AN HISTORICAL AND EXPERIMENTAL

STUDY OF THE TRANSFER OF TRAINING

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by

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Approved by:

[Signature]

Professor of Psychology

July, 1925.
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I. INTRODUCTION

The data presented in this thesis were obtained at the University of Kansas during the school year of 1924-25. The work was suggested and done under the direction of Dr. W. S. Hunter to whom the author wishes to express his hearty thanks and appreciation both for advice and helpful criticism given during the preparation of the historical review and the experimental work and for the assistance rendered in the preparation of the thesis.

Further the author is greatly indebted to the members of the Elementary Psychology Laboratory class who made the Experimental Section possible by serving as subjects.

In this study the author had a twofold purpose in mind. The first purpose was to make a thorough survey of the experimental data concerning the different phases of formal discipline, or transfer of training. Splendid historical summaries of transfer studies have been made by Thorndike (177), Rugg (162), Coover (56), and others. Most of these studies, however, were made from eight to twelve years ago, and none of the works include a survey of the experimental data obtained in the transfer studies of animals below man.

The second purpose of this study was to make a thorough investigation of bilateral transfer effects in mirror-drawing. The work was begun with the purpose of repeating Starch's experiment.
and, if possible, slightly extending it. Since this experiment has received wide recognition and now comprises one of the experiments given to the elementary students in most of the psychological laboratories, a repetition of the work under essentially the same conditions is much to be desired. Then, too, Starch made no control studies; he worked on a very small number of subjects; he did not establish any norm for the left hand performance to determine the relative ability of the two hands to improve; and his end tests were incomplete. The experimental part of this thesis presents a literal repetition of Starch's experiment and an additional experiment wherein the author attempts to overcome some of the shortcomings above mentioned.
II. HISTORICAL SUMMARY.

1. INTRODUCTION:

The present psychological conception of the transfer of identical elements is an immediate product of the old theory of formal discipline.

From Plato's time to the present formal discipline has been invoked as a defense of the course of mathematics. Since the Middle Ages when the doctrine flourished in justification of classical learning, the theory of formal discipline has been held as almost axiomatic; but, with the abandonment of the old faculty psychology, it has lost its main stronghold, and its subsequent subjection to experimental investigation, started by Volkmann in Germany and by James in this country, has left the theory on a somewhat unstable foundation.

Ever since the problem of formal discipline became the problem of the psychologists, there has been a gratifying absence of the unsubstantiated dogmatizing that once characterized the discussion. The reaction which was initiated against the older doctrine of formal discipline by the Herbartians, and which reached its height soon after the publication of the Thorndike-Woodworth experiments, seems now to have given place to a counter-reaction, which puts formal discipline, now usually spoken of in terms of "transfer of training" on a more scientific foundation.
The term transfer of training is usually applied to situations where the learning of one problem aids, hinders, or has no effect upon the acquisition of a second problem. The term positive transfer will be used as in Webb's work, to denote the results obtained when the learning in the first situation aids the learning in the second situation. Negative transfer will be used to denote the results obtained, when the learning in the first situation hinders the mastery of the second problem. There is also the possibility that the first learned material will have no effect upon the acquisition of the new material. In this case transfer of training will not be present. Results obtained in this last named instance will be referred to under the designation of absence of transfer.

The problem of transfer is usually investigated in somewhat of the following order: A given group of subjects forms a certain habit, which may be called habit A. They form a second habit, B. Will the formation of habit A aid, hinder, or have no effect upon the formation of habit B? A control group forms habit B only. Both groups should be equal in every respect.

The prime requisites of this type of experiment are: (1) That the tests shall afford a reliable measurement of a known observable difference or group of differences, (2) that the training shall not only be measurable but shall be capable of definite description in terms of changes in observable differences, and (3) that changes in efficiency in the final test shall be described with sufficient precision to indicate the dependence upon, or independence of, the training effect.
The study of transfer, like all other studies in memory, was started in Germany. Following in the wake of the German psychologist Wundt, there sprang up a group of psychologists who with untiring zeal sought to gather the facts from the large amount of theory induced by the faculty psychology. Here, with the experiments on memory, association, and attention, we find also the first experiment on formal discipline.

As early as 1858 Vollmann (189) reported an experiment on oross education. He found that by practicing the left arm in length discrimination until an initial sensitivity of 23.6 cm. improved to 11.2 cm., the right arm without any practice showed an improvement from 26.4 cm. to 15.7 cm.

In 1888 Lange (151) conducted some experiments on the process of simple reaction to sensitivity where he found considerable transference. The same year Urbantschitsch made an attempt to determine whether there is a cross-effect between the senses. While a uniform excitation was present to one sense, a sensation was occasioned through another. Under these conditions he determined whether in the functioning of the new sense there were any changes in the sensation of the originally stimulated sense. Listening to a tone lowered the limit for light; it also affected olfactory, gustatory, tactual and thermal sensations. He says, "The influence of one sense-excitation upon the sensations from other senses, appears clearly to be a valid psychological law." (p. 154)

Münsterberg (145) in 1898 made an attempt to determine
whether a habit associated with a given sensory stimulus can continue automatically while some effect of the previous and different habit associated with the same stimulus remains. He had carried his watch in the left-hand pocket so long that taking it from that side was automatic. He now practiced taking it out on the right-hand side until that habit was automatic. It was found that some effect of the first habit had remained, although the second habit became automatic, since it took less time to relearn the old habit than it took to learn the new one. It was also found that, if this process of relearning successfully by alternating the habit is continued, the time for relearning each habit grows less and less.

The first experimental investigation in this country was done by James (115) in 1890. His experiments were an attempt to determine the influence of training in memorizing one kind of verse upon the efficiency of memorizing other kinds of verse. He memorized 166 lines of V. Hugo's "Satyr" (in eight successive days) in 131-5/6 minutes. Then he memorized the first book of "Paradise Lost" working 20 minutes a day (time required not stated). After that he memorized 156 lines more of V. Hugo which required 151-1/2 minutes. James thought the increase in time required for the second memorizing was due to fatigue, so he persuaded four graduate students to try similar experiments. The following table shows the results:

<table>
<thead>
<tr>
<th>Subject Training</th>
<th>Average time per line learned Before training</th>
<th>After training</th>
<th>Residual</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Paradise Lost</td>
<td>60 sec.</td>
<td>67 sec.</td>
<td>-7 sec.</td>
</tr>
<tr>
<td>2. 416 Lines Gr. Post</td>
<td>14.75 sec.</td>
<td>14.44 sec.</td>
<td>0.21 sec</td>
</tr>
<tr>
<td>3. Not Reported</td>
<td>12.23 sec.</td>
<td>12.16 sec.</td>
<td>0.7 sec.</td>
</tr>
<tr>
<td>4. 450 lines of ?</td>
<td>3.67 sec.</td>
<td>3.04 sec.</td>
<td>0.63 sec</td>
</tr>
<tr>
<td>5. Not Reported</td>
<td>14.34 sec.</td>
<td>14.55 sec.</td>
<td>0.21 sec</td>
</tr>
</tbody>
</table>
No control group was used.

James concludes from these results that all improvement in memory comes through improvement in one's habitual methods of recording facts. He believes that there is no transfer of improvement in memory.

Ever since James announced the results of his experiments on the transfer effects of memory-training, this field of research has proved a fruitful source of experimentation. While it is true that James found no evidence of transfer, yet it is to James we must make acknowledgment for the inception of investigations which led Thorndike and Woodworth to a more thorough study of the problem. The findings of these latter men have greatly modified our psychological and educational concepts of transfer effects.

Peterson (150) repeated James' experiment, using nine subjects, two in the practice and seven in the control group. The results indicate clearly the insufficiency of the number of subjects, as well as the faulty method of conducting the practice series. In the training series the subjects lost about as much as the others gained, and yet gained more in the tests. The two together, however, gained in the tests more than twice as much, as the control group.

After the appearance of James' articles, there appeared a great number of reports on transfer of training most of which were interpreted as showing positive results.

In 1913 Woodworth and Thorndike (163), however, showed that much of the work had been falsely interpreted, and much of it, be-
cause of the unscientific methods used, was worthless. It was found: (1) that the end-tests in some experiments were too long to give as full opportunity as possible to transference. This was one of the difficulties in James' original experiment and was recognized by James himself. (2) That the end-tests were not always repeated on a control group. This is true of nearly all early studies. (3) That many of the investigators did not mention the amount of improvement made in the training series, with which the gain in the end-tests could be compared. Failure to observe these precautions makes impossible an accurate, quantitative interpretation of many of the early researches and even of some of the recent ones.

To present here historically the psychological experiments in their chronological order would result in much confusion. Instead an attempt will be made to review the different works in a topical fashion. However, this method of presenting the material is not without difficulties. First, because there is a great deal of overlapping, inasmuch as most of the investigators have not limited themselves to just one phase of the problem. Secondly, it is very difficult to outline a method of classifying the material, which is inclusive, and yet not too broad. Coover uses the following classification for presenting his material:

1. Habituation to Distraction.
2. Sensitivity.
3. Discrimination.
5. Reaction.
   a. Interference.
6. Memory.
7. Voluntary Control.

Webb (192) objects to this classification on the grounds that it is too broad. He objects to including, under the term transfer of training, the first and second headings, because these have to do with the effect that one activity has upon a simultaneous activity. According to Webb, transfer of training implies only the utilization of the effects of training, or learning, upon some subsequent activity. Since Cooper's first two classes deviate from this definition, he excludes them and adds instead three divisions which Cooper does not mention, namely, (1) Attention and Reproduction, (2) Cross Education, and (3) Sensori-Motor Learning.

It would seem that Cross Education would be subject to the same criticism that Webb offers to Sensitivity. Surely, in the transfer from one organ to a bilaterally-symmetrical one there is a simultaneous activity of the two organs of the body. It seems that, Webb thinks of the body as receiving stimuli in parts, and if different parts are stimulated simultaneously, there can be no transfer.

Thorndike (178) would go as far as to exclude Cross Education from his definition of transfer. He says, "The results of experiments in cross-education are not relevant to our problem, for the influence of training one part of the body in a certain task upon the efficiency of the bilaterally-symmetrical half of the body in the same task is a very peculiar case. The sensations from, or movements of, any pair of bilaterally-symmetrical organs are in a way quite different from those of a pair of organs taken at random."

(p. 367) Likewise Swift (175) says, "It would be a mistake to sup-
pose that such experiments in cross-education give support to the doctrine of formal discipline." (p. 190) Here again we note an attempt to differentiate between transfer of the so-called mental processes and Motor-Associations, treating transfer as if it were limited to only parts of the organism. Such a supposition, however, is hardly justifiable. The fact that cross-education does not fit into the program of the theory of identical elements, does not seem sufficient reason to exclude it from our definition of transfer of training. It is my opinion that if transfer takes place at all, it takes place for one function as well as for another function.

I shall attempt to review the Experimental Literature under the following classification:

I. Experimental Work on Human Subjects:
   1. Sensitivity, Inhibition and Facilitation.
   2. Reaction.
   3. Perception and Discrimination.
   4. Attention and Reproduction.
   5. Memory.
   7. Ideals.
   8. Interference.
   9. Cross Education.

II. Experimental Work on Animals below man.
2. EXPERIMENTAL WORK ON HUMAN SUBJECTS.

a. Sensitivity, Inhibition and Facilitation.

Urbantschitsch (183) studied pathological cases of the eye and ear, and found that stimulation also affects parts seemingly not immediately concerned. An hour's operation on the right eye showed on the left a relative enhancement of the capacity to see. In many patients with chronic catarrh of the middle ear, the observer was surprised to find that an important pathological influence was transferred from ear to vision. In later investigations, he demonstrated that the sensitivity of tactile, gustatory, olfactory, and visual stimulation can be increased by practice with auditory stimulation.

Epstein (76) set himself the task of either verifying or refuting Urbantschitsch's results by more carefully controlling the conditions of the experiment. He sought to find the influence of a sound sensation upon acuteness of vision and acuteness of color perception. The observer sat in a dark room and placed his eye to a telescope; the cap was removed and he reported the number of concentric rings on a rotating disc; the second stimulus was given during this fixation, and he reported changes in the field of vision occasioned by it. One hundred sixty-four experiments were made. Upon 60% of the reagents the sound impression increased both acuteness of vision and acuteness of color-perception; upon the other 40% it increased only the former.
Bennett (17) undertook to determine the influence in training of discrimination of arm-movements on the accuracy of visual discrimination of lengths. The apparatus he used consisted of two parallel, horizontal steel rods, two feet long and \( 1\frac{1}{3} \) inches apart. On the lower rod were two spools fixed immovably 25 cm. apart, and on the upper rod were two spools which were freely movable. In training, the two subjects were required to move the two movable spools on the upper rod to equate their distances to that of the immovable spool on the lower rod, through the sensation derived by the arm-movement. The final tests were estimates of length. The result of the experiment was negative; one subject showed improvement, but the other an equal degree of lack of improvement. No controls were made.

