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Quantitative Aspects of the Evolution of Concepts

An Experimental Study

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QUANTITATIVE ASPECTS OF THE EVOLUTION OF CONCEPTS[1]

Introduction

The functional and quantitative aspects of the evolution of concepts are at present in about the same state as were corresponding aspects of memory when Ebbinghaus published his monograph on that subject in 1885. This is true in spite of a very considerable activity on the part of experimenters in the field of the higher mental processes within recent years. The problem of generalizing abstraction has itself been directly attacked a number of times, notably by Moore (*8*) in 1905, by Grünbaum (*2*) in 1906-07, and by Miss Fisher (*1*) in 1912-13. But in every case the studies have been largely introspective in method, analytic in purpose, and qualitative in result. The functional and quantitative aspects of the problem remain almost untouched.

The reason for such a condition is of course not far to seek It lies in the great complexity of the process involved. Where many factors must be cooperating nearly or quite simultaneously within a single living process, it is not easy to keep all of them constant except one and at the same time to vary that one so as to make a direct quantitative comparison of the results of the several phases of its variation. Difficulty or ease of solution of a problem is, however, often largely an expression of the efficiency of the methods and technique available. Memory which had previously resisted the efforts of psychologists, became relatively accessible after Ebbinghaus invented a suitable method. It is hoped that the quantitative aspects of the evolution of concepts will ultimately yield to a similar technique. The present study is an effort to elaborate such a technique and to apply it to a number of the characteristic quantitative problems concerned with the evolution of concepts.

[1] Offered in partial fulfillment of the requirements for the degree of Doctor of Philosophy, University of Wisconsin, 1918.

The work began in 1912 with a year of preliminary experimentation in the Psychological Laboratory of the University of Michigan. This was continued the following year at the Eastern Kentucky State Normal School. In 1914 the work was transferred to the Psychological Laboratory of the University of Wisconsin, where the problem and technique soon took on their final form and where the work was continued until the spring of 1918. A preliminary report containing a description of the general technique and the results from a few subjects was submitted to the University of Wisconsin as a Master's thesis in 1915. An abstract of this work was also presented in a paper before the Chicago meeting of the Psychological Association of that year, together with a demonstration of an imperfect model of the apparatus used.

II

ANALYSIS OF THE EXTERNAL CONDITIONS UNDER WHICH CONCEPTS ARE EVOLVED[1]

For the results of a psychological experiment to be taken as characteristic of any actual life-process, it is obvious that the experiment must duplicate all of the conditions essential to that process. In comparatively simple processes especially where much is already known concerning them, the difficulty of determining in advance what are the essential characteristics, is not excessive. But in a highly complex and imperfectly known process such as that by which concepts are evolved, it may fairly be said to be great. Theoretically, perhaps the only way to decide positively whether a given factor is influential or not is to determine experimentally whether any different result is obtained in cases where *all* possible factors are included as compared with cases where all except this one are included. And for similar reasons, in the absence of such experimental determination with all other factors equal, the more completely the conditions of the life-process are duplicated in the experiment, the greater the probability that the results of the experiment will be true of the particular life-process. It is consequently incumbent on us at the very outset of such an investigation to make as complete and careful an analysis as possible of the external conditions which precipitate and condition the process in question.

No doubt concepts may be evolved in many different ways (*10*) just as associative learning may be performed in many different ways. But the evolution of concepts or generalizing abstraction, being a distinctly more complicated process, may reasonably be expected to present a considerably greater variety of forms. Some of these are comparatively simple, while others

[1] The customary historical survey is omitted here chiefly because of the paucity of material bearing upon our present problem. Contact is made with various studies in the course of the monograph, in the most appropriate connections.

are extraordinarily complex. One of the simplest and most primitive types of generalizing abstraction may be illustrated by the following experiment.

The writer held a lighted white paraffine candle in an otherwise dark room, about a foot from the face of a lively child of sixteen months. The child soon put her hand forward into the flame and extinguished it. When the candle was lighted again a moment later, she shrank away from it with a characteristic turning-away of the head, a peculiar facial expression and a drawing back of the hands against the sides of the body. The next day she was held up to an 8 C.P. glowing electric light bulb hanging from a cord. She had been fond of playing with this under similar circumstances for some weeks. But now she refused to touch it, responding with a similar turning-away of the head, the peculiar facial expression and the drawing back of the hands against the sides of the body as in the candle experiment. A moment later when the current was turned off and the bulb was no longer luminous but still warm, she took it in her hands as readily as ever. This was repeated several times on the following day with uniform results. Record was made on the same day.

Assuming that the candle experience was the cause of the changed reaction to the electric light bulb, it is evident that a reaction has been transferred from the former to the latter, presumably through the identical element of luminosity. The mere *abstraction* of this element from the gross complex of the candle situation resulted simply from the superior attention value of the brightness. The *generalization* resulted from a major associative bond being formed between the luminosity and the reaction of withdrawing. The changed reaction to the luminous lamp merely made outwardly manifest the *generalizing abstraction* which had already taken place.

A second characteristic type of generalizing abstraction is involved in the so-called inductive "steps" of formal instruction originated by Herbart. These briefly summarized are:

1. The subject is presented with a number of experiences, either simultaneously or in succession, each of which contains a certain characteristic common to the others.

2. The subject is brought to compare deliberately the various situations presented with a view to discovering similarities and differences among them.

3. Lastly the significant element common to all the experiences is deliberately sought out, found, and formulated in language.

Here the process is much more elaborate than the type previously described: a linguistic reaction replaces the protective; more than one concrete situation is used as a basis of the process; the act of generalization becomes for the subject a deliberate task, and largely an end in itself. The process has strong elements of artificiality, as will be pointed out in connection with the third and "standard" type of generalizing abstraction to be described presently. This of course implies nothing as to the usefulness of the "steps" as a method of instruction.

The third will be called the "standard" method of generalizing abstraction because it is believed to be the method by which the great majority of actual concepts are evolved. It is consequently the method which is made the basis of the experimental investigations to be described later and for that reason will be analyzed in much fuller detail than the others. In schematic outline the external factors conditioning this process may be briefly stated as follows: A young child finds himself in a certain situation, reacts to it by approach say, and hears it called "dog.". After an indeterminate intervening period he finds himself in a somewhat different situation, and hears that called "dog." Later he finds himself in a somewhat different situation still, and hears that called "dog" also. Thus the process continues. The "dog" experiences appear at irregular intervals. The appearances are thus unanticipated. They appear with no obvious label as to their essential nature. This precipitates at each new appearance a more or less acute *problem* as to the proper reaction. This problem largely monopolizes the focus of consciousness. Meantime the intervals between the "dog" experiences are filled with all sorts of other absorbing experiences which are contributing to the formation of other concepts. At length the time arrives when the child has a "meaning" for the word dog. Upon examination this meaning is found to be actually a characteristic more or less common to all dogs and not common to cats, dolls and "teddy-bears." But to the child the process of arriving at this meaning or concept has been largely unconscious. He has never said to himself, "Lo! I shall proceed to discover the characteristics common to all dogs but not enjoyed by cats and 'teddy-bears'." The formation of the concept has never been an end deliberately sought for itself (*7*, 204). It has always been the means to an end—the supremely absorbing task of physical and social reaction and adjustment. Such in brief is our "standard" or normal type of concept evolution.

It will be convenient at this point to consider the methods followed by the three experimenters who have attacked the problem of generalizing abstraction. According to our preceding analysis, all of them fall considerably short of fulfilling the conditions for the evolution of concepts, as it usually takes place in ordinary life.[2] This is particularly true of the studies of Moore and Grünbaum.

Moore[3] presented to his subjects in rapid succession, by means of a Ranchberg memory apparatus, groups of nonsense characters. One-fourth second was given to each exposure with a blank period of equal length between. Each group contained five distinct characters arranged in a horizontal row. One character was the same in all the groups, all the other characters different. The subjects were directed to determine as quickly as possible whether there was any common element in the series, and to terminate the series of exposures by pressing a key the instant this was realized. The subjects were then directed to report the recollection of their mental states during the process, particularly as to the nature of the common element found and the other characters seen.

Grünbaum (*2*) modified the method of Moore somewhat. He presented to his subjects simultaneously within a single visual field, two groups of simple distinct characters. One character was alike in each of the two groups, all the others different. The

[2] Their findings so far as they apply to the present study, will be considered as occasion arises.

[3] Op. cit.

two groups of characters were separated by a diagonal line. The exposures were for three seconds. The subjects were directed to first find the character common to the two groups as quickly as possible and then to examine the other characters during the remainder of the exposure. The subject then reported the nature of the character found, his recollection of the process of finding, and any other characters which he could remember.

In the first place, at least for an adult, the groups used by both the above experimenters must have contained an extremely weak unity even where the exposures were as brief as those used by Moore. The rôle of language in the process is utterly ignored, and the problem and reaction aspects are lacking in the sense in which they appear in the normal process. Moreover the generalizing is made a deliberate task instead of being incidental. Lastly there is the extreme brevity of the total process. Some of Moore's experiments average from four to six seconds, and Grünbaum's less than three seconds per generalization!

Miss Fisher (*1*) presented to her subjects visually in succession, complicated unitary nonsense forms containing common elements. The exposures were three seconds each, and there were ten forms in each series. Beneath each form of the series was printed conspicuously the same nonsense name. The subjects were told that at the end of the series they would be called upon to define the group name. Elaborate introspections were taken frequently throughout the process. Here we have a somewhat closer approximation to a *bona fide* process of concept evolution. Its approximation is to the distinctly artificial type exemplified by the Herbartian formal "steps" however, rather than to the process as it takes place spontaneously in ordinary life. Her experiences are ideally unitary. She partly recognizes the rôle of language, though its *guiding* function in generalization (*11*, 11; *14*, 149 ff. especially 161) is not realized any more than in the Herbartian "steps." Just as there, the mind of the subject is still tingling with the impression of the last experience when a new one of the same kind appears. The general nature of each new experience is known before it is presented. There consequently never exists any problem for the subject to discover a suitable reaction to the situation as such. As a further consequence, he does not utilize the results of his partial generalizations in coping with the succeeding situations. The problem so far as any exists is only a pseudo problem—that of deliberately and self-consciously discovering common elements. It is difficult to say what influence her constant and elaborate introspections had upon the process, though it is safe to assume that such an amount of irrelevant mental activity was not without its effect.

III

THE EFFICIENCY OF EVOLVING CONCEPTS BY PROCEEDING FROM THE SIMPLE TO THE COMPLEX

Experiment A

Problem

The first problem which we shall consider arises from the familiar educational injunction to "proceed from the simple to the complex." We shall try to determine experimentally how far this method justifies its reputation when applied to the evolution of concepts. How much if any more economical is it to evolve a concept by experiencing first the simpler concrete examples from which it is to be abstracted and proceeding progressively to the more complex and difficult examples, over an opposite order. In symbols, if the concept x is to be evolved from the series of concrete examples:

ax, bcx, defx, ghijx, klmnox, pqrstux,

is it more or less efficient to experience the examples in the simple-to-complex order (reading from left to right) or to experience them in the reverse or complex-to-simple order?

Technique

The general conditions under which concepts are ordinarily evolved have been roughly suggested in the last chapter. We must now formulate them more exactly and translate them into terms of experimental technique.

