta Psychologica, 1969, 30, 27-36.
- Kroll, W. Quality of simple reaction time and the psychological refractory period. Research Quarterly, 1969, 40, 105-114.
- Krump, K. The effect of complexity of interference in reaction time. Australian Psychologist, 1966, 1(1), 88.
- Kulpe, O. Outlines of Psychology. New York: MacMillan, 1895.
- Kummick, L. S. A scanning pupillometer. American Journal of Ophthalmology, Aug., 1959, 48, 259-262.
- Kunkel, Eberhard. Experimental investigation of the reliability of reaction time measurements. Zeitschrift fur Experimentelle & Angewandte Psychologie, 1964, 11(2), 301-313.
- Kupperian, J. E., Jr., & Golin, E. An electronic tachistoscope. American Journal of Psychology, 1951, 64, 274-276.
- Kurilova, L. M. On gradualness of the functional adjustment of the cutaneous-temperature analyzer with the action of light of various intensity on the skin and eye. Byulleten Eksperimental'noi Biologii i Meditsiny, 1967, 64(12), 17-19.
- Kurtz, A. K., & Smith, Mary C. Annotated bibliography of human factors laboratory reports (1945-1968). NAVTRADEVCE TR, 1969, No. IH-158, p.369.
- Kurz, R. B. Effects of three kinds of stressors on human learning and performance. Psychological Reports, 1964, 14(1), 161-162.
- Kushner, E. N. Effect of motivating instructions on simple reaction time. Perceptual and Motor Skills, 1963, 17, 321-322.
- Lacey, O. L., & Siegel, P. S. An improved potentiometric circuit for measuring the galvanic skin response. American Journal of Psychology, 1948, 61, 272-274.
- Lachar, Barbara, & Goggin, Judith. Effects of changes in word length on proactive interference in short-term memory. Psychonomic Science, 1969, 17(4), 213-214.

- Laird, D. A. The influence of noise on production and fatigue, as related to pitch, sensation level, and steadiness of the noise. Journal of Applied Psychology, 1933, 17, 320-329.
- Lamport, H.; Brookes, R. D.; Walter, C. W. P., & Putnam, T. J. A pursuit-meter with an application in aviation medicine; the effect of low atmospheric pressure. Journal of Aviation Medicine, 1943, 14, 336-345.
- Landauer, A. A., & Epstein, W. Does retinal size have a unique correlate in perceived size? Perception & Psychophysics, 1969, 6(5), 273-275.
- Landon, P. B., & Suedfeld, P. Information and meaningfulness needs in sensory deprivation. Psychonomic Science, 1969, 17(4), 248.
- Landis, C. An annotated bibliography of flicker-fusion phenomena. National Research Council, Vision Committee Secretariat, Ann Arbor, Mich., 1953.
- Landis, C. Determinants of the critical flicker-fusion threshold. Physiological Review, 1954, 34, 259-286.
- Latour, O. Evidence of internal clocks in the human operator. Acta Psychologica, 1967, 27, 341-348.
- Laughery, K. R., & Fell, J. C. Subject preferences and the nature of information stored in short-term memory. Journal of Experimental Psychology, 1969, 82(2), 193-197.
- Laughery, K. R., & Pinkus, A. L. Recoding and presentation rate in short-term memory. Journal of Experimental Psychology, 1968, 76(4, Pt. 1), 636-641.
- Laughery, K. R., & Harris, G. J. Visual and auditory intrusion errors in short-term memory. Journal of Experimental Psychology, 1970, 83(1, Pt. 1), 101-106.
- Laughery, K. R.; Harris, G. J., & Ulbricht, C. Visual similarity, presentation mode and presentation rate in a short-term memory recognition task. Psychonomic Bulletin, 1967, 1(2), 14-15.
- Lawrence, M.; Windsor, R. B., & Hegeman, J. S. Discrimination of a sound changing gradually in intensity. Journal of Aviation Medicine, 1949, 20, 211-220.
- Lawshe, C. H., Jr. The Purdue Industrial Training Classification Test. Journal of Applied Psychology, 1942, 26, 770-776.
- Lawson, R. B. Stereopsis and form disparity. Psychological Record, 1968, 18(3), 361-368.
- Leavitt, J. L. Motor learning task for changing degree of difficulty with minimal change in nature of task. Perceptual & Motor Skills, 1968, 27(3, Pt. 2), 1153-1154.

- Leckart, B. T., & Faw, T. T. Looking time: A bibliography. Perceptual & Motor Skills, 1968, 27, 91-95.
- Ledwith, F. The effects of hypoxia on choice reaction time and movement time. Ergonomics, 1970, 13, 465-482.
- Ledwith, F. The effects of hypoxia on an information-reduction task in humans. Psychonomic Science, 1968, 12(1), 29-30.
- Leeming, F. C. Effects of association value of trigrams and ITI on short-term memory. Psychonomic Science, 1968, 11(2), 67-68.
- Le Grand, Yves. The specification of luminous sources by the method of spectral bands. C. R. Acad. Sci. Paris, 1949, 228, 672-674.
- Lenox, J. R., & Lange, A. F. Validation of a corrected digital method of measuring changes in systolic blood pressure. Journal of Comparative & Physiological Psychology, 1969, 69(3), 454-458.
- Leonard, J. A. Tactual choice reaction: 1. Quarterly Journal of Experimental Psychology, 1959, 11, 76-83.
- Leont'ev, A. N., & Krinchik, E. P. On some properties of the process of information handling by man. Voprosy Psikhologii, 1962, 8(6), 14-25.
- Lepley, W. M. A miniature punch press. Journal of Psychology, 1947, 24, 209-210.
- Lerner, R. M. Brightness constancy and the span of apprehension. Perceptual & Motor Skills, 1968, 26(2), 442.
- Lesiw, W., & Goldstein, M. Relationships between size-matching test and pedestal sight gunnery performance. USAF Personnel Training Research Center Research Report, 1956, No. 56-29, vi, 16.
- Leslie, J. M., & Thompson, D. A. Human frequency response as a function of visual feedback delay. Human Factors, 1968, 10(1), 67-79.
- Lester, Gene. The Rod-and-Frame Test: Some comments on methodology. Perceptual & Motor Skills, 1968, 26(3, Pt. 2), 1307-1314.
- Leuba, H. R. Quantification in man-machine systems. Human Factors, 1964, 6, 556.
- Levine, F. J. Color-word test performance and drive regulation in three vocational groups. Journal of Consult. & Clinical Psychology, 1968, 32, 642-647.
- Levison, W. H.; Baron, S., & Kleinman, D. L. A model for human controller remnant. IEEE Transactions on Man-Machine Systems, 1969, MMS-10(4, Pt. 1), 101-108.

Levonian, E. Short-latency electrodermal reaction and traffic accidents. Perceptual & Motor Skills, 1967, 25(3), 913-916.

Levonian, E. Short-term retention in relation to arousal. Psychophysiology, 1968, 4(3), 284-293.

Lewis, M. F., & Mertens, H. W. Reaction time as a function of flash luminance and duration. Report No. AM 67-24, Federal Aviation Administration, Office of Aviation Medicine, Civil Aeromedical Institute, Oklahoma City, Oklahoma, Nov., 1967.

Lewinsohn, P. Some individual differences in physiological reactivity to stress. Journal of Compar. Physiol. Psychol., 1956, 49, 271-277.

Lewis, D., & Shephard, A. H. Devices for studying associative interference in psychomotor performance: 1. The modified Mashburn Apparatus. Journal of Psychology, 1950, 29, 35-46.

Lewis, M. F. Two-flash thresholds as a function of flash luminance and area. Perception & Psychophysics, 1968, 4, 241-244.

Lewis, M. R., & Mertens, H. W. Reaction time as a function of flash luminance and deviation. Office of Aviation Medicine Report, 1967, No. 67-24, 8.

Lewis, R. E.; de la Riviere, W. D., & Sweeney, D. M. Dual versus solo pilot navigation in helicopters at low level. Ergonomics, 1968, 11(2), 145-155.

Lhamon, W. T.; Edelberg, R., & Goldstone, S. A comparison of tactile and auditory time judgment. Perceptual & Motor Skills, 1962, 14(3), 366.

Lichtenstein, M.; White, C. T., & Harter, M. R. Note on estimation of short inter-flash intervals. Perceptual & Motor Skills, 1963, 17(3), 667-678.

Lichtenstein, M., & White, C. T. Relationships between inter-flash intervals at fusion, under conditions intended to eliminate neural "off" effects. Perceptual & Motor Skills, 1963, 17(3), 747-758.

Licklider, J. C. R. Basic correlates of the auditory stimulus. In S. S. Stevens (Ed.) Handbook of Experimental Psychology. J. Wiley & Sons: New York, 1951, 985-1039.

Lie, Ivar. Psychophysical invariants of achromatic colour vision: III. Colour constancy and its relation to identification of illumination. Scandinavian Journal of Psychology, 1969, 19(4), 269-281.

Lie, Ivar. Psychophysical invariants of achromatic colour vision: IV. Depth adjacency and simultaneous contrast. Scandinavian Journal of Psychology, 1969, 10(4), 282-286.

Lie, Ivar. Psychophysical invariants of acromatic colour vision: II. Albedo/illumination substitution. Scandinavian Journal of Psychology, 1969, 10(3), 176-184.

Lieblich, Israel, & Lieblich, Amia. Effects of different payoff matrices on arithmetical estimation tasks: An attempt to produce "rationality." Perceptual & Motor Skills, 1969, 29(2), 467-473.

Lightfoot, Charles. Contribution to the study of auditory fatigue. Journal of the Acoustical Society of America, 1955, 27, 356-364.

Lightfoot, Charles. Evaluation of threshold tracing audiometry as a method for studying effects of strong acoustic stimulation. USAF School of Aviation Med. Proj. Rep., 1955, No. 8, Proj. No. 21-1203-0001, p. 18.

Lightfoot, Charles, & Jerger, James F. Cumulative effects of repeated bursts of white noise on threshold for 4000-C.P.S. tone-pips. USAF School of Aviation Med. Proj. Rep., 1955, No. 10, Proj. No. 21-1203-0001, p. 10.

Lin Chung-Hsien. Some factors effecting the observation of stimuli from different directions. Acta Psychologica Sinica, 1963, 23(2), 113-120.

Lincoln, R. S. Rate accuracy in handwheel cranking. Journal of Applied Psychology, 1954, 38, 195-201.

Linden, Kathryn N., & Linden, J. D. Modern Mental Measurement: A Historical Perspective. Houghton Mifflin Co.: Boston, 1968, p. 114.

Lindsley, D. B., & Others. A study of performance under speed stress. OSRD, 1945; Publ. Bd., No. 18381. Washington, D.C.: U.S. Department of Commerce, 1946, p. 10.

Lippay, F., & Patzl, H. The dependence of the differential sensitivity of the kinesthetic sense upon the area of the cross-section of the active muscle. Pflüg. Arch. f. d. ges. Physiol., 1933, 231, 588-598.

Lister, A., & Bishop, J. W. Night vision in the Army: Report of 10,333 tests. British Medical Journal, 1943, 2, 325-327.

Liu, In-Mao. Response latency depends on response speed. Japanese Psychological Research, 1968, 10(4), 174-178.

Loch, W. E., & Haines, H. L. Habituation to caloric vestibular stimulation. Laryngoscope, St. Louis, 1946, 56, 43-45.

Locke, E. A. Effects of knowledge of results, feedback in relation to standards, and goals on reaction time performance. The American Journal of Psychology, 1968, 81, 566-574.

Locke, E. A., & Bryan, J. F. Goal-setting as a determinant of the effect of knowledge of score on performance. American Journal of Psychology, 1968, 81, 398-406.

Lockhart, J. H. Extreme body cooling and psychomotor performance. Ergonomics, 1968, 11(3), 249-260.

- Loeb, M. The influence of intense noise on performance of a precise fatiguing task. U.S.A. Med. Res. Lab. Rep., 1957, No. 268.
- Loeb, M., & Binford, J. R. Variation in performance on auditory and visual monitoring tasks as a function of signal and stimulus frequencies. Perception & Psychophysics, 1968, 4, 361-367.
- Loeb, M. A preliminary investigation of the effects of whole-body vibration and noise. U.S. Army Med. Res. Lab. Rep., 1954, No. 145, 1, 17, 11.
- Loeb, M., & Binford, J. R. Examination of some factors influencing performance on an auditory monitoring task with one signal per session. Journal of Experimental Psychology, 1970, 83(1, Pt. 1), 40-44.
- Loeb, M., & Fletcher, J. L. Impulse duration and temporary threshold shift. Journal of the Acoustical Society of America, 1968, 44(6), 1524-1528.
- Loess, H., & McBurney, Judith. Short-term memory and retention-interval activity. Proceedings of the 73rd Annual Convention of the American Psychological Association, 1965, 85-86.
- Loess, H., & Harris, R. Short-term memory for individual verbal items as a function of method of recall. Journal of Experimental Psychology, 1968, 78(1), 64-69.
- Loken, R. D. The color-meter: A quantitative color-vision test. American Journal of Psychology, 1942, 55, 563-568.
- Lothridge, C. D. Stereoscopic settings as functions of vertical disparity and target declination. Journal of General Psychology, 1953, 49, 241-260.
- Loucks, R. B. An evaluation of various psychological performance tests for altitude chamber research. AAF School of Aviat. Med., 1944; Publ. Bd., No. 15515. Washington, D.C.: U.S. Department of Commerce, 1946, p. 30.
- Loveless, N. E., & Holding, D. H. Reaction time and tracking ability. Perceptual & Motor Skills, 1959, 9(2), 134.
- Lovrinic, Jean H.; Burgi, E. J., & Curry, E. T. A comparative evaluation of five speech discrimination measures. Journal of Speech & Hearing Research, 1968, 11(2), 372-381.
- Low, F. N. Studies on peripheral visual acuity. Science, 1943, 586-587.
- Low, F. N. Effect of suprathreshold changes in brightness on form perception. American Journal of Physiology, 1948, 155, 409-419.
- Low, M. D., & Mc Sherry, J. W. Further observations of psychological factors involved in CNV genesis. Electroencephalography & Clinical Neurophysiology, 1968, 25(3), 203-207.

- Lowry, E. M. Some experiments with binocular and monocular vision. Journal of the Optical Society of America, 1929, 18, 29-40.
- Loy, A. W. The value of peripheral vision in depth perception as applied to aviation. U.S. Naval Med. Bulletin, 1930, 28, 13-18.
- Luce, R. D., & Green, D. M. Detection of auditory signals presented at random times: II. Perception & Psychophysics, 1970, 7(1), 1-14.
- Luchins, A. S. The autokinetic effect and gradations of illumination of the visual field. Journal of General Psychology, 1954, 50, 29-37.
- Luchins, A. S., & Luchins, Edith H. The Einstellung phenomenon and effortfulness of task. Journal of General Psychology, 1954, 50, 15-27.
- Luckiesh, M., & Moss, F. K. The dependency of visual acuity upon stimulus-distance. Journal of the Optical Society of America, 1933, 23, 25-29.
- Luckiesh, M., & Moss, F. K. A visual thresholdometer. Journal of the Optical Society of America, 1934, 24, 305-307.
- Luckiesh, M., & Taylor, A. H. Visual acuity at low brightness-levels. American Journal of Ophthalmology, 1944, 27, 53-57.
- Ludvig, Elek. The influence of dynamic visual acuity on the visibility of stationary objects viewed from an aircraft flying at constant altitude, velocity, and direction. U.S. Naval School of Aviation Med. Res. Rep., 1953, Proj. No. NM 001 075.01.03, Joint Report No. 3, 4.
- Lukin, L.; Polissar, M. J., & Ralston, H. J. Methods for studying energy costs and energy flow during human locomotion. Human Factors, 1967, 9(6), 603-608.
- Luschei, E.; Saslow, C., & Glickstein, M. Muscle potentials in reaction time. Experimental Neurology, 1967, 18, 429-442.
- Luthe, W. An apparatus for the analytical study of handwriting movements. Canadian Journal of Psychology, 1953, 7, 133-139.
- Lutze, E. Experiments concerning the impression of absolute size. Zsch. f. Psychol., 1931, 119, 272-310.
- Lynch, J. I. Exercise tolerance studies in an artificial atmosphere under increased barometric pressure. USN Submarine Med. Center Res. Rep., 1964, No. 11, Proj. MR 005.14-3002-4.
- Lynn, G. E. A test to detect collapse of the external ear canal during audiometry. Journal of Speech & Hearing Disorders, 1967, 32(3), 273-274.
- MacDougall, R. On the influence of varying intensities and qualities of visual stimulation upon the rapidity of reaction to auditory stimuli. American Journal of Physiology, 1903, 9, 116-121.
- Mackavey, W. R. Spatial brightness changes in Koffka's ring. Journal of Experimental Psychology, 1969, 82(3), 405-409.