Dunlap and Wells (73) gave visual and auditory stimuli simultaneously to four reagents in reaction-time experiments and found that, when the auditory stimulus was reacted to, the reaction-time was about 20 sigma longer than to the auditory stimulus alone; if the visual stimulus was reacted to, the reaction-time was about 20 sigma longer than to the auditory stimuli alone, but 40 sigma shorter than to the visual stimuli alone.

To determine the influence of training in monocular control of reversions in reversible perspective outlines, Wallin used an apparatus which consisted of drawings of a parallelepiped, a book, a table, and a pyramid. In three periods of 20 days each, 9249 trials were made in controlling reversions. The drill took place for the first 20 days averaged 40\%; for the second 20 days it aver-
aged 62%; and for the third 20 days it averaged 62%, a gain of 62% in all. Wallin concludes that the effect of training functioned on the unpracticed eye. As causes of transfer, he gives the following: "There is a general disposition to meet a given situation. Effects of practice are 'central', training of one eye establishes certain cortical tendencies and mental attitudes. The unused retina tended to respond in harmony with the central predisposition. Certain peripheral elements were also used conjointly." (p. 169-70)

Other experiments done in this field were those of Seashore and Junor (167), on the training of the voice by the aid of the eye in singing; those of Cooper and Angell (66), to test the general practice effect of special exercise, including experiments on the transfer of practice effects in sound to light discrimination, and transfer of practice in sorting cards to typewriter reactions; etc.

b. Reaction

Gilbert and Frackor (82) attempted to determine the amount of transfer of training from one type of reaction to other types of reaction. Three subjects were tested, first, in simple reaction to sound, to electric stimuli, to touch, to visual stimuli, and likewise to complex reaction to stimuli involving discrimination and choice. The training series consisted of simple and complex reactions to sound only, and it continued for twelve days. The results obtained in this experiment are given in the following table, which shows the percentage of gain in each of the end-tests:
The spread of improvement in reacting to various sensory stimuli.

<table>
<thead>
<tr>
<th>Individuals</th>
<th>Simple Reaction</th>
<th>Reaction with Discrimination</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>To Sound</td>
<td>Electric Touch</td>
</tr>
<tr>
<td>J.A.C.</td>
<td>12</td>
<td>3</td>
</tr>
<tr>
<td>C.C.P.</td>
<td>23</td>
<td>21</td>
</tr>
<tr>
<td>J.C.P.</td>
<td>13</td>
<td>16</td>
</tr>
<tr>
<td>Averages</td>
<td>16</td>
<td>17</td>
</tr>
</tbody>
</table>

J.C.P. was practiced only in reaction-time, while the other two were practiced in both, reaction and reaction with discrimination and choice.

Each of the forms of reaction show on a whole a distinct gain in the second end-tests. How much of this gain is actually due to the training series cannot be definitely determined because there were no controls made. In the opinion of the authors the results justified the following conclusions: "(1) That practice in reaction to sound reduces the reaction-time to other forms of stimuli by amounts almost equal to the reduction of the time of sound reaction itself. (2) That such practice alone does not reduce the time of discrimination and choice. (3) That practice in discrimination of sounds reduces also the time of discrimination of other forms of stimuli." (p. 75-76)

Angell and Moore (11) carried a long series of experiments with three reagents in reaction-time, in which the responses were made with the hand, the foot, or the lips, to auditory and visual stimuli, in both sensorial and motor forms. Most of the visual series were not begun until the auditory series had been completed,
and they showed a much shorter time than is usual for reaction to visual stimuli. The authors observed that the form of reaction was the same in both groups, and that the decrease in time in the latter must be referred to the practice-effect of the former.

Jastrow (116) made a comparison of the efficiency of two professional magicians in the various laboratory tests of tactile and muscular reaction, reaction-time, etc., with that of various groups of college students. The tests given included (1) tactile sensibility, (2) arranging series of weights in order, (3) tactile sensibility, (4) judgments of lengths of bars (with forefingers), (5) arbitrariness, moving hands equal distances from a central point, (6) estimating an area of a cross, (7) rapidity and accuracy of perceiving geometric figures, (8) rapidity of finger and arm movement, (9) reaction-time, (10) correlation of hand movements with discrimination of red and blue, and (11) quickness of perception of color and form and separate words in a sentence. With the Weber compass the magicians could distinguish the points at 3.5 mm. and 2.5 mm. respectively, and the average of miscellaneous individuals at 2 mm. In arranging in order five weights, each of which weighed 1/16th gram more than the previous weight, the miscellaneous group arranged 82% correct. One of the magicians failed in this test. Jastrow concludes "that the positive results of the investigation are small, but as far as they go they are consistent with the forms of dexterity that are utilized in sleight-of-hand performances. They also indicate that it may well be that special skill in one very specialized form of training may be only slightly influential upon other
form of capacity." (Taken from Bowins (93) p. 17)

Carrie W. Liddle (164) found that practice in discrimination and sorting of one set of cards bearing colors of geometric signs assisted in discriminating and sorting another set with different signs and colors.

c. Perception and Discrimination.

One of the most influential and comprehensive of the earlier works was that of Thorndike and Woodworth (163) who made an investigation to determine the transference of practice in estimating areas, lengths of lines and weights, to estimating areas, lines and weights of different sizes. They also measured the effect of practice in perceiving words containing certain letters, upon the accuracy and quickness of perceiving other words containing different letters. In one part of these investigations the authors made use for the first time of a control group. The test series consisted of:

I. a. Areas of the same size as rectangles, but of different shape.

b. Areas of the same shape, but from 140 to 300 sq. cm. in size.

c. Areas of different shapes and from 140 to 400 sq. cm. in size.

II. Estimating weights of from 120 to 1800 grams.

III. Estimating lines from 6 to 12 inches long.
IV. Ability to perceive words containing i and t, s and p, e and a, e and r, a and n, i and o, misspelled words and c's.

V. Perceiving English verbs.

The results were as follows:

I. The gain in the test series was only 64%, 50% and 53% as much as in the training series for estimating areas of rectangles.

II. For estimating weights the gain of the test series was only 39% as much as in the training series.

III. For estimating lengths of lines the training series showed a reduction of 25% of the initial errors, the test series showed no improvement.

IV. In the perception of words the improvement of the test series was 39% as much in speed and 25% as much in accuracy as the training series.

V. In perceiving other parts of speech the reduction of time was 21%, and omissions 70% for the training series, as compared with a reduction of 5% and an increase of omissions of over 100% for the test series.

The most important part of their conclusions is to be found in these words: "Improvement in any single mental function, no matter how similar, for the working of every mental function group is continued by the nature of the data in each particular case."

(Thorndike 198, p. 399)
These results were at that time considered so radical, that widespread interest in the problem was aroused, and, as a consequence, many investigations were inaugurated.

The experiments in marking out words and in estimating weights were repeated with two persons, in substantially the same way, by Cooper. Cooper's results differed radically from those of Thorndike and Woodworth, being positive in nature.

One of the most interesting experiments in connection with this problem, is the one on the perception of illusions, by Judd. (121) The purpose was to correct the Müller-Lyer Illusion. There were two observers one of whom was Judd, who says he was trained somewhat irregularly and with a background of abstract knowledge and expectation. Judd found that both he and the other subject learned to apprehend the lines correctly in about the same number of comparisons. When the figures were reversed and a second series of tests begun, Judd, who anticipated the effect of practice, adjusted himself to the new demands and rapidly overcame the illusion. The other subject showed greater error and no disposition to improve. Judd concluded that "the practice gained in the first series was transferred in both cases; in the one case it worked improvement; in the other it increased the illusion, and rendered the observer incapable of rapid readjustment." (pp. 35-37)

Other authors conducting transfer experiments on Perception and Discrimination include those of Bennett (17), to test the effect of discrimination of lengths by the eye as a result of practice in discriminating lengths by arm-movements; those of Cooper.
et Angell (56), to test the general practice in sound to light
discrimination, and the transference of practice in sorting cards
to typewriter responses; and those of Wallin (90), attempting to
test the reversibility of a number of reversible perspective out-
lines.

d. Attention and Reproduction.

Coover (57) made a series of transference experiments
which he lists under the head of attention, but it is doubtful as
he himself states, whether they are measures of attention any more
than other tests that have been reported under other headings. How-
ever, attention probably played an important part in most of the
tests that Coover employed.

The results obtained from the various end tests are rather
difficult to present. Coover attempted to interpret their
meaning from the standpoint of control of attention by comparing
the variability in the performance of the persons before and after
training, on the assumption that reduction in variability initiated
better attention. His general conclusion was that "as a measure of
attention our tests are inadequate, and the question of transference
of improvement under conditions of attention remains open." (p.163)

Rugg (163), emphasizes the importance of attention in an
experiment where he sought to determine the influence of a semester's
training in descriptive geometry upon specific abilities in the
mental manipulation of special elements, of three types, (a) non-
geometrical, (b) quasi-geometrical, (c) strictly-geometrical. In
conclusion he enumerates the "agencies of transfer":

(1) Conceptualizing abilities played an important part in developing methods of attack.

(2) Specific habits (adjustment of familiar cues) have carried over bodily, and tied together test and training series.

(3) Building attitudes of orientation in the general visual field.

(4) Practice in extending the range of attention has given increased facility in manipulating many elements of the same kind.

Whipple (201), by means of a telescoposcope studied the improvement in speed and accuracy of visual perception by exposing various material to view for a limited time, and the performance by:

(1) Native capacity, (2) the degree of attention, (3) specific capacity for given types of material, (4) ease of assimilation, (5) grouping, (6) and to ideational types.

Evans (77) conducted an experiment on transfer as related to training of attention. He says, "Now since attention consists partly in resistance to distraction, training to resist a certain or specific distraction constitutes a specific training of attention, and the transfer effect can be examined when other distractions are substituted for the one employed in training." He concludes from this experiment that "to attend well means ability to ignore non-essentials for the sake of essentials. With this abil-
ity to ignore the non-essential stimuli comes a certain feeling of self-confidence and self-reliance which stimulates the subject to active interest in the work. It is this attitude, or adjustment which makes transfer possible. We would expect little or no transfer effect to result from practice if an attitude or "set" or neural adjustment which had been previously acquired could not be used in the new situation." (p. 70)

Others working in this field were Ellenbech (68), who extended Whipple's experiment, and Foster, (80) who sought to determine the influence of attention on training in visualizing, on the ability to represent in images impressions recently given in sensations.

e. Memory.

The best known and most elaborate of the earlier investigations of transfer of memory-training was that of Ebert and Neumann. (75) They sought an answer to the following question: Is there a general memory function which can be perfected upon any material involving the use of memory, or, on the other hand, must we posit related or unrelated special memories? Six subjects were tested with a large range of material involving the use of memory. They were then trained by memorizing four lists of twelve non-sense syllables a day for eight days, after which they were retested with a series of tests similar to those used before the practice. Then there was another eight days training with non-sense syllables, followed by a third series of tests. The results indicate considerable improve-
ment in both training and the tests. The author concludes that there are, no doubt, related memory functions which can be perfected upon any material involving the use of memory, the development taking place proportionally to the degree of relationship of the test and practice material.

This experiment has been subject to severe criticism. The following shortcomings may be noted:

(1) The tests were so long as to give them too much special practice in the tests.
(2) There is no guarantee that the three test series were of equal difficulty.
(3) Too few (only six) subjects were used, and in three of the seven tests in immediate learning, there were only two.
(4) No control group was used.

Dearborn (65) tried to remedy this defect by repeating the test series only, and concluded as follows: "The results indicate that a considerable part of the improvement must be attributed to direct practice in the test series, and not to any spread of improvement from the practice series proper. There is further, at times, lack of correlation between the amount of improvement made in the practice and that made in the test series; occasionally a larger percentage of gain is made in the latter than in the practice itself. This again indicates the presence of direct practice in the test series. Some at least of the remaining general improvement found is to be explained simply in terms of orientation, attention, and changes
in the technique of learning." (pp. 44-45)

One of the most elaborate of the later investigations on the transfer effect of memory-training is that made by W. G. Sleight (105) of England. He takes his departure from a criticism of the works of Hart and Neumann, Fracker and Finch. The general nature of the criticism is the same as that already stated.

Ten cross-sectional tests were made before, in the middle, and after the training series following in the present order: (1) Remembering and reproducing the location of points in circles, (2) two series of six dates each and their corresponding events, (3) series of eight syllables, (4) a stanza of from eight to twelve lines of poetry, (5) learning a passage of prose, (6) reproducing the content of a passage of prose, (7) remembering locations on maps, (8) remembering dictated sentences, (9) memory span for letters, (10) remembering names.

