AN HISTORICAL AND EXPERIMENTAL
STUDY OF REACTION TIME

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-1920-
1. Azzo Azzi
   Discrimination of Reaction Time
   At the Psycho-Physiology of Aviators
   of the Bayal Navy at Naples. 1919,
   (unpublished).

2. Bache, R. Meade
   Reaction Time with Reference to Race
   Psy. Rev. 1895, II, 475-486.

   Types of Reaction

4. Bettman, Siegfried
   Uber die Beeinflussung einfacher psych-
   ischer Vorgänge durch Körperliche u.
   geistige Arbeit

5. Breitweiser, J. V.
   Attention and Movement in Reaction Time
   Archives of Psy. 1911, No. 18, 1-50.
6. Camis, Maris
Of the Psycho-Physiological Office of
Military Aviation at Turin, 1919,
(unpublished).

7. Camus et Nepper
Recherchis sur l'aptitude à l'aviation.
Bulletin de l'Institut Général
Psychologique, Annee 1917,
Nos. 1-3, 17e.

8. Cassell, E.E., and Dallenback, K. M.
The Effect of Auditory Distraction upon
Sensory Reaction Time

On Reaction Time and the Velocity of
the Nervous Impulse
Memoirs of the National Acad., 1896,
VII, 393-415.

10. Crane, Harry A.
A Study in Association Reaction Time

The Force and Rapidity of Reaction Movement


12. Dunlap, Knight, and Wells, G.R.

Some Experiments with Reaction to Visual and Auditory Stimuli


13. Ellis, A. C., and Shipe, M. M.

A Study of the Accuracy of the Present Methods of Testing Fatigue

Amer. J. Psy., 1903, XIV, 496-509.

14. Evans, John E.

The Effect of Distraction on Reaction Time with Special Reference to Practice and Transfer of Training

Arch. of Psy., 1916, No. 37, 1-106.

15. Farrand, Livingston

Note on 'Reaction Types'

Psy. Rev., IV, 297-299.
16. Froeberg, Evan
The Relation between the Magnitude of the Stimulus and the Time of Reaction
Arch. Psy., 1907, No. 8, 1-38.

17. Gemelli, Agastino, and Gradenigo, Guiseppe
Of the Psycho-Physiological Laboratory (unpublished).

18. Henke and Eddy
Mental Diagnosis by Association Reaction Method

19. Hill, A. R., and Watanabe, R.
Sensorial and Muscular Reactions

20. Helmholtz, H. L. F.
1850, 276-364.

21. Mashelyns
Astronomical Observations made at the Royal Observatory at Greenwich, 1795, Pt.iii.
22. Milroy, T. H.
   Fatigue, Studied in Reaction Time Experiments

23. Morgan, J. B.
   The Overcoming of Distraction
   Arch. ofPsy., 1916, No. 35, 1-86.

24. Müller, Johannes
   Handbúch der Physiologie
   (Coblenz), 1844, 581 pages.

25. Saffiatti, Francesco Umberto
   At the Psycho-Physiological Office at Turin (unpublished).

26. Scripture, E. W.
   Research in Reaction Time
   Yale Studies, 1896, IV, 12-16, 69-75.

27. Safford, T. H.
   The Psychology of the Personal Equation
   Science, 1897, N. S., VI, 784-789.
28. Swindle, P. F.

The Term Reaction Time Redefined

Amer. J. Psy., 1917, XXVIII, 508-518.

29. Titchener, E. B.

The Type-Theory of the Simple Reaction

Mind, 1895, IV, 506-515

30. Titchener, E. B.

Simple Reactions

Mind, 1895, IV, N. S.; 74-85.

31. Williams, R.D.

Experimental Analysis of Form of Reaction Movement


32. Wells, G. R.

The Influence of Stimulus Duration on Reaction Time


33. Whipple, M. G.

Reaction Time as a Test of Mental Ability

Amer. J. Psy., 1914, XV, 489-498.
34. Whipple, M. G.

Manual of Mental and Physical Tests


35. Woodrow, Herbert

Measurement of Attention

Psy. Rev. Mon., 1914, XVII, 1-158.

36. Woodrow, Herbert

The Faculty of Attention


37. Yerkes, Robert M., and Berry, Charles S.

The Association Reaction Method of Mental Diagnoses

Amer. J. Psy., 1909, XX, 22-38.
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I-INTRODUCTION

A-Definition of Reaction Time- By simple reaction time is meant the time which passes between the presented stimulus and the corresponding direct response. Titchener (30) has defined reaction time as the interval elapsing between the mental receiving of a sense impression and the execution of a movement in direct response to that impression. Swindle (28) has defined it as the time which intervenes between the presentation of the stimulus and the response in which we are interested. In the experimental section of this investigation, we are interested in the direct response to an auditory stimulus. When we speak of reaction time, we shall mean the time elapsing between the presentation of a stimulus and the corresponding direct response made by the subject.

B-Uses of Reaction Time- Reaction time has been used for various purposes. Before a psychological explanation of reaction time was offered, the physiological laboratory attempted
to use it as a means of measuring the velocity of a nervous impulse. Later, as the experiment was found to be a psychological one, it was transferred to the psychological laboratory, and there, has been used in different forms as a means of solving various problems. In the review that follows, we find that reaction time has been used as a measurement of racial and individual intelligence; as a means of detecting criminals by association reaction time tests; and as a method of measuring fatigue. Since the normal reaction time is disturbed by distracting stimuli, the increase in reaction time under distraction has been employed to measure the degree and duration of attention.

An influence, that has played a more or less important part in the determination of the length of any reaction time at critical moments, when much depends on clear thinking and quick action, has been the factor of emotions. Great individual difference is shown in the ability of different persons to resist emotional disturbances, while being confronted with another more important situation.
While the emotional influence, as a factor in determining the reaction time of an individual at critical times, has long been recognized in a general way, it is only recently that attempts in scientific determination of its influence have been made. During the 'World War' it was considered of sufficient importance to measure the influence of emotional stimuli on the reaction time of aviation candidates, and to consider their ability to resist such disturbances, as a partial basis of recommendation for that service. Great variations and personal differences in this ability were found, which will be discussed later.

C-Statement of Problem- The first purpose of this investigation is to partly summarize the psychology of reaction time, by reviewing experimental results bearing on its different uses; The second purpose is to supplement this historical summary with experimental data, illustrating individual difference in normal reaction time, in order to determine the relative effect

*See references (15, 20, 6, 1, 7.)
of an emotional stimulus on the time of individual reactions, and to determine the relation of such effect, if any, to the steadiness of hand control.

D-Acknowledgment- The author wishes to express her gratitude to Professor F. C. Dockeray for suggesting the problem and directing its procedure. She also wishes to express her thanks to Professor W. S. Hunter for many helpful suggestions. The students of the general psychology class, who made the experimental section possible by kindly consenting to act as subjects, are especially deserving of acknowledgment.
II-HISTORICAL REVIEW

A- Purpose of Historical Review- The Purpose of this historical review is to bring before the reader a partial summary of some of the most important investigations illustrating the different uses of the various forms of reaction time.

B- Use of Reaction Time in Determining Personal Difference- The first interest arising in reaction time resulted from the discovery of a 'personal difference'. In the year, 1796, the astronomer at the Greenwich Observatory (21), discovered that his assistant recorded the passing of a star across the median much too slowly. The method then used to record stellar transits was that of the eye and ear. The field of vision, in the telescope, was divided up into sections by means of vertical wires equal distance apart. The middle wire represented the meridian. The observer would first note the time from a clock and then count the beats of the pendulum as he watched the progress made by the star. By observing the star's position at the last beat
before, and the first beat after, it crossed the meridian wire, he was able to estimate the time required for the actual crossing.

It was in determinations of this sort, by the eye and ear method, that the 'personal difference' appeared. 'Personal equations' resulted from the comparison of individual estimates of time. To illustrate this: 'A' has an auditory reaction time of $130\,\sigma$, and 'B' has an auditory reaction time of $150\,\sigma$. By expressing these reaction times in the form of the 'personal equation' $150 - 130 = 20$ gives us at once the 'personal difference'. The reaction times 150 and $130\,\sigma$ represent the respective times, which have passed between the presentation of the stimulus, and the response of each subject.

C-Measurement of the Velocity of a Nervous Impulse— As the method of recording astronomical observations improved, the method of determining the 'personal equation' became useless in this field. The reaction time experiment later passed into the physiological laboratory and...
used to determine the velocity of a nervous impulse. In 1844 Johannes Müller (24) had predicted that the velocity of a nervous impulse would never be determined, as he estimated its speed equal to that of light. About six years later (1850), Helmholtz (20) performed an experiment, measuring the rate of a nervous impulse, which had just been predicted could never be done. His method was the reaction time method. He measured the time which passed between the moment a stimulus was given, and the beginning of a muscular contraction. He applied the stimulus as near as possible to, and as far as possible from, a muscle and then compared the times, taking into consideration the length of the nerve between the two places.

The work of Helmholtz's has since been repeated by many investigators. From their work the rate of a nervous impulse has been estimated to be approximately 30 m per sec.

Later Cattell and Lolley (9), in 1894, performed experiments in which they used elec-
trical, and tactual stimuli applied to different parts of the body, for the purpose of measuring a nervous impulse. The assumption was that the time of a nervous impulse would correspond to the unequal distances of the stimuli from the brain, and would manifest itself in different reaction times.

Their conclusions were, that the method was not suited to the problem, since there was no way of knowing, whether the velocity was the same throughout the process. But while the velocity of the plain nerve impulse could not in general be measured by the reaction time, the general result indicated, that it was quicker than was commonly thought, namely 30m per sec.

D-Types of Reaction- There was an attempt made in 1897 to explain reaction time in psychological terms. The explanation of the 'personal difference', as given by Sanford (26), was that the difference is due to the method of reaction used by different individuals. Those having a long
reaction time use the sensorial or deliberate form, while those having a shorter reaction time use the motor or muscular form. Many experiments have been performed demonstrating that there are two forms of reaction. Wells (30), Hill and Watanabe (19), Delebarre (11), Breitweiser (5), Farrand (15), and Williams (31) have done experimental work showing this to be a fact, and have also shown that of the two types, namely the motor or muscular, and the sensorial, that the sensorial usually has the longer reaction.