- Mackworth, N. H. Researches on the Measurement of Human Performance. Medical Research Council Special Report Series No. 268 (38 Old Queen Street, London, S.W.1); London: His Majesty's Stationery Office, 1950, Privy Council, p. 13, 43, 97-98. P. 53, 64, 65, 66, 99, 102, 103, 104, 121-124, 131-132, 130.
- Mac Corquodale, K. Effects of angular acceleration and centrifugal force on nonvisual space orientation during flight. Journal of Aviation Med., 1948, 146-157.
- Mackworth, N. H., & Millikan, Jane. Factors determining the visual selection of information within pictures. Psychonomic Bulletin, 1967, 1(2), 9.
- Mager, N. H. Practice tests for all jobs: Army, Navy, Air Corps, Government service, industry. New York: Crown, 1943. Pp. viii and 248.
- Maier, Norman R., & Thurber, James A. Innovative problem-solving by outsiders: A study of individuals and groups. Personal Psychology, 1969, 22(3), 237-249.
- Maltzman, I., & Morrisett, L., Jr. The effects of single and compound classes of anagrams on set solutions. Journal of Experimental Psychology, 1953, 45, 345-350.
- Maltzman, I., & Morrisett, L., Jr. Effects of task instructions on solution of different classes of anagrams. Journal of Experimental Psychology, 1953, 45, 351-354.
- Mandy-van Moerbeke, Marie P. Stroboscopic movement and modifications of intensity of the initial stimulus. Journal de Psychologie Normale et Pathologique, 1968, 65(4), 389-419.
- Man'kovskii, V. S. The influence of visual perception upon auditory localization of a sound source. Voprosy Psikhologii, 1969, 15(4), 57-65.
- Mann, C. W., & Boring, R. O. The role of instruction in experimental space perception. Journal of Experimental Psychology, 1953, 45, 44-48.
- Mansueto, C. S., & Adevia, G. Development and evaluation of a portable rod and frame test. Journal of Psychosomatic Research, 1967, 11(2), 207-211.
- Marion, R. Apparatus for studying three-dimensional motor skill. Perceptual & Motor Skills, 1955, 5, 19-22.
- Marks, Lawrence E. Brightness as a function of retinal locus in the light-adapted eye. Psychonomic Bulletin, 1967, 1(2), 4.
- Markstein, R. Ocular fatigue in terms of a differential measure. Indus. Psychotechn., 1932, 9, 65-78.
- Marteniuk, R. G. Differential effects of shock arousal on motor performance. Perceptual & Motor Skills, 1969, 29(2), 443-447.

- Martin, L. C., & Kaniowski, W. Flash visual acuity. Nature, London, 1947, 159, 25-26.
- Martin, L. C., & Pearse, R. W. B. The comparative visual acuity and ease of reading in white and coloured light. British Journal of Ophthalmology, 1947, 31, 129-144.
- Massaro, D. W. Retroactive interference in short-term recognition memory for pitch. Journal of Experimental Psychology, 1970, 83(1, Pt. 1), 32-39.
- Matheny, W. G., & Norman, D. A. The effective time constant in tracking behavior. NAVTRADEVCEEN Technical Report, 1968, No. 67-C-0034-3, 1-56.
- Mata, L. Psychophysical tests during flight; preliminary report. Rev. Sanid. Milit., B. Aires, 1941, 40, 314-317.
- Mathewson, J. W.; Miller, J. C., Jr., & Crovity, H. F. The letter span in space and time. Psychonomic Science, 1968, 11(2), 69-70.
- Matthews, M. L. Visual size differences discrimination: Effect of disc size and retinal locus. Perception & Psychophysics, 1969, 6(3), 160-162.
- Mavrides, Cynthia M., & Brown, D. R. Discrimination and reproduction of patterns: Feature measures and constraint redundancy as predictors. Perception & Psychophysics, 1969, 6(5), 276-280.
- Mays, L. L. A device for recording skin resistance with the electroencephalograph instrument. EEG Clin. Neurophysiol., 1953, 5, 313-316.
- Mayzner, M. S., & Schoenberg, K. M. Short-term retention and presentation rate. Psychonomic Science, 1965, 2(4), 111-112.
- Mc Allister, Dorothy Elsey. The effects of various kinds of relevant verbal pretraining on subsequent motor performance. Journal of Experimental Psychology, 1953, 46, 329-336.
- Mc Cleary, R. A. Palmar sweat as an index of anxiety: A field method suitable for large groups. USAF School of Aviat. Med. Proj. Rep., 1953, Proj. No. 21-1207-0004, Rep. No. 1, iii, 10.
- Mc Cleary, R. A. Psychophysiological effects of cold. 1. The role of skin-temperature and sensory sensitivity in manual performance decrement. USAF School of Aviat. Med. Proj. Rep., 1953, Proj. No. 21-1202-7004, Rep. No. 1, 16.
- Mc Cleary, R. A. A simple method for the physiological measurement of anxiety. Journal of Aviat. Med., 1953, 24, 508-513; 535.
- Mc Clure, G., & Smith, K. Simultaneous brightness contrast as a function of repeated trials. Psychonomic Science, 1969, 16(6), 314-315.
- Mc Cluskey, M. R.; Wright, A. D., & Frederickson, E. W. Studies on training ground observers to estimate range to aerial targets. HumRRO Technical Report, 1968, No. 68-5, xi, 52.

- McCormick, Ernest J., & Niven, Jarold R. The effect of varying intensities of illumination upon performance on a motor task. Journal of Applied Psychology, 1952, 36, 193-195.
- Mc Cormack, P. D.; Binding, F. R. S., & Chylinski, J. Effects on reaction time of knowledge of results of performance. Perceptual and Motor Skills, 1962, 14, 367-372.
- Mc Farland, A. The psychological effects of oxygen deprivation (anoxemia) on human behavior. Archives of Psychology, No. 145, 1932.
- Mc Graw, E. R.; Kleinman, K. M.; Brown, Marjorie L., & Korol, B. An accurate one channel basal level/response signal separator for skin resistance, incorporating pulse coding of the basal level. Psychophysiology, 1969, 6(2), 209-213.
- Mc Guire, J. C. Apparatus for presentation and continuous measurement of error in a two-dimensional compensatory tracking task. USAF WADC Tech. Rep., 1954, No. 54-335, v, 25.
- Mc Kenzie, R. E., & Elliott, Lois L. The effects of secobarbital and d-amphetamine on performance during a simulated tactical air mission. USAF SAM TDR No. 64-79, 11.
- Mc Kinney, J. P. Handedness, eyedness, and perceptual stability of the left and right visual fields. Neuropsychologia, 1967, 5, 339-344.
- Mc Laughlin, S. C., Jr. An automatic-recording visual adaptometer. Journal of the Optical Society of America, 1954, 44, 312-314.
- Mc Pherson, A., & Renfrew, S. Asymmetry of perception of size between the right and left hands in normal subjects. Quarterly Journal of Experimental Psychology, 1953, 5, 66-74.
- Mc Quire, J. C., & Kraft, C. L. Reaction of ten radar air traffic controllers to operational use of the telex twin-microphone, boom-type, split headset. USAF WADC Tech. Note, 1956, No. 56-541, iii, 10.
- Mech, E. V. Factors influencing routine performance under noise: 1. The influence of "set." Journal of Psychology, 1953, 35, 283-298.
- Medrow, W. A group test for color sensitivity for use in the German federal postal service. Indus. Psychotechn., 1932, 9, 94-95.
- Mefferd, R. B., Jr., & Wieland, Betty A. Apparent size-apparent distance relationships in flat stimuli. Perceptual & Motor Skills, 1968, 26(3, Pt. 1), 959-966.
- Meier, M. J., & Story, J. L. Selective impairment of Porteus Maze Test performance after right subthalamotomy. Neuropsychologia, 1967, 5(2), 181-189.

- Merikle, P. M. Processing capacity and short-term memory. Psychonomic Science, 1969, 17(6), 363-364.
- Merryman, J. G., & Allen, H. E. An improved electronic tachistoscope. American Journal of Psychology, 1953, 66, 110-114.
- Messerli, P. Tachistoscopic study of a complex figure. Revue de Psychologie Appliquée, 1969, 19(1), 1-15.
- Metfessel, M. The strobophotograph: A device for measuring pitch. Journal of General Psychology, 1929, 2, 135-139.
- Meyer, Max F. Auditory fatigue beyond and within the compass of the voice. American Journal of Psychology, 1954, 67, 538-543.
- Meyer, V.; Gross, C. G., & Teuber, H. Effect of knowledge of site of stimulation on the threshold for pressure sensitivity. Perceptual & Motor Skills, 1963, 16(3), 637-640.
- Michon, J. A. Studies on subjective duration: I. Differential sensitivity in the perception of repeated temporal intervals. Acta Psychologica, Amsterdam, 1965, 22(4), 441-450.
- Miles, P. W. Flicker fusion fields: II. Technique and Interpretation. American Journal of Ophthalmology, 1950, 33, 1069-1077.
- Miles, P. W. An analysis of depth factors in anisopia and anisodominance. American Journal of Ophthalmology, 1954, 37, 98-106.
- Miles, P. W. Factors in the diagnosis of aniseikonia and paired Maddox-rod tests. American Journal of Ophthalmology, 1947, 30, 885-897.
- Miles, P. W. Anomalous binocular depth perception due to unequal image brightness. A.M.A. Arch. Ophthalmology, 1953, 50, 475-478.
- Miles, W. Night vision: Flying demands light sensitivity and form acuity. Yale Sci. Mag., 1943, 18, 10-11; 28; 30.
- Miles, W. R. Comparison of functional and structural areas in human fovea. I. Method of entopic plotting. Journal of Neurophysiology, 1954, 17, 22-38.
- Miller, A. L., & Baker, R. A. The effects of shape, size, heterogeneity, and instructional set on the judgment of visual number. American Journal of Psychology, 1968, 81(1), 83-91.
- Miller, E. E.; Sheldon, R. W., & Bjorklund, J. F. Supplementary feedback: An explanation and experimental test. HumRRO Technical Report, 1969, No. 68-13, 16.
- Miller, J. G. The development of experimental stress-sensitive tests for predicting performance in military tasks. Technical Research Report PRB 1079, Contract DA-49-083 OSA-611 8-8-154, Adjutant General's Office, Department of the Army. Psychological Research Association, Washington, D.C., Oct., 1953. AD 23 189.

- Miller, James W., & Bartley, S. Howard. A study of object shape as influenced by instrumental magnification. Journal of General Psychology, 1954, 50, 141-146.
- Miller, J. W., & Ludvigh, E. Dynamic visual acuity when the required pursuit movement of the eye is in a vertical plane. U.S. Naval School of Aviation Med. Res. Rep., 1953, Proj. No. NM 001 075.01.02, (Joint Proj. Rep. No. 2), 5.
- Miller, R. L. Masking effect of periodically pulsed tones as a function of time and frequency. Journal of the Acoustical Society of America, 1947, 19, 798-807.
- Mirabella, A., & Goldstein, D. A. The effects of ambient noise upon signal detection. Human Factors, 1967, 9, 277-284.
- Mishima, Jiro. On the measurement of the mental tempo. Journal of Child Development, 1968, 4, 55-63.
- Misiak, H. The flicker-fusion test and its applications. Transactions of the N.Y. Academy of Sciences, Series II, 1967, 29, 616-622.
- Misiak, H., & Rzy, E. F. The effects of dextroamphetamine and phenobarbital on a simplified standardized CFF measure. Psychopharmacologia, 1968, 13, 346-353.
- Misiak, H.; Zenhausen, R., & Salafia, W. R. Continuous temporal evaluation of the effect of meprobamate on critical flicker frequency in normal subjects. Psychopharmacologia, 1966, 9, 457-461.
- Mita, T.; Abe, Z., & Byonshik, T. On the essential factors of Motokawa's method for measuring fatigue. Tohoku Journal of Exp. Med., 1951, 54, 45-52.
- Mizusawa, Kiyoe. Time sense apparatus. Japanese Journal of Psychology, 1950, 20(4), 18-22.
- Moldawsky, S., & Moldawsky, P. C. Digit span as an anxiety indicator. Journal of Consult. Psychol., 1952, 16, 115-118.
- Monjauze, R.; Plas, F.; Verdeaux, G.; Verdeaux, J.; Bourdinaud, J.; Missenard, A., & Le Febvre, R. Clinical research on the subject of a test on aviator's fatigue.
- Monnier, M. Principles of human "electro-oculograms" and "electro-nystagmograms". Bulletin Schweiz. Akad. Med. Wiss., 1952, 8, 413-425.
- Montague, W. E., & Hillix, W. A. Intertrial interval and proactive interference in short-term motor memory. Canadian Journal of Psychology, 1968, 22(2), 73-78.
- Montague, W. E.; Hillix, W. A.; Kiess, H. O., & Harris, R. Variation in reports of covert rehearsal and in STM produced by differential payoff. Journal of Experimental Psychology, 1970, 83(2, Pt. 1), 249-254.

- Montoye, H. J. The 'Harvard Step Test' and work capacity. Rev. Canad. Biol., 1953, 11, 491-499.
- Moore, T. J. Vibratory stimulation on the skin by electrostatic field: Effects of size of electrode and site of stimulation on thresholds. American Journal of Psychology, 1968, 81, 235-240.
- Morant, G. M. Body measurements in relation to work spaces in aircraft. In NATO ..., Anthropometry and Human Engineering, (see 39:6639), 3-17.
- Morgan, M. W. The direction of visual lines when fusion is broken as in duction tests. American Journal of Optometry, 1947, 24, 8-12.
- Morrell, Leonore K. Cross-modality effects upon choice reaction time. Psychonomic Science, 1968, 11(4), 129-130.
- Morrell, L. K. Intersensory facilitation of reaction time. Psychonomic Science, 1967, 8, 77-78.
- Morrell, L. K. Cross-modality effects upon choice reaction time. Psychonomic Science, 1968, 11, 129-130.
- Morrell, L. K. Temporal characteristics of sensory interaction in choice reaction times. Journal of Experimental Psychology, 1968, 77(1), 14-18.
- Mortimer, R. G.; Russell, R. E., & Tiffin, J. A device for the measuring of tracking performances. American Journal of Psychology, 1964, 77(1), 123-126.
- Morton, John. Categories of interference: Verbal mediation and conflict in card sorting. British Journal of Psychology, 1969, 60(3), 329-346.
- Moss, F. A.; Roe, J. H.; Hunter, O. B.; French, L., & Hunt, T. The measurement of fatigue by physiological methods. Journal of Experimental Psychology, 1931, 14, 423-438.
- Motokawa, Kioti. Retinal traces and visual perception of movement. Journal of Experimental Psychology, 1953, 45, 369-377.
- Motokawa, K., & Ebe, M. The physiological mechanism of apparent movement. Journal of Experimental Psychology, 1953, 45, 378-386.
- Moul, E. R. An experimental study of visual and auditory 'thickness.' American Journal of Psychology, 1930, 43, 544-560.
- Moyer, R. S., & Landauer, T. K. Time required for judgments of numerical inequality. Nature, 1967, 215(5109), 1519-1520.
- Mudd, S. Assessment of the fidelity of dynamic flight simulators. Human Factors, 1968, 10, 351-358.
- Mueller, C. G., & Lloyd, V. V. Stereoscopic acuity for various levels of illumination. Proc. Nat. Acad. Sci., Wash., 1948, 34, 223-227.