1. *The subject must be presented with a large number of unitary experiences each distinct from the rest.*

The basis for such a series of visual experiences was supplied by the 144 Chinese characters shown in Plate I. These characters were taken from a Chinese dictionary, and freely adapted to the present purpose wherever deemed necessary. They were drawn with great care in black ink upon cards two inches long and one inch wide. The characters thus prepared were presented

PLATE I.—Showing the Chinese characters which served as the material for the evolution of concepts.

to the subject one after another by means of a specially constructed apparatus.

This device somewhat resembled the drum form of Wirth memory apparatus. The slips on the drum held twelve cards. The periodic movements of the drum were controlled automatically and exactly by a simple pendulum clockwork which was built into the apparatus. By means of a special form of cam this clockwork released the drum at periods varying anywhere from one to six seconds as desired. Throughout the present study a uniform exposure-time of five seconds was employed. The movements of the pendulum were concealed from the subject by a screen of cardboard attached to the table upon which the apparatus rested. The sound of the ticking of the clockwork was reduced to that of an ordinary clock by an elastic escapement of special shape. In addition this escapement was attached to the pendulum by means of a piece of rubber which absorbed the greater part of the remaining vibration. When wound the apparatus would continue giving exposures accurately, of the required length and without any attention whatever from the experimenter for a period of from 40 to 50 minutes. The accurate automatic feature of the device was of the greatest value throughout the experiment. Indeed owing to the necessarily complex duties of the experimenter while the experiment was in progress, the study could not have been carried on without it.

2. *Each one of these unitary experiences must require a definite reaction from the subject at each presentation.*

This requirement was satisfied by having the subject respond to each character as it appeared by speaking a particular nonsense syllable.

3. *The reaction required must be identical for each individual within limited groups of experiences. The resulting groups must be numerous.*

This requirement was satisfied by having each of the twelve characters of the first horizontal row in Plate I (Series A) reacted to by speaking the word "ōō," the next row of twelve by speaking "yer" and so on. Thus each horizontal row of char-

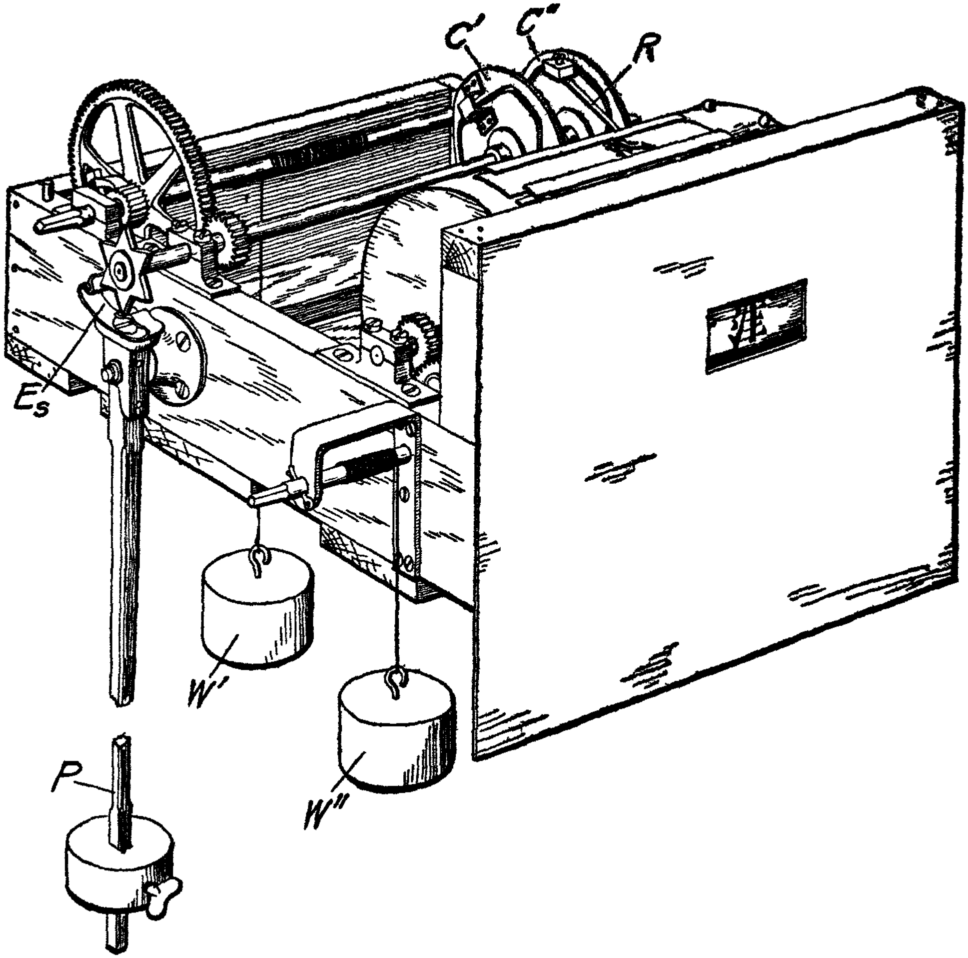


PLATE II. EXPOSURE APPARATUS.—P, pendulum with adjustable bob. Es, elastic escapement. C", cam attached to the escapement shaft. This cam controls by the rod R a secondary escapement (not shown by this view) which engages pins set in the farther end of the drum. This escapement releases at equal intervals of time, permitting the drum instantly to turn one twelfth of a revolution. C' is a second cam which may be used to secure movements of the drum at intervals of time one half as great. W' and W" are lead weights which drive the clockwork and the drum respectively. The drum has at equal intervals on its surface, twelve pairs of shallow grooves in which cards bearing characters are placed for successive exposure at the window. One of the characters is shown at the window as viewed by the subjects in experiments A to I.

acters constituted a separate reaction-group. There were twelve such groups in all, which are regarded as sufficiently "numerous" to satisfy the technical requirements of the experiment.

The twelve syllables used were pronounced as follows: ōō, yêr, lē, tä, dĕg, lĭng, huĭ, chŭn; vō, nă, nĕz, fĭd.

4. *All of the individual experiences which require a given reaction, must contain certain characteristics which are at the same time common to all members of the group requiring this reaction and which are NOT found in any members of the groups requiring different reactions.*[1]

This requirement is satisfied by the fact that all the characters (e.g. in Series A Plate I), contain certain strokes in common. These characteristic strokes for each of the twelve reaction-groups are isolated in the vertical column of characters labeled "concept." They may be easily observed imbedded in each of the characters in the group following but they are not found in any of the other groups.

5. *All of the individual experiences which require a given reaction must always be accompanied by the experience of a given word, which must never accompany experiences requiring a different reaction.*

This was accomplished in the early part of each experiment by the experimenter pronouncing the name in question in the middle of the exposure of each of the particular characters of a given reaction-group whenever they chanced to appear. The ticking of the clockwork marked the middle of the five-second exposure. The subject always repeated the syllable distinctly immediately after the experimenter. He was directed to anticipate the experimenter as soon as possible by himself speaking the required word during the two-and-one-half seconds of the exposure before the prompting should occur. A consistent reaction of this kind was always established after a longer or shorter series of exposures. In cases of successful reaction the subject heard the word spoken by himself in connection with the cor-

[1] This of course ignores the obvious fact that the same object may be conceived in numerous ways and that under different circumstances may require very different reactions. Only a slight modification of the technique here employed would be necessary to measure its influence which presumably is important. (See James, *4*, II, 333.)

responding character. Consequently there was no need for the experimenter to speak the word.

6. *The individual concrete experiences must take place in a random order and consequently one unanticipated by the subject.*

This was secured as follows: In the first place the characters were presented in "packs" of 12. An inspection of Plate I will show that a "pack" or *vertical* column of characters includes one representative of each reaction-group. Since the capacity of the drum was also 12, a "pack" of characters exactly filled the drum. Secondly the order of the representatives of the various reaction-groups in a given pack was fixed by chance, subject only to the qualification that the representatives of two or more reaction-groups should never come in immediate succession in any two successive "packs," and further that the representative of a given reaction-group should never appear first or last in more than one "pack."

7. *The experiences belonging to a given reaction-group must ordinarily be separated by one or more experiences belonging to the other groups.*

This is necessary effectually to efface any immediate memory images which might otherwise be superposed directly upon a second experience of the same reaction-group. This was secured by the procedure just described under (6) above.

8. *Each new experience, particularly at the beginning of the process, must precipitate the more or less acute problem of determining what reaction will secure satisfaction and avoid annoyance.*

This was adequately realized by the unanticipated order of the experiences described above, together with the fact that the subject was under obligation if possible of reacting promptly and correctly by pronouncing the name of each character as it appeared. If he could not react correctly he had the annoyance of failure, and if he succeeded he had the satisfaction of conscious success.

9. *In coping with new situations, the subject must constantly use any incipient stages of the concept that may be in existence at a given time, however imperfect and false such embryonic concept may be.*

This was automatically realized to the maximum by the continuous necessity of reacting correctly by naming the new characters as they appeared.

10. *The concept (in the mind of the subject) must never be an end in itself but rather a means to successful reactions to concrete experiences.*

This was secured by occupying the subject's mind as completely as possible with the problem of perfecting his reaction. Except where otherwise stated, great care was taken to avoid any other motive. In the instructions, all suggestions of abstraction of common elements, generalization or definition were studiously avoided. Positively he was led to believe that he was about to do a kind of memory experiment. He was told that he would be prompted in the middle of each exposure, that he should repeat the syllable each time when prompted and that as soon as possible he was to react before being prompted. This process was continued with the first "pack" until all the reactions were perfected, which to all intents and purposes really was a memorizing experiment.[2] At the beginning of the second "pack" the subject was told in a matter-of-fact way that the second set would be easier because the same names would be used as with the first set, so there would be no new names to learn. Just before exposing the first character, he was told to see how many of the new characters he could "guess" correctly before being prompted. This injunction to "guess" was given at the beginning of each succeeding series.

11. *A definite functional unit of measure must be provided.*

A thoroughly convenient and adequate functional measure of the perfection of a concept lies in the extent of the ability to react successfully to new but analogous situations (*12, 13*). If in a given time spent one method of evolving concepts gives ability to react successfully to 50 per cent of all new situations and another gives ability to react to 60 per cent of the same or

[2] Introspections taken at the conclusion of the experiments indicated that the greater part of the time of the subjects was always consumed in the immediate task of perfecting the required reaction. The most of them spent a little time however in seeking the common element. A few seem never to have attempted it.

similar new situations, the second method is obviously superior to the first to a definite intelligible amount and regardless of ability to define or any other subjective consideration. Accordingly only the first six "packs" of characters (Plate I) were used for the purpose of evolving the concepts. The remaining six "packs" (VII to XII) were reserved exclusively for testing or measuring the concepts thus evolved. In making up the test "packs" the characters were rearranged from the order as they appear in Plate I in such a way that in a given "pack" or drum-full, two or even three characters of a given concept might be present and of course not any of certain others. This was to prevent subjects from determining the identity of characters by a process of elimination. Three exposures were given of each one of these test "packs" (of course without promptings) and the subjects were encouraged to "guess" at them very freely if any suggestion whatever of a possible identity came to mind. This latter was done so as to get as far as possible the liminal as well as the supraliminal reactions and thus obtain a more adequate measure. The three reactions to each of the six test-characters of a given concept gave eighteen measures for each concept and a total of 216 measures for all twelve concepts with a given subject. This was our main measure.