The general method of experimenting used by Breitweiser (5) is as follows: the subject was given a stimulus and told to fix his attention on the movement made in response to the stimulus. After taking a series of 20 or more 'muscular' reaction times, the subject was given another series and this time he was told to fix his attention on the stimulus to be received. By comparing the average of each series, two distinct types were observed.

The general conclusions of Breitweiser were, that motor and sensory types of reaction
are easily distinguished in most individuals, and the sensory reactions are longer from 10 to 20 $\sigma$ for all individuals tested. If the subject was allowed to react without being told to direct his attention voluntarily on either the presented stimulus or his muscular reaction, the resulting reaction times could be classified into the sensory and motor types of responses, just the same as if his attention had been voluntarily directed on first one, and then the other. However, there was a small percentage which fell between the sensory and motor groups with respect to time. This was termed the normal group.

The work done by Farrand (15), who worked with two men entirely ignorant of reaction time, showed, on the other hand, the average of one to be 177 $\sigma$ when the attention was fixed on the stimulus, and an average of 254 $\sigma$ when the attention was fixed on the muscular movement. The second subject gave an average of 116 $\sigma$ for the muscular reaction and after attempting to shift his attention from his reacting finger to the sensation
received, failed completely.

Baldwin's Theory: Baldwin's study of the difference in reaction times showed clearly that there were different types, but he concluded, that the distinction between the sensory and motor types does not hold in the sense that the motor is always shorter. It may be shorter for some individuals and longer for others. His results point toward three different types, (1) those who give a longer reaction for the sensory than for the motor, (2) those who give a shorter reaction for the sensory than for the motor and (3) those who fall between these two extremes, giving a shorter reaction in favor of the motor form of response. This type corresponds with the 'normal' as given by Breitweiser.

Baldwin (3) attempts to explain this difference in reaction types by the reconciliation of two principles. The first is, that the motor form is shorter because it is partly automatic, that is to say, the thought of a movement is the beginning of it, and thus tends to shorten the reaction time,
and the second is, that the attention to a well learned movement often causes confusion, and in that way delays the progress of it. One of these two principles is used by each and every individual. The person who has, as his 'cue' of action, relied upon his sensation or special image, to start the movement, becomes confused, if his attention is directed toward the movement, and thus, it causes him to require more time for reaction; while the individual, who has habitually directed his attention upon the movement, requires a longer time, if he attempts to direct his attention upon the sensation. Professor Baldwin then concludes, that the reaction is an index of the type of 'cue' used by the individual tested. Thus he would expect the 'sensory' type to react more quickly sensorially than muscurally, and the motor type of person to react more quickly, muscurally.

Titchener (29) in discussing the Baldwin theory of reaction time says, that only a certain portion of those tested, proved to be capable of giving constant and regular reaction times; and
also, that those, who do react with some degree of constancy, show the sensorial-muscular difference. He states further, that there is no reason why the sensorial time should be longer than the muscular; therefore the sensorial-muscular difference is not a fact, from which inferences can be drawn. He concludes that the theory possesses something of the 'naturalness' and 'probability' which was claimed by Mr. Baldwin; but, that the evidences for it are so slight, that the theory is hardly more than conjecture. Titchener is not able to cite another explanation, which is equal to the one offered by Baldwin, yet he feels that the weight of evidence is against the general acceptance of the one presented.

E-Race Difference in Reaction Time. Races, as a whole, differ in their general characteristics. Besides differing in habits, inclinations, dispositions, temperament, tendencies, and physical differences, there has been found a difference in reaction time. In this discussion we are interested in the reaction time difference. Their reaction
times have been used to indicate a difference in general ability. The method, which has been most commonly used in determining the general intelligence of a race, has been that of mental tests. This method furnishes a means of determining the relative general ability of different groups of people under the same circumstances. The contents of these tests are based on the ability of the normal individual of the particular race by which they were constructed. If we give the negroes of Africa the Otis test, for example, and find that they test below the ability of the whites of America, we must bear in mind, that the Africans are at a disadvantage, because the tests were made by a different race, with habits, customs, etc, different from his own. The tests given are our tests, and not the negro's.

A test that eliminates environmental factors, race, habits, etc, and which enables judgment to be made from a basis common to all races, would make a possible measurement of racial intelligence. Up to the present time,
no such mental tests have been constructed.

In the reaction time test, as a measurement of mental ability, we find the element of quickness involved. Backe (2) made an experiment, testing the general intelligence of the Caucasian, the Indian, and the Negro by the reaction time method. His results are shown below:

<table>
<thead>
<tr>
<th></th>
<th>Auditory--A.D.</th>
<th>Vision--A.D.</th>
<th>Electrical Shock--A.D.</th>
</tr>
</thead>
<tbody>
<tr>
<td>White</td>
<td>146.9</td>
<td>164.9</td>
<td>136.0</td>
</tr>
<tr>
<td>Indian</td>
<td>116.2</td>
<td>135.6</td>
<td>114.5</td>
</tr>
<tr>
<td>Negro</td>
<td>130.0</td>
<td>152.8</td>
<td>122.0</td>
</tr>
</tbody>
</table>

These results show a decided racial difference in reaction time. As is seen the Indian has the shortest reaction time and the lowest average deviation, the Negro next and the Caucasian the longest of the three races.

Backe's explanation is as follows: Before men had a developed brain, all his movements were automatic or reflex actions, and consciousness and semi-consciousness played no part in them. The common belief that the more highly developed organisms respond more quickly, is true only of
the higher thought processes, and is not true of responses to auditory, visual, or tactual stimuli. Such stimuli as these cause or invite secondary reflex actions, and the more inferior an individual is intellectually, the quicker will be his reaction time. The origin of reflex action dates back to primitive peoples, when all action was wholly reflex. Backe explains the apparent superiority of the Negro to the Indian by saying, that the Indian has been through all the ages trying to develop the particular characteristic of quickness. Reaction time would, therefore, not be an accurate means of measuring the intelligence of the Indian, and comparing results with other races, because the Indian has developed that particular characteristic, and this would not be a common basis of measurement.

Measurement of Individual Intelligence Tests have been made for the purpose of measuring intelligence individually. The most generally accepted series are the Binet-Simon tests. These consist of various problems, which demand the dis-
play of intelligence in the solution of them. The problems are for the purpose of testing the native ability, and are supposed to have eliminated factors of education, environment or training. Since intelligence is made up of many phases of ability, the series of tests are constructed to call for the exercise of such special ability as the individual possesses.

Perhaps the chief objection to the individual intelligence test is the time required to administer one. Its constant growth in use in institutions is proof of the great service rendered in estimating the general intelligence of school children. Under general ability tests are tests for the feeble minded, vocational fitness, delinquents, superiority, for bases of grading, and for factors influencing mental development.

Whipple (34) has made an extensive study of mental and physical tests. As a special problem he (33) discussed the method of reaction time as a measurement of mental ability. In his
discussion he says that as yet the difference in reaction time of different groups, which has been assumed to indicate a difference in general intelligence, is largely due to poor experimental conditions, and cannot be used in any way as an index of constant difference in general intelligence. Whipple says on page 498, "The outcome of the reaction time tests upon school children will depend, not only upon objective conditions of the test, nature of instruction given, but also upon the ability of the child to understand and carry out these instructions. When a test is therefore affected in this way, any assumed correlation between the quantitative results, and the general intelligence of the group of children tested, is in reality, but a correlation of general intelligence with itself". As yet, we find no such conditions of giving reaction time tests; therefore, according to Whipple, reaction time tests cannot be used as a reliable method of testing general intelligence.
G-Association Reaction Time Tests-

Another use of reaction time is that of association time. For every idea perceived there are associating ideas following. The primary law of association is contiguity, that is to say, two ideas having been experienced together, either in space or time, if one appears later, the other tends to follow. The secondary laws of association, namely: recency, frequency, similarity, and primacy, help to explain why one particular idea, instead of another follows a given state of consciousness. For example, why should the word 'blue' bring to mind at one time 'book'; at another time 'sky'; and at a third time 'ink'. On the basis of the secondary laws of association the explanation may be given. The associated word which follows 'blue' depends upon the frequency, recency, primacy, and similarity, of which 'book', 'sky', of 'ink' had been experienced with 'blue'.

On the basis of the primary and secondary laws of association, the association reaction time tests have been made. The subject is given a
word and is told to respond with the first word that comes into his mind. The word spoken by the subject in response and the time required for it, are the criteria of determining whether the two words have been previously experienced together according to the laws of association.

An act performed at any time has numerous and various associations. Words pertaining to the act will consequently call forth other words connected with it. When the subject wishes to conceal the act performed, the word called forth by the stimulus word, if connected with the act, must be dismissed and another response made. This process will require a longer time than if the first word which came to mind, had been spoken.

The time required for the response is then just as significant as the nature of the response word.

An extensive study of association time and reaction time has been made by Crane (10). His problem was to determine, which of four subjects had performed an act. The method was as
follows: the subject was given words, as in the ordinary association tests, with the instruction that he was to respond with the first word that came into his mind. The stimulus word was exposed in an Aeh card apparatus which was in circuit with a lip key and a Hipp chronoscope. The arrangements were such, that, when the word was exposed, connections were made which started the chronoscope. The reply of the subject broke the current which stopped the chronoscope. At various intervals words were given, which were connected with the details of the act that had been performed. The criteria for detecting the guilty from the non-guilty were, the lengthened reaction time for the significant words, and the nature of the reaction words themselves. If the reaction time was short, the subject betrayed himself by the reaction word, if the reaction time was longer for a significant word, the subject betrayed himself by trying to conceal his guilt, which resulted in a lengthening of the reaction time. This lengthening of time, says Crane,
may be due to an emotional element connected with the experience, or it may be due to a conscious inhibition on the part of the subject.