The pupils were divided into four groups of approximately equal ability as determined by ten tests given before the training series. One group was trained in learning poetry; another in learning tables in multiplication, denominations, squares, fractions, etc; a third reproducing the thought content of prose selections of scientific, geographical, and historical material; and the fourth group had no special practice. The training period lasted four days a week, for six weeks, lasting 30 minutes each day. The method that Sleight used for treating his data is of importance. In his results Sleight indicates that he calls three scales of certainty of significance: First, those where the superiority or inferiority of a practice
group is at least five times the probable error; second, where the
difference is at least three times the probable error; and third,
where the difference is between two and three times the probable er-
ror. The remaining numbers he considers of no significance whatever.
According to this method of considering the results, the practice
series show neither superiority nor inferiority to the control group
in four tests: dates, poetry, letters, names. In the other tests
there are some significant differences. These are indicated in the
following table:

<table>
<thead>
<tr>
<th>Practice Groups</th>
<th>Tests</th>
<th>Superiority over Control</th>
<th>P. E.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poetry</td>
<td>Non-sense Syll.</td>
<td>66</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>Prose Subst.</td>
<td>22</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>Tap Test</td>
<td>50</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>Dictation</td>
<td>-32</td>
<td>12</td>
</tr>
<tr>
<td>Tables</td>
<td>Points in circles</td>
<td>48</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td>Non-sense Syll.</td>
<td>65</td>
<td>11</td>
</tr>
<tr>
<td>Prose Subst.</td>
<td>Literal Prose</td>
<td>21</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>Prose Subst.</td>
<td>31</td>
<td>11</td>
</tr>
</tbody>
</table>

In the analysis of his results, Sleight finds Thorndike's
early Law of 'Identical Elements' too simple. He says, "The relation
which produces transference is not necessarily (a) an external rela-
tion perceivable by an observer, nor (b) a relation perceivable by
the learner; but (c) a common factor, of the which the individual
mind makes use, consciously or unconsciously. The individuals
awareness of the usable common element may produce an earlier and
greater effect......" The common element "must be separable from
the complexes" in which it occurs. This disintegration resists
transference." The factors which make for transference are similarities of fundamental nature, such as specific forms of attention, imagery, rhythm; in short, similarities of procedure." Changes in these affect transference more than changes in material. The general conclusion to which the author is led is that "specific memory training is specific in its effects." (pp. 466-57)

Coover (57) criticizes Sleight in the following way: "(1) The unpracticed group was not unpracticed, since these tests involved processes largely exercised in the ordinary work of school. The influence tends to erase the difference between the practiced and the unpracticed groups. (2) There is sufficient indication by significant positive and negative values of the relationship of processes to count against merely specific effects of practice." (3) The assumption that "the mental processes have probably been independent" when the influence of training is not revealed by significant difference-scores, is opposed to the general introspective evidence of other investigators. (4) The criticism of irregularity of results, applied to Winch by the experimenter, seems applicable here, since his tables agree in but one entry." (p. 28)

Others working on transfer of memory-training were:

Bennett (17), who found that training in memorizing poetry improved memory for digits and for names of places; Frcolor (81), who found that memorizing series of sounds improved memory for series of grays, tones, pitches, a square of geometrical figures and verses of poetry; Gamble (87), finding that memorizing colors gave greater facility in
memorizing odors, and practice gained in memorizing odors and colors was transferred to memorizing non-sense syllables; Hall (155), memorizing poetry or prose in English or in a foreign language, or irregular verbs or vocabularies, improved memory for poetry and for non-sense syllables; Winch (204), experimenting to discover whether improvement in numerical accuracy transfers, found positive results; Lawn (133), finding interesting data in regard to the relation between mathematical and practical reasoning; Thorndike and Woodworth (183), testing the influence of special training in memorizing found negative results; and Janson (116), repeating parts of Ebbinghaus's experiments and finding positive results.


Judd and Scholakow (122) investigated the effect of knowledge of the principle of refraction upon learning to hit a target under water. It is from this experiment that Judd drew his theory of the transfer of general elements.

One group of boys was given a full theoretical explanation of refraction. The other group of boys was left to work out experience without theoretical training. These two groups began practice with the target under twelve inches of water. The theory seemed to be of no value in the first tests. The two groups gave about the same results. For the next test the conditions were changed. The twelve inches of water were changed to four. The difference of the two groups of boys now became apparent. The boys without theory were very much confused. Their errors were large and persistent.
On the other hand, the boys who had the theory, fitted themselves to
the four inches very rapidly.

Judd argues from these results for the interfering effect
of special training. He points out the importance of generalization
in learning. He says, "Mental life is compact, every experience has
possibility of generalization." (p. 37)

Webb (192) made a comparative study of humans and white
rats in the transfer of training. His plan was to determine the
effect of an acquired skill upon the acquisitions of other skills.
He employed 54 rats and 21 humans for learning mazes in various or-
ders. He measured the results in terms of the number of trials re-
quired, the number of errors made, and the amount of time needed to
learn the mazes. The following table gives the savings in learning
a second maze as compared with the learning of the first one:

Table IV

Average percentage of savings in transfer.

<table>
<thead>
<tr>
<th>Mazes</th>
<th>Trials</th>
<th>Rate</th>
<th>Errors</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-B</td>
<td>77.08</td>
<td></td>
<td>65.81</td>
<td>83.77</td>
</tr>
<tr>
<td>A-D</td>
<td>69.02</td>
<td></td>
<td>79.71</td>
<td>90.42</td>
</tr>
<tr>
<td>A-E</td>
<td>93.01</td>
<td></td>
<td>54.63</td>
<td>63.40</td>
</tr>
<tr>
<td>A-F</td>
<td>65.01</td>
<td></td>
<td>42.78</td>
<td>59.44</td>
</tr>
<tr>
<td>A-G</td>
<td>67.05</td>
<td></td>
<td>46.10</td>
<td>39.54</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Mazes</th>
<th>Trials</th>
<th>Rate</th>
<th>Errors</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-D</td>
<td>51.08</td>
<td></td>
<td>94.58</td>
<td>83.73</td>
</tr>
<tr>
<td>A-E</td>
<td>67.66</td>
<td></td>
<td>86.46</td>
<td>67.18</td>
</tr>
<tr>
<td>A-G</td>
<td>18.74</td>
<td></td>
<td>20.20</td>
<td>29.18</td>
</tr>
</tbody>
</table>
Webb concludes that the learning of one maze has a benefi-
cicial effect in the mastery of a subsequent maze situation, and that
the degree of transfer is dependent in part upon the degree of simi-
licity of two maze patterns. Webb further proves rather conclusively
that a high degree of positive transfer can occur on a purely sensori-
motor level.

Cooper and Angell's (56) investigation to test the general
practice effect of special exercise included experiments on the trans-
fer of practice effects in sound to light discrimination, and the
transfer of practice in card-sorting, to typewriter reactions.

They concluded from their experiments that training in card-
sorting is the cause of the increased ease and facility experienced by
the regular reagents in the second trial in typewriter reactions; but
this improvement is not considered due to identical elements. The
general condition that is common to both is the habit of stripping
the essential process of unnecessary and complicating accessories.
The cause of transference of facility is the formation of a habit of
reacting directly to a stimulus, which results in an equitable distrib-
ution of attention and the consequent power of concentrating the
attention.

Ruger, in an experimental study of the processes involved
in the solution of mechanical puzzles and in the acquisition of
skill in their manipulation, also studied the transfer effects, and
attempted to isolate the factors causing improvement. With the aid
of his subjects' introspective reports in connection with objective
measurements, Ruger made a classification of the transfer factors into: (1) general factors and (2) specific factors. It has seemed advisable to the writer to use the term transfer in a very broad sense to include the effect of any given experience on any subsequent one whether the transfer is one of method, or of material, or of motor processes, and whether it is positive or negative. To the writer the problem of consciousness considered in itself, and as to conditions of efficiency, seems to have many characteristics in common irrespective of the degree of relatedness of the material concerned.

Another excellent piece of work is that of A. T. Poffenberger (152) on "The Influence of Improvement in Simple Mental Processes upon Other Related Processes." This experiment is intended as an intensive study of the transference problem upon a small number of subjects with material that can be analyzed readily into stimuli and responses. His main conclusions are:

1. Where there are no identical bonds between stimulus and response in the two processes, the influence of one test upon another will be neither positive or negative, i.e., there will be neither transfer nor interference.

2. Where there are identical elements in the two situations or where a given response involves one or more bonds previously formed, there will be a positive transfer.

Fowler D. Brooks (31) made an attempt to determine the amount of transfer in mental multiplication and substitution and its relation to intelligence. His main conclusions follow:
1. Clearly, transfer does not take place from a few hours training in mental multiplication and substitution.

2. It is greatest in functions which are most closely related in content or processes, and in functions having little in common with certain emphasized ideals of procedure may be used.

3. The gain from practice does not spread much to functions having little in common with the training, and even fails to spread from training in substitution to other memory functions.

4. We do not know the permanence in training in any of our cases, nor do we know the relation of such permanence to mental age or degree of intelligence, although both of these problems are of great importance in the psychology of learning.

5. Transfer from mental multiplication to mental division is somewhat in proportion to both mental age and I Q, but the relation is not close, the coefficient ranging from .24 to .34.

6. If studies of transfer and intelligence are to be conclusive, we must have definite extensive knowledge of practice effect from taking tests for different chronological ages and different intellectual levels." (pp. 421-22)

Gates (185) in a recent article reported the results of a study designed primarily to test several features of an experimental technique commonly designated as the "control group method" and compared results obtained experimentally with results suggested (1) by pooled estimates of experts in education and psychology, and (2) by an analysis utilizing the methods of multiple correlations based upon the initial performance only.
Two types of training were adopted: (1) The Paragraph-
Question Method which consisted in reading ten minutes daily as
rapidly as possible mimeographed passages for the purpose of answer-
ing questions, calling for the main ideas. Each child had a booklet
containing eighty-five pages of this prepared material. Results were
scored; rate and comprehension computed; records made and displayed
daily for the benefit of the children. (2) The Oral-Recitation
Method consisted of reading materials from selected books for three
minutes followed by two minutes oral recitation; then three minutes
reading and two minutes recitation, a total of ten minutes daily,
the same as the other group. Speed was emphasized, measured, record-
ed and displayed; comprehension in the form of outlining the story or
ideas was emphasized but not objectively measured. Practice covered
a period of little more than one month.

To measure the amount of transfer, the following tests
were used:

1. Thorndike-McCall Scale for ability to understand paragraphs.
2. Monroe's Standardized Silent Reading Test, Revised.
3. Courtis Silent Reading Test Understanding of Paragraphs.
4. Courtis Silent Reading Test. Rate Score is number of words
   read per minute.
5. Word Perception Test.
6. Cancellation of unlike groups of digits.
7. Picture Naming Test.

Tests 5, 6 and 7 formed the basis of the analysis of the
control group technique.

Improvement both, specific and transferred, was computed in terms of multiples of the standard deviations of the distributions of ability in the initial tests.

Gates finds that with regard to the quantitative aspects of transfer the main facts are: "(1) The amounts of transfer are small; (2) they vary greatly depending on the similarity of materials and the methods of scoring; and (3) they differ according to the type of reading reading training." (p. 543) Gates finds further, that it is possible by means of statistical analysis of measured abilities in several functions to estimate roughly the relative amounts of transfer, at least under certain conditions. "Neither of these shorter methods is a satisfactory substitute for experimental analysis, but the technique of multiple correlations provides a supplement and check that, in many experiments as in the present one, may be profitably used." (page 558)

Other transfer tests in Sensori-Motor Association were made by:

(1) Louba and Hyde, (217) (writing English words in German script).
(2) Munsterberg (144), (habit association).
(3) Bergström (19), (card-sorting).
(4) Thorndike and Woodworth, (163) (estimating weights and lengths of lines).
(5) Rock, (27) (typewriting).
(6) Judd and Cowling, (120) (drawing with eyes open and eyes closed).
(7) Wallin, (160) (monocular control of reversions in reversible
perspective outlines).

(8) Johnson, (118) (skill in dumb-bells and in reacting to sounds).

etc.

g: Ideals.

Bagley (14) reports an experiment, made by Squire on the
transfer effects of special training in neatness in arithmetical work,
on neatness in other school work. The experiment was carried on in
the Montana State Normal College. Bagley says, "The results are al-
most startling in their failure to show the slightest improvement in
the Language and Spelling papers, although the improvement in the
arithmetical papers was noticeable from the very first." (Taken from
Martin 139, p. 21)

On the other hand, Ruediger (161) reports that neatness
cultivated in connection with one school subject did improve neat-
ness in other subjects. He maintains that transfer depends upon the
development of ideals. Habits of neatness acquired in one school
subject will transfer to other school subjects only in so far as an
ideal of neatness has been inculcated.

h: Interference.

Fair (18) concerned himself with determining the influence
of practice in tapping certain typewriter keys in response to series
of visual stimuli, on the efficiency of tapping different series;
and the influence of practice in repeating the alphabet in certain
ways on the efficiency of repeating it in other ways.

Fair concludes from his results that one kind of practice
helps in another kind. Interference plays a very small part in our mental life. It functions between two kinds of practices during a limited number of practices, and after a certain number, interference changes so as to function as transfer of practice. A habit associated with a given sensory stimulus or series of stimuli can continue automatically, while some effect of a previous and different habit associated with the same stimulus or series of stimuli remains.

Louise E. Ordall (147) working on the same problem concludes: "What Baird says in regard to the general ability given by special training is true of all learning. For no matter what new acquisition is undertaken if it is possible to master it, some previous general training has either been developed by the individual or through the inherited co-ordination of his ancestors." (p. 185)

Jastrow and Cairnes (116) found that simultaneous processes may interfere with each other or augment one of them. In general they agree with Baird and Ordall.