In addition there were three supplementary measures of some importance. The first and most important of these is based upon exactly the same principle as the main measure. At the first presentation of each succeeding "pack" of the evolution series (first six "packs," Plate I) there arises the necessity of reacting to the respective characters during the two-and-one-half seconds before the prompting takes place. This obviously gives the required functional measure and at a point of peculiar interest as it takes place periodically throughout the entire evolution process and enables us to trace the progress of the process from the first. As pointed out above the subjects were encouraged to react or "guess" very freely especially during the first time through each "pack" even in cases where they were extremely doubtful.

The second supplementary measure came from the evolution series also. It was furnished by the number of promptings which were required to perfect the reactions to each of the first six "packs." Clearly the farther advanced the evolution of the concepts in general, the fewer promptings will be required.

A third supplementary measure of the stage of the evolution of concepts, though by no means a functional one, is obtained by requiring the subject to define the concepts (by drawing them) at the end of the process. If desired these definitions may be called for at any time during the process though that might easily introduce a disturbing factor. For this reason it was never done except in special experiments carried out for this particular purpose.

Certain defects appear in all four of the measures described above. In the chief measure and in the first two supplementary measures the element of chance introduces a slight error. Subjects were encouraged to "guess" at doubtful cases and chance alone would give on the long run one correct guess out of twelve. This is but a slight possibility and its influence is reduced to insignificance by the fact that on the average only about 10 per cent to 15 per cent of the reactions were chance in this sense. But whatever influence actually resulted from this was effectually eliminated from the results by the fact that it was equal for each of the two sets of concepts compared.

In the first and second supplementary methods a slight error is introduced by the fact that the subject was sometimes able to react successfully to a character through a process of elimination. This error is slight however and in the long run may be expected to be equal for each of the two sets of concepts, and so can hardly disturb the results. These two supplementary measures are of distinctly less reliability than the main measure because they are based upon a so much smaller number of measures. And of the two the second, not being strictly functional in nature, is of distinctly less value than the first. The third supplementary measure, that of definition, is rather qualitative in its nature and is not functional. It has no unit of measure in any ordinary sense though it is possible to extract from such drawings a certain kind of quantitative value (see p. 43). Nevertheless this method may furnish important information concerning the evolution of concepts, and it might profitably be more fully employed than is the case in the present study.

12. *The disturbing influences of past training and experiences on the part of the subjects must be eliminated.*

This was effectually secured by the use of the strictly unfamiliar nonsense-material described above.

13. *The effects of individual differences as to the rate of learning among various subjects, of practice, of fatigue, of ennui, of obscure physical or psychic indispositions and spurts, and all sorts of other factors of a similar nature, which often seriously disturb quantitative experiments, must be completely equalized.*

This was accomplished at a single stroke by having the concepts of the two methods to be compared, evolved by the *same* subject and *simultaneously.* The advantage of this procedure can scarcely be overestimated. Six of the total twelve concepts were accordingly evolved by the simple-to-complex method and six by the complex-to-simple method. Thus if a subject is naturally slow, his native slowness appears equally in the simple-to-complex method and in the complex-to-simple method; and if he is slightly fatigued or fresh, his fatigue or freshness is absolutely constant for both methods. The writer regards this as the most important single feature of the technique employed.

14. *The technique must be so flexible that it may be possible to vary in a definite way any factor involved in the process without disturbing the constancy of any of the other factors.*

The requirement of varying the direction of the change of complexity in the various evolution series without disturbing any of the other factors, presented difficulties. These will be considered more in detail as the various means of avoidance are described from time to time. In the main the requirement was satisfied very simply. As previously pointed out, only the first six "packs" were used for the purpose of evolving the concepts, and are therefore spoken of as the "evolution" series just as the other six "packs" are spoken of as the "test" series. Now a glance at the evolution series of concept A (Plate I) will show that in the first character the common element stands out very clearly, it appears less clearly in the second, still less clearly in the third and fourth characters and least clearly of all in the fifth and particularly in the sixth character. In short the characters are arranged in the order of increasing complexity, difficulty or general obscurity of the common element. This we have called "simple-to-complex." The same is true of series, B, C, D, E, and F, which together make up half of the total twelve concepts. On the other hand a similar examination of the first six characters making up the evolution series of concepts G to L, the other half of the total twelve, will show that they are at first most complex and gradually become simpler and simpler from "pack" to "pack" as one moves from left to right, being most simple or clear at the sixth. In short these last six evolution series are arranged in the order of *decreasing* complexity or general obscurity of the common element. This we have designated as "complex-to-simple" order. From the above it may be seen that in experiencing the evolution "packs" in the order I, II, III, IV, V, VI, series A to F will be evolved in the simple-to-complex order while series G to L will be evolved simultaneously in the complex-to-simple order, and the same amount of time will be spent upon each of the two groups of concepts.

The method of determining the position of the respective characters in the series of increasing and decreasing complexity was based upon the general impression of clearness or obscurity of the common element as judged by the experimenter after having drawn them.[3] The twelve characters of a given concept series were carefully arranged in a row according to increasing complexity or obscurity. From this row the first, third, fifth, eighth, tenth and twelfth characters were taken and made respectively the first, second, third, fourth, fifth and sixth character of the evolution series. The rest were thrown by chance into the test series.

15. *The results must be protected from any distortion which might arise from lack of equality in the difficulty of the material employed.*

[3] This is true of Experiments A, B and C. In Experiment D, the final one on this particular problem, the characters were arranged according to experimentally determined functional difficulty.

Differences in difficulty among the various concept-series were not avoided and no particular effort was made to do so. The aggregate or average difficulty of the two groups of concepts compared however was practically equal, as may be seen by consulting Tables I, II, and III. This was a natural result of the fairly homogeneous nature of the material. But all possible disturbance of the results by slight difference in the difficulty of the two sets of material compared, was effectually eliminated by having only half of the subjects experience the "packs" in the order of I to VI as described above, while the other half experienced them in the reverse order. In the first case concepts A to F were simple-to-complex, while G to L were complex-to-simple. In the second case concepts A to F became complex-to-simple while concepts G to L became simple-to-complex, thus completely reversing the process in both cases. Consequently if in the first group of subjects concepts A to F should give on the tests a score of errors for the simple-to-complex method slightly in excess of what strict equality in the difficulty of the groups should show, when the process is reversed and concepts A to F have become complex-to-simple, they may be expected to give the same slight excess of errors to that method also. And when the results of all subjects are combined, these two equal excesses will neutralize each other and the final result will be effectually protected from disturbance from this source.

16. *Sufficient concepts must be evolved and sufficient measures taken from each to (largely) eliminate chance variation.*

This was approximately achieved by using with each subject six concepts and 108 measures on the final tests for each of the two methods compared, besides the secondary measures which furnish reliable corroborative evidence. In the most of the experiments later described ten subjects were used, giving a total of 2,160 measures on the tests above. In the four experiments on the economy of the simple-to-complex method of evolving concepts alone over 8,600 measures were taken.

An exact record was made of every reaction of the subject as the experiment was performed. Special mimeographed blanks were provided for the purpose. A plus sign was recorded for every correct reaction, a minus sign for every failure to react and the nature of the response was recorded in every incorrect reaction. These later are of course counted exactly as minus signs in the final tables. An exceedingly careful system of key letters and numbers was used to prevent errors in prompting, scoring, etc.

Except where otherwise stated all the experiments throughout the study were conducted in a small research room in the psychological laboratory of the University of Wisconsin. The room had one large window of northern exposure. The apparatus sat on the top of a sort of table 42 inches high and 16 inches wide, where the light of the window fell directly upon the exposed characters. The latter were about on a level with the subjects' eyes. The experimenter sat on a high stool behind the table and at one side of the apparatus. Short rest-periods were permitted between the various "packs" to avoid fatigue. The experiments described in the present chapter ordinarily consumed about three hours each. This included the rest-periods.

The subjects in the immediate experiments and in all the experiments except where otherwise stated were university students. In most cases they had little or no training in psychology and were thoroughly naïve. Ordinarily they regarded the work as a kind of memory experiment and were mainly interested in making a good score. It is safe to say that not one of the subjects used in this form of the experiment had the slightest suspicion that the ultimate purpose of the experiment was to compare the efficiency of two distinct modes of concept evolution. When informed of this at the end of the experiment they never failed to express more or less astonishment. For the above reasons no form of suggestion arising from preconceived theoretical considerations could enter to distort the results. Indeed the writer regards such subjects as distinctly more valuable than trained psychologists for such an experiment as the present one.

We may now briefly summarize the salient features of the technique described above with special reference to its application in Experiment A: The twelve characters of "pack" I are inserted in the twelve holders of the drum. The drum goes round and round without interruption making successive exposures of each character of exactly five seconds. The characters are stationary while being viewed. The experimenter pronounces the concept-name of each character at the middle of its exposure and the subject repeats it with care. After the first revolution of the drum the subject himself begins to react to the characters by pronouncing the name wherever possible, before being prompted. At length every character will be reacted to correctly at a single revolution of the drum. The characters are at once removed from the drum and replaced but in a *different* order. The prompting is then resumed as before until the subject has made a perfect score on each of two successive revolutions of the drum.

Then "packs" II, III, IV, V, and VI which comprise the evolution "packs" are inserted and learned one after the other. In these cases however, the "packs" are only learned in *one* order each, and to a perfect score on two successive revolutions of the drum. Less and less time is required for each succeeding "pack."

In order to equalize any possible inequality of difficulty inherent in concepts A to F as compared with the concepts G to L, half of the subjects learned the reactions to the "packs" in the order of VI, V, IV, III, II, I. In this case "pack" VI was learned in two orders by these subjects just as "pack" I was by the first half of the subjects.

Lastly the six test "packs" are presented. They are inserted on the drum one after another and merely given three revolutions each, i.e., three exposures to each character. The subject reacts wherever possible, no promptings being given. Sometimes the subjects were then asked to draw on a specially prepared blank the characteristics which a character must contain in order to be called "ōō," "yêr," "lē," etc.

Results

The results of the tests show a distinct advantage for the simple-to-complex method. They are given in a condensed form by subjects in Table I. There it appears that seven of the ten subjects show a more or less decided advantage for the simple-to-complex method. Out of a possible 108 errors in reacting to the tests of the simple-to-complex series, an average of 30.2

TABLE I

Showing the relative efficiency of the simple-to-complex method, Experiment A.

Subject	Order of experiencing evolution "packs"	Number of failures to react correctly on test series, out of possible 108. Simple-to-complex	Complex-to-simple	Advantage of simple-to-complex
Eat.	I to VI	9	34	+25
S. B.	" " "	27	35	+ 8
Mac.	" " "	62	60	— 2
M. B.	" " "	8	49	+41
Mau.	" " "	34	59	+25
Lie.	VI to I	14	36	+22
Pau.	" " "	25	19	— 6
Wan.	" " "	23	46	+23
Sch.	" " "	48	33	—15
Dav.	" " "	52	70	+18
Average		30.2	44.1	+13.9
M. V.				14.1
S. D.				16.3

failures was made, as against an average of 44.1 failures on the tests of the complex-to-simple series. This gives an average advantage of 13.9 points for the simple-to-complex method.[4]

The results are confirmed by both of the first two supplementary methods of measurement described on p. 15. The results of the first supplementary measure are shown in Table II. There

TABLE II

Showing the number of failures to react correctly at the first presentation of the characters of evolution "packs" by the respective methods.