- Muenzinger, K. F. The function of electric shock in the visual discrimination habit. Psychol. Bulletin, 1933, 30, 703.
- Mullins, Cecil J. Comparison of instructor aptitude test scores and general aptitude indexes achieved by a sample of basic airmen. USAF PRL Tech. Docum. Rep., 1962, No. 62-21, 3.
- Murdock, Bennet B., Jr. Serial order effects in short-term memory. Journal of Experimental Psychology, 1968, 76(4, Pt. 2), 1-15.
- Murdock, Bennet B., & Walker, Keith D. Modality effects in free recall. Journal of Verbal Learning & Verbal Behavior, 1969, 8(5), 665-676.
- Murphy, E. H., & Venables, P. H. The investigation of ear asymmetry by simple and disjunctive reaction-time tasks. Perception & Psychophysics, 1970, 8, 104-106.
- Murphy, R. E. Effects of threat of shock, distraction, and task design on performance. Journal of Experimental Psychology, 1959, 58, 134-141.
- Murray, H. G. Stimulus intensity and reaction time: Evaluation of a decision-theory model. Journal of Experimental Psychology, 1970, 84, 383-391.
- Myers, I.; Murphy, B.; Smith, S., & Windle, C. Experimental assessment of a limited sensory and social environment: Summary results of the HumRRO Program Research Memorandum, Task PIONEER VI, U.S. Army Leadership Human Research Unit, Presidio of Monterey, Cal., Feb., 1962. AD 653 786.
- Nachmias, J. Figural aftereffects in kinesthetic space. American Journal of Psychology, 1953, 66, 609-612.
- Nance, Roy Dale, & Others. The effect of distraction lights upon performance on the Mashburn serial coordination test. CAA Div. Res. Rep. No. 29, 1944; Publ. Bd. No. 50307. Washington, D.C.: U.S. Department of Commerce, 1947, p. 31.
- National Center for Health Statistics. Binocular visual acuity of adults. Vital and Health Statistics, PHS Pub. No. 1000--Series 11, No. 3, Public Health Service, Washington, D.C., June, 1964.
- National Center for Health Statistics. Comparison of two vision-testing devices. Vital and Health Statistics, PHS Pub. No. 1000--Series 2, No. 1, Public Health Service, Washington, D.C., June, 1963.
- National Health Survey, 1935-1936. Normal hearing by air and bone conduction. Hearing Study Series, Bulletin No. 4, 1938.
- National Research Council, Committee on Undersea Warfare. Panel on psychology and physiology. A survey report on human factors in undersea warfare. Washington: National Research Council, 1949, x, 541.
- Naylor, G. F. K. Effects of stress on the perception of direction. Australian Journal of Psychology, 1963, 15(1), 17-28.

- Naylor, J. C., & Carroll, R. M. A test of the progression-regression hypotheses in a cognitive inference task. Organizational Behavior and Human Performance, 1969, 4(4), 337-352.
- Nazzaro, James Russell. The bisection of a visual extent. American Journal of Psychology, 1964, 77(3), 403-413.
- Neely, J. C. A speed-of-perception measurement apparatus. British Journal of Ophthalmology, 1953, 37, 439-443.
- Neubert, F. R. Colour vision in the consulting room. British Journal of Ophthalmology, 1947, 31, 275-288.
- Newbrough, J. R. Performance of brain-damaged subjects on an auditory flutter fusion technique. Perceptual & Motor Skills, 1968, 27, 390.
- Newbrough, J. R., & Beck, E. C. A new apparatus for recording and a method for scoring autokinetic movement. Perceptual & Motor Skills, 1962, 15(3), 755-757.
- Nickerson, R. S.; Collins, A. M., & Markowitz, J. Effects of uncertain warning signals on reaction time. Perception & Psychophysics, 1969, 5, 107-112.
- Nickerson, R. S. The effect of preceding and following auditory stimuli on response times to visual stimuli. Acta Psychologica, 1970, 33, 5-20.
- Nickerson, R. S. Response time to the second of two signals following varied vs. constant intersignal intervals. Perception & Psychophysics, 1968, 4(2), 78-80.
- Niven, J. I.; Johnson, W.; Rand, G. W., & Pettit, W. A. Evaluation of a modified Verhoeff stereopter. U.S. Naval School of Aviation Med. Res. Rep., 1952, Proj. No. NM 001 057.09.01, 10.
- Nixon, C. W.; Mabson, W. E.; Trimboli, F., & Welch, B. E. Speech in an artificial atmosphere (30. helium--70. oxygen). USAF AMRL Technical Report, 1967, No. 67-125, vi, 27.
- Nixon, C. W., & Waggoner, C. E. Speech during weightlessness. USAF MRL Tech. Docum. Rep., 1962, No. 62-45, iii, 10.
- Noble, C. E.; Alcock, W. T., & Frye, R. L., Jr. The joint influence of practice and instructions on discrimination reaction time. Journal of Psychology, 1959, 48, 125-130.
- Noble, C. E.; Fuchs, J. E., & Thompson, J. D. A new automatic circuit for the Selective Mathometer (MK II). Journal of Psychology, 1963, 55(2), 241-257.
- Nomikos, H. S.; Opton, E.; Averill, J. R., & Lazarus, R. S. Surprise versus suspense in the production of stress reaction. Journal of Personality and Social Psychology, 1968, 8(2, Pt. 1), 204-208.

- Norman, Joyce L., & Kiker, Vernon L. Non-visual estimation of near space: A ratio scale. Perceptual & Motor Skills, 1969, 29(2), 451-459.
- Norris, Mary J. Effect of practice on true score and intra-individual variability for reaction and movement times for simple and complex movements. Research Quarterly, 1967, 38(3), 457-467.
- Nystrom, Charles O., & Grant, David A. Performance on a key pressing task as a function of the angular correspondence between stimulus and response elements. USAF, WADC Tech. Rep., 1954, No. 54-71, v, 16.
- Oatman, L. C., & Price, G. R. Rule of tonal relevance in auditory fatigue. Journal of the Acoustical Society of America, 1968, 43(1), 166-167.
- O'Brien, Brian, & Miller, Norma D. A study of the mechanisms of visual acuity in the central retina. USAF, WADC Tech. Rep., 1953, No. 53-198, iv, 54.
- Ogasawara, J. Phenomenal pathway of the apparent movement. Japanese Journal of Psychology, 1937, 12, 205-208.
- O'Connor, J. Administration and norms of the Finger Dexterity Test, Worksample 16. Human Engineering Laboratory, Technical Report No. 16, mimeographed. Stevens Institute of Technology, Hoboken, New Jersey, 1938.
- O'Connor, J. Born That Way. Baltimore: Williams and Wilkins, 1928.
- Ogilvie, John, & Daicar, Eva. The perception of curvature. Canadian Journal of Psychology, 1967, 21(6), 521-525.
- Ogle, K. N. Optics and visual physiology. A.M.A. Arch. Ophthalm., 1952, 47, 801-830.
- Ogle, K. N. Precision and validity of stereoscopic depth perception from double images. Journal of the Optical Society of America, 1953, 43, 906-913.
- Ogle, K. N., & Schwartz, J. T. Depth of focus of the human eye. Journal of the Optical Society of America, 1959, 49, 273-280.
- Ognjenović, Predrag. Pain and protopathic sensitivity. Psihologija, 1967, 1(1), 43-46.
- Ohwaki, Yoshikazu. Absoluteness of an absolute judgment on a contrast effect brought about by a series of different kinds of preceding stimuli upon an absolute judgment of a lifted weight. Toh. Psychol., Folia 1950, 12(1-2), 1-13.
- Oleron, Genevieve. Influence of the intensity of a sound on the estimation of duration. Annee Psychol., 1952, 52, 383-396.
- O'Hare, J. J.; Harris, J. D.; Ehmer, R. H., & Cohen, B. H. Some primary auditory abilities in pitch and loudness. USN MRL Rep., 1959, 18(11, Whole No. 316), 7.

- shannikova, A. E. The influence of deviation of work on the dependence reaction time on the intensity of a visual stimulus. Voprosy Psikhologii, 3, 9(6), 52-62.
- havsky, R. W., & Gregg, L. W. Information processing rates and task plexity. Journal of Experimental Psychology, 1970, 83(1, Pt. 1), 131-135.
- on, R., & Schwartz, R. Single and multiple solution five-letter words. Psychonomic Monograph Supplements, 1967, 2(8), 105-152.
- man, P. K. A portable rod-and-frame apparatus. Perceptual & Motor Skills, 8, 26(2), 503-506.
- el, T. W., & Hardy, J. D. Studies in temperature sensation. 1. A comparison of the sensation produced by infra-red and visible radiation. Journal of Optical Investigation, 1937, 16, 517-524.
- ach, J., & Solhknah, N. Size judgments of disks presented against the sky. Perceptual & Motor Skills, 1968, 26(2), 371-374.
- nstein, H. B. Reaction time as a function of perceptual bias, response s, and stimulus discriminability. Journal of Experimental Psychology, 1960, 86, 38-42.
- iston, D. W., & Finkelstein, B. The effects of confinement on intellectual perceptual functioning. Aeronautical Systems Division TR 61-577, Aerospace Medical Laboratory, AF Systems Command, USAF, Wright-Patterson AFB, Ohio, 1961.
- on, W. O., & Oplinger, K. A. A new portable meter for noise measurement analysis. Journal of the Acoustical Society of America, 1933, 5, 39-45.
- lak, M. S., & Kiesler, C. A. Dissonance arousal, task evaluation, and task performance. Psychonomic Science, 1968, 11(6), 197-198.
- ducci, A. Range-frequency compromise in judgment. Psychol. Monographs, 1933, 77(2, Whole No. 565), 1-29.
- ducci, A., & Sandusky, A. J. Limits on the applicability of signal detection theories. Perception & Psychophysics, 1970, 7(1), 63-64.
- ducci, A.; Thaler, H., & Anderson, N. H. Stimulus averaging and the context for judgment. Perception & Psychophysics, 1968, 3(2-B), 145-150.
- ker, David M. Effects of seasickness on error scores in mirror tracing. Journal of General Psychology, 1969, 81(1), 147-151.
- ker, J. F. Use of an engineering analogy in the development of tests to predict tracking performance. Office of Naval Research Contract Nonr-3065(00). Matrix Corp., Arlington, Va. Feb., 1964. AD 602 861.

- Parker, J. F. The identification of performance dimensions through factor analysis. Human Factors, 1967, 9, 367-373.
- Parker, J. F., & Fleishman, E. A. Prediction of advanced levels of proficiency in a complex tracking task. WADC Technical Report 59-255, Contract AF41(657)-64, Aerospace Med. Lab., Wright Air Dev. Div., ARDC, Wright-Patterson AFB, Ohio, Dec., 1959. AD 236 907.
- Parker, J. F., & Fleishman, E. A. Ability factors and component performance measures as predictors of complex tracking behavior. Psychol. Monographs, 1960, 74, Whole No. 503, 1-36.
- Parker, J. F.; Reilly, R. E.; Dillon, R. F.; Andrews, T. G., & Fleishman, E. A. Development of tests for measurement of primary perceptual-motor performance. NASA CR-335, Dec., 1965.
- Parker, J. W. The Response Analysis Tester (RATER) and Logical Inference Tester (LOGIT): II. Additional pilot study data. U.S. Naval Submarine Medical Center Report, 1968, No. 525, 5.
- Parks, R. B.; Wood, E. D., & Perkins, D. R. Development of the flexible gunnery proficiency evaluator. USAF Human Resources Research Center Technical Report, 1953, No. 53-23, v, 14.
- Parsons, O. A.; Phillips, L., & Lane, J. E. Performance on the same psychomotor task under different stressful conditions.- Journal of Psychology, 1954, 38, 457-466.
- Pascal, J. I. An improved perimeter-campimeter. Arch. Ophthal., Chicago, 1936, 16, 103-105.
- Pasnau, R. O.; Naitoh, P.; Stier, Serena, & Kollar, E. J. The psychological effects of 205 hours of sleep deprivation. Archives of General Psychiatry, 1968, 18(4), 496-505.
- Pauling, K. Touch measurements using a joint. Zsch. f. Sinnesphysiol., 1934, 65, 189-214.
- Payne, D. T.; Parry, M. E., & Harasymiw, S. J. Percentage of pupillary dilation as a measure of item difficulty. Perception & Psychophysics, 1968, 4(3), 139-143.
- Payne, R. B. The effects of drugs upon psychological efficiency. Journal of Aviat. Med., 1953, 24, 523-529.
- Payne, R. B., & Hauty, G. T. The effects of motion-sickness preventives upon certain perceptual-motor components of the pilot's task. USAF School of Aviat. Med. Proj. Rep., 1953, Proj. No. 21-1601-004, Report No. 3, iii, 4.
- Payne, R. B., & Hauty, G. T. The pharmacological control of work output during prolonged tasks. USAF School of Aviation Med. Proj. Rep., 1953, Proj. No. 21-1601-0004, Report No. 2, iii, 11.
- Payne, W. H. Reaction time as a function of retinal location. Vision Research, 1966, 7, 729-732.

- Payne, W. H. Visual reaction times on a circle about the fovea. Science, 1967, 155, 481-482.
- Pazos Abelenda, Libia E. Tests of fatigue. Arch. Lab. Psicopedagog., Montevideo, 1949, 5, 188-203.
- Peacock, L. J. A field study of rifle aiming steadiness and serial reaction performance as affected by thermal stress and activity. U.S. Army Med. Res. Lab. Rep., 1956, No. 231, ii, 9.
- Pearce, D. G., & Abel, Sharon M. Autokinesis of an intermittent luminance. Perceptual & Motor Skills, 1967, 25(1), 278-280.
- Pearson, L. A., & Tong, J. E. Two-flash fusion threshold: The influence of age, psychophysical method, instructions, viewing conditions, sex, and subject variability. British Journal of Psychology, 1968, 59, 407-414.
- Pearson, R. G. Task proficiency and feelings of fatigue. USAF School of Aviat. Med. Rep., 1957, No. 57-77, 5.
- Pease, V. P., & Sticht, T. G. Reaction time as a function of onset and offset stimulation of the fovea and periphery. Perceptual and Motor Skills, 1965, 20, 549-554.
- Peluffo, N. Constructions of relations and classes and their use in problem solving. Rivista di Psicologia Sociale e Archivio Italiano di Psicologia Generale e del Lavoro, 1969, 36(2-3), 109-142.
- Pepper, R. L., & Herman, L. H. Decay and interference effects in the short-term retention of a discrete motor act. Journal of Experimental Psychology, 1970, 83(2, Pt. 2), 1-18.
- Peretti, P. O. Effects on reaction time of random-false knowledge of results of performance. Perceptual and Motor Skills, 1970, 30, 838.
- Perrin, Fred H. A study in binocular flicker. Journal of the Optical Society of America, 44, 60-69.
- Peterson, L. R.; Johnson, Suzanne T., & Coatney, R. The effect of repeated occurrences on judgments of recency. Journal of Verbal Learning & Verbal Behavior, 1969, 8(5), 591-596.
- Pfaffman, C. International Symposium on Olfaction and Taste, III. New York: Rockefeller University Press, 1969.
- Pfaffman, C. Taste and smell. In S. S. Stevens (Ed.) Handbook of Experimental Psychology. New York: Wiley, 1951.
- Pfafflin, Sheila M. Detection of auditory signal in restricted sets of reproducible noise. Journal of the Acoustical Society of America, 1968, 43(3), 487-490.