Bergstrom (19) on the other hand, has reported experiments showing interference clearly. He finds that under certain simple conditions, interference effects of an association, bears a constant relation to the practice effects, and is equivalent to it.

Dulin and Washburn (142) found that there is less interference between complex than between simple processes. The processes of retroaction closely related to transfer of training, will not be discussed here.
i. Gross Education.

It has long been known that if an individual be given training in some operation which involves the musculature of one side of the body only, there will be an apparent improvement in the same or similar operations carried on through the corresponding musculature of the other side of the body, although this musculature has not been involved in the practice. If, for example, the individual is given practice in tracing the outline of a star as viewed in a mirror with the right hand only, and practice is continued until a considerable degree of improvement in speed and accuracy is attained, it will be expected that the individual will now show an improvement in the same respects in tracing the star with the left hand, as compared with his performance with the left hand before practice, although only the right hand has been employed in the practice work. This apparent carrying over the practice effect from one side of the body to the other, is technically known as Gross Education or as bilateral transfer of training.

The phenomenon of bilateral transfer is first recorded as observed by Weber and Fahlmer (124) in the case with which an individual's unpracticed hand made letters similar to those made by the practiced hand.

Scripture, Smith and Brown (166) state that improvement in strength of grip with one hand produced 60% as much gain in the other. They also report that Vollmann found that improvement in discrimination with the left arm was accompanied by approximately 60% as much gain in the other arm and that other instances showed
similar gains.

Davis (23) measured the effect of tapping with the great toe on the right foot upon the rate of tapping with the right hand, the left hand, and the left great toe. He found that the left toe improved 151% as much as the right toe, with which the practicing had been done, the right hand 100% as much, and the left hand 83% as much.

Woodworth (211) reports that practice in hitting dots with the left hand improved the right hand about 50% as much, and Swift found that practice in tossing balls with the right hand caused the left hand afterwards to improve in the same exercise more rapidly than it would otherwise have done.

Wissler and Richardson (209) concluded from data gathered by experiments with a hand dynamometer, that large transfer of training accrues to the unpracticed hand. The accessory muscles of one side gained approximately as much from the exercise of the fundamental muscles of the same side.

Wallin (190) trained observers in monocular control of illusive phases of reversible perspectives. The improvement that resulted from the training of one eye was shared by the untrained eye.

Baroesser (145) conducted some experiments on bilateral transfer from one hand to another, with subsidiary experiments designed to secure material for the interpretation of the bilateral effects. The apparatus consisted essentially of a Burroughs adding machine, subtractor model, ten columns, motor driven. The work of
the reactors was somewhat as follows:

A. Simple listing, which refers to reading the numbers from
the work sheet and putting the numbers read into the machine.

B. Observation, i.e., watching at close range other reactors
working at simple listing.

C. Auditory listing, when the reactors put into the machine
numbers from the work sheets read to them by the experimenter.

D. Number reading, when the reactors practiced reading the
numbers of the work sheets but did not operate the machine.

E. Machine training, where the reactors practiced on the machine
but did not have work sheets.

Further, the following conclusions:

1. In every case of simple listing, there is improvement of the
idle hand.

2. In every case of observation, there is improvement of the idle
hands; and where followed by simple listing, there is improvement of
the idle hand as well as of the practiced hand.

3. In every case of auditory listing, there is improvement of
both hands. When followed by simple listing, the idle hand made
improvement in the final tests.

4. The reactors reading the numbers without working the machine
showed improvement in both hands in the semi-final tests, and in sub-
sequent simple listing, the idle hand showed marked improvement in
the final tests.

5. In cases of reactors using the machine without work sheets,
the idle hand as well as the hand which worked showed improvement in
the semi-final tests; and in the subsequent simple listing, both the practiced and the idle hand showed improvement in the final tests. Every case therefore, presents positive evidence of "bilateral transfer of training." (p. 300)
3. EXPERIMENTAL WORK ON ANIMALS BELOW MAN.

Sensori-Motor Learning.

The first experiment in the animal field dealing specifically with the transfer of training was that of Hunter (107 and 109) done in 1916 and published in 1917. Hunter investigated the interference of auditory-motor habits in maze learning. White rats were used as subjects. In a T-shaped discrimination box the rats were trained to turn a certain direction if the stimulus was present and the opposite direction if the stimulus was absent. Hunter reports that there was a forward-acting interference between the first auditory-motor habit and the second. These findings were later verified by Yarborough and Pearce (217), who also extended the experiment to include the interference of visual-motor habits in maze learning, and obtained for this experiment the same results as for the former.

Hunter (108) refers to transfer effects in animal learning as early as 1911. While working with five pigeons in maze learning he observed that: "The habits acquired in maze learning labyrinth A by birds 1, 2, and 7, interfered with their learning of labyrinth B and resulted in a slow elimination of errors. The training in A made it possible for animals 1, 2, and 7, to reduce their time records permanently sooner than did Nos. 5 and 8 (in new maze learning)." (p. 301)

Webb (192) studied the transfer effects in maze learning with rats and humans. The essentials of the experiment have already
Wiltbank (206) continued the work of Webb in order to study the kind and degree of transfer in the white rats which were allowed to learn a maze after they had learned, either completely or partially, one or more other mazes. This work showed positive transfer in every case. Wiltbank believes that the positive transfer is due to:

1. The recession of the instinct of timidity carried over from one maze to another.

2. The kinaesthetic habits acquired while traversing the true path under the influence of the exploring instinct of curiosity.

3. The association formed between the animals running the maze, the end of the true pathway, and its gaining access to the food box.

4. Practice in elimination of errors, e.g., habitual resistance, overcoming tendencies to enter the blind alleys.

Ruger (163) likewise did work with the maze, using white rats for subjects. His purpose was to note the effect of previous semicircular canal practice, on practice on maze learning. He invented the ingenious method of pulling the rat in a car around the correct pathway a certain number of times to determine whether such training would aid the animal in learning the problem. No transfer was found.

Bogardus and Vonka (30) also made some tests upon the question of transference in the case of rats learning a maze. The animals were taught a certain maze. Then by the use of doors for
blocking the true pathway at certain points and for opening up the
pathway at new points, the correct pathway was altered in certain
respects. Then the animals were taught to run the new pathway. An
effort was made to make the maze different, each time any alteration
was made, in but one respect. These were arranged according to what
was judged their relative difficulty in order I, II, IV, III, V,
number I being the original maze. The actual order of difficulty in
learning these five proved to be, as shown by the table of results,
V, IV, III, I, II. These men conclude that in maze learning it is
evident that previous experiences are effective upon subsequent be-
havior, and these effects are advantageous according to circumstances.
No controls were made.

Yerkes' (214) study on "The Dancing House" has furnished
some data bearing on the question of transference. Animals which had
not been previously trained on a simple labyrinth (C) succeeded in
making the trip correctly for the first time on the average after
19.7 trials. Animals which had previously learned the labyrinth (B)
succeeded in making the first correct trip in (C) after 7 trials.
The learning of (B) without previous training required 3.2 trials.
After previous training on (C), the learning of (B) required 5 trials.

Thorndike (181) reports in his experiments with the cats
in the problem boxes, that previous experience makes a difference in
the quickness with which the cat forms the associations. After get-
ting out of eight or six boxes by different sorts of acts, the cat's
general tendency to claw at loose objects within the box, is strength-
ened, and its tendency to squeeze through holes and bite the bars in
weakened; accordingly it will learn associations along the general line of the old not quickly.

Harry R. Wylie (213) undertook to determine the actual conditions under which transfer, both positive and negative, takes place; to state the explanatory principles in a definite and usable way; and to define the two problems of positive and negative transfer accurately and completely in terms of each other as to their similarities and differences. To accomplish this he emphasizes two essentials: (1) Simplicity of problems, and (2) the reduction of the problem to perceptible and definitely measurable objective terms of sensory stimulus and motor response. Since this combination is hard to obtain with humans, white rats were used for the experiment. In all, close to 175 animals were used in the experiment.

Two series of experiments were planned and carried out. In the first series the attempt was made to teach the animals a definite positive response to one sort of sense stimulus. Then a second sort of sense stimulus was substituted for the first. The purpose was to see whether and to what extent such a response would carry over to the second. This series falls into two groups: (a) where the response was first learned to the light stimulus and then the sound stimulus was substituted for the light; (b) where the response was first learned to the sound stimulus and the light stimulus substituted for the sound.

In the second series a negative response was required in all cases. The purpose was the same as in the positive series.
This series falls into six groups: (a) where the response was learned to the light and the sound substituted, (b) where the response was learned to the light and the electric shock substituted, (c) where the response was first learned to the sound and the light substituted, (d) where the response was first learned to the sound and the electric shock substituted, (e) where the response was first learned to the electric shock and the light substituted, (f) where the response was first learned to the electric shock and the sound substituted.

Wylie concludes that "the results of the experiments go to support the general contention that the fact of transfer cannot be doubted, that is, of positive or advantageous transfer. It has been found that in every case learning a response to one situation, having a given element or stimulus as the dominant or controlling factor, is a help in learning the same response to the same situation but having a different element or, not present before as the dominant or controlling factor; that even in some situations the learning process for one sort of dominant stimulus is actually reduced in length so much by first introducing another dominant stimulus, that the time and effort for both is less than for one alone. Such was actually the case in learning the negative response to the sound.

Looking at the results from the point of view of "generalized response" or "generalized habit" we can say that responses are not always particular, but may become truly general; that is
the same response may serve for situations whose dominant stimuli are as different as can be found, provided the other features are the same and remain constant. This is really the reverse of the cases usually spoken of under the term 'general habits'. In such cases the dominant features are supposed to remain the same while the minor features vary from one case to another. So 'generalized habit' cannot always be said to depend upon similarity of depend upon similarity of dominant features in the situations responded to, or upon lack of discriminations of such dominant features. We can secure 'generalized responses' where the dominant features of the situation are actually different for the organism making the responses, provided we can take differences of sense channel as the basis for discrimination of stimuli. In such cases there would be difference of neural pathways, at least in the sensory portion of such pathways. The 'identical elements' in such pathways would be at least partially in the association and motor portions. Complete identity cannot be said to be present.

According to the results given, one, and only one, of the conditions of the degree of advantageous or positive transfer clearly shown is the simultaneous presentation of the two controlling or dominant stimuli after the responses to one has been learned. While in practically every case considerable disturbance was produced at the introduction of the new stimulus along with the old, yet the presence of the old habit helped in every case in learning the new. Thus variations in stimuli allow of positive or advantageous trans-
for effects, while variations in response, an aspect of the problem which has not been tested in these experiments, produce negative effects." (pp. 64-65)

Pechstein (69) made an attempt to determine what part transfer plays in the "whole and part method" of maze learning. He used both, human and white rats for subjects. He found that:

"(1) Transfer factors operate at their full value in 'part' procedure.

(2) This transfer is general and specific. The important general items are a general maze habit, consciousness of power, and favorable emotional tone. The specific items refer to the details of the maze pattern.

(3) Transfer fails to render the final areas of a complex motor problem easily mastered. 'Part' procedure reverses these conditions.

(4) Learning effort does not vary directly with the length of material.

(5) The inherent advantages of part learning are mainly the complete utilization of the transfer items and the avoidance of diminishing returns due to the excessive length of the motor problem."
4. THE MIRROR-DRAWING EXPERIMENT.

The interesting phenomena of mirror-writing are mentioned in the psychological literature as early as the '90's, if not before; but the first use of mirror-drawing as a psychological experiment appears to be found in Honri's article on the muscular sense and in his monograph on tactual space perception of the same year, 1898.

W. F. Dearborn (66) independently experimented with mirror-drawing in 1905, though his work was not reported until other writers, likewise independently, had hit upon a similar idea. He used this experiment to demonstrate the 'trial and error method' of learning; showing that it is in certain conditions regularly employed, even in adult human learning.

In this experiment the subject was directed to trace out the figure of a star by means of its image as seen in a mirror. Dearborn found that after several trials most subjects learned to trace the figure with but few errors. As an indication that this improvement on the basis of the trial and error procedure had not necessarily resulted in any more general acquaintance with the real difficulty involved, a pattern with eight numbers arranged in a circle, was substituted for the star and the subject asked to place his pencil at the dot in the centre of the figure and draw a line without hesitation and with but a single rapid movement toward the numeral designated by the operator, thus connecting the various numbers.
Dearborn further suggested that this experiment could be used for demonstrating transference from the right to the left hand. He however, does not publish any results obtained by the experiment, suggesting it merely as a good method of indicating the trial and error method of learning, and as a possible means for furnishing a test for cross education.

In addition to Dearborn's work, Judd (120), Starch (170), and Hill (101), have called attention to the usefulness of mirror-drawing as a demonstration experiment to illustrate the acquisition of motor-habits, the trial and error method of learning, etc.

Burt, (41) Yocum and Gallo (216), Miss Woitonsall (199) and others have used mirror-drawing to test quickness of learning and its correlation with sex, intelligence, and other factors.