The difference in association time for different parts of speech was determined by a list of words consisting of nouns, verbs, and modifiers. He found that the reaction times for the modifiers were shorter than for verbs or nouns. Nouns used as modifiers, such as 'brick-wall', made the reaction time shorter. This was explained by the fact of the use of modifiers preceding nouns in speech. Some of the reasons for long reaction times, as given by Crane, are:

1- Visual images tend to retard reaction.
2- Confusion lengthens reaction time.
3- Ideas are difficult to express in a single word.
4- Two or more associations may appear together.
5- No associations may appear at all.
6- Length of word retards reaction time.
7- Emotion and conscious inhibition may influence reaction time.
Crane performed some criminal association tests with several students. One of the group performed an act, and the problem was to determine by means of association tests which one was guilty. The first case proved successful, the guilty one was judged guilty. The second case proved unsuccessful, the innocent one was accused. The third was also unsuccessful, as the guilty one was judged innocent.

On the basis of this experiment, Crane concluded that the test had no practical value, and even with accurate measurements of reaction time, the method is not reliable in determining a guilty conscience.

The conclusions of Henke and Eddy (18), drawn from a series of experiments conducted before a group of psychology students, were quite different from those of Crane. The method of procedure was very similar. Directions were
printed for a particular set of performances and handed to three students. One was to follow the directions and on returning to the class attempt to conceal the fact. The second was to make no attempt to conceal it. The third was to do nothing with the instructions. The problem of the class was to discover which one had performed the act and was trying to conceal it, which one had performed it and was not trying to conceal the fact, and which was innocent. A list of 38 words was prepared and given to each subject on his return. The time was recorded by the use of a chronoscope which measured in one-hundredths of a second. A lip key was used by the experimenter to start the pendulum of the chronoscope at the time the word was given. When the subject spoke the associated word into the mouthpiece, the circuit breaker was released, which caused the reaction time to be recorded by the chronoscope. The response made and the time required were the criteria of judgment. The judgment of the class was correct for all three cases.
Henke and Eddy concluded from this experiment, that accurate judgment is reasonably certain if the situation is so controlled, that the test takes the simple form of determining between two possible alternatives the exact motive being known by the experimenter. Under such conditions it is further possible for a third person who has observed the experiment to pass accurate judgment in discriminating the guilty from the non-guilty. Furthermore, they concluded, that the knowledge of the association reaction method on the part of the subject does not make a correct judgment impossible, but the possibilities of a correct diagnosis decrease as the disadvantages of the experimenter over the subject, and the number of possible diagnosis increases.

Yerkes and Berry's problem, in the use of association reaction time, was to determine which of two possible acts a person had performed. Two boxes were placed side by side: in one was a dancing mouse and in the others a pack of cards. One member of the psychology class was selected to go into the room containing the two boxes, examine one
and return to the class, to be tested by the association reaction time method, to determine which one he had examined.

Two lists of 30 words each, had previously been prepared. In one list were significant words pertaining to the 'mouse-box', and the other list contained significant words regarding the 'card-box'. The subject was instructed to conceal, if possible, his knowledge of the contents of the box he had examined, and to respond by speaking as quickly as possible the first word that came to his mind, as the list was given him by the experimenter. The same time the experimenter gave the subject a word, he pressed the reaction key, which set the Hipp-chronoscope in motion, and, as the subject gave his response, the experimenter released the key which caused the time to be recorded by the chronoscope. After the words had been given from both lists, the length of the reaction time and the associated word as given by the subject were the bases of determining which of the two boxes the subject had examined. Upon these
bases a correct judgment was made by the class.

In the second experiment the problem was to judge which of two persons had performed a certain series of acts. The apparatus was arranged as before, and the method of procedure was the same. In this experiment a list of 100 words was prepared and given to the subject in the same manner as previously. Again the judgment of the class was correct.

From these results, Crane concluded that the method was not a reliable one, Henke and Eddy thought that the method was reasonably certain, while Yerkes and Berry stated that the possibilities of the tests had not yet been demonstrated. If association reaction time is an adequate means of determining the guilty from the non-guilty, it would find extensive use in the juvenile, as well as in the judicial courts. Further investigations are necessary in order to determine to what extent the method may be satisfactorily used in the future.

**H-Effect of Distraction on Reaction Time**

Everyday observation shows that distraction, of one
kind or another, has an influence on what we are voluntarily attempting to do. Every voluntary act requires a certain degree of attention. If attention is in any way disturbed, corresponding results follow. Distraction may be of a positive or a negative nature, depending upon the circumstances under which we are accustomed to labor. An individual who has habitually been working, reading, or studying under distraction of an exterior nature, becomes adapted to them. These exterior stimuli no longer serve as a distraction, but have become a part of the environment in which he works. If the exterior stimulus is removed, the absence of it serves as the distraction and the subject finds it difficult to do as efficient work.

A slight distraction often serves to stimulate one for better work. The attention oftens wanders if conditions are "too favorable". A slight resistance to be overcome causes one to put forth greater effort than is necessary for the correction of the distraction. This fact
may be illustrated by the work of Morgan (23). He required his subjects to press a certain key when a certain color appeared on a disk, and to press another key when another color appeared. Distractions were introduced which called for close attention on the part of the subject. Such distractions as, a buzzing noise, a fire-bell, a bell with the hammer removed striking against a box, and a phonograph were used. These were placed in different positions with respect to the subject. The quickness of response was measured by reaction time. Reactions were taken with and without distraction. In most subjects distraction caused a lengthening in reaction time at first, but later caused a shortening of reaction time and more accurate responses.

The effort put forth by the subject was measured by the pressure exerted on the key. This showed that the pressure was greater during distraction than without it, and that breathing was also deeper. The explanation of these re-
results is that the subject put forth greater effort than was necessary to overcome the distraction and consequently did better work.

In studying the effect of different distractions on reaction time, we have the problem of attention entering. Since the subject either attends to the sensation received or the response made, or to both, distraction may stimulate him to quicker action or it may retard his reaction time.

In the work done by Dunlap and Wells (12) regarding the relation of the length of reaction time to distraction, only the two reactions, auditory and visual, were considered. The apparatus, which was a Hipp chronoscope, was so arranged that either the visual or the auditory stimulus could be given, or a combination of the two, with the possibility of varying the intensity of each. When a combination of the two stimuli was presented, the experimenters discovered that the subject's attention, after the warning signal, was on the stimulus, to which
he was to respond, and that he was only conscious of the accompanying stimulus after its presentation. All the subjects reported, that the reaction 'seemed' to follow immediately upon the sound stimulus, but there 'seemed' to be a pause or hesitation after the flash appeared. It was found that the visual reaction time was shortened, when accompanied by an auditory stimulus. This fact was not explained as being due to the reaction to sound instead of to light, for the reaction to the flash with the sound accompanying (Fs) was shorter than the reaction to the flash, when both are discriminated from sound. Also the time reaction to the sound, discriminated from the flash, was shorter than the time reaction of the flash discriminated from the sound. In discriminating the flash when accompanied by the sound (Fs) from sound alone (s), and the sound when accompanied from the flash (Sf), from the flash alone (F), the subject's attention was sensory, and all efforts were put into the discrimination of the one from the other, that is, all attention was given to
the single stimulus whichever it might be, and practically none to the combined form. Furthermore, it was observed that more errors, false reactions, occurred in the (Sf-F) series than in the (Fs-S), but that the reaction time for the (FS-S) was longer than for the (Sf-F), thus making it difficult to determine which stimulus had the greater detracting effect.

The facts noted from this investigation are: first, the difference between the auditory and visual reaction times is considerable; second, that the shortening of the visual reaction time, when the auditory stimulus accompanies the visual stimulus, can not be explained as due to the sound instead of the light, as the reaction to (Fs) is generally shorter than the reaction to (F), when both are discriminated from (F); third, the time of reaction to sound discriminated from light is shorter than the time for the reaction to light discriminated from sound; fourth, three of the subjects showed a difference between the two types of reaction. No general conclusions
could be drawn from these results, since the investigations and number of subjects were limited.

In the study of the effect of auditory distraction upon reaction time, Cassel and Dallenback (8) used three forms of distraction, and determined the effect upon the sensory reaction. The first form was continuous throughout the reaction; the second was continuous through the reaction but paused during the introspective report of the subject; the third began just before and ended just after the reaction. These three forms of distraction were termed, continuous, intermittent, and interrupted continuous, respectively.

The subject was given a practice series until the average deviation was less than 10% of the reaction time. In this experiment the subject was to react sensorially. The directions for sensory reactions were read to him each day. The apparatus consisted of a Hipp chronoscope and an electric sound hammer, an electric tuning fork was used as
the continuous distractor, a metronome for the interrupted continuous, and an electric bell for the intermittent distractor. Each day a series of normal reactions were taken as a control series, and for every ten distraction series, four such normal control series were taken.

From their results Cassel and Dallenback concluded that the inhibiting effect of distraction varies with its duration and regularity. The continuous distraction had the least, the interrupted next, and the intermittent had the most effect. They conclude from these results that: (1) Distraction may inhibit and lengthen the reaction, it may facilitate and shorten the reaction or it may become habitual and have no effect at all; (2) The effect of distraction is dependent upon the temporal relation of the distractor and upon the conscious attitude of the observer during the distraction; (3) The distraction most resistant to habituation is the intermittent, the least resistant is the continuous; (4) The passive attitude is conducive to a constant sensory reaction of normal length, and and active attitude to a slow and
variable reaction.

Evans (14) has made a study of the effect of distraction on reaction time. His problem, as stated, was concerned with the effect of distraction on reaction time and the effect of dealing with reaction. His method was as follows: two rooms were used, the subject in one and the experimenter in the other. The room occupied by the subject was painted black, lighted only by a small lamp, thus making it possible for the subject just to see the point at which the light stimulus would appear. With the touch stimulus, the room was well lighted. Three forms of stimuli were used, namely; light, sound, and touch. Each was presented alone and with the touch, sound, and light distraction.