Subject	Order of experiencing "packs"	Total number of failures to react correctly at first presentation. Simple-to-complex ("packs" given in chronological order) I	II	III	IV	V	VI	Complex-to-simple ("packs" given in chronological order) I	II	III	IV	V	VI
Eat.	I to VI	6.0	3.7	3.0	2.0	.2	2.0	6.0	5.0	5.0	3.5	2.8	1.2
S. B.	" " "	6.0	2.0	1.0	1.0	.5	2.5	6.0	5.5	4.5	3.5	4.5	3.5
Mac.	" " "	6.0	3.0	4.0	4.0	5.0	4.0	6.0	3.0	5.0	4.0	4.0	2.0
M. B.	" " "	6.0	5.5	2.5	1.5	1.0	2.0	6.0	5.0	3.8	3.5	2.5	3.0
Mau.	" " "	6.0	3.0	3.0	2.0	3.0	2.0	6.0	5.0	4.0	3.0	3.0	5.0
Lie.	VI to I	6.0	2.0	3.0	2.0	2.0	1.5	6.0	4.0	3.0	4.5	3.0	2.0
Pau.	" " "	6.0	5.0	5.0	5.0	5.0	2.0	6.0	6.0	5.0	1.0	3.0	4.0
Wan.	" " "	6.0	4.5	3.0	3.5	2.0	1.0	6.0	5.5	5.0	2.0	1.5	.5
Sch.	" " "	6.0	3.0	4.0	4.0	4.0	2.0	6.0	6.0	6.0	5.0	2.0	3.0
Dav.	" " "	6.0	5.0	3.5	4.0	4.5	3.5	6.0	5.0	3.0	4.0	2.0	3.5
Average		6.0	3.7	3.2	2.9	2.7	2.25	6.0	5.0	4.4	3.4	2.8	2.77

[4] A computation of the "unreliability" of this average shows that there is one chance in about 286 that there is no advantage for this form of the simple-to-complex method. (Thorndike, E. L., Mental and Social Measurements, Chap. XIII.)

appear in chronological order the number of failures to react correctly at the first presentation of the respective evolution "packs," for the simple-to-complex and the complex-to-simple methods respectively. Owing to the small number of measures taken on a given "pack" with a single subject, there is considerable variation in the figures in the body of the table. The final averages however show a decided and consistent advantage for the simple-to-complex method. This appears very clearly in Figure I where the relation of the two sets of averages is shown graphically. These curves show not only a distinct superiority for the simple-to-complex method but at what an early stage in

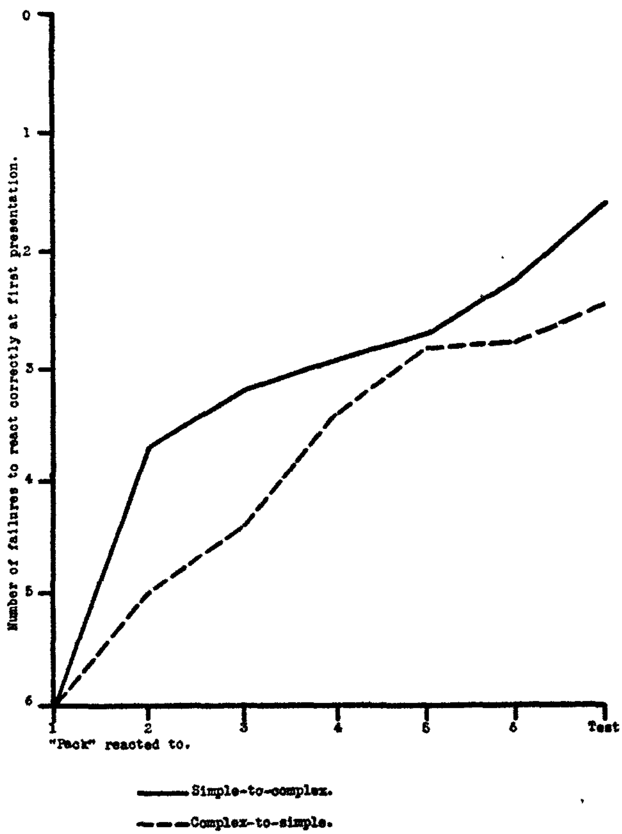


FIGURE I.—Showing the rate of improvement in ability to react to new situations, evolution series, Experiment A.

the process this superiority is established. Already at the beginning of the second "pack," it is greater than at any other time in the process. Indeed there is a distinct tendency for the curves to converge near "pack" VI. This however is doubtless due largely to the fact that the characters of the upper (simple-to-complex) curve are at their maximum difficulty at this point, thus tending to increase faulty reactions and so to make the curve fall. On the other hand the characters of the lower curve are at their minimum of difficulty which tends to make a minimum of faulty reactions and so to elevate artificially the curve at this point.

The superiority of the simple-to-complex method is shown once more by the second supplementary measure. The comparative results by this method are shown in Table III. Here appear the total number of promptings required at each stage of its evolution for the six concepts being evolved simultaneously by the respective methods. As in Table II there is considerable variation in the individual scores but the final averages still show a distinct superiority for the simple-to-complex method. This is shown graphically in Figure II. Thus by all of the three methods employed, the simple-to-complex method of evolving concepts has proven the better of the two.

TABLE III

Showing the number of promptings required to perfect the reaction at each succeeding "pack" of the evolution series for the two methods compared, Experiment A.

Subject	Order of experiencing "packs"	Total number of promptings required to perfect reaction at each succeeding "pack". Simple-to-complex ("packs" given in chronological order)						Complex-to-simple ("packs" given in chronological order)					
		I	II	III	IV	V	VI	I	II	III	IV	V	VI
Eat.	I to VI	32	12	5	1	0	1	39	26	12	4	3	1
S. B.	" " "	47	6	2	0	2	4	37	19	13	5	6	4
Mac.	" " "	39	13	9	13	8	7	43	13	9	13	9	3
M. B.	" " "	51	8	5	6	2	2	33	12	10	20	6	4
Mau.	" " "	26	3	4	6	3	4	32	10	7	6	4	7
Lie.	VI to I	24	2	5	3	3	1	26	5	5	5	1	3
Pau.	" " "	24	18	13	10	8	3	23	20	15	4	3	5
Wan.	" " "	23	10	11	7	4	0	28	26	17	4	1	0
Sch.	" " "	60	12	16	11	8	6	43	15	15	9	4	5
Dav.	" " "	37	14	13	12	10	7	44	24	8	8	2	7
Average		36.3	9.8	8.3	6.9	4.8	3.5	34.8	17.0	11.1	7.8	3.9	3.9

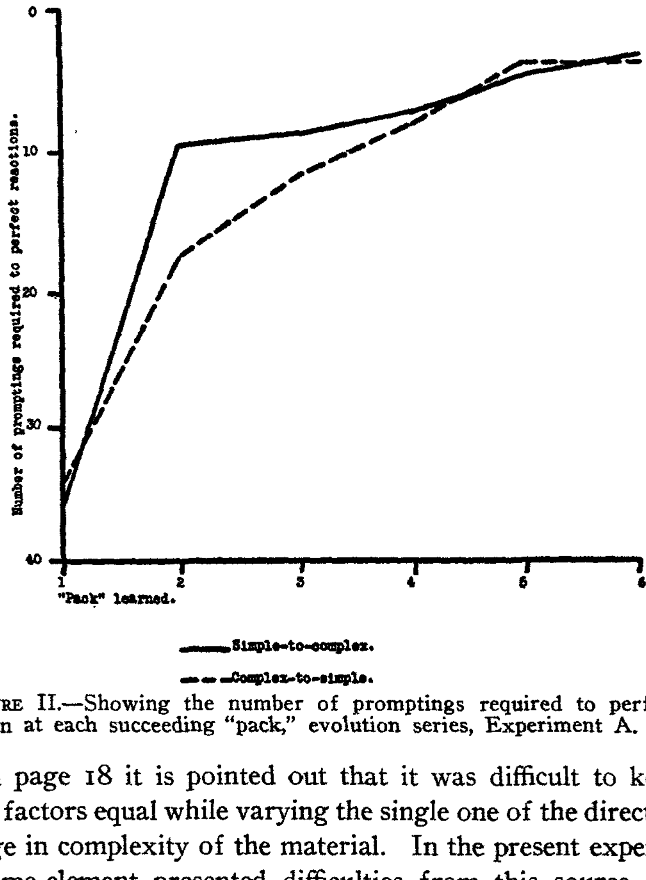


FIGURE II.—Showing the number of promptings required to perfect the reaction at each succeeding "pack," evolution series, Experiment A.

On page 18 it is pointed out that it was difficult to keep all other factors equal while varying the single one of the direction of change in complexity of the material. In the present experiment the time-element presented difficulties from this source. It is true that according to the technique employed the total time consumed by each of the two methods was bound to be absolutely equal. Despite this, an important time-relation remained grossly unequal. An examination of the distribution of time among the various "packs" (p. 30) shows that about four time as much was given to the simple end of the simple-to-complex evolution series as to the simple end of the other. Clearly this alone might account for the advantage obtained for the simple-to-complex method in the present experiment if it be assumed that the simple end of such a series is more efficient in the evolution of functional concepts per unit time. That such is actually the case is strongly suggested by the fact that the entire advantage gained by the simple-to-complex method is secured on the first one or two "packs" (Figure I), where an excessive amount of time is spent upon the easy end of those series.

Accordingly three new experiments were instituted. One (Experiment B) reduced the disproportion of time spent upon the simple ends of the respective series evolved by the two methods. In the other two (Experiments C and D) it was equalized entirely.

Experiment B

In this experiment the same material, apparatus and general technique were employed as in Experiment A, except that instead of learning the first (chronological) "pack" in two orders, it was here learned in only *one*. All "packs" were learned as usual until a perfect score was made on two successive revolutions of the drum. Thus the only difference between the present experiment and the one just described lies in reducing the time spent upon the first "pack." Eight subjects were used in the experiment.

The results in general confirm those found in Experiment A though upon a somewhat reduced scale. The smaller advantage here shown for the simple-to-complex method tends strongly to confirm our suspicions as to its origin which were expressed above. The results are shown by subjects in Table IV. Six of

TABLE IV

Showing the relative efficiency of the simple-to-complex method, Experiment B.

Subject	Order of experiencing evolution "packs"	Number of failures to react correctly on test series, out of possible 108. Simple-to-complex	Complex-to-simple	Advantage of simple-to-complex
Rig.	I to VI	36	38	+ 2
Bot.	" " "	49	43	— 6
Wey.	" " "	31	18	—13
Hen.	" " "	40	54	+14
Cop.	VI to I	29	44	+15
Dum.	" " "	6	20	+14
Sym.	" " "	42	47	+ 5
M. C.	" " "	33	71	+38
Average		33.2	41.9	+ 8.7
M. V.				11.6
S. D.				14.56

the eight subjects show a more or less striking tendency to greater efficiency by the simple-to-complex method. The final averages show a score of 33.2 failures to react out of a possible 108 as compared with 41.9 failures by the complex-to-simple method. This gives a net advantage of 8.7 points for the simple-to-complex method[5] against one of 13.9 by the method of Experiment A — a perceptible reduction.