Hill (101) used the mirror-drawing test on a group of five students to illustrate the trial and success method of learning in the case of adults. Slight modifications in the Dearborn apparatus were introduced. Hill also introduced a combination of semi-circles in addition to the star. The class tests were made individually in an adjoining room during the first quarter of an hour of recitation periods for two weeks. Data were also gotten from eight persons outside the class, one of the group making drawings during forty-seven consecutive days. Graphical representations were exhibited to show curves of improvement in time and errors. The tests were extended to demonstrate the transfer of practice effect; both similar (star) and dissimilar (semi-circles)
forms, as modifying the objective factor, were used. Unexpected large practice effects of initial and terminal tests resulted when a whole figure of either pattern was used for right and left hands. He found (1) that for both hands the improvement was greater for stars (identical designs) than for semi-circles (slightly different). (2) that improvement in the unpracticed left hand is less than that for the right for stars; (3) that the skill in producing dissimilar figures (semi-circles) remains almost the same in both hands, with an advantage to the left.

It will be noticed from this review that:

1. The experiments were done individually in a separate room.
2. No controls were made.
3. No instructions are specified.
4. There are no indications as to what constitutes an error, and no time records are given.

Calfee, (46) Yoskan and Calfee (216), Burt, Weidensall (199), Whipple, and Hill (101) were interested in:

(1) Establishing norms.
(2) Individual differences.
(3) Dependence on sex.
(4) Dependence on practice.
(a) General practice-effects.
(b) Individual differences in practice-effects.
(c) Persistence of practice.
(5) Dependence on intelligence.
(6) Relation of speed and accuracy.
(7) Reliability.

(8) Various correlations.

Yeonam and Colsee (216), using the patterns of twelve points or numbers, similar to the pattern described by Dearborn, furnish us the best norms for mirror-drawing. Their results are shown in the following table:

### Table V.

<table>
<thead>
<tr>
<th>Group</th>
<th>Trial</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
<th>V</th>
<th>VI</th>
<th>Aver.</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Median</td>
<td>243.0</td>
<td>121.0</td>
<td>53.0</td>
<td>82.0</td>
<td>66.0</td>
<td>50.0</td>
<td>110.33</td>
</tr>
<tr>
<td></td>
<td>M.V.</td>
<td>91.9</td>
<td>45.5</td>
<td>28.1</td>
<td>54.7</td>
<td>24.7</td>
<td>17.1</td>
<td>56.57</td>
</tr>
<tr>
<td></td>
<td>Slowest</td>
<td>517.0</td>
<td>215.0</td>
<td>205.0</td>
<td>180.0</td>
<td>158.0</td>
<td>113.0</td>
<td>210.00</td>
</tr>
<tr>
<td></td>
<td>Fastest</td>
<td>69.0</td>
<td>61.0</td>
<td>41.0</td>
<td>45.0</td>
<td>40.0</td>
<td>32.0</td>
<td>53.66</td>
</tr>
<tr>
<td>II</td>
<td>Median</td>
<td>92.0</td>
<td>65.0</td>
<td>43.0</td>
<td>41.0</td>
<td>35.0</td>
<td>23.0</td>
<td>54.70</td>
</tr>
<tr>
<td></td>
<td>M.V.</td>
<td>64.1</td>
<td>33.9</td>
<td>25.6</td>
<td>19.5</td>
<td>21.9</td>
<td>14.2</td>
<td>27.40</td>
</tr>
<tr>
<td></td>
<td>Slowest</td>
<td>700.5</td>
<td>337.5</td>
<td>305.5</td>
<td>193.5</td>
<td>201.8</td>
<td>171.0</td>
<td>232.37</td>
</tr>
<tr>
<td></td>
<td>Fastest</td>
<td>21.5</td>
<td>23.5</td>
<td>15.5</td>
<td>16.5</td>
<td>17.8</td>
<td>17.0</td>
<td>23.26</td>
</tr>
<tr>
<td>III</td>
<td>Median</td>
<td>167.5</td>
<td>105.0</td>
<td>82.0</td>
<td>68.0</td>
<td>56.0</td>
<td>43.0</td>
<td>57.83</td>
</tr>
<tr>
<td></td>
<td>M.V.</td>
<td>104.2</td>
<td>59.5</td>
<td>30.5</td>
<td>19.7</td>
<td>19.9</td>
<td>13.5</td>
<td>33.38</td>
</tr>
<tr>
<td></td>
<td>Slowest</td>
<td>752.0</td>
<td>277.0</td>
<td>270.0</td>
<td>175.0</td>
<td>121.0</td>
<td>105.0</td>
<td>155.33</td>
</tr>
<tr>
<td></td>
<td>Fastest</td>
<td>72.0</td>
<td>48.0</td>
<td>40.0</td>
<td>34.0</td>
<td>33.0</td>
<td>25.0</td>
<td>46.97</td>
</tr>
</tbody>
</table>

Group I comprised 30 elementary school boys, Group II, 52 women, and Group III, 51 men in the freshman class of the University of Texas.

Results from a more limited number of the college students with the star test are shown in this table:

### Table VI.

**Effect of practice on speed in Mirror-Drawing.**

(Shipple)

<table>
<thead>
<tr>
<th>Number</th>
<th>1st</th>
<th>1st.</th>
<th>2d</th>
<th>3d</th>
<th>4th</th>
<th>5th</th>
<th>2d</th>
</tr>
</thead>
<tbody>
<tr>
<td>Men....</td>
<td>11</td>
<td>122</td>
<td>160</td>
<td>62</td>
<td>60</td>
<td>67</td>
<td>58</td>
</tr>
<tr>
<td>Women..</td>
<td>25</td>
<td>149</td>
<td>127</td>
<td>67</td>
<td>76</td>
<td>67</td>
<td>67</td>
</tr>
</tbody>
</table>

Results from a more limited number of the college students with the star test are shown in this table:
Whipple (203) found that individual differences in performance were striking. Thus, in the star test the time consumed in making the first tracing ranged, in Whipple's test of 36 students, from about 50 sec. to more than 8 minutes. In the larger group of students examined by Yoakum and Calfee, differences ranged from 31.5 sec. to 762 sec., while the fastest girl tested by Miss Wellensley had a record of 18 sec., as compared with 2072 sec., for the slowest reformatory woman.

That girls decidedly surpass boys and that women surpass men is shown in most of the published results in mirror-drawing. Miss Calfee's (48) averages for six trials give for the freshman women 64.4 sec., P.E. 22.3, for the freshman men 101 sec., P.E. 28.5. She finds that only 6 per cent of the men reach the woman's median, while 90.6 per cent of the women reach the men's median.

The tables given above show that even a single trial produces a decided reduction in time. The median time for elementary school boys, for example, is cut in halves in the pattern test, while that for men and women is reduced one-third by the first trial. Yoakum and Calfee (216) have shown that practice curves compounded of the performances of a group of subjects show a smooth drop, but the curves of individuals are not necessarily of this form. On the contrary, it is possible to separate subjects into groups that show the 2d trial slower than the first, or the third slower than the second, etc. These investigators summarize these facts by saying: "Some subject gain control of the situation by
a fairly regular procedure; others temporarily lose control at some point in the series. The majority of the latter lose control at the fourth or fifth trial in series of six tests." (p. 290)

The effect of even a short period of mirror-drawing seems to be very persistent. Thus, Burt (41) administered 6 tests in succession during which the average speed fell from 103 to 59.5 sec. Twelve weeks later, two tests were given in succession; the average speed developed was 34.5 sec. in the first, and 27.4 sec. in the second. In other words, the seventh test surpassed the sixth, made 12 weeks previously, a condition found in the records of 16 out of 26 boys. Hill's (101) work shows that skill developed by one trial a day, continued for 60 days, is so persistent that after an interruption of three years the first trial in re-learning is as fast as the 32d and more accurate than the 60th trial of the original series, and that in four retrials a speed and accuracy has been regained that is equal to the final records of the original series.

There seems to be a close relationship between ability in mirror-drawing and intelligence. Burt (41) reports a correlation between speed and estimated intelligence of 0.67, P.E. .07 for elementary school boys. In another group of English school children a correlation of 0.60 was found, according to Burt and Moore. Miss Calfee, however, found no such relations in her group of elementary school children chosen to duplicate Burt's conditions. Her correlation with school grades were virtually zero (0.07); similarly for the college students the correlation with grades was .07 in the case
of men and 0.19 in the case of the women.

There has been found to be a close relationship between speed and accuracy in the mirror-drawing experiment. Correlations between time and errors obtained by Miss Woidensall are for the students 0.63, for the maids 0.67, for the reformatory women 0.61. Whipple (203) working with college students finds a correlation of 0.63, P.E. .02.

The tests seem to assure quite satisfactory reliability. Yealam and Calfee (216) find that the coefficient of relation between the first and the second test as shown in the above table amounts to 0.73. Burt and Hoore give a reliability coefficient of 0.52.

It will be noticed that none of the last mentioned authors experimenting with mirror-drawing were interested in the phase of bilateral transfer. Dearborn recommends the experiment for demonstrating transfer effect, but does not publish any data concerning it. The only work of importance then, where the mirror-drawing experiment was used to demonstrate bilateral transfer, is that of Starch.

Starch (170), in an experiment in which he himself served as the subject, measured the amount of transfer of improvement in tracing with the right hand a star outline as seen in the mirror, to tracing the same outline with the left hand. The test consisted of, first, one tracing with the left hand, then a series of 100 tracings with the right hand, and after that another tracing with
the left hand. He took only one trial a day for 102 consecutive days. He repeated this with another subject, having him make 52 tracings, one on each consecutive day. The first and last tracing was likewise done with the left hand. Both times and errors were recorded for each tracing.

It was found that a considerable amount of practice gained with the one hand was transferred to the other hand. Thus the 100-days practice with the right hand effected an improvement in the left hand of 92% in accuracy and of 84% in speed. A single left-hand record, made at the expiration of this period showed, in comparison with a single left-hand record before practice began, an improvement of 81% in accuracy and of 85% in speed.

Further, Starch had ten laboratory students make first one tracing with the left hand, then ten tracings with the right hand, and at the end finish the other half of the begun star with the left hand. These students improved on an average of 63% with the right hand where they received the practice. At the same time they improved at an average of 49% with the left hand where they did not receive practice. Starch concludes: "Taking these results together they show that the left hand profits to the extent of 20% of the gain made by the right hand." (p. 23)

Starch, however, does not make any statement as to how much should be deducted from the gain in order to make the proper allowance for the first left hand tracing. He did not run any control group to determine this effect.
Starch's experiment then, is the only work done in mirror-drawing that gives us data concerned directly with bilateral transfer effects. This experiment, however, has several serious defects. The following shortcomings may be noted:

1. No controls were made.

2. Too few subjects were used.

3. No specifications were made as to what constitutes an error.

   If error records are to have any significance, definite error criteria must be established and closely observed throughout the experiment.

4. The end tests were incomplete. Starch had his laboratory students trace only one-half star for each end test. It has been found that there are difficult places in the star varying with different individuals. Consequently half-trials would not be fair trials for the end tests.

5. No norm was established for the left hand performance, to determine the relative ability of the two hands to improve.
5. SUMMARY OF HISTORICAL REVIEW.

After the review of some ninety-five experiments on human subjects and thirteen experiments on animals below man, it is important to discover any consensus of belief which may exist with reference to transfer of training. However, any classification that we attempt must at best be arbitrary.

Ebert and Neumann, Coover and Angell, Judd, Winch, Hallin, Fracker, Urbantschitsch, Runserberg, Ballenbush, may be considered among the more prominent proponents of the doctrine of formal discipline. On the other hand, Thorndike and Woodworth, Stone, Sloight, Whipple, Swift, Jastrow, Squire, Martin, Gates, Rowins, Pyle, either as a result of personal investigation, or a review of experimental work in this field, align themselves with the opposition. Nearly all admit improvability with practice and its transference to material, similar or closely related in content. Prominent among the believers in a spread of training where identical elements exist are Thorndike and Woodworth, Whipple, Starch, Sloight, Martin, Webb, Gates and others. The term "Identical Elements" is used quite broadly; it includes identity of form or procedure, identity of substance or content, identity of aim or ideal. All psychologists seem to be in accord that where there is identity of substance, improvement increases according to the general laws of a practice curve until a physiological limit has been reached. Among those who emphasize identity of method or procedure as an explanation of transference,
with great stress on the concentration of attention are, Thorndike and Woodworth, Munsterberg, Angell, Coover, Bagley, Ruger, Judd and Fracker. Ruediger, Ruger, Lewis and Bagley are impressed with the necessity of an aim or ideal. Some of the experiments also demonstrate the existence of negative transfer or interference. This is shown by the works of Bergstrom, Bair, Ordall, Jastrow and Cairnes, Meichen working with humans, and Hunter, Yarborough and Pearce, Webb and Wiltbank working with animals below man. The experimenters working in the animal field have emphasized the importance of objective elements in the interpretation of transfer of training. Webb (192) for instance, who worked with rats in the maze says, "Our facts indicate that transfer is to a large extent a function of the particular relationship existing between two activities. A determination of the laws and conditions of this phenomenon must involve a thorough and complete analysis and definition of the essential relations obtaining between any two activities. This suggests that such complex activities as are involved in the mastery of a maze situation constitute a poor medium for any comprehensive analysis of transfer. Experiments must be devised by the results of which we will be able to diagnose the relation between two activities; such as keeping the reaction similar but varying the stimulus, or keeping the stimulus constant and varying the reaction." (p. 57-58) The suggestions made by Webb were followed out by Wylie in his experiment conducted two years later.
6. THEORETICAL VIEWS.