The light stimulus appeared on a dark gray background through an opening 5 cm. in diameter, which was placed 10 in. from the subject's eyes. The sound stimulus was produced by a sounding hammer of standard form, placed on a solid table.
This hammer weighed 2 grams and adjusted to fall 5mm. The touch stimulus was produced by a touch key which weighed 15 grams and fell the distance of 25 cm., striking the inner side of the subject's index finger of his left hand. The subject sat with his eyes closed, after he had adjusted the touch key, and remained so until after the presentation of the stimulus.

The distracting stimuli were of three forms: light, sound, and touch. These were produced by different arrangements, each having a different intensity from that of the stimulus, so that there was no difficulty in discriminating them from the reaction stimuli. When the distraction was applied, it occurred at regular intervals of 1 2/3 seconds and the reaction stimulus was given about 1/2 second before the end of the 1 2/3 seconds period. In each case the distracting stimulus was more intense than the stimulus to which the reaction was made. The Hipp chronoscope, as improved by Cattell and Dalley, was used to record reaction times.
The chronoscope was tested and adjusted before each experiment. Ten reactions were made and recorded, and then the chronoscope was again adjusted, then ten more readings taken. This process was repeated five times, when simple reactions were made, and ten times when distraction was added. One-hundred-fifty reactions constituted a day's work.

The subjects in the practice group were given a period of training in reacting to a certain stimulus with a definite distracting stimulus; this period of practice was much longer than the training obtained in reacting to the series previously used. The subjects were given the training in the following order:

Subjects A & B,
1- Preliminary control tests.
2- First practice series,
   Stimulus=light ............... Distraction=light.
3- Second practice series,
   Stimulus=light ............... Distraction=sound.
4- Third practise series,
    Stimulus=light.............Distraction=touch.
5- Final control tests.

Subjects C & D.
1- Preliminary control tests.
2- First practice series,
    Stimulus=sound.............Distraction=sound.
3- Second practice series,
    Stimulus=sound.............Distraction=light.
4- Third practice series,
    Stimulus=sound.............Distraction=touch.
5- Final control tests.

Subjects E & F.
1- Preliminary control tests.
2- First practice series,
    Stimulus=sound.............Distraction=none.
3- Second practice series,
    Stimulus=sound.............Distraction=sound.
4- Third practice series,
    Stimulus=sound.............Distraction=light.
Fourth practice series,
Stimulus=sound...........Distraction=touch.

In his study Evans found, that all distractions affected the reaction time by making it longer, and the greatest distraction occurred at the beginning of the series. Light caused the greatest distraction at the beginning, but its influence waned rapidly. The first practice series reduced the time of the other series of reactions about 50%. He found that there was a period of adaptation in the daily work in both the series with and without distraction. Practice caused a period of rapid adaptation to the distraction, which was followed by a period of much slower adaptation, but the effect of the distraction was never completely overcome, that is, the reaction with the distraction was never as short as without it. Evans found that the relative variability of reaction time with distraction was greater than the variability without distraction. Sound was found to be a more effective form of distraction
than either light or touch, and the distractive effect was greater when the distraction was the same form as the stimulus. The reaction time of both the trained and untrained subjects was lengthened by the distracting stimulus.

Evans then worked on the transfer of training as related to attention. In this experiment six subjects were required to go through an extensive course of training in reacting to one stimulus, with and without distractions. Before and after this training a group of six subjects were tested in reacting to sound, touch, and light; these tests were also given to a control group of five subjects. These tests were given with and without distraction. Comparisons were then made, first, between the practice and control group; second, between the different subjects belonging to the control group, since some were trained with light and some with sound; third, between the original reactions of each of the trained subjects and their reactions to changing to a modification of the experiment.
after they had received their special training. In the preliminary tests, the same stimulus with the same distractions was presented to the subjects in the same order, both in the practice and in the control groups. Nearly an hour was required for each the preliminary and the final tests. Short periods of rest occurred between each series of reactions which excluded the element of fatigue.

Evans's conclusions were: (1) that the ability gained by continuous practice in reaction time to one stimulus seemed to be transferred when the reactions were made to another stimulus; (2) a very definite gain was made when reactions were made to a stimulus different from the one used in practice but the same distraction; (3) training in reacting to a stimulus without distraction had very little effect on reacting to the same stimulus with distraction except possibly to cause a slight reduction in variability; (4) practice in reacting to a particular distraction aids in reacting to a new stimulus.
with the same distraction; (5) practice has a tendency to decrease the variability of reaction time, also, to reduce the period of adaptation to other reacting situations; (6) transfer of attention is possible because the subject learns to ignore the non-essentials. The ability to learn to ignore the non-essentials and to subordinate the minor to the major element is the same as good attention. By measuring the distracting effect of a distracting stimulus by means of reaction time, the attention may be measured.

I- Measurement of Attention by Means of Reaction Time- Since reaction time is effected by distraction, and attention is required for reaction, the measurement of attention by means of the difference in reaction time with and without distraction is another possible use of reaction time. There are in general four principal methods used for the purpose of measuring attention. The rate of fluctuation in stimuli for feeble intensity has been noted for different conditions of attention, and thus enables the degree of attention to be
measured. A second method consists in measuring the organic changes in the rate and depth of breathing, in rate and force of heart beat, and in blood pressure; all these organic changes have been used to indicate the different degrees of attention. The third method of determining the measurement of attention is the efficiency with which a certain test is performed. It is in this third method that the reaction time test has been used. Some of the other tests that have been used in this third method for this purpose are: the counting and marking of dots for a short period of time, learning poems and nonsense syllables, and the cancelling of letters.

These three methods really measure the product of attention rather than the process. The fourth method, which is more reliable than any of the above three, is the determination of the intensity of a distracting stimulus sufficient to decrease the efficiency with which a subject performs a given task. By correlating the effect of such a distracting stimulus with the introspective
report of the subject, attention may then be measured. This fourth method is the one involved in Woodrow's (35) experiment on measuring the degree of attention. In this experiment he used the reaction time tests as the task to be performed, calculating the difference in reaction time with and without distraction.

The apparatus for this investigation consisted primarily of a Wundt sound hammer arranged in circuit with a Hipp chronoscope and a Scripture reaction key, the reaction being an upward one which broke the current.

The subjects for this experiment were two advanced students and the experimenter. The subjects worked in a separate room from the experimenter. They were instructed to react as quickly as possible after the occurrence of the stimulus. Preparatory periods ranging from 1 to 32 seconds were used. These periods occurred between the warning signal and the presentation of the stimulus. Twenty-five reactions were given before the interval was changed. Each sitting lasted
about an hour and occurred the same time of each day. After testing the chronoscope, 25 reactions were taken with the one second preparatory interval; then 25 with a two second interval; then 25 with a four second interval; and so on up by steps of four seconds through a twenty-four seconds period, and in some cases a thirty-two second period was used.

Later in the experiment the warning signal was omitted, and the subject was required to react to every sound of the series, the sounds being repeated at the same rate. The different intervals were given with different series. The subject was instructed to use the motor form of response. The stimulus was then presented in an irregular order, such as; 5, 10, 19, 7, 3, 13, and 16, seconds.

Results of this work showed that the regular interval near two seconds was the most favorable interval. As the interval is shortened below or lengthened beyond this most favorable point, the reaction time increases.
This increase beyond the most favorable region is at first rapid, but becomes less and less marked as the period becomes longer. The increase continues to intervals over 24 seconds and is in accordance with the law \( y = A + B \log x \), (where "\( y \)" equals reaction time, "\( A \)" and "\( B \)" are constant and "\( x \)" equals the duration of the interval). In the series of irregular intervals little difference in reaction time occurs with the different intervals, and the reaction time obtained with each interval depends largely on the order in which the intervals are presented and on the individual characteristics of the subject. There was a general tendency for longer reactions to occur with the longest and shortest intervals of the series. There was also a tendency for the shortest reaction times to occur with the median interval.

Having concluded that the amount of distraction produced by the irregular series of intervals is measured by the increase in reaction time beyond the most favorable interval of 2 seconds, Woodrow next undertook to correlate
this detraction effect with the effect of decreasing intensity of the stimulus. He assumed that the intensity of stimulus is a condition of attention in the reaction time experiment. Four light stimuli of different intensities were used and in each case, for each intensity, the detractive effect produced by unfavorable intervals was determined. The apparatus and the method of procedure were the same as those used in the first part of the investigation. The subject fixated on a dark cross, the exact place where the light would appear, and when the light appeared he reacted by lifting his finger, using the motor type of reaction. In this part of the work, warning signals were given.

With each of the four intensities reactions were made with periods varying from 1 to 28 seconds. Intensities were termed bright, dim, quite dim, and very dim. Reactions to all four intensities with the interval of 2 seconds were made. With all four a prolongation of the 2 second period produced a regular increase in
reaction time, occurring more rapidly at first than later. The four curves for representing the four intensities with corresponding intervals were similar in form.

The conclusions for the reactions to the different visual intensities at different intervals were the same as those for the auditory reaction with different preparatory periods. The same law holds for any degree of intensity. "The absolute increase in reaction time produced by a given decrease in intensity of a stimulus, increases as the duration of the preparatory interval is increased beyond 2 seconds". This increase was more rapid at first than later as the period was gradually increased. The equation, $y = A + b \log x$, shows that the increase in reaction time produced by a decrease in intensity, may be considered as being made up of a factor that varies with the variation in the length of the preparatory intervals; also of a factor that remains constant. The prolongation of reaction time increases with a decrease in intensity of
the stimulus. Intensity, then, is a condition of attention and different degrees of attention. This fact may be stated as a law: that the degree of attention varies inversely with the absolute increase in reaction time produced by unfavorable periods. Attention may then be ranked, equating it with the reciprocal of the absolute prolongation in reaction time, produced by the use of intervals other than 2 seconds, and the absolute detracting effect of a detractor of attention varies inversely as the degree of attention upon which the detractor acts.