These results are further confirmed by the two secondary measures which show the relative efficiency of the two processes from the beginning. The increase in ability to react to new cases

TABLE V

Showing the number of failures to react correctly at the first presentation of the successive evolution "packs" for the respective methods, Experiment B.

Subject	Order of experiencing "packs"	The number of failures to react correctly at first presentation. Simple-to-complex ("packs" given in chronological order) I	II	III	IV	V	VI	Complex-to-simple ("packs" given in chronological order) I	II	III	IV	V	VI
Rig.	I to VI	6.0	3.5	2.5	2.0	2.0	4.0	6.0	5.5	6.0	3.0	3.5	3.5
Bot.	" " "	6.0	5.0	3.0	3.5	3.5	4.0	6.0	4.5	5.0	2.5	4.5	3.0
Wey.	" " "	6.0	2.0	3.0	3.0	2.0	2.0	6.0	6.0	5.0	4.0	1.0	3.0
Hen.	" " "	6.0	1.0	1.0	.0	.0	.0	6.0	6.0	6.0	5.0	5.0	2.0
Cop.	VI to I	6.0	4.0	3.0	3.5	2.0	2.0	6.0	6.0	5.0	4.0	4.0	4.0
Dum.	" " "	6.0	2.5	2.0	2.0	2.0	.0	6.0	5.0	3.5	2.5	2.0	1.0
Sym.	" " "	6.0	5.0	3.0	3.0	3.0	4.0	6.0	6.0	3.0	4.0	2.0	3.0
M. C.	" " "	6.0	5.0	3.0	4.0	3.0	4.0	6.0	4.0	5.0	5.0	4.0	5.0
Average		6.0	3.5	2.5	2.6	2.2	2.5	6.0	5.4	4.8	3.8	3.2	3.1

throughout the evolution series is of special significance and is shown for the two methods separately in Table V. The final averages of the two series are shown graphically in Figure III. While showing the superiority of the simple-to-complex method, it also furnishes additional confirmation of our suspicion concerning its cause. The curves of Figure III, just as in Figure I, show that the rise in the upper or simple-to-complex curve takes place almost entirely during the first part of the process, ("packs" I, II and III) which, it will be remembered, is its easy end. On

[5] A computation of the "unreliability" of this average shows that there is one chance in about 22 that the "true" average would not show an advantage for the simple-to-complex method.

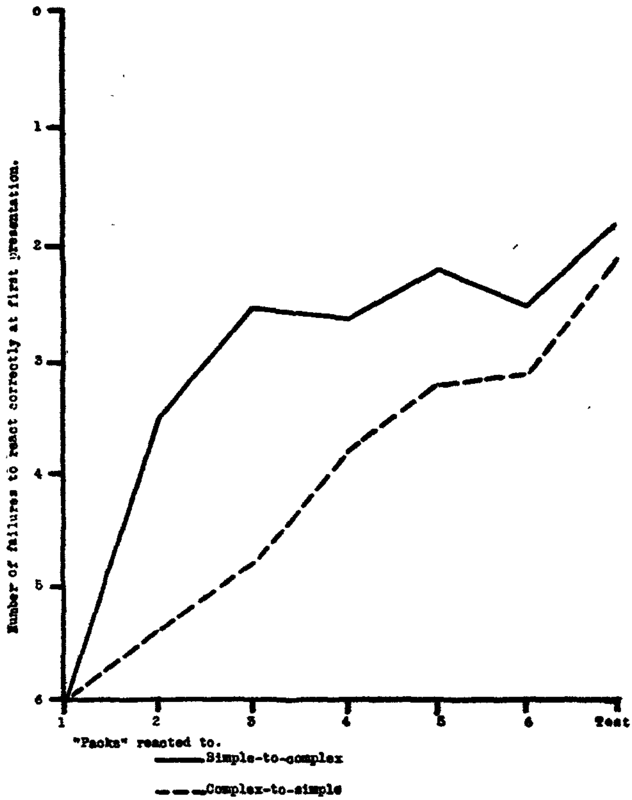


FIGURE III.—Showing the rate of improvement in ability to react to new situations, evolution series, Experiment B.

the other hand the lower or complex-to-simple curve, makes a much greater comparative rise at "packs" IV, V and VI which is also *its* easy end. Much of this is clearly due merely to the difference in difficulty of the characters presented for reaction, but not all. At "pack" IV, in spite of the fact that the simple-to-complex characters are here slightly the more difficult of the two, the curve shows almost twice as great an advantage for the method as was shown by the tests, where the material is equally difficult for both methods. Evidently from the fourth "pack" on, the simple characters of the complex-to-simple series have proven more efficient in evolving functional concepts than the complex characters of the simple-to-complex series, for they have greatly reduced the advantage of the simple-to-complex method which was present at the end of the third "pack." Given more time on the last three "packs," this advantage might be completely eliminated. Clearly then, any method which spends a greater proportionate time upon the simple or more efficient end of the series, will tend strongly for that reason alone to be a more efficient method, and vice versa. As already pointed out the smaller advantage obtained for the simple-to-complex method in the present experiment accords with this view. The average number of minutes spent upon each "pack" in the two experiments is as follows:

Pack	I	II	III	IV	V	VI
Experiment A	17.9	9.2	7.6	5.8	5.1	4.8
Experiment B	17.0	10.8	10.4	7.6	7.3	6.5

Thus in Experiment A the two "packs" at the simple end of the complex-to-simple series received only 33 per cent as much time as the corresponding end of the simple-to-complex series, while in Experiment B this inequality is reduced so that the ratio is 50 per cent.

TABLE VI

Showing the number of promptings required to perfect the reaction at each succeeding "pack" of the evolution series for the two methods compared, Experiment B.

		Number of promptings required at each succeeding "Pack."											
		Simple-to-complex ("packs" given in chronological order)						Complex-to-simple ("packs" given in chronological order)					
Subject	Order of experiencing "packs"	I	II	III	IV	V	VI	I	II	III	IV	V	VI
Rig.	I to VI	97	31	13	7	1	15	78	39	29	12	19	10
Bot.	" " "	40	24	13	14	3	12	36	35	16	24	14	9
Wey.	" " "	40	4	6	4	3	4	40	14	16	8	2	3
Hen.	" " "	61	13	32	6	13	3	88	25	35	16	27	15
Cop.	VI to I	46	27	15	8	5	3	55	36	21	9	3	16
Dum.	" " "	13	4	3	2	1	0	15	10	7	5	3	1
Sym.	" " "	28	29	11	7	8	7	30	19	12	9	3	5
M. C.	" " "	35	18	9	5	4	5	60	16	10	10	8	12
Average	....	45	19-	12.8	6.6	4.7	6.1	50.2	24.2	18.2	11.6	9.9	8.9

The promptings throughout the evolution series are shown in Table VI. The final averages by the two methods show a consistent advantage for the simple-to-complex method. They appear graphically in Figure IV.

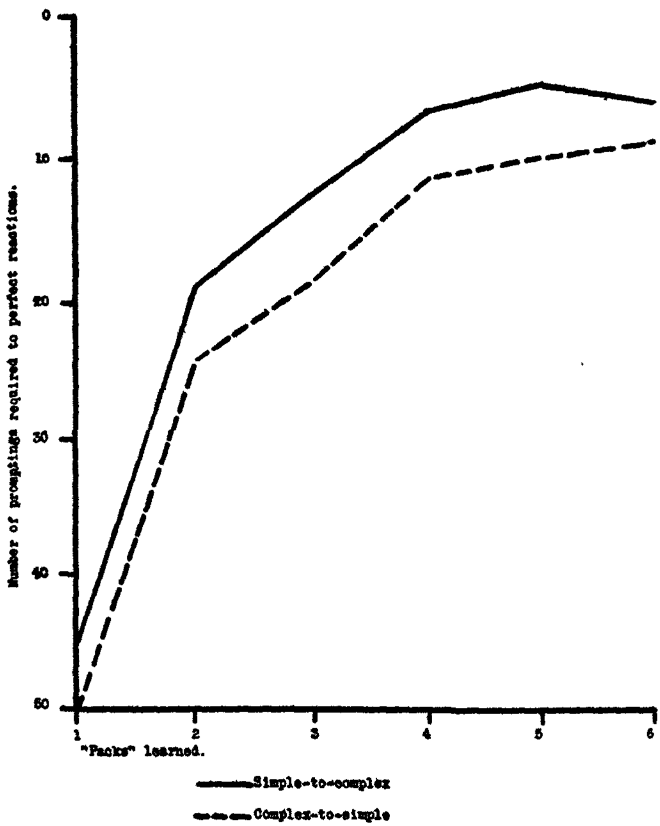


FIGURE IV.—Showing the number of promptings required to perfect the reaction at each succeeding "pack," evolution series, Experiment B.

EXPERIMENT C

In setting up this experiment the main object was to equalize the time-elements as completely as possible for the simple halves of the two groups of series compared. Obviously the only way to do this was to give the same number of exposures to every pack of the evolution series. After considerable deliberation, nine exposures per "pack" were selected as the number most likely to yield results comparable with the two previous experiments. It was the average number of exposures actually given in Experiment B.

In thus equalizing the time element, some fears were entertained lest a second and equally disturbing factor might be introduced which would have a somewhat similar effect, viz. an unequal distribution of attention and effort. It is of course evident from the number of exposures necessary to be given to the different "packs" in Experiment B (p. 30) that the average subject will not have perfected his learning of the first two "packs" at the ninth exposure but will have completed the learning of the *last* two "packs" some time *before* the ninth exposure. Other things equal it might reasonably be expected that there would be a certain amount of dimunition of the attention in the latter packs after the reaction had been perfected. In order to prevent this if possible, rest periods were introduced between each of the "packs." And when the subject had perfected the learning before the ninth exposure he was warned to maintain the same degree of attention as before. In this connection it must be pointed out also that association bonds are by no means at their maximum strength when they are just capable of producing the reaction in two and one-half seconds. Considerable effort on the part of the subject is still required to make the correct response and the continued repetitions show their influence in the increased speed of the reactions.

After all possible precautions have been taken there still remains doubt upon this point. But clearly any disturbing effect of this factor will be favorable to the simple-to-complex series. If the results still show a tendency to greater economy by the simple-to-complex method, the meaning will be ambiguous, as it might be due to either of the two possible variable factors involved. But if the advantage should disappear it would be strong confirmation of our previous results pointing to the greater amount of time spent upon the more efficient half of the simple-to-complex series as the cause of the greater efficiency which was found for that method.

The results of the tests show this to be the case. They appear in Table VII. While there is, as usual, considerable variation among the individual subjects, about as many favor one method as the other. The final average for all subjects gives an almost identical score for both methods. The difference is only one

TABLE VII

Showing the relative efficiency of the simple-to-complex method, Experiment C.