Phelan, J. G., & Gustafson, C. W. Reversal and nonreversal shifts in acute brain-injured with injury diffusely localized. Journal of Psychology, 1968, 70, 249-259.

Phelps, J., & Zubek, J. P. The effect of prolonged visual deprivation on various cutaneous and auditory measures. Psychonomic Science, 1969, 14, 194-195.

Phillips, Laura W.; Griswold, R. L., & Pace, N. Cognitive changes at high altitude. Psychological Reports, 1963, 13(2), 423-430.

Pierce, W. O'D. The selection of colour workers. Human Factors, 1934, 8, 286-290.

Pieron, H. Vision in intermittent light. In W. D. Neff (Ed.) Contributions to Sensory Physiology. Academic Press: New York, 1965.

Pierson, W. R. Noise and aircrew effectiveness. Aerospace Med., 1971, 42(8), 861-864.

Pierson, W. R., & Rasch, P. J. Generality of a speed factor in simple reaction and movement time. Perceptual and Motor Skills, 1960, 11, 123-128.

Pierson, W. R., & Rich, G. Q. Energy expenditure and fatigue during simple repetitive tasks. Human Factors, 1967, 9(6), 563-566.

Pigg, Leroy D., & Kama, William N. Visual acuity in relation to body orientation and G-vector. USAF MRL Tech. Docum. Rep., 1962, No. 62-74, iii, 14.

Pilisuk, M.; Skolnick, P., & Overstreet, E. Predicting cooperation from the two sexes in a conflict simulation. Journal of Personality & Social Psychology, 1968, 10, 35-43.

Pinegin, N. I. The curve of absolute cone-sensitivity of the eye in the region of the spectrum from $\lambda = 302$ to $\lambda = 950$ m μ . Probl. Fiziol. Optiki, 1947, 4, 11-16.

Pinegin, N. I., & Bulanova, K. N. The acuity of discrimination as a function of contrast for the test objects: Landolt's circles, squares, and airplane shapes. Probl. Fiziol. Optiki, 1947, 4, 126-130.

Pinegin, N. I. Absolute photopic sensitivity of the eye in the ultra-violet and in the visible spectrum. Nature, 1944, 154, 770.

Pinegin, Lawrence. The RADC visual sensitometer. USAF RADC Tech. Note, 1957, No. 57-256, iii, 7.

Pinson, E. A. Army Air Forces--Eastman Night Vision Tester (Model 2). AF, Engng. Div., 1943; Publ. Bd., No. 6947. Washington, D.C.: U.S. Department of Commerce, 1946, 11.

- Pinson, E. A., & Chapanis, A. AML portable radium plaque night vision tester. Air Surg. Bulletin, 1945, 2, 285.
- Pishkin, V.; Shurley, J. T., & Wolfgang, A. Assessment of drugs in decision-making under stress. Diseases of the Nervous System, 1968, 29, 841-843.
- Pitz, G. R., & Geller, E. S. Revision of opinion and decision times in an information-seeking task. Journal of Experimental Psychology, 1970, 83(3, Pt. 1), 400-405.
- Plakhtienko, V. A., & Sofronov, V. V. O. The formation of a psychomotor skill in operators. Voprosy Psikhologii, 1969, 15(3), 81-92.
- Poffenberger, A. T. Reaction time to retinal stimulation with special reference to the time lost in conduction through nerve centers. Arch. Psych. N.Y., No. 23, 1912.
- Pollack, Irwin. Discrimination of mean temporal interval within jittered auditory pulse trains. Journal of Acoustical Society of America, 1968, 43, 1107-1112.
- Pollack, Irwin. Periodicity discrimination for auditory pulse trains. Journal of the Acoustical Society of America, 1968, 43, 1113-1119.
- Pollack, Irwin. Monaural and binaural threshold sensitivity for tones and for white noise. Journal of the Acoustical Society of America, 1948, 20, 52-57.
- Pollack, Irwin. Asynchrony: The perception of temporal gaps within periodic auditory pulse patterns. Journal of the Acoustical Society of America, 1967, 42(6), 1335-1340.
- Pollack, Joan D. Reaction time to different wavelengths at various luminances. Perception & Psychophysics, 1968, 3(1-A), 17-24.
- Poock, G. K.; Tuck, G. A., & Tinsley, J. H. Physiological correlates of visual monitoring. Perceptual & Motor Skills, 1969, 29(1), 334.
- Pope, L. T. Attention level and visual and auditory monitoring performance. USAF AMRL Tech. Docum. Rep., 1962, No. 62-97, iii, 20.
- Porteus, S. D. New applications of the Porteus Maze tests. Perceptual & Motor Skills, 1968, 26(3, Pt. 1), 707-798.
- Poulton, E. C. On increasing the sensitivity of measure of performance. Ergonomics, 1964, 8(1), 69-76.
- Poulton, E. C. Memorization during recall. British Journal of Psychology, 1953, 44, 173-176.
- Poulton, E. C. Eye-hand span in simple serial tasks. Journal of Experimental Psychology, 1954, 47, 403-410.

- Poulton, E. C. Environment and Human Efficiency. Thomas: Springfield, Ill., 1970.
- Priestley, B. S., & Medine, M. M. A new attachment for the projection perimeter. American Journal of Ophthalmology, 1954, 37, 261-262.
- Prod'homme, Lucien. Diffusimetre visual (visual diffusimeter). Rev. Opt. (Theor. Instrum.), 1953, 32, 615-618.
- Pudritzki, Gunter. An electronic apparatus for the determination of optical fusion frequency with movable observing glasses. Z. Psychol., 1957, 160, 302-306.
- Pylyshyn, Z. W., & Agnew, J. N. Absolute judgment of distance as a function of anxiety and exposure time. Perceptual & Motor Skills, 1962, 14(3), 411-418.
- Raab, D. H., & Grossberg, M. Reaction time to changes in the intensity of white noise. Journal of Experimental Psychology, 1965, 69, 609-612.
- Rabb, D., & Fehrer, E. The effect of stimulus duration and luminance on visual reaction time. Journal of Experimental Psychology, 1962, 64, 326-327.
- Rabb, D.; Fehrer, E., & Hershenson, M. Visual reaction time and the Broca-Sulzer Phenomenon. Journal of Experimental Psychology, 1961, 61, 193-199.
- Rabbitt, P. M. A. Errors and error correction in choice-response tasks. Journal of Experimental Psychology, 1966, 71, 264-272.
- Rabbitt, P. M. A. Times for transitions between hand and foot responses in a self pace task. Quarterly Journal of Experimental Psychology, 1966, 18, 334-339.
- Rabbitt, P. M. A. Three kinds of error-signaling responses in a serial choice task. Quarterly Journal of Experimental Psychology, 1968, 20, 179-188.
- Rabbitt, P. M. A., & Phillips, S. Error-detection and corection latencies as a function of S-R compatibility. Quarterly Journal of Experimental Psychology, 1967, 19, 37-42.
- Rabbitt, P. M. A. Set and age in a choice-response task. Journal of Gerontology, 1964, 19, 301-306.
- Rabbitt, P. M. A. Response-facilitation on repetition of a limb movement. British Journal of Psychology, 1965, 56, 303-304.
- Rabbitt, P. M. A., & Birren, J. E. Age and responses to sequences of repetitive and interruptive signals. Journal of Gerontology, 1967, 22, 143-150.
- Rabbitt, P. M. A., & Vyas, S. M. An elementary preliminary taxonomy for some errors in laboratory choice RT tasks. Acta Psychologica, 1970, 33, 56-76.
- Rabideau, G. F. Differences in visual acuity measurement obtained with different types of targets. Psychological Monographs, 1955, 69, No. 395, 1955.

Rabideau, G. F. Field measurement of human performance in man-machine systems. Human Factors, 1964, 6, 663-672.

Rabinovich, R. L. On physiological regulation of human rhythmic muscular activity. Zhurnal Vysshei Nervnoi Deyatel'nosti, 1968, 18(4), 712-717.

Rabkine, E. B. Color test for determining chromatic thresholds. Prob. Fiziol. Opt., 1941, 1, 113-115.

Räffel, G. Visual and kinaesthetic judgments of length. American Journal of Psychology, 1936, 48, 331-334.

Raxworthy, W. K. Some aspects of color perception in viewing color prints. PSA Journal, 1952, 18A, 654-656; 710-712.

Ray, Verne F. Techniques and problems in the study of human color perception. Southwest Journal of Anthropology, 1952, 8, 251-259.

Reason, J. T., & Graybiel, A. Changes in subjective estimates of well-being during the onset and remission of motion sickness symptomatology in the slow rotation room. USN AMI NASA Joint Report, 1969, No. 1083, p. 17.

Reason, J. T. Individual differences in auditory reaction time and loudness estimation. Perceptual & Motor Skills, 1968, 26(3, Pt. 2), 1089-1090.

Reason, J. T., & Graybiel, A. Magnitude estimations of Coriolis sensations. USN AMI NASA Joint Report, 1969, No. 1082, p. 12.

Reason, J. T., & Graybiel, A. Progressive adaptation to Coriolis accelerations associated with 1-RPM increments in the velocity of the slow rotation room. USN AMI NASA Joint Report, 1969, No. 1081, p. 16.

Reger, S. N., & Voots, R. J. Design and construction of an automatic, self-testing, recording, pulse-tone audiometer. USAF School of Aviat. Med. Rep., 1957, No. 57-64, 20.

Reid, J.,; Van Nuys, K.; Davies, S., & Ammons, R. B. Evaluation of some scoring alternatives for use with the Standard Anagram Task. Proceedings of the Montana Academy of Sciences, 1963, 23, 264-272.

Reid, W. G. Drivers aptitude tests of the third armored division. Milit. Surg., 1942, 91, 401-411.

Reilly, R. E., & Cameron, B. J. An integrated measurement system for the study of human performance in the underwater environment. Contract No. N00014-67-C-0410, Work Unit No. NR 196-074, Office of Naval Research. Biotechnology, Inc., Falls Church, Va., Dec., 1968. AD 680 028.

Reitz, W. E., & McDougall, L. Interest items as positive and negative reinforcements: Effects of social desirability and extremity of endorsement. Psychonomic Science, 1969, 17(2), 97-98.

- Remington, R. J. Analysis of sequential effects in choice reaction times. Journal of Experimental Psychology, 1969, 82, 250-257.
- Renshaw, S. Object perceived-size as a function of distance. Engng. Exp. Sta. News, Ohio State Univ., 1953, 25(4), 44-48.
- Requin, J. Some data on neurophysiological processes involved in the preparatory motor activity to reaction time performance. Acta Psychologica, 1969, 30, 358-367.
- Restle, F. Speed of adding and comparing numbers. Journal of Experimental Psychology, 1970, 83(2, Pt. 1), 274-278.
- Retanova, E. A.; Zinchenko, V. P., & Vergiles, N. Y. Investigating perceptual acts in connection with the problem of insight. Voprosy Psikhologii, 1968, 14(4), 44-48.
- Reuning, H. A new flicker apparatus for measuring individual differences. Journal of Nat. Inst. Pers. Res., Johannesburg, 1955, 6, 44-54.
- Révész, G. A revision of Gestalt psychology. Schweiz. z. Psychol. Anwend., 1953, 12, 89-110.
- Rey, P.; Guggenheim, P., & Meyer, J. J. A technique for recording repeated EEGs from identical locations. Electroencephalography & Clinical Neurophysiology, 1968, 24(4), 383-385.
- Rey, P., & Rey, J. P. The effects of two types of fluorescent lighting on a visual task and "fatigue" tests. Ergonomics, 1963, 6(4), 393-401.
- Reynolds, B., & Adams, J. A. Effect of distribution and shift in distribution within a single training session. Journal of Experimental Psychology, 1953, 46, 137-145.
- Reynolds, B., & Adams, J. A. Motor performance as a function of click reinforcement. Journal of Experimental Psychology, 1953, 45, 315-320.
- Reynolds, D. Effects of double stimulation: Temporary inhibition of response. Psychological Bulletin, 1964, 62, 333-347.
- Reynolds, G. S. The effects of stress upon problem-solving. Journal of General Psychology, 1960, 62, 83-88.
- Reynolds, H. N., Jr. Temporal estimation in the perception of occluded motion. Perceptual & Motor Skills, 1968, 26(2), 407-416.
- Roades, P. D., & Ammons, Carol H. A paced target-hitting task. Motor Skills Res. Exch., 1950, 2, 10-13.
- Richards, Alan M. Monaural loudness functions under masking. U.S. Naval Submarine Medical Center Report, 1968, No. 509, 7.

- Richards, A. M. The code-copying capabilities of radiomen under simulated atmospheric noise conditions. USN Submarine Medical Center Report, 1968, No. 523, iii, 4.
- Richards, Whitman. Time estimates measured by reproduction. Perceptual & Motor Skills, 1964, 18(3), 929-943.
- Richter, M. New developments in the examination of the colour sense. Klin. Mbl. Augenheilk., 1951, 119, 561-575.
- Riegel, K. F., & Birren, J. E. Age differences in choice reaction times to verbal stimuli. Gerontologia, 1967, 13, 1-13.
- Riffenburgh, Ralph S. Ocular fatigue in the radar operator. U.S. Armed Forces Med. Journal, 1953, 4, 71-72.
- Ringel, R. L., & Fletcher, Hilary M. Oral perception: III. Texture discrimination. Journal of Speech & Hearing Research, 1967, 10(3), 642-649.
- Rintelmann, W. F., & Harford, E. R. Type V Békésy pattern: Interpretation and clinical utility. Journal of Speech & Hearing Research, 1967, 10(4), 733-744.
- Riopelle, A. J., & Bevan, W., Jr. The distribution of scotopic sensitivity in human vision. American Journal of Psychology, 1953, 66, 73-80.
- Rittenhouse, C. H., & Goldstein, M. Target flight characteristics as determinants of training transfer and task difficulty in flexible gunnery. USAF Pers. Train. Res. Cent., Res. Bull., 1954, No. AFPTRC-TR-54-90, iv, 30.
- Roberts, D. M., & Lewis, L. Individual differences in memory and the serial position effect. Psychonomic Science, 1968, 12(2), 77-78.
- Robertson, C. J. Measurement of speed of adjustment of eye to near and far vision. A further study. Arch. Ophthal., Chicago, 1936, 15, 423-434.
- Robinson, D. N. Visual reaction time and the human alpha rhythm: The effects of stimulus luminance, area, and duration. Journal of Experimental Psychology, 1966, 71, 16-25.
- Rochels, K. H. An instrument for objective determination of visual acuity. Klin. Mbl. Augenheilk., 1950, 116, 31-34.
- Rock, I., & Victor, J. Vision and touch: An experimentally created conflict between the two senses. Science, 1964, 143 (Whole No. 36060), 594-596.
- Rockway, Marty R. Bilateral reminiscence in pursuit-rotor learning as a function of amount of first-hand practice and length of rest. Journal of Experimental Psychology, 1953, 46, 337-344.
- Roelofs, C. O., & Zeeman, W. P. C. Apparent size. Ophthalmologica, 1955, 129, 166-186.
- Roff, M. A factorial study of tests in the perceptual area. Psychometric Monographs, 1953, No. 8, v, 41.