This work was followed by the measurement of attention by observing differences in reaction times to a change in intensity. In this experiment four intensities of light were used and dimmed by smoked glass. Medium, weak, weaker, and very weak designated the intensities according to degrees.

Woodrow found that the time of a reaction varied with a change in intensity. This fact was shown by a change in reaction time with either the
regular or irregular series when the difference in intensity between the two presented stimuli were decreased. He concluded that by measuring the increase in reaction time, due to a change in intensity of the stimulus, attention can be measured independently of wide variations in retinal intensity. In the summation of his work Woodrow states that the degree of attention involved in reacting may be measured: (1) by obtaining the average time of 30 reactions, using regularly repeated preparatory intervals of 2 seconds; (2) by the average time of 30 reactions with a set of irregularly mixed preparatory intervals of widely different lengths; (3) by equating the degree of attention with the reciprocal of the absolute difference between the afore-mentioned average reaction times.

In the above experiment Woodrow has shown that the "absolute detraction effect varies inversely as the degree of attention given to the change in stimulus to which the reaction occurs and that the reciprocal of the
detraction effect may therefore be taken as a measure of the degree of attention". In his study on "Outline As a Condition of Attention" (36), which followed the above experiment, he found it necessary to determine whether a variation in the definiteness of outline of a stimulus caused a variation in the degree of attention to some change in the stimulus. The change used in the stimulus was a decrease in intensity of the lights. This particular study is valuable because Meads had shown introspectively that outline was a condition of attention, while the detraction method offered an objective non-introspective test of the same thing.

The method of procedure for studying the effect of definiteness of outline as a condition of attention was as follows: Two visual stimuli were used, both having the same intensity, but one was a definitely outlined square, and the other was without form. Reaction times were then determined for a slight decrease of intensity for both lights, each with regularly re-
peated 2 second preparatory periods and with irregular preparatory intervals varying from 4 to 20 seconds. The reciprocal of the absolute prolongation in reaction time produced by the irregular series of intervals was taken as a measure of the degree of attention to the decrease in intensity. If the reaction time was shorter for the definitely outlined square, then for the formless spot it would mean that definiteness of outline was a condition of attention.

At each sitting 25 reactions were taken with the regularly repeated intervals of 2 seconds and 25 with the irregularly repeated intervals. This was done for both the square and spot stimuli.

In the results obtained Woodrow found that there was always a prolongation in reaction time for the irregularly arranged intervals and for the regular interval of 2 seconds; but that this increase in reaction time was greater for the spot than for the square. This would indicate very conclusively that definiteness of outline was
a condition of attention as revealed by the length of reaction times to the change of intensity.

Woodrow has shown in these experiments, that the reaction time of an individual varies with the degree of attention and can therefore be used successfully as a means of measuring it.

J-Reaction Time as a Measurement of Fatigue—The problem of fatigue is one upon which much work has been done. Fatigue may be of two forms, mental and physical. In measuring mental efficiency, two methods have been used. In the first, during the mental work, the subject is interrupted at various times and given a different task to perform. The subject's efficiency is then measured by the degree of success with which he performs the task. In the second method, the subject is given a task and performs it throughout the period of investigation. This method may be termed the continuous test of fatigue. The changes in the mental efficiency is measured by the amount and the
accuracy of his accomplishments in equal periods of time.

This first method, that of giving first one test and then another, is not as satisfactory a method as the second. The changes from one task to another includes different degrees of interest which is either a positive or negative disturbing factor. The attitude of the subject, for all the tests, cannot be hoped to be the same.

Physical fatigue and mental efficiency are closely related. In the first place physical fatigue may decrease mental efficiency in quantity and quality of the work done; it may serve as a distractor and thus stimulate the subject for greater effort and increase his efficiency, or it may show no effect at all. In testing for the relation between mental and physical fatigue, Ellis and Shipe (13) have made a study of the accuracy of the different methods. Their experimental study dealt with the testing of reaction time as a means of measuring fatigue.
They used the drop shutter and the Hipp chronoscope for testing the reaction time of the recognition of words. When comparing the reaction time with the fatigue work, as measured by the ergograph, a corresponding decrease was expected which did not occur. Ellis and Shipe concluded that either the reaction time method or the ergograph method was unreliable. Other forms of measuring fatigue, such as, adding tests, writing the cubes of numbers up to nine, or memorizing, etc, were introduced with negative results as to the reliability of the method. Reaction time tests for measuring fatigue were not satisfactory according to Ellis and Shipe.

Scripture (26) also conducted a series of experiments dealing with the relation of reaction time to fatigue. His apparatus consisted of a chronoscope and smoked drum so arranged that the length of time the subject held the pressed key was recorded, in addition to the reaction time. A downward movement broke the current causing a mark to be made upon the smoked
drum which continued until the key was released. The reaction time continued through a long interval. Records were taken at the beginning and at the end. Results showed longer and more irregular reaction times at the end than at the beginning. The time of holding the key pressed was also increased. Reaction times were then taken at eight-thirty o'clock in the morning before the general day's work began and again at five o'clock in the evening. As a result he found that a longer time was required at the close of the day than at the beginning for reaction. According to Scripture reaction time increases with fatigue.

Similar to Scripture's work is that of Milroy (22), conducted however on a slightly different plan and using the visual stimulus as well as the auditory. Milroy's apparatus recorded the reaction time graphically by a pendulum myograph. Responses were made with the middle finger of the right hand by closing a Morse key. Reactions were made over a period of 40 minutes. After some practice the subject
was able to make an auditory record of 167 \( \sigma \) for the first 10 minutes, and for the last 20 minutes of the 40 minute period his record had increased to 210 \( \sigma \). For the visual reaction time the element of fatigue was not so evident. It took longer for the fatigue to manifest itself, the time being 30 minutes, whereas in the auditory responses, the fatigue was evident at the end of 20 minutes. The reaction time length for the visual stimulus was 180 \( \sigma \) for the first 20 minutes and 201 \( \sigma \) for the last 20 minutes of the 40 minute period. Rest periods of 10 minutes were not sufficient to overcome the fatigue produced by the 30 minutes of responses. Changing from one sort of stimulus to another did not rest the individual. Twenty minutes of auditory reaction times were then taken, seven minutes of the visual and then back again to five minutes of auditory responses. It was found that the average of the last five minutes of the auditory was just as long as if the auditory stimulus had been given continuously. The subject was then given an
auditory stimulus for 20 minutes which was followed by fatigue work, consisting of counting clicks at the rate of three per second. This produced little or no sign of fatigue manifested by reaction time, even when continued from 30 to 60 minutes. The introduction of a stimulus produced a marked prolongation of reaction time or an omittance of the response entirely.

A very thorough study of the measurement of fatigue by means of reaction time has been made by Bettman (4). He served as his own subject, aided by an assistant. His work consisted in determining the length of choice reactions before and after fatigue. Fifteen choice reactions were taken before and three hundred after the rest period. He would either walk two hours, add an hour, or rest an hour, then take the reaction time after each period. He found that reaction time was decreased after physical work and increased after mental work. There were however a greater number of false reactions after physical
labor, indicating a lack of control or a decrease of mental efficiency. When he used the combination of adding, learning of nonsense syllables, and fifty choice reactions, he found that these results indicated a similar condition, that is, a decrease in mental efficiency manifested by an increase in reaction time for either form of work.

**K-Reaction Time as a Basis for Recommending Candidates For Air Service**  The relation of reaction time to motor control and emotional resistance is a very recent problem. Very little work has been done relating to the question.

The physical and mental examinations required of the men at the different camps during the 'World's War' led to psychological investigations regarding qualifications of individuals best fitted for different departments of service. Among the numerous demands for the practical application of psychology was that of selecting men best fitted to become aviators. Up to this time it was commonly believed that an aviator must be endowed with an unusual amount of superhuman character-
ISTICS PLUS AN ENORMOUS AMOUNT OF VENTUREsome, daring spirit. The movements made in controlling an aeroplane, such as, keeping the balance, judging distance, etc, were considered more difficult than in other fields of work, and required superior ability on the part of the aviator.

While much depends upon the qualifications of a successful aviator, we find, as we do in other vocations, special abilities best suited for that work. Among these, short reaction time, good motor control, and good emotional stability, were considered first.

A study of the relation of reaction time to motor control was first made by the French in 1917, conducted by Camus and Nepper (7). This work was in connection with the tests given to candidates in the air service. In the single reaction time tests, the D'Arsonval chronoscope was used. Over one-thousand cases were tested, these giving an average of auditory and tactual reaction times of 144 $\sigma$ and 142 $\sigma$ respectively.
and a visual reaction time of 193 $\tau$. If a candidate had an average of not more than $10 \sigma$ above these averages he was judged capable of becoming a pilot. Ten reactions were considered a sufficient number for a reliable average to be obtained.

Investigations were also made to determine the effect of an emotional stimulus upon hand movement. The blood pressure, hand movement, and breathing were recorded by the kymograph. The subject sat with his back toward the experimenter; he was told that a pistol shot would occur during the experiment. The results of these tests were then compared with the reaction time results. Both the average reaction time and the average deviation were considered. Those with good muscular control showed very little deviation from the normal curve when the emotional stimulus was presented. On the basis of reaction time tests and emotional control tests, the subjects were divided into five classes: (1) those with normal reaction time who did not manifest
excitability made the best pilots; (2) those with normal reaction time and who gave only a slight emotional reaction were next; (3) the type with a slightly irregular reaction time and who manifested a slightly emotional reaction was the third class that was considered eligible; (4) those with a large deviation in reaction time and extreme in emotional reaction; and (5) those with irregular reaction time but with moderate emotional reaction were barred from aviation service.