The experimental facts as a whole leave a rather confused impression on one's mind and resist organization into any simple statement of how far improvement wrought by special practice spreads beyond the functions primarily exercised. Psychologists as a whole are divided on the question as to how transfer takes place. If improvement in one mental function is accompanied by, or produces improvement in other functions, how may the changes in those other mental functions be explained? How does change in function carry over to others? It will be noticed from the above review literature that psychologists are still divided among themselves between two general theories: (1) the theory of identical or special connections, and (2) the theory of generalization or common capacities. Thorndike may be considered the chief exponent of the first and Judd of the second theory.

The theory of identical elements is based on the doctrine that learning or changes in mental capacities consist of the establishment of specific conditions or associations between various specific elements. One form of exercise has influence upon another capacity whenever connections established in the former may also be used in the latter. This theory as a whole is antagonistic to formal discipline.

The theory of generalization attempts to explain spread of improvement in terms of recognition of application of an experience
obtained in one connection to other connections and is probably
more satisfactory to the formal disciplinarian.

The theory of identical elements, when the term 'identical
elements' is used in a liberal manner, has the advantage of describ-
ing the situation in concrete definite concepts, and lends itself
fairly well to the interpretation of experimental results. The dis-
cussion of the generalist or disciplinarian is usually not in as
tangible terms, but is likely to be very different from the state-
ments of the experimentalist when the former reduces his argument to
specific terms.

It would seem that the two theories are not necessarily an-
tagonistic but when sanely interpreted are useful supplements to each
other. The theory of identical elements has helped to make the dis-
cussion of transfer of training concrete, and the theory of general-
ization will help to emphasize the general recognition of the identi-
cal elements in as many situations as possible.

The greatest difficulty, however, in the field is that psy-
chologists have assumed that transfer is limited to a conscious recog-
nition of elements. This is the chief reason why no more progress
has been made in the field of transfer. Too much stress has been
laid on the so-called mental processes which at best are unobserva-
ble. There is urgent need for a reconsideration of the former
promises of transfer. If any fruitful results are to occur there
must be a change in the method of investigating transfer effects.
The subjective method must give way to the objective method.
Nylie (213) said, "It seems to the writer, therefore, that if the experiments upon this problem are to have any finality and accuracy for the solution of the problem they will have to begin with such conditions as will either keep the response as a whole constant and vary the stimulus or situation, one factor at a time, or keep the stimulus or situation as a whole constant and vary the response one factor at a time. From such a simple beginning we could then pass, as experience and technique indicate, to tests where more than one factor of the stimulus or situation was varied while the response remained constant, or to tests where one or more factors in the stimulus or situation and one or more of the factors in the response were varied while the others in the stimulus and in the response remained constant." (p. 6) Such a plan, if followed, would, no doubt, bring fruitful results.

The mirror-drawing experiment, easily lends itself to such an objective study of bilateral transfer effects as heroin described. The experimental work will be discussed in the next section.
III. EXPERIMENTAL SECTION

The experimental portion of this thesis has a twofold purpose. The first is to repeat Starch's experiment; and the second is to extend his work by making group studies. In these group studies the immediate object was to determine to what extent the practice gained with one hand in mirror-drawing will be transferred to the idle hand.

1. A Repetition of Starch's Experiment.

a. INTRODUCTION:

In repeating Starch's experiment the essential problems to be investigated are: (1) The nature of the learning curves indicating the improvement in mirror-drawing, and (2) the amount of bilateral transfer from the practiced to the idle hand.

b. APPARATUS:

The apparatus used in this experiment is the same as that used by Starch and described by him in the Psychological Bulletin, Vol. VIII, 1910, p. 20. It consists of a simple and convenient wooden frame for holding up a mirror and the star to be traced, and for shielding the hand from direct view.

c. METHOD:

This experiment was performed in the Psychological Laboratory of Kansas University in the winter term of 1924-25. It was begun February 16, and ended May 30. It is a literal repetition
of Starch's experiment. Two subjects, including the writer, served in this experiment. The experiment as performed by the writer was as follows: (a) One record was made with the left hand. (b) One hundred trials were made with the right hand at the rate of one a day on consecutive days without interruption, except between the 15th and 16th and between the 55th and 56th records. (c) A final record was made with the left hand. Another subject who made 50 records with the right hand (on 50 consecutive days), and one record before and one after with the left hand, started her experiment the same day as the writer and ended it April 4.

The general procedure of each day's performance was as follows: One of the star outlines was placed on the base of the apparatus just in front of the mirror so that the arrow was nearest the mirror, and the crossbar perpendicular to the base of the mirror. The subject, seated comfortably at the apparatus, adjusted the screening board so that the image of the star could be seen in the mirror only. Beginning at the crossbar and going in the direction indicated by the arrow, the subject traced the star as rapidly as possible trying to stay on the line. When, however, he found himself moving away from the line he brought the point of his pencil back to the same place where he got off, before he continued the tracing. The exact time in seconds, as registered by a stop-watch, and the errors were recorded on the outline of the star after each trial. It was also properly labeled as to the day and the order in which it was made. After every trial both the writer and
the other subject counted the errors, and if there was a difference in results the mean of the two was accepted as authentic. An error consisted of any corrective movement.

The experiment was performed every day at 3:30. In only a few cases was there a deviation from this time.

d. RESULTS:

Tables VII and VIII show the bilateral transfer effect in the left hand occasioned by the practice in the right hand. Table VII gives the first and last record of the left hand and the first ten and the last ten records of the right hand.

Table VII.

Showing the bilateral transfer from the right to the left hand for the subject making 100 records.

<table>
<thead>
<tr>
<th>Trials</th>
<th>Time in secs</th>
<th>Errors</th>
</tr>
</thead>
<tbody>
<tr>
<td>First left hand trial</td>
<td>1.</td>
<td>53</td>
</tr>
<tr>
<td>First ten right hand trials</td>
<td>1.</td>
<td>79</td>
</tr>
<tr>
<td></td>
<td>2.</td>
<td>41</td>
</tr>
<tr>
<td></td>
<td>3.</td>
<td>48</td>
</tr>
<tr>
<td></td>
<td>4.</td>
<td>35</td>
</tr>
<tr>
<td></td>
<td>5.</td>
<td>32</td>
</tr>
<tr>
<td></td>
<td>6.</td>
<td>23</td>
</tr>
<tr>
<td></td>
<td>7.</td>
<td>27</td>
</tr>
<tr>
<td></td>
<td>8.</td>
<td>22</td>
</tr>
<tr>
<td></td>
<td>9.</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>10.</td>
<td>25</td>
</tr>
<tr>
<td>Last ten right hand trials</td>
<td>91.</td>
<td>7.5</td>
</tr>
<tr>
<td>---------------------------</td>
<td>-----</td>
<td>-----</td>
</tr>
<tr>
<td></td>
<td>92.</td>
<td>6.5</td>
</tr>
<tr>
<td></td>
<td>93.</td>
<td>7.5</td>
</tr>
<tr>
<td></td>
<td>94.</td>
<td>8.0</td>
</tr>
<tr>
<td></td>
<td>95.</td>
<td>8.5</td>
</tr>
<tr>
<td></td>
<td>96.</td>
<td>8.0</td>
</tr>
<tr>
<td></td>
<td>97.</td>
<td>7.5</td>
</tr>
<tr>
<td></td>
<td>98.</td>
<td>8.0</td>
</tr>
<tr>
<td></td>
<td>99.</td>
<td>8.5</td>
</tr>
<tr>
<td></td>
<td>100.</td>
<td>6.5</td>
</tr>
</tbody>
</table>

Per cent of improvement in the first 100 trials: 93% 77%

| Last left hand trial | 2. | 12.5 | 23 |

Per cent of improvement in the left hand: 70% 30%
Table VIII

Showing the bilateral transfer from the right to the left hand for the subject making fifty records.

<table>
<thead>
<tr>
<th>Time</th>
<th>Errors</th>
</tr>
</thead>
<tbody>
<tr>
<td>First left hand trial</td>
<td>39 secs.</td>
</tr>
<tr>
<td>First ten right hand trials</td>
<td>165</td>
</tr>
<tr>
<td></td>
<td>64</td>
</tr>
<tr>
<td></td>
<td>87</td>
</tr>
<tr>
<td></td>
<td>46</td>
</tr>
<tr>
<td></td>
<td>45</td>
</tr>
<tr>
<td></td>
<td>70</td>
</tr>
<tr>
<td></td>
<td>24</td>
</tr>
<tr>
<td></td>
<td>28</td>
</tr>
<tr>
<td></td>
<td>23</td>
</tr>
<tr>
<td></td>
<td>33</td>
</tr>
<tr>
<td>Last ten right hand trials</td>
<td>7.</td>
</tr>
<tr>
<td></td>
<td>6.8</td>
</tr>
<tr>
<td></td>
<td>6.5</td>
</tr>
<tr>
<td></td>
<td>8.5</td>
</tr>
<tr>
<td></td>
<td>6.8</td>
</tr>
<tr>
<td></td>
<td>7.8</td>
</tr>
<tr>
<td></td>
<td>9.8</td>
</tr>
<tr>
<td></td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>7.8</td>
</tr>
<tr>
<td>Per cent of improvement</td>
<td>95%</td>
</tr>
<tr>
<td>Last left hand trial</td>
<td>16.5 secs.</td>
</tr>
<tr>
<td>Per cent of improvement</td>
<td>83%</td>
</tr>
</tbody>
</table>
Table IX

<table>
<thead>
<tr>
<th>Our Own Results</th>
<th>Starch's Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subject making 100 records.</td>
<td>Subject making 100 trials</td>
</tr>
<tr>
<td>Preferred Non-preferred</td>
<td>Preferred Non-preferred</td>
</tr>
<tr>
<td>100 trials. 2 trials</td>
<td>100 trials. 2 trials</td>
</tr>
<tr>
<td>Time Errors Time Errors</td>
<td>Time Errors Time Errors</td>
</tr>
<tr>
<td>91 77 76 50</td>
<td>64 92 65 81</td>
</tr>
<tr>
<td>Subject making 50 records</td>
<td>Subject making 50 records</td>
</tr>
<tr>
<td>Average of time and errors</td>
<td>Average of time and errors</td>
</tr>
<tr>
<td>Average Average</td>
<td>Average Average</td>
</tr>
<tr>
<td>81 85</td>
<td>82 88</td>
</tr>
</tbody>
</table>

The results of this experiment are consistent in showing a considerable amount of improvement in the idle hand as well as in the practiced hand, i.e., the hand making only two records improved almost as much as the hand making 100 records. The question now arises: How much of the improvement in the idle hand is due to practice in the other hand? This cannot be ascertained, since we have no way of telling how much of the improvement in the idle hand is due to practice obtained in this hand in the end-tests. However, in this experiment the improvement of the idle hand is great enough to warrant the conclusion that a certain amount of it must be due to practice in the other hand; since the improvement of the idle hand is greater than the improvement in the other hand occasioned by two trials. However, to determine more closely the degree of bilateral transfer, group studies must be made wherein a control group serves as a check on the improvement made in the end-tests.
The effect of practice with the right hand upon the left hand was found to be less in our experiment than that found by Starch, as shown in Table IX. For Starch the improvement with the right hand from the first to the last record was 84 per cent in time and 92 per cent in errors, average 88 per cent. In my own case the improvement with the right hand from the first to the last trial was 91 per cent for time and 77 per cent for errors, average 84 per cent. It will be noticed that these results are the reverse from those found by Starch, i.e., in my own case the per cent. of gain is higher for time than for errors.

Furthermore, in our experiment, the improvement of the left hand record made after, compared with the one made before, the right hand practice, was 76 per cent for time and 30 per cent for errors, average 53 per cent. For Starch this improvement was 85 per cent for time and 81 per cent for errors, average 83 per cent.

The other subject who made fifty trials with the right hand showed an average improvement of 61 per cent, and in the before and after trials with the left hand, an average improvement of 65 per cent. Starch found in his experiment of which this is a repetition, an average improvement of 68 per cent for the left hand.

Figure 1 represents the writer's and Starch's learning curves of time and errors for 100 trials; Curve I and II represent our own records in time and errors, and curves III and IV represent Starch's findings in time and errors.
It will be noticed that Starch's error curve drops considerably below ours. For the time records just the reverse is true. Here the writer's curve passes below Starch's curve. Figure 3 further shows that Starch's time-curve remains above the error-curve, and Figure 2 shows the reverse of this for the writer's records. This means that in Starch's experiment accuracy exceeded speed, whereas in the writer's experiment, speed exceeded accuracy. These differences may be explained in several ways. The first explanation is that they may be accounted for by individual differences. A second explanation is that the differences are due to the relative emphasis placed upon the improvement in accuracy and speed by the two authors.
Figure III

Starch's Learning Curves for Mirror-Drawing.
The Learning Curves of the Subject Taking Fifty Trials.