- Rohrer, J. H., & Hoffman, E. L. An apparatus for studying the perception of light-movements. American Journal of Psychology, 1954, 67, 143-146.
- Roloff, Louise L. Kinesthesia in relation to the learning of selected motor skills. Res. Quart. Amer. Assn. Hlth. Phys. Educ., 1953, 24, 210-217.
- Roscoe, S. N. Flight by periscope. U. Ill. Bull., 1951, 48(55), 46. (Aeronautics Bull., No. 9.)
- Rosen, H. R., & Roberds, W. M. A device for measuring intensity of illumination. Science, 1933, 78, 241-242.
- Rosenthal, H. J. The small reaction apparatus. Das Klein-Reaktionsgerat. (AAF, T-2 Translation 752, 1946; Publ. Bd., No. 34831.) Washington, D.C.: U. S. Department of Commerce, 1946, p. 8.
- Roske, H. Impairment of visual capacity by vibrations. Industr. Psychotech., 1937, 14, 153-155.
- Ross, D. A. Lengthening of time estimates in four different temporal patterns of visual light stimulation. Psychonomic Science, 1969, 16(4), 194-195.
- Ross, Helen E. Water, fog, and the size-distance invariance hypothesis. Journal of Psychology, 1967, 58(3-4), 301-313.
- Ross, Helen E.; Dickinson, D. J., & Jupp, B. P. Geographical orientation under water. Human Factors, 1970, 12(1), 13-23.
- Ross, S.; Hussman, T. A., & Andrews, T. G. Effects of fatigue and anxiety on certain psychomotor and visual functions. Journal of Applied Psychology, 1954, 38, 119-125.
- Roth, A. Measurement of vibration sense. War Med., Chicago, 1943, 4, 280-282.
- Rotter, G. S. Clock-speed as an independent variable in psychological research. Journal of General Psychology, 1969, 81(1), 45-52.
- Roweton, W. E. Performance effects of massed and distributed practice upon constant and variable forms of the letter-pathways test. Psychonomic Science, 1968, 10(10), 333-334.
- Rowland, L. S. An evaluation of the ISCC Test for Color Deficiency in Selection of Air Force Personnel. AAF School of Aviation Medicine, Project No. 54, Report No. 1, Randolph Field, Texas, May 29, 1942.
- Rowland, L. S. Selection and validation of tests for color vision: A test for ability to distinguish terrain colors. AAF School of Aviation Medicine, Project No. 137, Report No. 1, Randolph Field, Texas, May 31, 1943.
- Rowland, W. M., & Mandelbaum, J. Testing night vision. Air Surg. Bull., 1944, 1, No. 8, 14-15.

Royer, F. L., & Garner, W. R. Perceptual organization of nine-element auditory temporal patterns. Perception & Psychophysics, 1970, 7(2), 115-120.

Rschevkin, S. N., & Rabinovitch, A. V. The problem of the quantitative estimation of the intensity of a sound. Rev. Acoust., 1936, 5, 183-200.

Rudmose, H. W.; Clark, K. C.; Carlson, F. D.; Eisenstein, J. C., & Walker, R. A. Voice measurements with an audio spectrometer. Journal of the Acoustical Society of America, 1948, 20, 503-512.

Ruffer, W. The influence of colored light on human performance. Indus. Psychotechn., 1928, 5, 161-177.

Rusmore, J. T. The R-G Pegboard Test of Finger Dexterity. Journal of Applied Psychology, 1942, 26, 523-529.

Rutgers, G. A. W. The differential threshold near a glare source. Rev. Opt. (Theor. Instrum.), 1949, 28, 33-37.

Rutschmann, J., & Link, R. Perception of temporal order of stimuli differing in sense mode and simple reaction time. Perceptual & Motor Skills, 1964, 18, 345-352.

Ryan, A. H., & Ranseen, E. L. Palmer skin resistance (P.S.R.) during a standard period of controlled muscular activity as a measure of physical fitness and fatigue. American Journal of Psychology, 1944, 142, 68-79.

Ryan, T. A.; Bitterman, M. E., & Cottrell, C. L. Relation of critical fusion frequency to fatigue in reading. Illum. Engng., N. Y., 1953, 48, 385-391.

Ryan, T. J.; Orton, C., & Pimm, June B. Discrete-trial instrumental performance related to reward schedule and developmental level. Journal of Experimental Psychology, 1968, 78(1), 31-37.

Rycroft, B. W. Night vision in the army. British Medical Journal, 1942, Part 2, 576-577.

Safonov, V. A. New variant of a method for studying tactile and pain sensitivity in man. Fiziologicheskii Zhurnal SSSR, 1967, 53(3), 357-359.

Sales, B. D.; Cole, R. A., & Haber, R. N. Mechanisms of aural encoding: V. Environmental effects of constants on vowel encoding. Perception & Psychophysics, 1969, 6(6-A), 361-365.

Salvendy, G.; Seymour, W. D., & Corlett, E. N. Comparative study of static versus dynamic scoring of performance tests for industrial operators. Journal of Applied Psychology, 1970, 54, 135-139.

Sampson, H. Binocular interaction in serial adding. Australian Journal of Psychology, 1962, 14(1), 9-21.

- Sampson, Jeffrey R. Further study of encoding and arousal factors in free recall of verbal and visual material. Psychonomic Science, 1969, 16(4), 221-222.
- Sanders, A. F. Some aspects of reaction processes. Acta Psychologica, 1967, 27, 115-130.
- Sanders, A. F. Some variables affecting the relation between relative stimulus frequency and choice reaction time. Acta Psychologica, 1970, 33, 45-55.
- Sanders, A. F. Short-term memory for spatial positions. Nederlands Tijdschrift Voor de Psychologie en Haar Grensgebieden, 1968, 23(1), 1-15.
- Sanders, Lois J. Instrumentation for measurement of lingual strength. Journal of Speech & Hearing Research, 1968, 11(1), 189-193.
- Sandstrom, C. I. Orientation in the Present Space. Stockholm, Sweden: Almqvist and Wiksell, 1951, p. 193.
- Santa Maria, D. L. Pre-motor and motor reaction time differences associated with stretching of the hamstring muscles. Journal of Motor Behavior, 1970, 2, 163-173.
- Sasaki, E. H. Effect of transient weightlessness on binocular depth perception. USAF AMRL TRD, No. 63-134, 14.
- Saupe, J. L. Trouble shooting electronic equipment: An empirical approach to the identification of certain requirements of a maintenance occupation. Urbana, Ill.: Bur. Educational Research, U. of Illinois, 1954, vii, p. 127. (AF Contract No. 33(038)-13236, Project No. 507-007-0001.)
- Schaefer, H. Experiments on the scale of variations of the threshold of the human fovea for red light. Klin. Mbl. Augenheilk., 1949, 115, 690-699.
- Schaefer, K. R., & Carey, C. Effect of increased CO₂ concentrations on flicker fusion frequency and alpha blocking time. Fed. Proc., 1953, 12, 125-126.
- Schaefer, T.; Ferguson, J. B.; Klein, J. A., & Rawson, E. B. Pupillary responses during mental activities. Psychonomic Science, 1968, 12, 137-138.
- Scheidemann, Norma V. A collapsible mirror-tracing apparatus. American Journal of Psychology, 1950, 63, 447.
- Scheidemann, Norma V. An electrical device for mirror-tracing. American Journal of Psychology, 1951, 64, 276-278.
- Schiff, W., & Thayer, S. Cognitive and affective factors in temporal experience: Anticipated or experienced pleasant and unpleasant sensory events. Perceptual & Motor Skills, 1968, 26(3, Pt. 1), 799-808.

- Schlosberg, H. A projection tachistoscope. American Journal of Psychology, 1931, 43, 499-501.
- Schmeck, R. R., & Ribich, F. Rigidity as a function of task complexity. Psychonomic Science, 1969, 17(6), 323.
- Schmidt, Ingeborg. Evaluation of the Grether self-administering color vision test. USAF School of Aviation Med., Spec. Rep., 1953 (March), 10.
- Schmidt, Ingeborg. New tests for the examination and training of color vision. III. Color Vision Multitester (signal lamp) for Aviation. USAF School of Aviation Med., Proj. No. 21-09-006, Rep. No. 3, 1952, III, 14.
- Schmidt, Ingeborg, & Bingel, Abraham G. A. Effect of oxygen deficiency and various other factors on color saturation thresholds. USAF School of Aviation Med., Proj. Rep., 1953, Proj. No. 21-31-002, III, 21.
- Schmidt, R. A., & Stull, G. A. Premotor and motor reaction time as a function of preliminary muscular tension. Journal of Motor Behavior, 1970, 2, 96-100.
- Schmitt, O. H., & Mac Pherson, C. H. An ac operated portable electrometer-type millivoltmeter. Rev. Sci. Instrum., 1954, 25, 912.
- Schober, Herb. A visual signal projector for accurate and reproducible subjective far-vision determination. Klin. Mbl. Augenheilk., 1950, 116, 22-31.
- Schouten, J. F., & Bekker, J. A. M. In A. F. Sanders (Ed.) Attention and Performance. Acta Psychologica, 1967, 27, 143-153.
- Schroeder, S. R. Selective eye movements to simultaneously presented stimuli during discrimination. Perception & Psychophysics, 1970, 7(2), 121-124.
- Schulte, B. Combating fatigue by adapting the job to the man. Mensch u. Arbeit., 1952, 5(2), 88-103.
- Schumsky, D. A.; Grasha, A. F.; Trinder, J., & Richman, C. L. List length and single-trial short-term memory. Journal of Experimental Psychology, 1969, 82(2), 238-241.
- Schwab, R. S. Motivation in measurements of fatigue. In Floyd & Welford, Symposium on Fatigue, (see 28:5511), 143-148.
- Schwartz, R., & Olson, R. Are alleged single solution anagrams really single-solution? Journal of Verbal Learning & Verbal Behavior, 1968, 7, 567-568.
- Scott, Jimmy, & Snyder, Frederick. "Critical reactivity" (Pieron) after abrupt awakenings in relation to EEG stages of sleep. Psychophysiology, 1968, 4(3), 370.
- Scott, M. Gladys. Measurement of kinesthesia. Res. Quart. Amer. Assn. Hlth., Phys. Educ., 1955, 26, 324-341.

- Scow, J.; Krasno, L. R. ; & Ivy, A. C. The immediate and accumulative effect on psychomotor performance of exposure to hypoxia, high altitude and hyper-ventilation. Journal of Aviation Med., 1950, 21, 79-81.
- Seashore, R. H., & Adams, R. D. The measurement of steadiness: A new apparatus and results on marksmanship. Science, 1933, 78, 285-287.
- Seashore, R. H. Stanford motor skills unit. Psychol. Monographs, 1928, 39, 51-66.
- Segal, S. J., & Fusella, V. Effects of imaging on signal-to-noise ratio, with varying signal conditions. British Journal of Psychology, 1969, 60(4), 459-464.
- Seibel, R. Discrimination reaction time for a 1,023-alternative task. Journal of Experimental Psychology, 1963, 66(3), 215-226.
- Sekuler, R. W., & Abrams, M. Visual sameness: A choice time analysis of pattern recognition processes. Journal of Experimental Psychology, 1968, 77(2), 232-238.
- Seminara, J. L., & Shavelson, R. J. Lunar simulation. Human Factors, 1969, 11(5), 451-462.
- Semmes, Josephine. Somatosensory changes after penetrating brain wounds in man. Cambridge, Harvard University Press, 1960.
- Senturia, B. H. The influence of airplane noise on auditory thresholds. Ann. Otol., etc., St. Louise, 1953, 62, 331-349.
- Seymour, P. H. K. Response latencies in judgments of spatial location. British Journal of Psychology, 1969, 60, 31-39.
- Shaffer, L. H. Transition effects in three-choice reaction with variable S-R mapping. Journal of Experimental Psychology, 1967, 73, 101-108.
- Shavelson, R. J. Lunar gravity simulation and its effect on human performance. Human Factors, 1968, 10, 393-402.
- Shephard, A. H., & Abbey, D. S. Manifest anxiety and performance on a complex perceptual-motor task. Perceptual & Motor Skills, 1958, 8, 327-330.
- Shephard, A. H., & Lewis, D. Devices for studying associative interference in psychomotor performance: II. The modified two-hand coordinator. Journal of Psychology, 1950, 29, 53-66.
- Sheppard, D. Subjective assessments of firmness: The use of a rating scale. Quarterly Journal of Experimental Psychology, 1953, 5, 1-9.
- Sheppard, D., & Scott Blair, G. W. Subjective assessments of firmness. Quarterly Journal of Experimental Psychology, 1952, 4, 101-108.

- Sheridan, J.; Foulke, E.; & Alluisi, E. Some factors influencing the threshold of electro-cutaneous stimulus. Perceptual & Motor Skills, 1966, 22, 647-654.
- Sherrick, C. E., Jr. Variables affecting sensitivity of the human skin to mechanical vibration. Journal of Experimental Psychology, 1953, 45, 273-282.
- Shikano, S. An analysis of fusion frequency. Acta Soc. Ophthal. Jap., 1951, 319-324.
- Shipley, Elizabeth F. A signal detection theory analysis of a category judgment experiment. Perception & Psychophysics, 1970, 7(1), 38-42.
- Shnidman, Susan R. Avoidance conditioning of skin potential responses. Psychophysiology, 1969, 6(1), 38-44.
- Shouksmith, G. A series of insoluble problems for studying cognitive style. Journal of Psychology, 1969, 73(2), 245-248.
- Shulman, P. F. The Strabismometer and its function. Optom. Wkly., 1957, 48, 1747-1749.
- Shurtleff, D. A., & Marsetta, M. Y. Visual search in a letter-canceling task reexamined. Journal of Experimental Psychology, 1968, 77(1), 19-23.
- Siddall, G. J., & Anderson, D. M. Fatigue during prolonged performance on a simple compensatory tracking task. Quarterly Journal of Experimental Psychology, 1955, 7, 159-165.
- Sidowski, J. B.; Morgan, R., & Eckstrand, G. Influence of task complexity and instructions upon simple and discrimination reaction times. Journal of Experimental Psychology, 1958, 55, 163-166.
- Siegel, A. I.; Bulinkis, J. J.; Hatton, R. W., & Lanterman, R. S. Description and use of the Performance Analytic Device. Wayne, Pa.: Applied Psychological Services, 1963, v, 94.
- Siegel, A. I., & Lanterman, R. S. A portable test battery for comparatively evaluating operator performance in full-pressure suit assemblies. USAF AMRL TR 68-74, 1968, 75.
- Siegel, A. I.; Schultz, D. G., & Lanterman, R. S. Investigation into factors affecting control activation: III. Rotary switches; number and activation sequence. Applied Psychological Services, 1962, iv, 21.
- Siegel, Harry. Prick threshold stimulation with square-wave current; a new measure of skin sensibility. Yale Journal Biol. Med., 1953, 26, 145-154.
- Siegel, M. H. Color discrimination and luminance. Perception & Psychophysics, 1969, 6(3), 163-165.
- Siegel, M. H. Discrimination of color: III. Effect of spectral bandwidth. Journal of the Optical Society of America, 1963, 53(7), 874-877.