In the Psycho-Physiological Office for examining aeronauts in Italy, Gradenigo and Gemelli (17) have made tests of psycho-motor activities and also used their results as a means of selecting candidates for the aviation service. In the single reaction time investigations, the limit of fitness for the aviation service was established for visual reaction time at 200 $\sigma$, and for auditory reaction time it was placed at 170 $\sigma$, with a maximum average deviation not greater than 30 $\sigma$. The inability of the subject
to adapt himself, as was revealed by the variability in reaction time, was considered one of the bases of judging a candidate unfit for that service.

The investigations of Professor Saffiatti (20), which took place at Turin about the same time, resulted in placing the visual reaction time at 170 to 200, and the normal auditory reaction time at 130 to 150. This was approximately the same as Gradenigo and Gemelli's determinations. If the visual reaction time was longer than 200, and the auditory reaction time was longer than 150, they were called slow reactions, and the individual was considered unqualified for serving as a pilot.

Saffiatti's apparatus consisted of a Hipp chronoscope, a visual stimulus which was a two candle power lamp, and an auditory stimulus which was produced by a hammer falling a certain distance. Professor Saffiatti thinks that the reaction times are sufficient for judging the psychophysical normal ability of a candidate, providing
the experiment is conducted with unity of technique and standardized method. He found, however, that there is a great difference in reaction time depending upon the variation of the time of notice. If the time of notice of the appearance of the stimulus were kept constant, then the reaction time was regular and normal, but if the time were suddenly changed, the result was abnormal. Lengthening the time notice beforehand, resulted in a shortened reaction time. Changing from a long interval to a short one, the subject was able to adapt himself quickly, while if the intervals were irregular he was unable to adapt himself at all. Beyond a certain limit of time, notice beforehand was of no value.

In the determination of choice reaction time, the apparatus consisted of five lights arranged in a cross, the four outside lights indicating the movement to be made. When one of the four lights appeared as a stimulus, the subject was to respond by moving a lever or shaft in the direction indicated. If the fifth
light, the center one, was given as a stimulus, the subject was to make no response. This arrangement was used by Gradenigo and Gemelli and also by Saffiatti.

As the choice reaction serves to give an account of the inhibitive activities of the individual, inhibition was determined for each individual tested. Saffiatti (20) placed the normal choice reaction between 350° and 500° with a deviation between 40° and 70°. He also found that no errors occurred in responding to the stimulus that indicated movement, but a few resulted from the negative stimulus. In the choice reaction time experiment of hand and foot, Gradenigo and Gemelli (17) arranged that the subject should react first with one member, and then with the other, or in combination. This arrangement was supposed to be much the same as that found in the control of an aeroplane. The choice which the pilot must make among the various movements is of great importance, so the apparatus was such that the movements resembled those made by a pilot while in air.
Their results showed that the reaction of the left hand, either by itself or with another member, is quicker than that of the right hand. This fact was also found to be true of the left foot. They also found that this promptness of the left member is more noticeable in the sensorial reactions than in the muscular type of response.

The reaction time for more than one member was found to be a little greater than the reaction time of just one. Also, the simultaneous reactions with several members were not only longer, but the individual made more errors, such as first responding with one movement and then with another, instead of both together. In the sensorial reactions, this tendency favored the movement of the left member first. This was not true in the muscular reactions, for the right often preceded the left. In the combined movements of hands and feet, one was as prompt as another in sensorial tests, but in muscular tests, the reaction time of the feet was slightly shorter.
They concluded that these results are evidences that the difference in reaction is not due to a physiological cause, but to a psycho-physiological inclination produced by the tests, that is, the tests caused the subject to attempt to react with both members simultaneously. These members each have a different reaction time; the intention of the subject is, that they should react together, which tends to cancel the difference in reaction time, and causes one to precede the other producing the effect of rhythm.

Professor Azzo Azzi (1) used this same five light arrangement in his research on discriminative reaction time. When the upper right hand light appeared the subject was to respond with his right hand, when the lower right hand light appeared he was to respond with his left foot, on the appearance of the fifth light, in the center, no response was to be made.

The average time, errors of the average, average deviation, coefficient of variation
percentage of errors, were all determined in addition to the extreme values in a series of thirty.

The conclusions of the normal values were placed as follows:

**Average time of slowness**: 50 \( \sigma \).

**Average deviation**: 120 \( \sigma \).

**Average coefficient of variability**: 200 \( \sigma \).

**Percentage of Errors**: 80 \( \sigma \).

Subjects with the above values of reactions were recommended as candidates eligible for the air service. The following were considered abnormal reactions, and candidates with such reactions were rejected as unfit to become aviators.

**Average time of slowness**: 680 \( \sigma \).

**Average deviation**: 220 \( \sigma \).

**Average coefficient of variability**: 360 \( \sigma \).

**Percentage of errors**: 2260 \( \sigma \).
In a series of rhythmical reactions, Gradenigo and Gemilli found that the pause between the warning signals and the presentation of the stimulus had an influence on the reaction time. Shortening the pauses caused the reaction time to be shorter. If the stimulus were feeble, the reaction time was increased. In combined and simultaneous reactions, if the individual directed his attention toward the stimulus, the reaction time for that stimulus was shorter.

Professor Saffiatti (25) in determining the influence of the length of the interval on rhythmical reaction time observed, that if the interval between the presentation of each stimulus were constant, the normal reaction time disappeared. After the individual had become adapted to the period, the reactions were automatic, which caused him to act, even when no stimulus was presented.

In studying the curves of reaction time after nervous exhaustion Saffiatti's results showed two distinct types. The slow type with a reaction time as long as 220 $\sigma$ to 230 $\sigma$ showed nervous exhaustion and weakness and the unsteady
type showed nervous excitement. The subjects of this type tend to react to stimuli, when otherwise under normal conditions, they would not do so. They are excited and unsteady, hence, they make many false movements.

The experimenters concluded from their results, since the aviator must react to the various stimuli with different movements, a candidate for air service should have a stable and regular reaction time. He should be able to adapt himself, by means of practice, to new conditions of reaction, and also be able to divide his attention among various stimuli. Those who perceive promptly, distinguish clearly, and remember well, make the best pilots.

Professor Camis (6) at the Psycho-Physiological Office of Military Aviation at Turin, performed some experiments on the degree of resistance to emotional stimuli. This resisting ability of the individual was also used, as one of the factors in judging a subject suitable or otherwise for air service.
The method followed by Professor Camis was an examination of breathing, trembling, and vasomotor and cardiac alterations, immediately following an emotional stimulus. The experiment was made of three parts: (1) determining a series of reaction times; (2) producing by means of the proper stimulus an emotional state; (3) determining a second series of reaction times. The stimulus was such as would arouse fear, surprise, shuddering, or fright. An explosion of a fire-cracker near the subject; or a hissing gush of wind directly on the subject's neck, or directly behind his neck or sleeve, were the most common forms of emotional stimuli used. For the normal reaction time the average of 20 or 30 readings was taken. This average was then compared with the average of 20 or 30 reactions times taken immediately after the emotional stimulus had been given. The average time was found to be increased in the majority of cases. Examination of single values often revealed the individual differences, which were not apparent on studying just the average and average deviations. Therefore an account was made of the
deviations from the average of each single reaction by means of a graphic method. The average reaction time, after being determined, was represented on the graph by a straight horizontal line, and the distance of this line, from the ordinate axis, was measured in time units on the abscissa axis. The successive reactions following the emotional stimulus, were located on the graph, with respect to reaction time and place in series. Then these points were connected, which gave the graphical representation of the single reactions. Any change brought about by the emotional stimulus could be seen at once by comparing the curve representing the normal series, with that representing the series after the stimulus had been given.

An increase in the first reaction time was noticed after the stimulus had been given, but reactions following this, again approached normal. The duration of the change in reaction time was then found to be important, because the stronger the stimulus, the longer the duration. It was found necessary to keep an account of the speed with which
a subject returned to his normal reaction time. Errors were considered expressions of lack of coordination of the functional element, therefore, their frequency was recorded. Errors such as missed reactions to stimuli, false reactions when no stimulus had been given, and repeated reactions, did not occur, when the subject understood the technique of the experiment.

Camis then conducted some experiments with the idea of determining the influence of the emotional stimulus on choice reaction times, which is a higher and more complex form of behavior. The apparatus consisted of the 'five light' arrangement as was used by Gradenigo and Gemelli (17). The subject was to respond to four of the lights and make no response to the fifth one in the center. The method of procedure was practically the same as Gradenigo and Gemelli's. A large number of reaction times were taken from which the average and the average deviation were determined. All errors were carefully noted, as they often showed defects and lack of coordination of the functional elements, which constitute the psycho-motor reactions,
and also showed the emotional state of the subject. The frequency and kind of errors, after the emotional stimulus had been given, often revealed the pathological state, which was not observed in the reaction time. The majority of the errors resulted in responding to the negative stimulus, which was also true of Gradenigo and Gemelli's investigation.

The effect of an emotional stimulus on the inhibitory functions was then determined. A series of 50 reactions were taken before and after the presentation of the emotional stimulus. By comparing the two results the effect could be determined. Camis found that in a majority of cases the duration of the inhibition to react was decreased, thus making the reaction time shorter, which was not the result one would expect. This shortening of reaction time was explained, as being due to the fact that a moderately intense emotional state may frequently increase the speed, which the psychic process develops. It may be possible to use the variation of the curve of the
simple reaction time to judge the emotional resistance of the subject, but nothing as yet has been done. The investigations made thus far, regarding the resistance of emotional stimulus and reaction time, have been made by the French and Italians. No such investigations have been carried on by Americans.
III- SUMMARY OF HISTORICAL REVIEW

In the summary of the historical review we may conclude from the preceding experiments that:

1. There is undoubtedly a personal difference in reaction time.
2. There are different types of reactions, namely: motor, sensory, and mixed, and individuals, responding muscicularly, usually show a shorter reaction time.
3. As yet, the data on reaction time as a means of measuring racial and individual differences, does not demonstrate satisfactorily, the validity of such a method for testing general intelligence.
4. The investigators do not agree, regarding the reliability of the association reaction tests as a means of discriminating the guilty from the non-guilty. From the work at hand the investigations seem to point toward a possible development of the test, as a valid means of discriminating the criminal from the innocent.
5. From the investigations of Woodrow we conclude that the degree of attention may be relatively measured by the reaction time method.
(6) The results of Ellis and Shige, Scripture, Milroy, and Bettman, show that the reaction time is lengthened by fatigue, and that fatigue may be relatively measured by the increase in the normal reaction time. (7) The measurement of reaction time, and the ability of individuals to resist emotional stimuli, as shown by the reaction time, serves, according to the French and Italian claims, very successfully as a partial bases for recommending candidates for air service.
IV- EXPERIMENTAL SECTION

A-Purpose of the Experimental Section-The purpose of this experimental section is to supplement the previous historical review with data illustrating individual difference in normal reaction time. This is done in order to determine the relative effect of an emotional stimulus on the time of individual reaction, and to determine the relation of such effect, if any, to the steadiness of hand control. This investigation follows those of the French and Italian. The first tests were made to determine to what extent practice will reduce reaction time, and whether practice is manifested after the first few trials.