Errors Figure IV.

Time in secs.

a. PURPOSE:

In this experiment Starch's work was extended by making group studies. The writer sought to remedy the shortcomings of the previous experiment: (1) By making control studies. A control group took only the end-tests to serve as a check on the amount of improvement gained by the practice group in the end-tests. The control group and the training group were similar, especially in regard to their Otis scores. (2) By using a comparatively large number of subjects in each experiment. (3) By establishing a norm for the left hand performance to determine the relative ability of the two hands to improve.

The purpose of this experiment as of the former was to determine to what extent the practice gained with one hand in mirror-drawing is transferred to the idle hand.

The apparatus of this experiment was the same as that of the former.

b. METHOD:

These experiments were performed in the Psychological Laboratory of the University of Kansas on April 30, May 7, May 20 and June 16. A total of 195 subjects was used in the various tests. Of these 60 served as experimenters, leaving 135 to act as subjects. The first group of tests was carried on with the Elementary Psychology Laboratory classes. Out of a group of over 150 students 100 were selected to serve as subjects. Only students who had not per-
formed the experiment before served as subjects. The other 50 students served as experimenters. The 100 subjects were divided into two groups, one group containing 52 subjects and the other 48 subjects. Each of these two groups was further divided into a control group and a practice group with an equal number of subjects in each group. Whether a subject was to belong to a control group or a practice group was determined by his intelligence score according to the Otis Intelligence Test, which all undergraduates of the University of Kansas are required to take. Students who had just entered the University or who for some other reason had not taken the Intelligence Test, were tested by the writer. The method of selecting students for the two groups was to match their Otis scores in units, as indicated in Table X. All students having similar Otis scores were matched, and thus formed two groups. One group served as a control group and the other as a training group. They were divided as follows:

EXPERIMENT A.

To determine the improvement in the idle hand resulting from practice in the preferred hand.

1. Training Group I (26 subjects, average Otis score 164).
   a. One trial with the non-preferred hand.
   b. 50 trials with the preferred hand.
   c. One trial with the non-preferred hand.

2. Control Group I. (26 subjects, average Otis score 164).
   a. One trial with the non-preferred hand.
   b. One trial with the preferred hand.
c. Interpolated rest, one hour. (subjects were instructed not to think of tests).

d. One trial with the non-preferred hand.

3. Control Group II. (26 subjects, average Otis score 151).
   a. One trial with the non-preferred hand.
   b. Interpolated rest, one hour.
   c. One trial with the non-preferred hand.

EXPERIMENT B.

To determine the improvement in the idle hand resulting from practice in the non-preferred hand.

1. Training Group II. (24 subjects, average Otis score 162).
   a. One trial with the preferred hand.
   b. 50 trials with the non-preferred hand.
   c. One trial with the preferred hand.

2. Control Group III. (24 subjects, average Otis score 162).
   a. One trial with the preferred hand.
   b. One trial with the non-preferred hand.
   c. Interpolated rest, one hour.
   d. One trial with the preferred hand.

3. Control Group IV. (9 subjects, average Otis score 161).
   a. One trial with the preferred hand.
   b. Interpolated rest, one hour.
   c. One trial with the preferred hand.

No subject served in more than one group, and no experimenter served as a subject.
The elementary laboratory students who served in this experiment were divided into two large sections and these sections were further divided into four classes meeting at different periods of the day as follows: Beginning at 8:30 to 10:30; from 10:30 to 12:30; from 1:30 to 2:30; and from 2:30 to 4:30. Students of one large section served in experiment A, and students of the other large section served in experiment B. Each experiment was given in one day, and was conducted during the regular laboratory meeting time. The time for conducting the various tests was divided as follows:

1. Control Group.

   (1) Instructions and one trial, 15 min.
   (2) Interpolated rest, one hour. (During this time the training group received practice.)
   (3) Another trial with the same hand, 10 min.

2. Training Group.

   (1) Instructions and one trial, 15 min.
   (2) 50 trials with the other hand, from 40 min. to 1 hr. and 15 min.
   (3) Another trial with the same hand as used in the first trial, 10 min.

The subjects serving as experimenters received preliminary training a week before the final tests. The whole purpose and the plan of the experiment were explained to them in detail. They further all received training by first acting as experimenter and then as subject. The following directions were given to them: "The purpose of this experiment is to determine to what extent practice
in one organ affects the performance in a bilaterally-symmetrical organ. The subject will be asked to make first, one trial with non-preferred hand, then fifty trials with the preferred hand, and after that another trial with the non-preferred hand. This constitutes the plan for the training group. The control group will be asked to trace first, one star with the non-preferred hand, and after an hour of interpolated rest, another star with the non-preferred hand. The procedure of practicing the non-preferred hand will be just the reverse. Your part in these experiments is to record the time of each trial, and count and record the number of errors made. Listen carefully as I give the directions: Take a position on the left side of the subject. Place on the mirror-drawing platform one of the stars in such a position that the crossbar on the outline lies perpendicular to the base of the mirror. Place the point of the lead pencil upon the crossbar of the star and assist the subject to grasp the pencil, permitting him to see the image of the star in the mirror only. Have your stopwatches at a position where you can start them the moment you give the subject the signal to start. When the subject is ready, say "go", at which second start your watches. Count all the errors by marking them down on a sheet of paper as they are made. Every movement away from the line, must, of course, be compensated for, by a return movement. The idea is to register the number of these errors, or corrective movements. Thus every move away from the line and every retracing movement will constitute an error. After every trial record the time in seconds in the lower right-hand corner, and the
errors in the lower-left-hand corner on the outline of the star.
Also label it properly, numbering it in the order in which it is
made, denoting whether it was made with the right or left hand.
Now be sure to remember these four points:

1. Keep the subject supplied with stars. As soon as one is
finished, place before him another one, until they are all gone.

2. Start your watches the moment the subjects start work, and
stop them the moment they stop work.

3. Do not forget to count the errors.

4. Do not forget to label each star properly after each tracing. The success of these experiments will depend chiefly upon the
accuracy with which your work is done." The experimenters were fur-
ther asked to copy those directions and to study them carefully.

The subjects received the following instructions: "Take a
comfortable position at your apparatus. Adjust the screening board
so that you can see the image of the star in the mirror only. Take
the pencil in your non-preferred hand (or the preferred hand accord-
ing to the order of the test), and place the point of it upon the
crossbar of the star starting in the direction indicated by the ar-
row. When the experimenter says "go", trace the outline of the star
as you see it in the mirror as rapidly as you can. Don't stop to
figure out what you ought to do, but keep your pencil going in some
direction, and try to stay on the line. If, however, you find your-
self moving away from the line, bring your pencil back to the same
point where you got off before you continue the tracing. Every ad-
justing and every retracing movement will constitute an error.
Trace first, one star with the non-preferred hand, then fifty with the preferred hand, and after that another one with the non-preferred hand.

Now remember these five points:

1. Look only in the mirror.

2. Do not stop while tracing the star.

3. If you find yourself moving away from the line, bring your pencil back to the same place where you got off, before you continue the tracing.

4. Work as rapidly as you can.

5. Your improvement will be determined by accuracy and speed.
Table X.

Table of Otis scores for subjects serving in Experiment A.

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<tr>
<th>Subject</th>
<th>Training Group I</th>
<th>Control Group I</th>
<th>Control Group II</th>
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</thead>
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Average Score: 164
Table XI.
Table of Otis scores for the subjects serving in Experiment B.

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<tr>
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Average Score: 162
o. RESULTS:

Table XII gives the average individual performance in time and errors of Training Group I, practicing the preferred hand, each subject making 50 trials.

The Table shows that the reduction in time and errors is rapid at first, then slower, and that maximal speed is not attained for a long time, apparently not until some 45 trials.

Figure V further shows that practice curves compounded of the performance of a group of subjects show a comparatively smooth drop. The curves of individual subjects are not necessarily of this form: on the contrary, it is possible, as Yoakum and Calfee have shown (216, p. 290), to separate subjects into groups that show the second trial slower than the first, or the third slower than the second, etc.

The learning curves show that practice produces a reduction of corrective movements that parallels fairly closely the reduction in time. In Training Group I (See Table XII) there is perfect correlation between time and errors, for Training Group II (See Table XIII) the correlation is also high.
Table XII.

Average performance of 26 subjects practicing the preferred hand. Training Group I.

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<th>Trial</th>
<th>Time</th>
<th>Errors</th>
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<td>7.8</td>
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</tbody>
</table>

Per cent of Improvement: . . . . 83%. . . . . 86%. 

- 51 -
In order to determine the bilateral transfer from one hand to the other it is essential that we should have similar data concerning the improvement of both hands. It has been taken for granted by others working with the mirror-drawing experiment that both hands have an equal ability to improve in a given task. Again others hold that the non-preferred hand has a greater ability to improve than the preferred hand, because the preferred hand has already reached a certain degree of efficiency in general. It is evident that such a difference, if it existed, should be taken into consideration in determining bilateral transfer. Knowing the relative ability of the two hands to improve, would enable one to determine how much of the improvement differences between right and left hands might be accounted for by natural differences in improvement for both hands at the same task. Starob did not consider this factor. He says, "Ten laboratory students who made ten records each with the right hand improved on the average of 55 per cent. In the before and after records, tracing with the left hand of one outline each time, the average improvement was 49 per cent. Taking these results together they show that the left hand profits to the extent of 90 per cent of the gain made by the right hand." (170, p. 25) Thus Starob takes for granted that the ability of the left hand to improve equals the ability of the right hand to improve.
### Table XIII.

Average performance of 21 subjects practicing the non-preferred hand. Training Group II.

<table>
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<th>Trials</th>
<th>Time (Secs)</th>
<th>Errors</th>
</tr>
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<td>25.8</td>
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<td>19</td>
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<td>13.3</td>
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<td>15.5</td>
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<td>12.7</td>
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<td>13.3</td>
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<td>13.3</td>
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<td>34</td>
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<td>12.9</td>
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<td>12.2</td>
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<td>38</td>
<td>21.6</td>
<td>12.7</td>
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<td>24.4</td>
<td>11.8</td>
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<td>40</td>
<td>24.2</td>
<td>11.6</td>
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<tr>
<td>42</td>
<td>24.9</td>
<td>11.6</td>
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<td>43</td>
<td>23.4</td>
<td>12.1</td>
</tr>
<tr>
<td>44</td>
<td>24.6</td>
<td>12.0</td>
</tr>
<tr>
<td>45</td>
<td>23.3</td>
<td>12.2</td>
</tr>
<tr>
<td>46</td>
<td>23.7</td>
<td>13.2</td>
</tr>
<tr>
<td>47</td>
<td>24.7</td>
<td>11.7</td>
</tr>
<tr>
<td>48</td>
<td>23.1</td>
<td>11.9</td>
</tr>
<tr>
<td>49</td>
<td>23.1</td>
<td>12.5</td>
</tr>
<tr>
<td>50</td>
<td>24.2</td>
<td>10.6</td>
</tr>
</tbody>
</table>

For cent of improvement from the first to the last trial: 80% to 80%

First four and last four trials: 72% to 70%
Figure V.

Curve III.

Time in secs.

Curve I.

Curve IV.

Errors

Trials.
Table XIII shows the average individual performance in time and errors of Training Group II, practicing the non-preferred hand, each subject receiving 50 trials.

The experimental conditions of Training Group II differed from those of Training Group I, in that Training Group II had two less subjects than Training Group I, and that the average utis score of Training group II was 162 instead of 104. In all other respects the experimental conditions of the two groups were identical.

Table XIV gives the average per cent of improvement for Training Groups I and II.

In comparing the results obtained by practicing the preferred and the non-preferred hand, we find that the per cent of improvement in time from the first to the last trial, is 88 per cent for both hands. Taking the mean of the first four and the last four performances we have a time improvement of 62 per cent for both hands.

The per cent of improvement for errors is 88 per cent for the preferred hand, 60 per cent for the non-preferred hand, determined by the first and last trial. By taking the mean of the first four and the last four trials, we find an improvement of 80 per cent for the preferred hand and 70 per cent for the non-preferred hand.

These results suggest that the relative ability of the two hands to improve is about the same, showing a slight preference for the preferred hand. The records also show that the preferred hand gains a greater degree of efficiency in both time and errors than the non-preferred hand.
These same facts are demonstrated in the learning curves of Figure V. Curves I and II are the preferred hand time and error curves, and curves III and IV are the non-preferred hand time and error curves. The comparatively equal degree of improvement in both hands is shown by the constant overlapping of the two curves.

Table XIV.

The Average Per cent of Improvement for Training Groups I and II.