- Siegenthaler, B. M., & Hochberg, I. Reaction time of the tongue to auditory and tactile stimulation. Perceptual and Motor Skills, 1965, 21, 387-393.
- Siegmán, A. W. Intercorrelation of some measures of time estimation. Perceptual & Motor Skills, 1962, 14(3), 381-382.
- Silkett, A. F., & Driscoll, Mae A. Simple circuit for measuring variations in electrical resistance of a human being under emotional stress. Trans. III. Acad. Sci., 1949, 42, 128-129.
- Silverman, L.; Schulte, H. F., & First, M. W. Further studies on sensory response to certain industrial solvent vapors. Journal of Industr. Hyg., 1946, 28, 262-266.
- Simon, C. W. Effects of stress on performance in a dominant and a non-dominant task. USAF, WADC Tech. Rep., 1954, No. 54-285, vi, 41.
- Simon, J. R. Ear preference in a simple reaction-time task. Journal of Experimental Psychology, 1967, 75, 49-55.
- Simon, J. R. Choice reaction time as a function of auditory S-R correspondence, age, and sex. Ergonomics, 1967, 10, 659-664.
- Simon, J. R. Effect of ear stimulated on reaction time and movement time. Journal of Experimental Psychology, 1968, 78, 344-346.
- Simon, J. R. Reactions toward the source of stimulation. Journal of Experimental Psychology, 1969, 81, 174-176.
- Simon, J. R., & Craft, J. L. Effects of an irrelevant auditory stimulus on visual choice reaction time. Journal of Experimental Psychology, 1970, 86, 272-274.
- Simon, J. R.; Hinrichs, J. V., & Craft, J. L. Auditory S-R compatibility: Reaction time as a function of ear-hand correspondence and ear-response-location correspondence. Journal of Experimental Psychology, 1970, 86, 97-102.
- Simon, J. R., & Small, A. M., Jr. Processing auditory information: Interference from an irrelevant cue. Journal of Applied Psychology, 1969, 53, 433-435.
- Simon, J. R.; Small, A. M., Jr.; Ziglar, R. A., & Craft, J. L. Response interference in an information processing task: Sensory versus perceptual factors. Journal of Experimental Psychology, 1970, 85, 311-314.
- Simon, J. R. Effects of exposure to localized vibration on hand steadiness. Perceptual & Motor Skills, 1969, 28(1), 91-94.
- Simon, J. R. Reaction time as a function of the cue properties of an auditory display. Journal of Applied Psychology, 1968, 52(3), 224-226.
- Simon, J. R.; De Crow, T. W.; Lincoln, R. S., & Smith, K. U. Effects of handedness on tracking accuracy. Perceptual & Motor Skills Research Exchange, 1952, 4, 53-57.

- Simonds, J. S. "VITA" time estimation apparatus: control data on 10 normal volunteers. U.S. Army: Edgewood Arsenal EATH 114-9, July, 1967.
- Simpson, H. M. Effects of a task-relevant response on pupil size. Psychophysiology, 1969, 6(2), 115-121.
- Simpson, H. M., & Hale, Shirley M. Pupillary changes during a decision-making task. Perceptual & Motor Skills, 1969, 29(2), 495-498.
- Singer, G. The influence of two varieties of proprioceptive information on judgments of the spatial position of an object while the visual input is transformed. Psychonomic Science, 1968, 11(8), 295-296.
- Singleton, W. T. Deterioration of performance on a short-term perceptual-motor task. In Floyd & Welford, Symposium on Fatigue (see 28:5511), 163-172.
- Sinha, Durganand. A simple apparatus for testing performance: Punching test. Journal of Psychol. Res., Pakistan, 1958, 2, 83-84.
- Sinha, Durganand, & Singh, Tripat Raj. Manifest anxiety and performance on problem solving tasks. Journal Consult. Psychol., 1959 (Oct.), 23, 469.
- Sixtl, Friedrich. The time-order error in estimating exposure time as a function of stimulus duration, of time between stimuli, and of repetitions of the experiment. Zeitschrift fur Experimentelle & Angewandte Psychologie, 1963, 10(2), 209-225.
- Skinner, Paul H., & Antinoro, Frank. Study of pre- and post-stimulatory fatigue in pitch perception. Journal of the Acoustical Society of America, 1968, 44(5), 1423-1427.
- Skinner, Paul H., & Jones, Howard C. Effects of signal duration and rise time on the auditory evoked potential. Journal of Speech & Hearing Research, 1968, 11(2), 301-306.
- Sky, A. W. An apparatus for a frustration task. Aust. Journal Psychol., 1950, 2, 116-120.
- Slack, C. W. Learning in simple one-dimensional tracking. American Journal of Psychology, 1953, 66, 33-44.
- Slak, Stefan. Information, similarity, and vocalization in short-term recognition memory for numbers. Perceptual & Motor Skills, 1969, 29(2), 387-393.
- Slamecka, N. J. Choice reaction-time as a function of meaningful similarity. American Journal of Psychology, 1963, 76(2), 274-280.
- Slater-Hammel, A. T. Reaction time to light stimuli in the peripheral visual field. Research Quarterly, 1955, 26, 82-87.
- Slater-Hammel, A. T. Psychological refractory period in simple paired responses. Research Quarterly, 1958, 29, 468-481.

Slater-Hammel, A. T. Variability, accuracy, and refractoriness of a transit reaction. Research Quarterly, 1960, 31, 217-228.

Sloan, L. L. Measurement of visual acuity. A.M.A. Archives of Ophthalmology, 1951, 45, 704-725.

Sloan, L. L. New test charts for the measurement of visual acuity at far and near distances. American Journal of Ophthalmology, 1959, 48, 807-813.

Sloan, L. L. Selection of color vision tests for the Army Air Forces: A summary of studies made at the Army Air Forces School of Aviation Medicine. Arch. Ophthal., Chicago, 1946, 36, 263-283.

Sloan, L. L., & Altman, Adelaide. Aniseikonia and the Howard-Dolman test. Journal of the Optical Society of America, 1953, 43, 473-478.

Slocum, Helen Margaret. The effect of fatigue induced by physical activity on certain tests in kinesthesia. Dissertation Abstr., 1953, 13, 1084-1085.

Smets, Gerda. Time expression of red and blue. Perceptual & Motor Skills, 1969, 29(2), 511-514.

Smith, A. A. An electromyographic study of tension in interrupted and completed tasks. Journal of Experimental Psychology, 1953, 46, 32-36.

Smith, E. E. Choice reaction time: An analysis of the major theoretical positions. Psychological Bulletin, 1968, 69, 77-110.

Smith, F. L.; Sweet, A. L., & Bartlett, N. R. The discrimination of small differences in the time of mechanical stimulation. Journal of Experimental Psychology, 1949, 39, 569-574.

Smith, G. H. Size-distance judgments of human faces (projected images). Journal of General Psychology, 1953, 49, 45-64.

Smith, L. E. Increased strength, reaction time and speed of limb movement. Perceptual & Motor Skills, 1970, 30, 775-781.

Smith, L. E. Individual differences in forearm "strengths" measured at various angles and locations. Perceptual & Motor Skills, 1968, 27(3, Pt. 2), 1091-1097.

Smith, L. E. Individual differences in arm strength, speed, reaction time, and three serial reaction time-movement time "programs." Perceptual & Motor Skills, 1968, 26(2), 651-658.

Smith, M. C. Stimulus response compatibility and parallel response selection. Canadian Journal of Psychology, 1967, 21, 496-503.

Smith, S. The essential stimuli in stereoscopic depth perception. Journal of Experimental Psychology, 1946, 36, 518-521.

Smith, S. Development of a complex-time-shared, perceptual-motor skills task for use in studies of isolation and confinement. Research Report, HF 022.01.03-1002, Report No. 15, Naval Medical Research Institute, Bethesda, Md., August, 1966. AD 637 817.

Smith, S., & Myers, T. I. Time-shared, perceptual-motor skills during seven days of isolation. Psychonomic Science, 1967, 9(2), 99-100.

Soar, R. S. Height-width proportion and stroke width in numeral visibility. Journal of Applied Psychology, 1955, 39, 43-46.

Soar, R. S. Stroke width, illumination level, and figure-ground contrast in numeral visibility. Journal of Applied Psychology, 1955, 39, 429-432.

Solandt, D. Y., & Best, C. H. The Royal Canadian Navy colour vision test lantern. Canadian Med. Assn. Journal, 1943, 48, 18-21.

Solar, Diana; Davenport, G., & Bruehl, D. Social compliance as a function of field dependence. Perceptual & Motor Skills, 1969, 29(1), 299-306.

Sommer, H. C., & von Gierke, H. E. Hearing sensations in electric fields. Aerospace Medicine, 1964, 35, 834-839.

Spengler, E. Investigations with a new apparatus on the exact testing of muscle and nerve excitability in man. Zsch. Ges. Exp. Med., 1930, 69, 337-355.

Spigel, I. M. Size constancy and critical flicker-frequency. American Journal of Psychology, 1964, 77(3), 469-471.

Spilker, B., & Callaway, E. "Augmenting" and "reducing" in averaged visual evoked responses to sine wave light. Psychophysiology, 1969, 6(1), 49-57.

Spring, K. H. An Apparatus for measuring the steadiness of aim of a rifle. Quarterly Journal of Experimental Psychology, 1952, 4, 179-180.

Srivastava, S. S. et. al. Load carriage by infantry soldier: Criteria for assessment of physiological and psychological fatigue. Defence Science Journal, 1968, 18, 53-60.

Stabell, Ulf, & Stabell, Bjorn. Color threshold measurements in scotopic vision: II. Test-stimulation varied. Scandinavian Journal of Psychology, 1968, 9(2), 129-132.

Stabell, Ulf, & Stabell, Bjorn. Color threshold measurements in scotopic vision: III. Simultaneous color contrast. Scandinavian Journal of Psychology, 1968, 9(2), 133-137.

Stachnik, Thomas. Transitional probability in anagram solution in a group setting. Journal of Psychology, 1963, 55(2), 259-261.

Stanek, R. J. Surface and volume judgments of three-dimensional shapes. Psychonomic Science, 1968, 11(4), 121-122.

- Stanley, Gordon. Exposure-time and the apparent length of an illuminated rotating arc-line. Perception & Psychophysics, 1968, 4(2), 71-72.
- Stanley, Gordon. Stimulus-range and magnitude estimates of distance based on object-size. Australian Journal of Psychology, 1968, 20(1), 67-78.
- Stecher, Sidney. Luminance-difference thresholds and simultaneous contrast. American Journal of Psychology, 1968, 81(1), 27-35.
- Stecher, Sidney. Temporal and spatial effects in luminance discrimination. Perception & Psychophysics, 1968, 4(3), 155-158.
- Stecher, Sidney, & Sandberg, Michael. The relationship between binocular brightness matches and luminance difference discriminability of successively presented light flashes. Perception & Psychophysics, 1970, 7(2), 86-90.
- Steger, J. A., & Sherman, H. Thresholds of control-display lag as a function of display movement rates. Psychonomic Science, 1968, 11(8), 267-268.
- Steinkamp, G. R.; Hawkins, W. R.; Hauty, G. T.; Burwell, R. R., & Ward, J. E. Human experimentation in the space cabin simulator. Development of life support systems and results of initial seven-day flights. TR 59-101, AU, SAM, USAF, Brooks AFB, Texas, Aug., 1959. AD 226 790.
- Stelmach, G. E. Distribution of practice in individual differences and intra-variability. Perceptual & Motor Skills, 1968, 26(3, Pt. 1), 727-730.
- Stern, R. M., & Lewis, Nancy L. Ability of actors to control their GSRs and express emotions. Psychophysiology, 1968, 4(3), 294-299.
- Sternberg, S. The discovery of processing stages. Acta Psychologica, 1969, 30, 276-315.
- Stevens, J. C. Brightness function: Binocular versus monocular stimulation. Perception & Psychophysics, 1967, 2(10), 451-454.
- Stevens, S. S. Tactile vibration: Change of exponent with frequency. Perception & Psychophysics, 1968, 3(3-8), 223-228.
- Stevens, S. S., & Gerbrand, R. A twin-oscillator for auditory research. American Journal of Psychology, 1937, 49, 113-115.
- Stewart, K. C. A new instrument for detecting the galvanic skin response. Journal of Speech & Hearing Disorders, 1954, 19, 169-173.
- Sticht, T. G., & Sitterley, T. E. Frequency and latency of response to offset-onset sequences of cutaneous stimulation. Psychonomic Science, 1965, 1, 425-426.
- Sticht, T. G. Threshold and response-latency as a function of the rise-time of A.C. electrical stimuli. American Journal of Psychology, 1968, 81, 384-390.

- Stiles, W. S. Photometer for measuring the scotopic candlepowers of self-luminous ophthalmic test objects. British Journal of Ophthalmology, 1944, 28, 629-637.
- Stock, B. The symmetrical haptic indication of points in space. Zsch. f. Sinnesphysiol., 1933, 64, 229-250.
- Stoddard, S. E. A device for studies in weight discrimination. Journal of General Psychology, 1947, 37, 201-202.
- Stoll, A. M. A wide-range thermistor radionometer for the measurement of skin temperature and environmental radiant temperature. Rev. Sci. Instrum., 1954, 25, 184-187.
- Stone, M. Models for choice reaction time. Psychometrika, 1960, 25, 251-260.
- Stopol, M. S. The consistency of stress tolerance. Journal of Personality, 1954, 23, 13-29.
- Strauss, Milton E. Cognitive style and the use of incidental cues in problem solving. Journal of Psychology, 1969, 73(1), 69-74.
- Street, R. F. A Gestalt completion test. Teach. Coll. Contrib. Educ., 1931, No. 481, pp. vii and 65.
- Streeter, Harrison. A new instrument for measuring tactile sensitivity. Psychophysiology, 1969, 5(4), 446-448.
- Stroop, J. R. Interference in serial verbal reactions. Journal of Experimental Psychology, 1935, 18, 643-661.
- Stroud, J. B. Apparatus for measuring muscular tensions. Journal of Experimental Psychology, 1931, 14, 184-185.
- Studebaker, G. A. Clinical masking of the nontest ear. Journal of Speech & Hearing Disorders, 1967, 32(4), 360-371.
- Suedfeld, P., & Landon, P. B. Motivational arousal and task complexity. Journal of Experimental Psychology, 1970, 83(2, Pt. 1), 329-330.
- Sugimoto, Sukeo; Kida, Mitsuro; Teranishi, Tsunenobu, & Yamamoto, Atsuo. Time estimation during prolonged sensory deprivation. Japanese Journal of Aerospace Medicine & Psychology, 1968, 6(1), 1-5.
- Sulzman, J. H.; Cook, E. B., & Bartlett, N. R. The reliability of visual acuity scores yielded by three commercial devices. Journal of Applied Psychology, 1947, 31, 236-240.
- Surwillo, W. W. A device for recording variations in pressure of grip during tracking. American Journal of Psychology, 1955, 68, 669-670.