The apparatus used was the Bergstrom chronoscope (Columbia University Model) manufactured at the University of Michigan, modified so the magnetic coils controlling the reaction pointer were fastened to the shaft of the pendulum. When the current was broken the disk of the reaction pointer was released from the magnets and forced by
DESCRIPTION OF FIG. I

1. Chronoscope, mounted on box in center of table.
2. Switch No. 2, furthest to the right, clamped to table.
3. Switch No. 1, furthest to the left, clamped to the table.
4. Sounder, just at left of the chronoscope.
5. Reaction key, just back of sounder.
6. Relay, at left of sounder.
7. Klopsteg fall apparatus, at the left of table.
8. Switch No. 3, at the bottom of fall apparatus.
9. Split core magnet, at the top of the fall apparatus.
means of a spring against rubber stops. Four Edison storage cells were used in each circuit to operate the chronoscope.

During the time between the presentation of the stimulus and the direct response of the subject, the pointer of the chronoscope fell with the pendulum; when the subject made his response by pressing the reaction key the disk of the pointer was pushed from the coils of the pendulum and held by rubber stops, thus causing it to record the time. The scale was divided into five sigma divisions. The reaction key was a small brass right angle lever, about three centimeters in length, which was easily operated. The weight of the subject's finger on the horizontal portion was often sufficient to break the contact. The perpendicular half of the lever came in contact with a platinum pointed brass screw which was connected to the chronoscope.

A Wundt hammer produced the auditory stimulus. The hammer was connected with a 12 volt current which was kept constant throughout
the experiment. When the experimenter closed Switch No.1 (as is shown in Fig. II) the current passed through the magnets of the sound hammer and caused the hammer to strike with uniform intensity. To insure perfect connection the contacts of the hammer were gold plated.

A large cardboard was set up between the subject and the experimenter to avoid the possibility of the experimenter giving any unconscious help in any way, and also to obstruct from the view of the subject the sounding hammer to which he was to respond. No part of the apparatus was seen by the subject during the experiment with the exception of the reaction key which he operated.

The method of procedure was as follows: the subject sat before the apparatus with his forearm resting on the table, and his right index finger placed lightly on the reaction key. The experimenter then placed the pendulum in position and set the pointer at zero. The signal "Ready" was then given which signified that the subject was to close the reaction key, thus connecting it with the chronoscope. In a few seconds the ex-
A - BATTERIES.
B - CHRONOSCOPE.
C - SOUNDER.
D - RELAY.
E - SWITCH NO. 2.
F - SWITCH NO. 1.
G - SWITCH NO. 3.
H - REACTION KEY.
perimenter gave the warning signal "Now" and from 1/2 to 2 seconds later closed Switch No.1 which caused the sounder to produce the stimulus. The signal "Now" caused the subject to hold himself in readiness for the sound, to which he was to respond. Upon hearing the auditory stimulus the subject made his direct response by pressing the reaction key on which his index finger had been resting, thus breaking the current through the chronoscope.

Students of the General Psychology Class were the subjects in this experiment. Each was instructed to sit before the apparatus with his forearm resting on the table and his index finger resting on the reaction key. He was told the meaning of each signal and instructed to react as soon as possible after hearing the sound and to use the same finger. No further instructions were given.

The first part of the work consisted simply in determining the reaction time of six students. The average reaction time of these
persons varied from 120 \( \sigma \) to 178 \( \sigma \) with deviations ranging from 17 \( \sigma \) to 23 \( \sigma \) respectively. Subject No.3 had an average reaction time of 120 \( \sigma \) and an average deviation of 17 \( \sigma \), which showed a greater coefficient of variability* than subject No.5, who had an average reaction time of 178 \( \sigma \) and an average deviation of 23 \( \sigma \). Subject No.2 showed an average deviation of 30 \( \sigma \), which is longer than No.5's. His reaction time was, however, shorter than No.5's, being only 166 \( \sigma \), thus making his coefficient of variability much greater. The other subjects, Nos. 1, 4, and 6, had an average reaction time of 76 \( \sigma \), 152 \( \sigma \), and 125 \( \sigma \), with average deviations of 19 \( \sigma \), 20 \( \sigma \) and 22 \( \sigma \) respectively.

Three other subjects were given two series each, the reaction time of the first series ranged from 150 \( \sigma \) to 177 \( \sigma \) and the deviations varied from 4 \( \sigma \) to 28 \( \sigma \). In the three

*Coefficient of variability is the percentage difference between the average reaction time and average deviation.
cases the reaction time was decreased in the second series, and in two cases the average deviation was decreased. With subject No. 7 the average deviation was increased from 26 in the first series to 28 in the second series, as is shown in the table.

Subject No. 10 was given 4 series of 40 readings each with short periods of rest in between. His reaction times were as follows: 177 σ, 142 σ, 124 σ, and 126 σ. A decrease of time is shown in the second over the first, while the third and fourth are approximately the same for both, but both shorter than the second. The deviations of the second, third and fourth series are approximately the same but are less than the average deviation of the first. These results are shown in Table I. The coefficient of variability of the first two series are approximately the same but there is an increase in the last two although a decrease in reaction time.

Nine series of 40 readings each were
<table>
<thead>
<tr>
<th>Subjects</th>
<th>Series</th>
</tr>
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<tbody>
<tr>
<td>7</td>
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<tr>
<td>8</td>
<td>150 128 26 23</td>
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<tr>
<td>9</td>
<td>177 148 20 14</td>
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<td>10</td>
<td>177 142 124 126 28 20 22 23</td>
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<tr>
<td>11</td>
<td>157 127 139 113 125 123 123 124 123 20 21 12 15 13 10 13 16 16</td>
</tr>
<tr>
<td>12</td>
<td>149 130 144 125 146 132 128 123 128 23 21 17 18 11 15 16 14 17</td>
</tr>
</tbody>
</table>

TABLE I

AVERAGE AND AVERAGE DEVIATION OF AUDITORY REACTION TIME SHOWING EFFECT OF PRACTICE
given to subjects No. 11 and 12. In both cases one series a day was taken. After the fourth series there was practically no reduction, either in the average reaction time or in the average deviation. For all the subjects tested the greatest reduction in reaction time occurred in the second series.

B - Relation of Steadiness to Reaction Time - Testing the ability of muscular control and the measurement of reaction time constituted the second part of the experimental work. The apparatus used for the steadiness was composed of a brass stylus connected with the batteries and a brass disk containing different sized holes. This apparatus was so arranged that every contact of the stylus against the brass disk made a complete circuit. After taking a series of auditory reaction times, the experimenter adjusted the plate so as to expose the 5/32 inch hole on a level with the subject's nose. The subject was instructed to hold the stylus in his right hand as he would a pencil, stand squarely on both feet close enough
to the apparatus so that he could conveniently put the end of the stylus in the hole and endeavor to avoid its edges. Every contact made completed the circuit which caused the movement to be recorded by the Hollerith counter. During the test he was instructed to breathe quietly and regularly and to avoid any inhibitory tendencies. He was told to hold his arm free from his body, though not in an awkward position. He was required to stand for one minute in this position. The number of contacts made in this length of time was taken as the measurement of the individual's steadiness, or his ability of muscular control. When the directions were understood the subject put the stylus into the hole, but the experimenter did not start the time until the subject had the stylus completely in the hole. All contacts made in the process of putting the stylus in and taking it out of the hole were deducted from the number recorded by the Hollerith counter. Four trials consisting of one minute periods were taken. The average of these four were considered
as the final measurement of the motor control.

If the subject held the stylus firmly against the edge of the hole, one contact would be recorded during the one minute period. This fact was not discovered by the majority of students until after their steadiness had been tested. The attitude of the subjects was good and no attempt to use the discovery was ever made. After the steadiness test another series of auditory reaction times was taken. This constituted the work of each subject for this test.

Seventeen subjects were thus tested and their results are given in Table II. Eleven of the seventeen were able to reduce their reaction time in the second series but showed an increase in their average deviation; four were able to reduce their reaction time but showed an increase in their average deviation; the remaining two, Nos. 13 and 19, showed a longer reaction time for the second series and a greater deviation. The reaction times varied, in this test, from 115 to 246° for the first series, with a range
in variation from 13 to 53 $\sigma$. Subject No. 28 showed an exceedingly long reaction time with a long variation, while No. 13 had a short reaction time with a small variation. These two subjects are the extremes of this group and illustrate the great individual difference. The extreme length of No. 28's reaction time, which was $246 \sigma$, cannot be explained. In the second series the reaction time ranged from $122 \sigma$ to $214 \sigma$, and the average deviation from 13 to 36 $\sigma$. Subjects, Nos. 14 and 28, are the extreme cases in the second series.