<table>
<thead>
<tr>
<th>Training Group I</th>
<th>Training Group II</th>
</tr>
</thead>
<tbody>
<tr>
<td>(26 subjects)</td>
<td>(24 subjects)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Trial</th>
<th>Time</th>
<th>Errors</th>
<th>Time</th>
<th>Errors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Improvement from first to last trial</td>
<td>68</td>
<td>68</td>
<td>68</td>
<td>68</td>
</tr>
<tr>
<td>Improvement from mean of first four to last four trials</td>
<td>82</td>
<td>80</td>
<td>82</td>
<td>70</td>
</tr>
</tbody>
</table>

In order to measure exactly the amount of bilateral transfer we must know how much of the improvement in the idle hand is due to practice obtained by that hand in the end-tests. This we can never know for any experimental group, so we infer it from the gains of the control group. We thus estimate the bilateral transfer occasioned by the practice in a training group, by subtracting from the training group's average improvement in the idle hand the average improvement made by the control group in that hand. This gives us the net amount of bilateral transfer which we shall designate residual gain.
Table XV shows the average individual transfer of the preferred to the non-preferred hand, determined by the difference between the mean improvement of the practice group and that of the control group.

Table XV.

Showing the improvement of the non-preferred hand by virtue of practicing the preferred hand. (20 subjects in each group)

<table>
<thead>
<tr>
<th>Trial</th>
<th>Control Group I</th>
<th>Training Group I</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Time secs.</td>
<td>Errors</td>
</tr>
<tr>
<td>First</td>
<td>228.1</td>
<td>70.1</td>
</tr>
<tr>
<td></td>
<td>Interpolated</td>
<td>50 trials with prefered hand.</td>
</tr>
<tr>
<td></td>
<td>Time secs.</td>
<td>Errors</td>
</tr>
<tr>
<td>Last</td>
<td>137.1</td>
<td>34.4</td>
</tr>
<tr>
<td>Per cent of improvement...32...........50.............82...........76.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Residual gain of the practice group..........................48%...........28%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

It will be noticed that Control Groups I and III were not entirely unpracticed in what represented their idle hand. The subjects in these two control groups received one trial with the supposed-to-be-idle hand. This hand, in order to give full allowance for transfer from the practiced to the idle hand in the training group, should have remained entirely idle. These control groups are, therefore, in a sense practice groups, in that they received practice in both hands. The results thus obtained are, however, very valuable
in showing the relative improvement of the idle hand under conditions where it remains entirely idle, and under conditions where it receives only one trial.

In order to determine how much improvement there would be in the idle hand for a control group having no practice with the preferred hand, another group of 26 subjects was experimented on. Fifteen of these subjects were students of the Elementary Psychology Lecture class and the other eleven were students of the Elementary Psychology Laboratory class of the 1925 summer session. The first fifteen subjects received their tests under the same experimenters that served in the first control group, but the other eleven subjects worked under experimenters from the Elementary Laboratory class of the summer session, having had the same training and instructions as the first set of experimenters. The average Intelligence Level of this group was lower than that of the former group. (See Table X.)

Table XVI shows the average per cent of bilateral transfer from the preferred to the non-preferred hand, determined by the difference of the mean improvement of the practice group and the mean improvement of Control Group II.
Table XVI.

Showing the improvement of the non-preferred hand by virtue of the preferred hand practice. (25 subjects in each group).

<table>
<thead>
<tr>
<th>Second Control Group</th>
<th>Practice Group I</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trial</td>
<td>Time</td>
</tr>
<tr>
<td>1st</td>
<td>256.6 sec.</td>
</tr>
<tr>
<td>Rest</td>
<td>Practice</td>
</tr>
<tr>
<td>Last</td>
<td>135</td>
</tr>
<tr>
<td>Per cent of Improvement</td>
<td>46</td>
</tr>
<tr>
<td>Residual Gain</td>
<td>36</td>
</tr>
</tbody>
</table>

One would expect that the control group receiving three trials in mirror-drawing would show greater improvement than the control group receiving only two trials. But the reverse seems to be true. The second control group improved 7 per cent more in time and 5 per cent more in errors than the first control group receiving an extra trial. There are two possible explanations for this. One is, that there may have been retroactive inhibition caused by the work of the one hand followed immediately by the work of the other hand. The difference in the degree of similarity between the two acts may have had an inhibitory effect on the subjects. The second explanation is, that the difference in improvement of the two groups is due to their difference in intelligence. The average Otis score of the first control group was 165, as compared with an Otis score of 154 for the second control group.
There seems to be a slight indication that the per cent of improvement varies inversely with the rise and fall of the test score.

The fifty students of the training series I were divided into two groups. One group was composed of students having an Otis score above 165 points and the other group was composed of students falling below 165.

The following table shows the initial performance and the relative per cent of improvement of these two groups:

Table XVII.

<table>
<thead>
<tr>
<th>Average Otis score above 165</th>
<th>Average Otis score below 165</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time sec. Errors Time sec. Errors</td>
<td></td>
</tr>
<tr>
<td>Initial trial 180.7 51.6 223.8 72.5</td>
<td></td>
</tr>
<tr>
<td>Per cent of Improvement 76 64 81 65</td>
<td></td>
</tr>
</tbody>
</table>

It was formerly believed by Thorndike and others that a close relationship existed between intelligence and the slope of a learning curve. Hicks and Carr published an important article on "Human reaction in the maze" in 1912 wherein they discussed the various criteria of intelligence ability. They bring up the discussion of the relationship between slope of the curve and intelligence as originally presented by Thorndike, Hobhouse and Watson. However, Carr and Hicks dissent from the views previously held. Hunter quotes these men as follows: "Our results indicate that the rational status of a group of animals cannot be inferred from the slope of a curve in so far as this slope is dependent upon the
number of trials or the relative rate of elimination. They indicate, moreover, that the inferences as to intelligent status are legitimate in so far as the slope is determined by the factor of total values eliminated but that the relation between the abruptness of the slope and the degree of rational ability is just the inverse of that assumed by Thorndike and Hobhouse. Hunter in correlating the improvement of humans in the pencil maze with that of the Otis score, gets results confirming this position. He finds, in inspecting his results, that his data "fails to show any close relationship between general intelligence score and either the first or last half of learning." Hunter further publishes data concerning the effect that the learning of one maze has upon another. A group of subject learned two mazes, maze A and maze A'. Maze A' had the same pattern as maze A, but with the turns reversed. It was learned after maze A in the experiment on habit interference. In discussing the results, Hunter says, "All (results) are negative (where the Otis score is involved). Even the amount of time saved in passing from one maze to the other appears to be inversely related to the Otis score. This, if true, would not necessarily mean that the most intelligent subjects would profit least by training; but would mean, in this experiment, that the most intelligent subjects work within the lower time limits and have the least improvement to make." This last statement is confirmed by the results of my experiment. The group with the low Otis score

1(parenthesis mine)
made an average initial time score of 223.8 secs. and an error score of 72.5; whereas the group with the high Otis score made an average initial time score of 180.7 secs. and an error score of 51.6. The group with the high Otis score also reached a higher efficiency in both time and errors.

Table XVIII shows the average individual bilateral transfer of the preferred hand by virtue of practicing the non-preferred hand, determined by the difference between the mean improvement of the practice group and that of the control group.

Table XVIII

<table>
<thead>
<tr>
<th>Trial</th>
<th>Control Group III</th>
<th>Practico Group II</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Time secs. Errors</td>
<td>Time secs. Errors</td>
</tr>
<tr>
<td>1st</td>
<td>246.4 101.2</td>
<td>203.3 50.6</td>
</tr>
<tr>
<td>Rest</td>
<td>Practice</td>
<td></td>
</tr>
<tr>
<td>Inst</td>
<td>198.1 34.</td>
<td>22.</td>
</tr>
<tr>
<td>Per cent of Improvement</td>
<td>48 68</td>
<td>63 63</td>
</tr>
<tr>
<td>Residual Gain</td>
<td>30 -3</td>
<td></td>
</tr>
</tbody>
</table>

Table XIX indicates the residual gain of the practice group as compared with the second control group of 9 subjects taken from the General Psychology Laboratory class of the 1925 summer session, and tested under the same conditions as those already described. The average Otis score of this group was 161.
Table XIX.

<table>
<thead>
<tr>
<th>Control Group IV</th>
<th>Practice Group II</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Trial</strong></td>
<td><strong>Time secs.</strong></td>
</tr>
<tr>
<td>1st</td>
<td>301.3</td>
</tr>
<tr>
<td><strong>Rest</strong></td>
<td>Practice</td>
</tr>
<tr>
<td>Last</td>
<td>130.4</td>
</tr>
<tr>
<td><strong>Per cent of</strong></td>
<td>Improvement</td>
</tr>
<tr>
<td>Residual gain</td>
<td>63</td>
</tr>
</tbody>
</table>

Tables XVIII and XIX show similar results to those indicated in Tables XVI and XVII, namely that the preferred (instead of the non-preferred hand in the other case) hand profits in improvement by virtue of an hour's practice with the non-preferred hand at mirror-drawing. The only exception to this conclusion is evidenced by the error record of the practice group when compared with the first control group as indicated in Table XVIII. The residual gain in errors in this case is found to be -3 per cent. However, when compared with the second control group, the residual gain in errors is 6 per cent. The time records show a positive transfer throughout all the experiments.
V. SUMMARY AND THEORETICAL DISCUSSION.

1. In every case of Mirror-Drawing there is improvement of the idle hand.

2. The improvement is less in this experiment, than that found by Starch. The subject taking 100 trials made an average time and errors improvement of 65 per cent in the idle hand. Starch found this improvement to be 83 per cent. The subject taking 50 trials made an average time and errors improvement of 65 per cent in the idle hand, compared with 68 per cent as found by Starch.

3. The relative ability of the preferred and non-preferred hand to improve at Mirror-Drawing is about equal for both hands, however, the preferred hand gains a greater degree of efficiency at the same task, than the non-preferred hand.

4. A considerable amount of bilateral transfer takes place from an hour's practice in Mirror-Drawing. This is indicated by the group practicing the preferred hand as well as by the group practicing the non-preferred hand.

5. There are fair indications that the per cent of bilateral transfer in a given group, varies inversely with the individual's Intelligence Test Score. Subjects with a low Otis score showed a greater per cent of improvement in the idle hand, than subjects with high Otis scores, although the latter group worked in a smaller range of improvement.

Our results, therefore, present positive evidence of 'bilateral transfer of training'.
What is the explanation of this bilateral transfer of improvement?

The phenomena of bilateral transfer have been given various tentative explanations, mostly in terms of physiological theories. The problem cannot, however, be divorced from the more general problem of transfer of training, since it involves the complex processes as well as co-ordinations established in the central nervous system.

Wissler and Richardson (209) attribute the bilateral transfer to a general diffusion of the motor current in the central nervous system, which causes the idle organ to benefit by the practice of a bilaterally-symmetrical organ. They say, "It seems certain that the exercise of any muscle reacts upon all other related muscles, which is to say that diffusion takes place in both inward and outward directions." Their leading hypotheses are:

"a. That the exercise of an accessory muscle has a greater reactionary effect upon the adjacent fundamental muscles than upon the more remote.

b. That an accessory muscle of one arm gains as much from the training of the fundamental muscle of the same side. In terms of motor discharge this indicates that these centers occupy the diffusion level.

c. The reactionary, or secondary, gain of the fundamental arm muscles from the exercise of accessory arm muscles, is less than when the conditions are reversed -- i.e., the fundamental muscles practiced and the accessory reacted upon. This is in harmony with
the accepted order of motor development." (p. 35)

This explanation however, leaves out of account any functioning of the complex processes, which no doubt are involved in the mirror-drawing experiment. The explanation is further based on more assumptions concerning physiological conditions of the body, and thus seems worthless as a psychological explanation of the transfer phenomena.

We shall attempt a psychological explanation based upon objective criteria obtained by the results of the experiment, and by the verbal report of the subjects.

It appears to us that bilateral transfer in mirror-drawing is not specifically due to practice effects, but to the improvement of common elements of the following type: More concentrated effort, emotional adjustment, bodily orientation, ability to resist distracting factors, general adaptability to a novel situation, etc.

1. The emotional factor is probably responsible in part. The anxious nervous attitude of the initial tests has given way to a definite "set for records", and hence in the final tests, better control of the motor reactions is maintained. This is evidenced by the introspective reports of the subjects. Their general bearing indicated nervousness, especially in the first trial. They were anxious to know whether this was a test of their intelligence. The following remarks were common: "I can't trace this star." "I always find myself moving the wrong way," etc.

2. General habits and conditions may have improved, e.g., more
concentrated effort occasioned by the game attitude of trying to exceed previous records; greater bodily orientation, especially using the non-preferred hand; the use of imagery, such as developing a muscular 'feel' or other cues, rather than developing visual cues; greater ability to resist distracting factors; and general adaptability to a novel situation.

3. Perhaps the transfer is in part due to the fact that a motor impulse from the 'higher centers' leading to set reactions with one hand, has acquired influence on the other hand. Students with a high Otis score attained a greater degree of efficiency than students with a low Otis score, indicating that complex processes are directly involved in mirror-drawing.
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