Subject	Order of experiencing evolution "packs"	Number of failures to react correctly on test series, out of a possible 108. Simple-to-complex	Complex-to-simple	Advantage of simple-to-complex
Tay.	I to VI	28.5	27.0	— 1.5
Hag.	" " "	70.5	44.5	—26.0
Bon.	" " "	46.0	32.0	—14.0
Fin.	" " "	11.0	5.0	— 6.0
Rei.	" " "	79.0	86.0	+ 7.0
Nor.	VI to I	21.0	18.0	— 3.0
Old.	" " "	35.0	58.0	+23.0
Tor.	" " "	37.0	57.0	+20.0
Eva.	" " "	49.0	32.0	—17.0
Osm.	" " "	79.0	85.0	+ 6.0
Average	....	45.6	44.45	— 1.1
M. V.	....			12.1
S. D.	....			14.87

point, and even this is reversed and in favor of the complex-to-simple method.

As in the previous experiments, the results of the supplementary measures support those of the tests. The comparative functional efficiency of the two methods in reacting to new cases is shown from the beginning of the process in Table VIII. The final averages of the two methods are shown graphically in Fig-

TABLE VIII

Showing the number of failures to react correctly at the first presentation of the successive evolution "packs" for the respective methods, Experiment C.

Subject	Order of experiencing "packs"	The number of failures to react correctly at first presentation: Simple-to-complex ("packs" given in chronological order) I	II	III	IV	V	VI	Complex-to-simple ("packs" given in chronological order) I	II	III	IV	V	VI
Tay.	I to VI	6.0	4.0	2.0	3.0	2.0	4.0	6.0	4.5	3.5	2.0	1.0	.5
Hag.	" " "	6.0	6.0	4.5	4.0	2.0	4.5	6.0	6.0	3.0	4.0	5.0	4.0
Bor.	" " "	6.0	5.0	3.0	4.0	4.0	3.5	6.0	6.0	3.5	4.5	2.5	1.0
Fin.	" " "	6.0	6.0	5.0	1.0	1.0	2.5	6.0	5.0	3.5	3.0	2.5	1.0
Rei.	" " "	6.0	5.0	4.0	5.0	4.5	3.0	6.0	5.5	4.5	6.0	5.0	2.5
Nor.	VI to I	6.0	6.0	3.5	2.0	2.0	.5	6.0	6.0	5.0	3.0	2.0	2.0
Old.	" " "	6.0	4.5	2.5	4.0	5.0	3.0	6.0	5.0	4.0	4.0	3.0	5.5
Tor.	" " "	6.0	5.5	3.5	4.0	2.5	3.0	6.0	5.0	4.5	3.5	2.5	4.0
Eva.	" " "	6.0	5.0	4.5	3.0	2.0	2.5	6.0	4.5	4.5	3.0	2.0	3.0
Osm.	" " "	6.0	5.5	6.0	3.5	6.0	5.5	6.0	5.5	5.5	4.5	5.0	5.5
Average	....	6.0	5.25	3.85	3.35	3.1	3.2	6.0	5.3	4.15	3.75	3.05	2.9

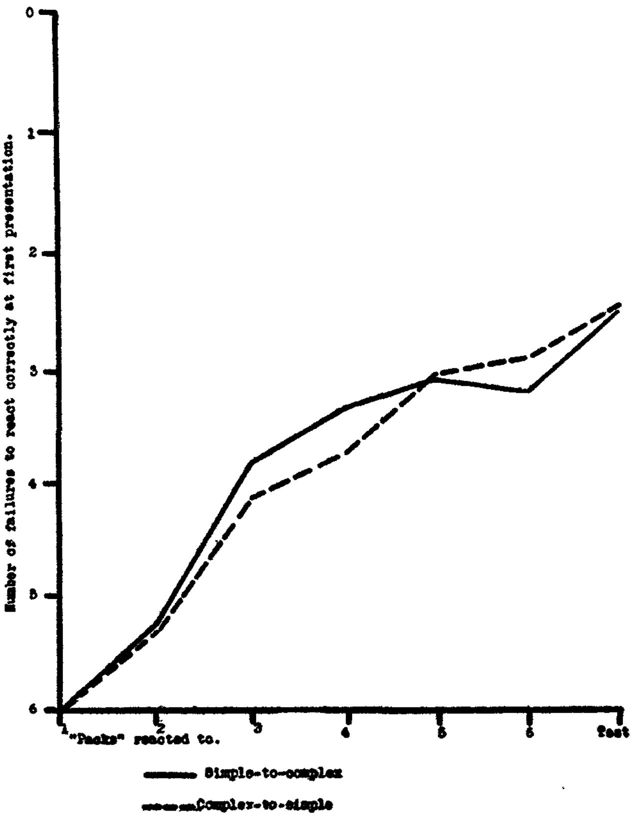


FIGURE V.—Showing the rate of improvement, in ability to react to new situations, evolution series, Experiment C.

ure V. The two curves follow an almost identical course. But the differences, small as they are become significant when taken in connection with the corresponding processes of Experiments A and B. (Figures I and III.) Here we find again that the simple-to-complex method rises more rapidly at first. At "pack" IV it attains its greatest advantage in spite of the fact that its characters are the more difficult of the two at this point. But the remainder of the curve shows that this advantage is entirely lost during the second half of the evolutionary process as was anticipated above. No advantage appears by the simple-to-complex method as such.

Experiment D

Owing to the importance of the question under investigation, it was thought desirable to repeat Experiment C under more rigid conditions. It will be recalled that the characters of the evolution series in the previous experiments were arranged according to the complexity or general obscurity of the common elements as determined by the subjective impression of the experimenter. In the present experiment the criterion of arrangement was the actual functional difficulty of the individual characters. This was readily determined for the characters of the original *test series* by computing the aggregate number of failures to react correctly for each character as shown by the test records of 25 subjects. The characters of the original test series were accordingly converted into a new evolution series while the old evolution series became a new test series. This criterion has the distinct additional advantage that it shows relatively *how great* the increase or decrease of complexity or difficulty is, which we are dealing with. The average increase in percent of failures for the entire group is approximately 5 per cent from step to step and fairly uniform:

20.5%, 25.6%, 29.7%, 34.8%, 41.8%, 54.7%

TABLE IX

Showing the relative efficiency of the simple-to-complex method, Experiment D.

Subject	Order of experiencing evolution "packs"	Number of failures to react correctly on test series, out of possible 108. Simple-to-complex	Complex-to-simple	Advantage of simple-to-complex
Joh.	I to VI	65	44	—21
And.	" " "	10	22	+12
Woo.	" " "	65	57	— 8
Mur.	" " "	61	72	+11
E. H.	" " "	46	68	+22
Sch.	" " "	23	17	— 6
Hem.	VI to I	55	37	—18
Adl.	" " "	39	63	+24
Cra.	" " "	11	33	+22
Pet.	" " "	79	71	— 8
M. H.	" " "	70	66	— 4
Tig.	" " "	45	44	— 1
Average		47.4	49.5	+ 2.08
M. V.				13.3
S. D.				15.0

And while an inspection of the characters according to the new arrangement makes it possible that we have here a factor slightly different from that aimed at in the previous experiments, it is also probable that we are dealing with a distinctly more fundamental and significant type of complexity.

The results of the experiment confirm in every detail those already obtained. When the same amount of time is spent on each member of the evolution series, there is no advantage in favor of proceeding from the simple to the complex. Of the twelve subjects, seven show an advantage for the complex-to-simple method while an average of all gives a negligible advantage of 2.09 in favor of the simple-to-complex method with a mean variation of 13.4. The score is shown by subjects in Table IX. The course of the successes by the two methods as shown by the initial reaction to the characters of the evolution series is given in Table X. The averages of the two methods are plotted in Figure VI. The characteristic features of the corresponding curves of Figure V are here repeated in detail though on a greatly increased scale.[6]

TABLE X

Showing the number of failures to react correctly at the first presentation of the successive evolution "packs" for the respective methods, Experiment D.

Subject	Order of experiencing "packs"	The number of failures to react correctly at first presentation. Simple-to-complex ("packs" given in chronological order)						Complex-to-simple ("packs" given in chronological order)					
		I	II	III	IV	V	VI	I	II	III	IV	V	VI
Joh.	I to VI	6	5	5	5	4	5	6	5	6	4	4	3
And.	" " "	6	0	0	0	1	3	6	6	2	2	1	1
Woo.	" " "	6	6	6	5	3	4	6	4	4	5	3	2
Mur.	" " "	6	6	6	4	4	4	6	6	5	4	3	2
E. H.	" " "	6	6	5	5	3	6	6	6	6	5	2	3
Sch.	" " "	6	2	0	2	1	1	6	4	4	2	0	0
Hem.	VI to I	6	4	3	4	3	6	6	6	6	3	4	3
Adl.	" " "	6	6	5	4	4	3	6	5	5	6	4	3
Cra.	" " "	6	4	4	3	2	3	6	4	5	4	4	3
Pet.	" " "	6	4	5	4	5	6	6	5	5	5	4	4
M. H.	" " "	6	5	4	6	5	4	6	6	6	5	3	4
Tig.	" " "	6	5	4	3	3	3	6	6	5	3	3	2
Average		6.0	4.4	3.9	3.7	3.2	4.0	6.0	5.3	4.9	4.0	2.9	2.5

[6] This probably reflects the greater psychological potency of the present method of arranging the characters.

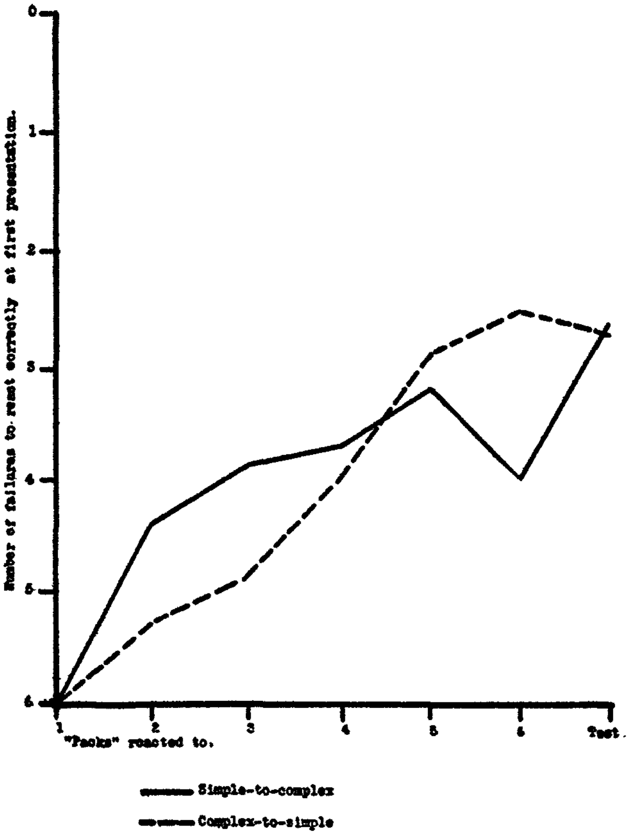


FIGURE VI.—Showing the rate of improvement in ability to react to new situations, evolution series, Experiment D.