In the steadiness test a great individual difference is also shown. Subject 26 had an average steadiness of 2 contacts while Subject 21 showed an average steadiness of 45 contacts. The individual differences are manifested in reaction time, in average deviations, and in muscular control. Correlations were made between the average reaction time and the steadiness, also between average deviations and steadiness. Between the reaction time and steadiness a correlation was
# TABLE II

**AVERAGE AND AVERAGE DEVIATION AUDITORY REACTION TIME ALSO STEADINESS OF EACH INDIVIDUAL**

<table>
<thead>
<tr>
<th>Subjects</th>
<th>Av.R.T.</th>
<th>Av.R.T.</th>
<th>Steadiness</th>
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<th>Subjects</th>
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<th>Av.R.T.</th>
<th>Steadiness</th>
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Correlation between steadiness and reaction time = .70

Correlation between steadiness and average deviation = .32

Av.R.T. = average reaction time
Av.D. = average deviation
found of .70 with a probable error of ±.08, and the correlation between the average deviation and steadiness was .32 with a probable error of ±.15. These correlations were both positive and significant.

C-Relation between Reaction Time, Motor Control, and Emotional Resistance - In this part of the experimental work the object was to determine the effect of an emotional stimulus upon the normal reaction time and upon the average deviation of different subjects, and also to determine whether there is any correlation between emotional stability and steadiness.

The same chronoscope and apparatus used in the previous tests were employed in this experiment. The apparatus was tested each day before the reaction time of the subjects was recorded, for average deviation was to be considered as well as average reaction time. The Klopfsteg fall apparatus was used for testing the accuracy of the chronoscope. Figure I illustrates the apparatus and its connections. By connecting
with 4 and 5', as is shown in the diagram, the fall apparatus was connected with the chronoscope. The falling distance of the steel ball was set at 50 cm. When Switches Nos. 1 and 2 were closed the current was sent through the relay which then held the armature and made connections with the coil of the Klopsteg fall apparatus. This coil held the steel ball in position until Switch No. 2 was opened. Then the ball was released and fell striking Switch No. 3. At the same time, the coils of the relay released the armature which then made contact through the coils of the chronoscope, and caused the pendulum to be released. As Switch No. 3 was opened by the falling steel ball, the current leading to the coils, which held the pointer as it swung with the pendulum, was broken, the pointer was released and the time recorded. The time required for the ball to fall was constant, but we are not certain that the armature did not vary in its time of movement. This fact would, however, favor the assumption that the
chronoscope might be more accurate than the test would indicate.

The method of testing the chronoscope proceeded as follows: the pointer was set at the zero mark, the pendulum placed in position, and Switches, Nos. 2 and 3, closed. The steel ball was placed below the split core magnet and held in position by the magnetic power of the coils. When all was ready Switch No. 2 was opened; the steel ball then fell striking Switch No. 3, and the time was recorded. This process was repeated ten times. If there was a variation in the ten readings greater than ten sigma, the apparatus was readjusted until a series was obtained with a variation of ten sigma or less. The average reaction times then obtained were reduced to absolute time according to the test readings.

The subjects in this experiment were 24 general psychology students, 15 women and 9 men. They were introduced into the laboratory with no knowledge of the aim, method or purpose of
the experiment. Each was given the same instructions as were given in the previous experiment. The experimenter set the pointer at zero and placed the pendulum in position as before. When all was ready the signal was given which caused the subject to hold himself in readiness for the stimulus, which followed from 1/2 to 2 seconds later. In addition he was told to keep his attention focused, as much as possible, upon what he was supposed to do, with the fact emphasized that if the attention was allowed to wander the reaction time would be longer, thus causing him to make a poor record. No other instructions were given. The same auditory stimulus was used as was used in the previous tests.

The subject was given several practice reactions which were not recorded. A series of 50 consecutive reaction times was then taken, after which the subject was given the steadiness test. This test was the same as that used in the preliminary work with the exception of the intro-
duction of a smaller hole, which was \( \frac{1}{8} \) of an inch in diameter. This smaller hole measured the finer tremor as well as the grosser. Only one, one-minute trial was given for each hole. After the determination had been made for the coarser and finer tremor, the subject was allowed to rest about ten minutes, then another series of 50 reaction times was taken, which completed the first day's work.

The second day's work up to the point of taking the second series of 50 was just the same as the first day's work. But at this point on the second day an emotional stimulus was introduced. The subject by this time had had a practice of 150 reactions after which he would ordinarily have reacted normally. The emotional stimulus was either a slight induction current or a shrill whistle. When the current was used, the subject was given the two electrodes to hold in his left hand. A broad plate of copper was held in his palm and a small wire end between thumb and forefinger. Nothing was told him of what to
expect, but the two electrodes, no doubt, suggested the electricity to him. He was usually told if anything did happen to pay no attention to it. At various and irregular intervals through the second series of 50, a key was pressed by the experimenter just following the signal, "Now", which sent a current through the hand and arm of the subject. This happened from five to seven times during the last half of the second day's work. The subject was held in suspense not knowing when the emotional stimulus would appear.

When the whistle was used the subject had no cause for even suspecting anything different than had been, as the whistle had laid on the table before him during the previous reactions. A long rubber tube extended from the whistle to the experimenter who blew it at various intervals just after the "Ready" signal, and just before the "Now" signal. The subject was thus taken wholly by surprise. The whistle was used as the emotional stimulus with nine of the
subjects (these are marked in Table III, showing their results) and the electricity was used with the other fifteen.

There were four correlations made. The first correlation was between the average of the steadiness of the smaller hole and the average of the third series of reaction times. The second correlation was between the average deviation of the third series of reaction times and the same steadiness record. The third correlation was between the difference in the time of the third and the fourth series of 50, and the steadiness. The fourth correlation was between the difference of the average deviation of the third 50 and the average deviation of the fourth 50.

All correlations were made by the Pearson's product moments method. The third series of fifty was used because it was thought that this represented more nearly a normal series of reaction times as the subjects had previously had 100 practice reactions. Likewise the smaller hole was used as
it could more accurately record the degree of tremor.

The highest correlation was found between the difference of the average deviation of the third series and the average deviation of the fourth, and steadiness. This correlation value is $0.59$ with a probable error of $0.09$. This would indicate that the emotional stimulus resulted in causing a greater variation in reaction times rather than just lengthening them, as the correlation between the increase in the length in reaction time and steadiness was only $0.49$, while the correlation between the increase in variability and steadiness was $0.59$. An increase in disturbance of the average deviation correlates with the increase in steadiness. The correlation between the variations of the normal reaction time and the steadiness, was found to be $0.37$ with a probable error of $±.11$. The correlation between the normal length of reaction time and steadiness was the same as that between the increase in reaction time and steadiness, which
was .47 with a probable error of ±.10. These correlations are all positive and are large enough to be significant.

The following table shows the correlations in tabulated form:

<table>
<thead>
<tr>
<th>Correlation</th>
<th>Value</th>
<th>Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>r between ad4-ad3 and steadiness</td>
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<td>±.09</td>
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<tr>
<td>r between rt4-rt3 and steadiness</td>
<td>.47</td>
<td>±.10</td>
</tr>
<tr>
<td>r between ad3 and steadiness</td>
<td>.37</td>
<td>±.11</td>
</tr>
<tr>
<td>r between rt3 and steadiness</td>
<td>.47</td>
<td>±.10</td>
</tr>
</tbody>
</table>

The reaction times vary for the third series from 137 σ for No. 9 to 229 σ for No. 20. Subject No. 9 shows no decrease in reaction time or in deviation. His first day's work was better than the first half of the second, also his reaction time was not as greatly affected as his average deviation when the emotional stimulus was introduced. The former showed an increase of only 40% while the latter showed an increase of 73%. Subject No. 20 showed the same general result with an increase in reaction time of 14%, and 105% in variation.
Subject No. 23 is an exceptional case. This subject showed practically no change resulting from the emotional stimulus on reaction time, and 100% reduction in variation. In this case the distracting stimulus (induction coil) seemed to have served as a stimulus to greater and more consistent effort. Subjects, Nos. 12 and 19, showed great ability in resisting the emotional stimulus. The steadiness of No. 12 was good, but No. 19 had a record in the steadiness that was considered higher. Both of them showed an increase in reaction time but their variations remained undisturbed.

Twenty-two of the subjects showed an average increase of 19% in length of reaction time in the fourth series over that of the third. Of the twenty-two subjects, eleven were classed as having high or medium high tremor while nine had good muscular control showing an increase in reaction time of 8%. Two subjects of the twenty-four, Nos. 1 and 23, showed a decrease, or no change, in reaction time. No. 1 showed an increase in variability from 16 to 29
TABLE III

AVERAGE, AVERAGE DEVIATION, AND STEADINESS OF EACH SUBJECT.

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TABLE III (cont'd)

Sub. = subject
Av. R.T. = average reaction time
Av. D. = average deviation
S(1) = steadiness with 5/32 inch hole
S(2) = steadiness with 1/8 inch hole
* = subject with whom the whistle was
    used as the emotional stimulus
which was an 81% increase, while No. 23 showed a 100% decrease as stated above. With both of these subjects the steadiness test varied greatly for the two days tested. Subjects Nos. 3, 4, and 24, also showed a variation in steadiness.

Subject No. 7 showed good muscular control and slow reaction time with little ability to resist emotional stimuli. No. 8, a very nervous individual, showed poor ability in steadiness, and little ability to resist emotional stimuli, as evidenced by great increase in reaction time and in variation.

The results are not so unequivocal as might be expected when we consider the dogmatic statements of some investigators, particularly the recent reports of the French and Italian physiologists and psychologists. However the following conclusions may be tentatively formulated.
V CONCLUSIONS

From the results obtained we conclude:

(1) Those persons with a long reaction time are apt to have poor muscular control, and will manifest little ability to resist emotional stimuli; while on the other hand, those that have a short reaction time will have good muscular control, and will be more able to resist emotional disturbances.

(2) Persons that show a great variation in reaction time will likewise show poor muscular control and less ability to resist an emotional disturbance.

(3) Individuals who are able to resist emotional disturbances will usually have a short reaction time, small variation, and good muscular control.

(4) Subjects with good muscular control will also have a quick reaction time with small variation and good ability to resist an emotional stimulus.