- Surwillo, W. W. Relationship between electrical potential of the skin and skin temperature. Perceptual & Motor Skills, 1967, 25(2), 465-470.
- Swartz, P.; Norris, E. B., & Spragg, S. D. S. Performance on a following tracking task (modified SAM two-hand coordination test) as a function of radius of control cranks. Journal of Psychology, 1954, 37, 163-171.
- Sweeney, H. M. Human decelerator. Journal of Aviation Med., 1951, 22, 39-41 and 49.
- Sweet, A. L. Temporal discrimination by the human eye. American Journal of Psychology, 1953, 66, 185-198.
- Swets, J. A.; Markowitz, J., & Franzen, O. Vibrotactile signal detection. Perception & Psychophysics, 1969, 6(2), 83-88.
- Swingle, P. G. Effects of prior exposure to cooperative or competitive treatment upon subjects' responding in the prisoner's dilemma. Journal of Personality & Soc. Psychology, 1968, 10, 44-52.
- Swink, J. R. Intersensory comparisons of reaction time using an electro-pulse tactile stimulus. Human Factors, 1966, 8, 143-145.
- Talland, G. A. The effect of warning signals on reaction time in youth and old age. Journal of Gerontology, 1964, 19, 31-38.
- Taran, V. A., & Kofanov, Y. N. Determining the transmission function of a human operator by means of an analog computer. Voprosy Psikhologii, 1969, 15(3), 150-155.
- Tarpy, R. M., & Marshall, J. F. Effects of interference in STM with minimum covert rehearsal. Psychological Reports, 1969, 24(3), 723-726.
- Taub, J. M., & Berger, R. J. Extended sleep and performance: The Rip Van Winkle effect. Psychonomic Science, 1969, 16(4), 204-205.
- Taylor, C. D. Visual perception versus visual plus kinaesthetic perception in judging colored weights. Journal of General Psychology, 1930, 4, 229-246.
- Taylor, F. W. R. The discrimination of subliminal visual stimuli. Canadian Journal of Psychology, 1953, 7, 12-20.
- Taylor, I. L., & Sumner, F. C. Actual brightness and distance of individual colors when their apparent distance is held constant. Journal of Psychology, 1945, 19, 79-85.
- Tedeschin, J.; Lesnick, S., & Gahagan, J. Feedback and "washout" effect in the prisoner's dilemma game. Journal of Personality & Soc. Psychology, 1968, 10, 31-34.
- Teghtsoonian, Martha, & Teghtsoonian, Robert. Scaling apparent distance in natural indoor settings. Psychonomic Science, 1969, 16(6), 281-283.

- Taylor, D. H. Latency components in two-choice responding. Journal of Experimental Psychology, 1966, 72, 481-487.
- Teichner, W. H. Recent studies of simple reaction time. Psychological Bulletin, 1954, 51, 128-149.
- Teichner, W. H., & Kobrick, J. L. Effects of prolonged exposure to low temperature on visual-motor performance. Journal of Experimental Psychology, 1955, 49, 122-126.
- Teichner, W. H., & Wehrkamp, R. F. Visual-motor performance as a function of short-duration ambient temperature. Journal of Experimental Psychology, 1954, 47, 447-450.
- Tejmar, J. Age differences in cyclic motor reaction. Nature, London, 1962, 195, 813-814.
- Teplov, B. M. The dependence of the absolute visual threshold on the presence of an additional stimulus in the field of vision. Journal of General Psychology, 1936, 15, 3-11.k
- Terstenjak, Anton. Two studies on the audio-visual inter-action. Bulletin du Centre d' Etudes et Recherches Psychotechniques, 1963, 12(2), 149-159.
- Thackray, R. I. Correlates of reaction time to startle. Human Factors, 1965, 7, 74-80.
- Thatcher, Karen; Kappler, T.; Wisecup, P., & Fischer, R. Personality trait dependent performance under psilocybin (Part II). Diseases of the Nervous System, 1970, 31, 181-192.
- Thomas, E. A., & Legge, D. Probability matching as a basis for detection and recognition decisions. Psychological Review, 1970, 77(1), 65-72.
- Thomas, G. J. Visual sensitivity to color: A comparative study of four tests. American Journal of Psychology, 1943, 56, 583-591.
- Thompson, C. P., & Poling, D. R. Free recall of successive lists: Effect of category size and category repetition. Psychonomic Science, 1969, 16(4), 201-202.
- Thompson, L. W., & Botwinick, J. Age differences in the relationship between EEG arousal and reaction time. Journal of Psychology, 1968, 68, 167-172.
- Thompson, L. W.; Opton, E., Jr., & Cohen, L. D. Effects of age, presentation speed, and sensory modality on performance of a "vigilance" task. Journal of Gerontology, 1963, 18, 366-369.
- Thompson, Merrell E.; Thompson, Jean P., & Dusek, E. Ralph. Tests of motor ability or gross muscular coordination. USAF Human Resources Research Center, Research Bulletin, 1953, No. 53-25, iii, 35.

Thurmond, J. B.; Binford, J. R., & Loeb, M. Effects of signal to noise variability over repeated sessions in an auditory vigilance task. Perception & Psychophysics, 1970, 7(2), 100-102.

Thurstone, L. L., & Mellinger, J. J. The Stroop Test. Chapel Hill, N. C.: The Psychometric Laboratory, University of North Carolina, No. 3, 1953.

Thwing, E. J. Spread of perstimulatory fatigue of a pure tone to neighboring frequencies. Journal of the Acoustical Society of America, 1955, 27, 741-748.

Tiffin, J., & Asher, E. J. The Purdue Pegboard, norms and studies of reliability and validity. Journal of Applied Psychology, 1948, 32, 234-247.

Tiffin, J., & Rabideau, G. F. Reduced trials and reliability of visual-acuity thresholds obtained by the method of constant stimuli. Journal of Applied Psychology, 1955, 39, 78-81.

Tinker, M. A. A flexible apparatus for recording reading reactions. Journal of Experimental Psychology, 1932, 15, 777-778.

Tinker, M. A. A noiseless exposure apparatus. American Journal of Psychology, 1931, 43, 640-642.

Todd, J. W. Reaction to multiple stimuli. Archives of Psychology, New York, 1912, 3, No. 25.

Tolin, P., & Simon, J. R. Effect of task complexity and stimulus duration on perceptual-motor performance of two disparate age groups. Ergonomics, 1968, 11(3), 283-290.

Tombaugh, Tom N., & Tombaugh, Jo. The effects of apparent task solubility and reward upon the duration of problem solving behavior. Psychol. Rec., 1963, 13(1), 83-87.

Tomoda, Z. The perception of figures based upon form and size. Japanese Journal of Psychology, 1937, 12, 433-450.

Tomndorf, J., & Brogan, F. A. Short-duration auditory fatigue after white-noise stimulation: Development of a routine test procedure. USAF School of Aviation Medicine Project Report, 1953, Project No. 21-1203-0001, Report No. iii, 14.

Urook, Attila, & Somogyi, Istvan. "Frequency reactometer": A new method and device for measuring reaction time. Magyar Pszichologiai Szemle, 1962, 19(4), 20-425.

Urook, N., & Derbyshire, A. J. Computation of the nystagmogram. Acta Otorhinolaryngologica, 1968, 65, 70-78.

Warrance, E. P. Crew performance in a test situation as a prediction of field and combat performance. HFDRL Report No. 33, Human Factors Oper. Res. Lab., olling AFB, Washington, D.C., March, 1953. AD 14 473.

- Trabka, E. A., & Roetling, P. G. Image transformations for pattern recognition using incoherent illumination and bipolar aperture masks. Journal of the Optical Society of America, 1964, 54(10), 1242-1252.
- Traquair, H. M. An Introduction to Clinical Perimetry. London: Kimpton, 1931.
- Travis, E. L., & Griffith, P. E. Electric current thresholds at audio-frequencies. American Journal of Psychology, 1936, 48, 422-433.
- Trevarthen, C., & Tursky, B. Recording horizontal rotations of head and eyes in spontaneous shifts of gaze. Behavior Research Methods & Instrumentation, 1969, 1(8), 291-293.
- Trimble, O. C. An apparatus for the study of the relative roles of phase and intensity in sound-localization. American Journal of Psychology, 1931, 43, 638-640.
- Troland, L. T. The Principles of Psycho-physiology. Vol. 2. New York: Van Nostrand, 1930, pp. xxi and 397.
- Trumbo, D. Instrumentation in motor skills research. American Psychologist, 1969, 24(3), 289-292.
- Tsai, Loh S., & Newbold, Jeanie. Nature, reliability, and administration of the Number-Joining (Trail Making or Pathways) Test. Proceedings of the 77th Annual Convention of the American Psychological Association, 1969, 4(Pt. 1), 161-162.
- Tsao, J. C. Time interval and error of tactual-kinesthetic localization. Acta Psychol. Sinica, 1962, No. 3, 231-240.
- Tufts College. Fatigue tests; continuous 13½ hours tracking fatigue test. (OEMsr-581, Report 2, 1942; Publ. Bd. No. L 77775.) Washington, D.C.: U.S. Department of Commerce, 1947, 10.
- Tufts College. Correlation between the Keystone and Bott tests of stereopsis and influence of size of test stimuli in judgments of stereopsis. (1942; Publ. Bd. No. 58189.) Washington, D.C.: U.S. Department of Commerce, 1947, 8.
- Turvey, M. T.; Fertig, J., & Kravetz, S. Connotative classification and proactive interference in short-term memory. Psychonomic Science, 1969, 16(4), 223-224.
- Tuttle, W. W., & Janney, C. D. An apparatus for localizing warm and cold receptors. Science, 1950, 111, 722-723.
- Tyler, D. B. The fatigue of prolonged wakefulness. Federation Proceedings, 1947, 6, 218.
- Umanskii, L. I.; Chernyshev, A. S., & Tarasov, B. V. A group sensorimotor integrator. Voprosy Psikhologii, 1969, 15(1), 128-130.

- Underwood, Benton J. Attributes of memory. Psychological Review, 1969, 76(6), 559-573.
- Underwood, Benton J., & Freund, Joel S. Testing effects in the recognition of words. Journal of Verbal Learning & Verbal Behavior, 1970, 9(1), 117-125.
- Underwood, Benton J., & Richardson, J. Some verbal materials for the study of concept formation. Psychological Bulletin, 1956, 53, 84-95.
- U.S. Dept. Army. AGO. PRB. The development of experimental photopic visual acuity tests. Personnel Res. Br. Res. Note, 1953, No. 14, 28.
- U.S. Dept. Army. AGO. PRB. The development of experimental stress-sensitive tests for predicting performance in military tasks. Personnel Res. Br. Tech. Res. Rep., 1953, No. 1079, 67.
- U.S. National Defense Research Committee. On the relation of atmospheric 'boil' to magnification and base length of stereoscopic ranging instruments. Report to the Services No. 95: Div. 7, Fire Control. (1945; Publ. Bd., No. 34120.) Washington, D.C.: U.S. Department of Commerce, 1946, p. 23.
- Uttal, William R. Masking of alphabetic character recognition by ultrahigh-density dynamic visual noise. Perception & Psychophysics, 1970, 7(1), 19-22.
- Vacchiano, R. B.; Strauss, P. S.; Ryan, Sharon, & Hockman, L. Pupillary response to value-linked words. Perceptual & Motor Skills, 1968, 27, 207-210.
- Valter, Vladmír. Measuring of autokinetic movement. Psychologické Štúdie, 1960, 2, 157-162.
- Valter, Vladmír. The precision of methods for the intermittent light stimulation. Psychologické Štúdie, 1960, 2, 163-165.
- van der Burgh, A. The weight of the human factor in road traffic. Netherlands Transport, 1969, 21(3), 60-63.
- Van der Ven, A. H. G. S. A work curve analysis of the Bourdon-Wiersma Test. Nederlands Tijdschrift voor de Psychologie, 1964, 19(3), 300-308.
- Van Heuven, J. A. On the estimation of the size of circular disks. Z. Psychol., 1942, 153, 81-90.
- Van Houten, Patricia L., & Zenhausern, Robert. Meprobamate and absolute auditory thresholds. Journal of Auditory Research, 1967, 7(3), 253-257.
- Van Liere, D. W. Characteristics of the muscle tension response to paired tones. Journal of Experimental Psychology, 1953, 46, 319-324.
- Vaughan, H. G., Jr.; Costa, L. D.; Gilden, L., & Schimmel, H. Identification of sensory and motor components of cerebral activity in simple reaction-time tasks. Proceedings of the 73rd Annual Convention of the American Psychological Association, 1965, 179-180.
- Vaught, Glen M. Change in tactual form discrimination error scores as a function of vibratory stimulation. Psychonomic Science, 1967, 9(8), 487-488.

- Vega, Arthur. Use of Purdue Pegboard and finger tapping performance as a rapid screening test for brain damage. Journal of Clinical Psychology, 1969, 25(3), 255-258.
- Verhoeff, F. H. Simple quantitative test for acuity and reliability of binocular stereopsis. Arch. Ophthalm., Chicago, 1942, 28, 1000-1019.
- Vernon, J. A.; Mc Gill, T. E.; Gulick, W. L., & Candland, D. K. Effect of sensory deprivation on some perceptual and motor skills. Perceptual & Motor Skills, 1959, 9(2), 91-97.
- Vernon, W. M. Comparative aversiveness of self-delivered versus other-delivered shock. Proceedings of the 77th Annual Convention of the American Psychological Association, 1969, 4(Pt. 2), 813-814.
- Verplanck, William S.; Cotton, John W., & Collier, George H. Previous training as a determinant of response dependency at the threshold. Journal of Experimental Psychology, 1953, 45, 10-14.
- Verriest, G. Further studies on acquired deficiency of color discrimination. Journal of the Optical Society of America, 1963, 53(1), 185-195.
- Verrillo, R. T.; Fraioli, A. J., & Smith, R. L. Sensation magnitude of vibrotactile stimuli. Perception & Psychophysics, 1969, 6(6-A), 366-372.
- Versteeg, A. Effect of a border on reaction time to onset and offset stimulation in the fovea. Perceptual and Motor Skills, 1970, 31, 235-238.
- Verwoerd, H. F. The distribution of "attention" and its testing. Journal of Applied Psychology, 1928, 12, 495-510.
- Vidacek, S. Effect of fatigue on the reproduction of arm movements and the stability of fist pressure. Arch. Hig. Rada, 1957, 8, 229-254.
- Vince, M. A. The relation between hand movements and intellectual activity in a skilled task. Quarterly Journal of Experimental Psychology, 1955, 7, 82-90.
- Vincent, D. F., & Wolters, A. W. A simple mirror tachistoscope. British Journal of Psychology, 1931, 22, 67-72.
- Vollmer, E. P.; King, B. G.; Birren, J. E., & Fisher, M. B. The effects of carbon monoxide on three types of performance at simulated altitudes of 10,000 and 15,000 feet. Journal of Experimental Psychology, 1946, 36, 244-251.
- von Bahr, Gunnar. Studies on the depth of focus of the eye. Acta Ophthalm., Kbb., 1952, 30, 39-44.
- von Békésy, G. Sweetness produced electrically on the tongue and its relation to taste theories. Journal of Applied Physiology, 1964, 19, 1105.

- von Fieandt, K. Experiments on spatial form and the distribution of brightness. Z. Psychol., 1943, 153, 113-122.
- Vreuls, D., & Schmidt, J. F. Model for effect of a second visual stimulus upon reaction time to the first. Perceptual & Motor Skills, 1966, 23, 323-328.
- Wade, J. E. Switch performance under conditions of weightlessness. Report No. MRL-TDR-62-73, Aerospace Medical Div., 6570 AMRL, Wright-Patterson AFB, Ohio, June, 1962.
- Wade, J. E. Psychomotor performance under conditons of weightlessness. USAF MRL Tech. Docum. Rep., 1962, No. 62-73, iii, 7.
- Wade, N. J. The interaction of postural systems in visual orientation. Perception & Psychophysics, 1969, 6(5), 309-310.
- Wade, N. J. Effect of instructions on visual orientation. Journal of Experimental Psychology, 1970, 83(2, Pt. 1), 331-332.
- Wade, N. J., & Day, R. H. Development and dissipation of a visual spatial after-effect from prolonged head tilt. Journal of Experimental Psychology, 1968, 76(3, Pt. 1), 439-443.
- Wade, N. J. Visual orientation as a function of head tilt. Perceptual & Motor Skills, 1969, 29(2), 573-574.
- Waked, Nabil W. The measurement of rotational speed with a sonometer. Science, 1955, 121, 609-610.
- Wald, G. A portable visual adaptometer. Journal of the Optical Society of America, 1941, 31, 235-238.
- Wald, G. The spectral sensitivity of the human eye. 1. A spectral adaptometer. Journal of the Optical Society of America, 1945, 35, 187-196.
- Walk, Dieter E. Finger dexterity of the pressure-suited subject. USAF AMRL-TDR No. 64-41, 11.
- Walk, R. D., & Wellin, F. A response board for group experiments in problem solving and concept formation. Psychol. Rep., 1955, 1, 335-338.
- Wallach, Hans, & Norris, Cynthia M. Accommodation as a distance cue. American Journal of Psychology, 1963, 76(4), 659-664.
- Wallach, Hans; O'Connell, D. N., & Neisser, Ulric. The memory effect of visual perception of three-dimensional form. Journal of Experimental Psychology, 1953, 45, 360-368.
- Wallach, Hans, & Zuckerman, Carl. The constancy of stereoscopic depth. American Journal of Psychology, 1963, 76(3), 404-412.
- Wallis, C. P., & Audley, R. J. Response instructions and the speed of relative judgments. British Journal of Psychology, 1964, 55(2), 121-132.