As there, the simple-to-complex method shows a distinctly better score on "packs" II, III and IV, the curves cross between "packs" IV and V, and the complex-to-simple method shows a better score on "packs" V and VI, only to come together on the test, which was the only place in the series where the material reacted to was of the same difficulty for both methods. As pointed out in previous experiments the advantage shown for the respective methods in the various "packs" was largely due to the actual difference of difficulty in the characters reacted to in each case. But if this factor alone were operating the curves should have crossed between "packs" III and IV instead of later. At "pack" IV we know that the simple-to-complex characters are about 5 per cent more difficult than the complex-to-simple. This acting alone would have reversed almost exactly the positions of the two curves. The fact that they were not reversed shows clearly that the simple characters of the simple-to-complex method have been distinctly more efficient than the complex characters of the complex-to-simple method up to that point i.e. during the first three "packs." That this advantage was absent at the end of the evolutionary process as evidenced by the tests, shows with equal clearness that the simple characters at the end of the complex-to-simple series worked with equal efficiency when their chance arrived, and that the order of arrangement as such probably has no influence upon the efficiency of the process whatever.

Summary and Conclusions

The results of Experiments A, B, C and D may be briefly formulated as follows:

1. In the evolution of functional concepts simple experiences are more efficient than complex ones. This appears to be true regardless of whether the simple experiences take place at the beginning or end of the process of evolution.

2. Concrete experiences in the simple-to-complex order appear to be no more efficient in the evolution of functional concepts than when in the complex-to-simple order if inequalities of the time-factor are excluded.

3. But if each individual experience in the evolution series is continued until the reaction to it is just perfected before passing to the next, there is a distinct advantage in favor of the simple-to-complex method. This is due to the fact that under this method a greater amount of time is spent upon the simple or efficient end of the simple-to-complex series than upon the corresponding end of the complex-to-simple series. It seems not improbable that whatever belief may exist as to the greater economy of the simple-to-complex order may have arisen from the natural tendency to spend a disproportionate amount of time

upon the first cases in the series just as was done in Experiments A and B. Thus understood there is a real economy by this procedure.

Caution must be exercised in applying results such as the above to the conditions of instruction, for example, and that for a number of reasons. In the first place, as pointed out above (p. 5), there are very considerable differences between the conditions of the present experiment and those usually found in formal instruction. Under such different conditions, especially in respect to the immediately successive experiencing of the cases of a given concept-series and the general lack of the functional reaction throughout the series, the relations found above to obtain between the two might be considerably altered.

A general criticism and evaluation of the method employed in the above experiments may be made at this point. The great weakness as well as strength of the present method lies in its abstractness, particularly in the use of nonsense-material. Obviously, results from such material must be verified and checked up by further experiments with the more complex material of every day life. Even there an economy might conceivably hold for one kind of material and not for another, such is the specific nature of psychological functions. An example in point is seen in Ebbinghaus' "law of forgetting." It was found to hold though upon a reduced scale, for many kinds of "intellectual" material but probably not at all for thoroughly learned muscular habits (*15*, II, 309 ff).

On the other hand the advantages of the method are very great. This is particularly true of a study which is attempting to make a preliminary exploration in a little known field such as the present. The advantage consists largely in extreme simplicity, uniformity, flexibility and general controlability of the material employed. Here again the classical work of Ebbinghaus on memory may be profitably considered. Perhaps it is not too much to say that owing largely to the abstract nature of his method and particularly to the extreme managability of his material, he made as great a contribution to our knowledge of the quantitative aspects of memory in two or three years as has resulted from all the enormous amount of work done on memory since that time. The work done since was of course just as necessary as his. The point is that by the use of abstract experiments there is an enormous economy of time and energy in reaching preliminary conclusions as to where the truth may probably be found in the complex material of everyday life. In short it sets the problem for the concrete experiment and has limited practical value until verified by the latter. But here again the history of memory experimentation may be encouraging, for hardly one of the principles worked out by Ebbinghaus has failed to find its counterpart in the complex material of every day life, though often with limitations. This suggests that even with the limitations mentioned above, a certain amount of presumption arises that the tendencies found in the present experiments may prove true even of so artificial a process as formal instruction.

IV

THE EFFICIENCY OF RECEIVING CONCEPTS WITHOUT THE LABOR OF GENERALIZING ABSTRACTION

Experiment E

A second theory of essentially quantitative implications has long been held concerning the evolution of functional concepts. This theory is that to have functional value, concepts must be evolved from the concrete by each individual for himself (*6*, 229). Practice has on the other hand very often (though apologetically) striven to give the concept to the individual outright. But while theory asserts stoutly the greater functional efficiency of concepts evolved by the individual himself as compared with those given to him outright, it has not been determined how much greater is the efficiency, much less how it would vary (if at all) with different amounts of time available for the process. Here then we find our problem: Is it more or less efficient to spend a given amount of time in perfecting the reaction to an abstract characteristic never seen in its concrete setting, or to spend the same amount of time perfecting reactions to a series of concrete situations with the incidental amount of generalizing abstraction?

The main features of the method utilized are the same as those employed in the experiments just described, in particular Experiment B. It differed from Experiment B in having half of the characters of the evolution series replaced by their respective common elements. That is to say, the characters comprising the six members of each of the evolution series G to L say, would be replaced in every case by the common element shown in the first vertical column headed "concept" (Plate I). The other half of the evolution series (A to F) remain exactly as before in the simple-to-complex order. Thus in learning the evolution "packs" in the order I to VI, there would be a simultaneous comparison of (1) evolving concepts by the simple-to-complex method

TABLE XI

Showing the relative efficiency on the tests of the two methods of evolution being compared, Experiment E.

Subject	Concept given outright in:	Number of failures to react correctly on the tests out of a possible 108. Concept given outright	Simple-to-complex	Advantage of giving concept outright
Smi.	Series A to F	58	71	+13
Dec.	" " " "	39	61	+22
San.	" " " "	55	47	− 8
Cod.	" " " "	26	53	+27
Kiv.	" " " "	45	26	−19
Oma.	Series G to L	54	55	+ 1
Hjo.	" " " "	65	71	+ 6
Col.	" " " "	70	46	−24
Clo.	" " " "	87	87	0
Sta.	" " " "	37	45	+ 8
Average		53.6	56.2	+ 2.6
M. V.				12.8
S. D.				15.13

(Series A to F) with (2) receiving concepts in the abstract apart from their concrete setting (Series G to L). As in the previous experiments the necessity of equalizing any differences in difficulty which might be inherent in the two groups of concepts compared made it necessary to reverse the process with half of the subjects. In this case the naked common elements were given in Series A to F and the simple-to-complex method in Series G to L. Otherwise the experiment was exactly as in Experiment B, each "pack" being learned to a perfect score on two successive revolutions of the drum.

Ten subjects were used in the experiment. They were university students from a class in introductory psychology.

Contrary to the expectation of the experimenter, there was no advantage for either of the two methods compared. The results of the tests are shown in Table XI. As usual the variation among the individual subjects is considerable but about as many favor one method as the other. The final averages are almost equal, there being a difference of only 2.6 points. This however is in favor of the method of giving the concepts outright. But in view of a S.D. nearly five times as great, this has slight significance.

From the nature of the evolution series in this experiment no supplementary measure was obtained from this source. However, at the conclusion of the respective experiments, five of the subjects (two of the first group and three of the second) were asked to draw on a specially prepared blank their idea of what a character must contain to be called by the various names such as "ōō," "yer," "le," etc. Even to casual inspection, these drawings show a very striking superiority for the concepts which were given outright. In order to get a quantitative determination of the extent of this superiority, four persons of considerable psychological training compared each drawing with the corresponding one in the first column of figures of Plate I and then scored the drawings on a scale of ten. The scoring was done without knowledge

TABLE XII

Showing the relative ability to define by the two methods of acquiring concepts, Experiment E.

Subject	Concept given outright in:	Relative functional efficiency: Concept given outright	Relative functional efficiency: Simple-to-complex	Relative efficiency in definition: Concept given outright	Relative efficiency in definition: Simple-to-complex
Dio.	Series A to F	64%	43%	55%	38%
Cod.	" " " "	76%	51%	89%	77%
Oma.	Series G to L	50%	49%	68%	32%
Hjo.	" " " "	40%	34%	73%	18%
Col.	" " " "	35%	57%	71%	27%
Average	....	53.0%	46.8%	71.2%	38.4%

of the method used to produce the individual drawings. The average score of the respective groups of concepts as thus determined is shown by subjects in Table XII. The final averages show that where the concepts are given outright, the defining ability is much greater in proportion to functional ability than where they are abstracted by the subject. Where the concepts are evolved by the subject himself, the percentage of efficiency in definition is eight points *less* than the functional efficiency by the same process, while by the abstractly given concepts the per cent of efficiency in definition is eighteen points *more* than the functional efficiency attained by the same method. The score on the "definitions" by the "given" method, is nearly thirty points higher than its functional efficiency would require by the method of actual evolution by the subject.

The results of the experiment may be briefly summarized as follows: Where the evolutionary process has reached an average efficiency of approximately 50 per cent,

1. Concepts given outright show a functional efficiency equal to concepts evolved by the subject himself from concrete cases in the simple-to-complex order.

2. The ability to define the concept by drawing is about twice as great where the concepts are given outright as where they are evolved from the concrete by the subjects themselves.

3. From (1) and (2) follows the corrollary that ability to define is not necessarily a true index of the functional value of a concept (*17*, 141 ff).

It must be noted that the above experiment covers only one of three or four possible cases of the present problem. It may be that very early in the process, say at a point where only about 20 or 25 per cent of efficiency is attained, the advantage would be distinctly with the "given" concepts that at an efficiency of around 50 per cent (the present case) there would be no consistent advantage for either method; and that at a normal efficiency of about 90 per cent the advantage will pass over decidedly to the simple-to-complex method.[1]

There is a further limitation upon the generality of the above results even for the region of a 50 per cent development of the process. Above we have likened the giving of the concepts in the present experiment to the process of formal instruction by definition, which educational reformers have inveighed against so much. In reality the present method probably suffers from only one of the two evils with which instruction by definition is afflicted. One is its *abstractness* and the other is that the *verbal* nature of definitions brings it about that even the abstract meaning of the definition is *imperfectly comprehended*. In the present experiment only the *abstractness* was involved, for presumably the abstract element itself was immediately and completely experienced.

[1] Since this was written, additional experiments along the lines here indicated, show that some at least if not all of the above conjectures will be realized. The writer hopes to complete these experiments and publish the results as a separate study in the near future.

V

THE EFFICIENCY OF EVOLVING CONCEPTS BY A COMBINED METHOD OF ABSTRACT PRESENTATION AND CONCRETE EXAMPLES

Experiment F

In the last chapter we found reason to suspect that mere abstract information is of rather doubtful efficiency in coping with new situations in the later stages of the process of generalizing abstraction. Where the process has been approximately half completed, its efficiency is about the same as by the simple-to-complex method. The problem accordingly arises: May not a combination of the two methods be more efficient than either alone? Specifically, is it more or less efficient to evolve functional concepts by first receiving the abstract characteristic and then a concrete case, or to have the subject evolve it entirely for himself by the simple-to-complex method?