- Walsh, T. M.; O'Leary, J. P., & Schena, R. M. A technique and apparatus for studying motor-planning behavior. American Journal of Psychology, 1968, 81(1), 102-105.
- Walston, C. E., & Warren, C. E. Analysis of the human operator in a closed-loop system. USAF Hum. Resour. Res. Cent. Res. Bull., 1953, No. 53-32, 111, 33.
- Wapner, S.; Weinberg, J.; Glick, J. A., & Rand, G. Effect of speed of movement on tactual-kinesthetic perception of extent. American Journal of Psychology, 1967, 80(4), 608-613.
- Wapner, S., & Werner, H. Experiments on sensory-tonic field theory of perception: V. Effect of body status on the kinesthetic perception of verticality. Journal of Experimental Psychology, 1952, 44, 126-131.
- Ward, W. D. Studies on the aural reflex. III. Reflex latency as inferred from reduction of temporary threshold shift from impulses. Journal of the Acoustical Society of America, 1962, 34, 1132-1137.
- Warden, C. J., & Brown, H. C. A preliminary investigation of form and motion acuity at low levels of illumination. Journal of Experimental Psychology, 1944, 34, 437-449.
- Wargo, M. J. Human operator response speed, frequency, and flexibility: A review and analysis. Human Factors, 1967, 9, 221-238.
- Warm, J. S., & Foulke, E. Effects of rate of signal rise and decay on reaction time to the onset and offset of acoustic stimuli. Perception & Psychophysics, 1970, 7, 159-160.
- Warm, J. S.; Foulke, E., & Smith, K. L. Effects of rotation and redundancy on the tactual perception of form. Psychonomic Bulletin, 1967, 1(2), 7-8.
- Warm, J. S.; Loeb, M., & Alluisi, E. A. Variations in watchkeeping performance as a function of the rate and duration of visual signals. Perception & Psychophysics, 1970, 7(2), 97-99.
- Warm, J. S.; Smith, R. P., & Caldwell, L. A. Effects of induced muscle tension on judgment of time. Perceptual & Motor Skills, 1967, 25(1), 153-160.
- Warren, C. E.; Fontaine, A. B., & Clark, J. R. A two-dimensional electronic pursuit apparatus. USAF Hum. Resour. Res. Cent. Res. Bull., 1952, No. 52-26, viii, 104.
- Warren, H. W., & Thomson, W. J. Anagram solution as a function of transition probabilities and solution word frequency. Psychonomic Science, 1969, 17(6), 333-334.
- Warren, N. A comparison of standard tests of depth perception. American Journal of Optom., 1940, 17, 208-211.
- Warren, N. Over-compensation in time relationships of bilateral movements of the fingers. American Journal of Psychology, 1935, 47, 580-596.

- Warrick, M.J. Counters for airborne use. USAF, WADC Technical Report, 1954, No. 54-266, iii, 9.
- Waszak, M., & Obrist, W.D. Relationship of slow potential changes to response speed and motivation in man. Electroencephalography and Clinical Neurophysiology, 1969, 27, 113-120.
- Watson, L., & Tolan, T. Hearing Tests and Hearing Instruments. Baltimore: Williams and Wilkins Co., 1949.
- Waugh, N.C. Retrieval time in short-term memory. British Journal of Psychology, 1970, 61(1), 1-12.
- Way, T.C., & Gottsdanker, R. Psychological refractoriness with varying differences between tasks. Journal of Experimental Psychology, 1968, 78(1), 38-45.
- Weaver, H.B., & Roberts, J.R. A discriminative serial action apparatus. Journal of Experimental Psychology, 1942, 31, 171-176.
- Webb, W.B., & Kaspar, J.C. The ability to reproduce task cues and the ability to perform the task. Perceptual & Motor Skills, 1956, 6, 291-294.
- Webster, R.B. Pattern discrimination as a function of fill, distortion, and noise. Perceptual & Motor Skills, 1963, 16(2), 361-367.
- Wedell, C.H. Absolute judgment of pitch. Psychological Bulletin, 1933, 30, 546.
- Weidemann, W. A new and simple adaptometer. Klin. Mbl. Augenheilk., 1952, 121, 563-573.
- Weinstein, S. Tactual sensitivity of the phalanges. Perceptual & Motor Skills, 1962, 14, 351-354.
- Weinstein, S., Sersen, E.A., & Weinstein, D.S. An attempt to replicate a study of disarranged eye-hand coordination. Perceptual & Motor Skills, 1964, 18(2), 629-632.
- Weiss, A.D. The locus of reaction time change with set, motivation, and age. Journal of Gerontology, 1965, 20, 60-64.
- Weiss, W. Effects of response scales on the expected distribution of judgments of social stimuli. Psychological Reports, 1963, 13(2), 411-414.
- Weiss, W. Influence on judgment of increasing asymmetry of stimulus series. Perceptual & Motor Skills, 1963, 17(2), 371-376.
- Weiss, W. Effect of response system on development of standards for end categories. Psychological Reports, 1963, 13(2), 543-546.

- Weiss, W., & Hodgson, D.A. Influence of unbalanced response scales on size judgments. Journal of Experimental Psychology, 1963, 66(1), 37-46.
- Weitz, J. The effect of shape- and color-coding of airplane controls. American Psychologist, 1946, 1, 446.
- Welford, A.T. The psychologist's problem in measuring fatigue. In: Floyd and Welford, Symposium on Fatigue, 183-191.
- Welford, A.T. Evidence of a single-channel decision mechanism limiting performance in a serial reaction task. Quarterly Journal of Experimental Psychology, 1959, 11, 193-210.
- Welford, A.T. The "psychological refractory period" and the timing of high-speed performance--a review and a theory. British Journal of Psychology, 1952, 43, 2-19.
- Welford, A.T., Brown, R.A., & Gabb, J.E. Two experiments on fatigue as affecting skilled performance in civilian air crew. British Journal of Psychology, 1950, 40, 195-211.
- Weston, H.C. Visual fatigue. Optician, 1952, 124, 602.
- Weston, H.C. Visual fatigue, with special reference to lighting. Trans. Illum. Engrng. Soc., London., 1953, 18, 39-66.
- Westrope, M. Relations among Rorschach indices, manifest anxiety and performance under stress. Journal of Abnormal and Social Psychology, 1953, 48, 515-523.
- Weymouth, F.W., & Hirsch, M.J. The reliability of certain tests for determining distance discrimination. American Journal of Psychology, 1945, 58, 379-390.
- Wheaton, G.R., Zavala, A., & Van Cott, H.P. The effects of map design variables on map user performance. American Institute for Research Technical Report, 1967, No. R67-3, 72.
- Whillans, M.G. Human factors in aircraft design. In: NATO ..., Anthropometry and Human Engineering, 113-123.
- Whimbey, A.E., & Ryan, S.F. Role of short-term memory and training in solving reasoning problems mentally. Journal of Educational Psychology, 1969, 60, 361-364.
- White, C.S., Humm, J.H., Armstrong, E.D., & Lundgren, N.P.V. Human tolerance to acute exposure to six percent carbon dioxide in air and in oxygen. USAF, Sch. Aviat. Med., Project Report, 1953, No. 21-1402-0001, Report No. 1, iii, 13.
- White, M.J. Signal-detection analysis of laterality differences: some preliminary data, free of recall and report-sequence characteristics. Journal of Experimental Psychology, 1970, 83, 174-176.

White, M.S. The value of the pseudo-isochromatic color vision test in original applicants for military flying. Military Surgery, 1941, 89, 801-805.

White, W.J., Warrick, M.J., & Grether, W.F. Instrument reading III: check reading of instrument groups. Journal of Applied Psychology, 1953, 37, 302-307.

Whitley, J.D., & Elliott, G.M. Learning component in repetitive maximal static contractions. Perceptual & Motor Skills, 1968, 27, 1195-1200.

Wicke, J.D., & Lindsley, D.B. Apparatus for randomly determining visual stimulus positions using a "forced-choice" psychophysical procedure. American Journal of Psychology, 1969, 82(3), 410-413.

Wickelgren, W.A. Unidimensional strength theory and component analysis of noise in absolute and comparative judgments. Journal of Mathematical Psychology, 1968, 5(1), 102-122.

Wickens, D.D., Schroder, H.M., & Snide, J.D. Primary stimulus generalization of the GSR under two conditions. Journal of Experimental Psychology, 1954, 47, 52-56.

Wiebe, V.R. A study of tests of kinesthesia. Res. Quart. Amer. Ass. Hlth phys. Educ., 1954, 25, 222-230.

Wierenga, R.D. An evaluation of a pilot model based on Kalman filtering and optimal control. IEEE Transactions on Man-Machine Systems, 1969, MMS-10, 108-117.

Wilkinson, R.T. Artificial "signals" as an aid to an inspection task. Ergonomics, 1964, 7(1), 63-72.

Wilkinson, R.T. Some factors influencing the effect of environmental stressors upon performance. Psychological Bulletin, 1969, 72(4), 260-272.

Wilkinson, R.T., & Morlock, H.C. Auditory evoked response and reaction time. Electroencephalography and Clinical Neurophysiology, 1967, 22, 313-324.

Williams, R.D. The properties of the visual excitation-curves. Ohio Journal of Science, 1934, 34, 265-283.

Willmorth, N.E. Influence of overlap on speed and accuracy in screening imagery. U.S. Army PRO Technical Research Note, 1967, No. 180, 34.

Willmorth, N.E., & Birnbaum, A.H. Influence of screening and overlapping image on speed and accuracy of photo interpretation. U.S. Army BESRL Technical Research Note, 1967, No. 182, 37.

- Wilson, C.L. (Ed.) Project Mercury Candidate Evaluation Program. WADC TR 59-505, Aerospace Medical Lab, WADC, ARDC, USAF, WPAFB, Ohio, December, 1959.
- Windes, J.D. Reaction time for numerical coding and naming of numerals. Journal of Experimental Psychology, 1968, 78, 318-322.
- Wingrove, R.C., & Edwards, F.G. Measurement of pilot describing functions from flight test data with an example from Gemini X. IEEE Transactions on Man-Machine Systems, 1968, MMS-9, 49-55.
- Wingrove, R.C., Edwards, F.G., & Lopez, A.E. Some examples of pilot/vehicle dynamics identified from flight test records. IEEE Transactions on Man-Machine Systems, 1969, MMS-10, 131-132.
- Winnick, W.A. Two kinds of familiarization in tachistoscopic recognition, paired-associate learning, and free recall. Psychonomic Science, 1969, 16(4), 217-218.
- Wise, J.A. Estimates and scaled judgments of subjective probabilities. Organizational Behavior & Human Performance, 1970, 5(1), 85-92.
- Withers, W.C.R. A new tachistoscope and cycling timer. British Journal of Psychology, 1954, 45, 217-219.
- Witmer, L.R. The association value of three-place consonant syllables. Journal of Genetic Psychology,
- Wohlwill, J.F. Over-constancy in distance perception as a function of the texture of the stimulus field and other variables. Perceptual & Motor Skills, 1963, 17(3), 831-846.
- Wood, M.E. Continuously adaptive versus discrete changes of task difficulty in the training of a complex perceptual-motor skill. Proceedings of the 77th Annual Convention of the American Psychological Association, 1969, 4, 757-758.
- Worley, J.K., & Markley, R.P. Distance discrimination in a reduced cue setting. Psychonomic Science, 1969, 17(4), 237-238.
- Worthington, A.G. Paired comparison scaling of brightness judgments: a method for the measurement of perceptual defense. British Journal of Psychology, 1969, 60(3), 363-368.
- Wortz, E.C. Work in reduced-gravity environments. Human Factors, 1969, 11(5), 433-440.
- Wright, W.D., & Nelson, J.H. A subjective photometer. Journal of Scientific Instruments, 1935, 12, 373-377.
- Wyke, M., & Chorover, S.L. Comparison of spatial discrimination in the temporal and nasal sectors of the monocular visual field. Perceptual & Motor Skills, 1965, 20(3), 1037-1045.

- Yacorzynski, G.K. The threshold of flicker fusion as a function of excitation and inhibition due to conditioning. Journal of Experimental Psychology, 1944, 34, 335-342.
- Yela, M., & Pascual, M. The structure of mechanical aptitude. Revista de Psicologia General y Aplicada, 1968, 23(95), 1050-1053.
- Yokose, Z., & Kawamura, H. A study of the direction of the field force in shape perception. Report No. 1: Japanese Journal of Psychology, 1952, 23, 133-143.
- Yoshino, H., Takayoshi, & Oyamada, T. Studies on sensory deprivation: VI. Part 5. Effects of sensory deprivation of various performance tests. Tohoku Psychologica Folia, 1967, 26, 26-37.
- Young, I.M., & Wenner, C.H. Effects of masking noise on the SISI test. Journal of Auditory Research, 1968, 8(3), 331-337.
- Zacks, J.L., & Freedman, S.J. Active and passive movement in the production of kinesthetic tilt after-effects. Perceptual & Motor Skills, 1963, 16(3), 702.
- Zajac, J.L. Investigations on depth perception in indirect vision. British Journal of Psychology, 1953, 44, 132-144.
- Zavala, A., Locke, A., Van Cott, H.P., & Fleishman, E.A. The analysis of helicopter pilot performance. American Institutes for Research Technical Report, 1965, No. R65-1, 102.
- Zegers, R.T., & Cahill, M.C. The latency of pricking pain sensation: I. The effect of Acetophenetidin and Anacin. II. The effect of repeated stimulation. Journal of Psychology, 1965, 59, 101-108.
- Zeidner, J., Gordon, D.A., Goldstein, L.G., & Marks, M.R. Dark-adaptation time for testing night-vision ability. U.S.A. Person. Res. Br. Note, 1954, No. 25, 37.
- Zeitlin, L.R., & Cramer, R.L. Further studies on frequency discrimination of pure and complex tones. U.S. Army Medical Research Laboratory Report, 1957, No. 248, ii, 10.
- Zelkind, I., & Ulehla, J. Estimated duration of an auditory signal as a function of its intensity. Psychonomic Science, 1968, 11(6), 185-186.
- Zener, K.E., & Weaver, E.G. A multiple-choice apparatus. American Journal of Psychology, 1929, 41, 647-648.
- Ziegler, P.N. Single and dual axis tracking as a function of system dynamics. Human Factors, 1968, 10(3), 273-276.
- Zoble, E.J., & Lehman, R.S. Interaction of subject and experimenter expectancy effects in a tone length discrimination task. Behavioral Science, 1969, 14(5), 357-363.

Zotterman, Y. Olfaction and Taste. New York: Pergamon Press, 1963.

Zubal, O. Preliminary investigation for development of an electronic psychomotor skill tester of V/STOL pilots. U.S. Army Human Engineering Laboratories Technical Note, 1968, No. 12-68, 29.

Zuckerman, M., Levine, S., & Biase, D.V. Stress response in total and partial perceptual isolation. Psychosomatic Medicine, 1964, 26(3), 250-260.

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