The method of attacking the problem was very similar to that employed in Experiment E. Two changes were made to adapt it to the present problem: In the first place all the characters of evolution series G to L were reversed so that they stood normally in the simple-to-complex order in exactly the same sense as series A to F (Plate I). After being reversed the characters falling in "packs" I, III and V were replaced by the naked common elements used in Experiment E. Otherwise the learning was exactly as usual, to a perfect score on two successive revolutions of the drum. In this way series A to F would be experienced in the ordinary simple-to-complex order. But series G to L would be experienced as: first the "concept" given abstractly, second an example, third the "concept" given abstractly again, fourth another example, fifth the "concept" given abstractly once more and lastly another example. Thus series G to L was evolved from an alternation of abstract presentation and example, the examples being in the simple-to-complex order. As usual in

TABLE XIII

Showing the functional efficiency of combining abstract presentation with the giving of concrete experiences, Experiment F.

Subject	Combination method in:	Combination method	Simple-to-complex	Advantage of combination method
		Number of failures to react correctly in the test out of a possible 108.		
Wat.	Series A to F	38	45	+ 7
Fee.	" " " "	27	57	+30
Bec.	" " " "	19	28	+ 9
Gor.	" " " "	33	64	+31
Cro.	" " " "	1	14	+13
Out.	Series G to L	15	38	+23
Jac.	" " " "	15	28	+13
Sla.	" " " "	48	42	— 6
Sur.	" " " "	28	61	+33
Whi.	" " " "	21	41	+20
Average		24.5	41.8	+17.3
M. V.				10.1
S. D.				11.8

order to avoid error from possible difference in difficulty between the two groups of concepts, the process was reversed with half of the subjects in which case series A to F were alternate abstract presentation and example, while series G to L were simple-to-complex.

The tests revealed a decided advantage for the combination method over the simple-to-complex method. The results of the tests are shown in Table XIII. All but one subject gave a distinct

TABLE XIV

Showing the number of failures to react correctly at the first presentation of the successive evolution "packs," Experiment F.

The number of failures to react correctly at first presentation.

Subject	Combination method in Series:	Combination method I	II	III	IV	V	VI	Simple-to-complex method I	II	III	IV	V	VI
Wat.	A to F	(6)	5	(3)	2	(1)	5	6	6	4	4	4	5
Fee.	" " "	(6)	6	(0)	3	(1)	6	6	6	2	3	4	4
Bec.	" " "	(6)	5	(3)	3	(0)	3	6	4	3	4	4	1
Gor.	" " "	(6)	1	(1)	1	(0)	4	6	6	6	1	3	5
Cro.	" " "	(6)	3	(0)	0	(0)	4	6	3	2	2	1	2
Out.	G to L	(6)	5	(1)	3	(0)	5	6	4	2	3	0	2
Jac.	" " "	(6)	4	(0)	3	(1)	2	6	3	3	2	1	2
Sla.	" " "	(6)	4	(3)	3	(2)	4	6	5	6	4	2	3
Sur.	" " "	(6)	5	(2)	2	(0)	4	6	6	5	4	1	4
Whi.	" " "	(6)	6	(2)	5	(1)	2	6	6	4	3	4	1
Average		(6.0)	4.4	(1.5)	2.5	(.6)	3.9	6.0	4.9	3.7	3.0	2.4	2.9

advantage for the combination method. The final averages show that the combination method gave only 24.5 failures to react successfully out of a possible 108, while the simple-to-complex method gave a score of 41.8 failures to react successfully. This gives an advantage to the combination method of 17.3 points.[1]

Fortunately also we can get some, though imperfect, indications as to the relative functional efficiency of the two methods from the beginning of the process. This is yielded as usual by the ability to react to the new cases at the first presentation of each "pack" of the evolution series. The result is shown in Table XIV. In the combination method, only "packs" II, IV and VI have any significance as to the progress of the conceiving process, for they alone are new cases. Such of the final averages as are significant, are shown graphically in Figure VII, where it is seen that the advantage of the combination method appears immediately and probably increases throughout the process. An apparent exception is seen in "pack" VI. There the errors by the combination method suddenly increase greatly and considerably exceed those by the simple-to-complex method, which itself has increased a certain amount normal to this "pack". Immediately afterward on the tests, the advantage is restored to the combination method. An inspection of the data in Table XIV shows that the tendency for the larger score on the sixth "pack" by the combination method was shared by the majority of the subjects. It is possible that this particular method of evolving concepts may be especially weak at this stage of its progress, when it comes to functioning on unusually difficult novel situations. In this connection it may be well to recall that owing to the technique employed (p. 19) it is impossible that the difference noted should be caused either by differences in difficulty of the material or by individual differences of the subjects in rate of learning.

The results of the experiment may be formulated as follows:

1. A combination of abstract presentations and concrete ex-

[1] A computation of the "unreliability" of this average shows that there are only about twelve chances in ten million that the "true" average would not show an advantage for the combination method.

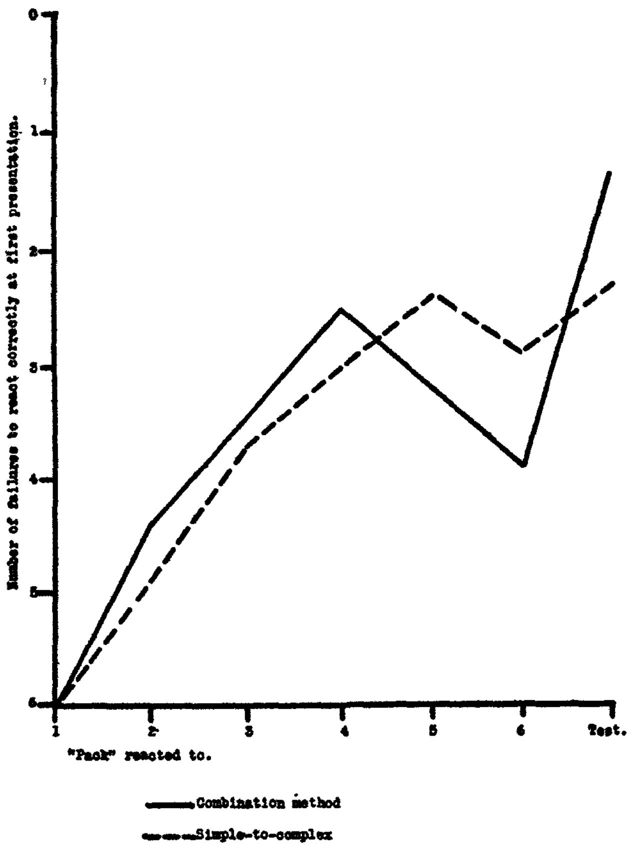


FIGURE VII.—Showing the origin of the advantage of the combination over the simple-to-complex method, evolution series, Experiment F.

amples is upon the whole distinctly more efficient in evolving functional concepts than either method alone.

2. The advantage of the combination method appears at the beginning of the process and probably continues to increase at a fairly uniform rate through the first two-thirds of the process, as far as it was carried in the present experiment.

3. It may be that at certain stages of perfection, concepts evolved by the combination method are less efficient in coping with new situations of exceptional difficulty than when evolved by the simple-to-complex method.

The above experiment has considered only one of an important group of problems: Is it more economical to make the abstract presentation at the beginning or end of the process? What is the relative efficiency of making the abstract presentation in the middle of the process, and having it both preceded and followed by concrete cases? Is it better to have the abstract presentation and the concrete cases alternate frequently as above, or to have the first half of the time devoted to one method and the second half to the other? Would it be better to have the abstract presentation come at the beginning or end of the process? What is the most economical distribution of time that could be devoted to the two methods in the combination?

Clearly the above experiment has only broached the problem of the economy of abstract presentation. Numerous other problems of a similar nature will at once suggest themselves. The explorational aim of the present study will have been attained if the general economy of the combination method is shown, and an adequate and convenient technique for the solution of the various subsidiary problems demonstrated.

VI

THE EFFICIENCY OF EVOLVING CONCEPTS FROM A SERIES OF CONCRETE CASES WHERE THE ATTENTION IS ATTRACTED TO THE COMMON ELEMENT *IN SITU*

Experiment G

Closely related to the method of concept evolution by abstract presentation, is that of demonstration. For our purpose demonstration consists essentially in the presentation of a series of concrete cases and directing the attention of the subject to the essential characteristic of each in its concrete setting. The problem before us then is: What is the relative efficiency of evolving functional concepts from concrete cases in which the attention of the subject is continuously attracted to the significant common element, as compared with the ordinary simple-to-complex method.

Only a slight modification of the technique of Experiment F was necessary in order to adapt it to the present problem. As there, *all twelve* of the evolution series were arranged in the simple-to-complex order with the simple end of the series at "pack" one. But with half of the evolution series, e.g., G to L, the characters were redrawn so the common element appeared in a saturated red, everything else being the same. The redrawing was done with great care and the new characters except for the color of the common element, were practically identical with the originals. It was assumed that the color would attract the attention of the subject mildly but continuously to the common element. Nothing whatever was said concerning the color however, the same instructions as usual being given. With half of the subjects the process was reversed, series A to F being given in the simple-to-complex order with the common element in red, and series G to L as normal simple-to-complex. Ten university students were used as subjects.

The tests reveal a decided advantage in favor of attracting attention to the significant common element *in situ*. The results

TABLE XV

Showing the relative number of failures to react correctly on the tests for the two methods compared, Experiment G.

Subject	Common element in red Series:	Common element in red	Simple-to-complex	Advantage of common element in red
		Number of failures to react on test out of possible 108.		
Wen.	A to F	17	58	+41
Hal.	" " "	53	63	+10
Con.	" " "	13	41	+28
Mar.	" " "	51	61	+10
Moe.	" " "	23	27	+ 4
Bec.	G to L	27	42	+15
Col.	" " "	21	43	+22
Mel.	" " "	19	24	+ 5
Lin.	" " "	39	50	+11
McK.	" " "	27	15	—12
Average		29.0	42.4	+13.4
M. V.				10.5
S. D.				13.7

of the tests are shown in Table XV. Nine of the ten subjects showed a more or less decided superiority where the common element was given in red while the average of all yields only 29 failures to react successfully out of a possible 108 as against 42.4 by the ordinary simple-to-complex method. This gives a net advantage of 13.4 points in favor of attracting attention to the common element in its concrete setting.[1] It does not appear to be quite so efficient as the alternate abstract presentation and concrete example (Experiment F) which yielded an advantage of over 17 points at almost exactly the same stage of the normal simple-to-complex process. But the significance of such small differences is not great where the variation is so considerable.

In this experiment we are again able to get some indication as to the relative functional efficiency of the two methods throughout the process from the beginning. This is furnished as before by the number of failures to react successfully to the evolution

[1] A computation of the "unreliability" of the average shows that there is only one chance in about one thousand that the "true" average would not show an advantage for attracting attention to the common element *in situ*.

TABLE XVI

Showing the relative efficiency of the respective methods in reacting to the evolution series at first presentation, Experiment G.

Subject	Common element in red in Series:	Number of failures to react at first presentation of evolution series. Common element in red I	II	III	IV	V	VI	Simple-to-complex method I	II	III	IV	V	VI
Wen.	A to F	6	5	4	1	0	1	6	4	3	3	2	2
Hal.	" " "	6	6	5	2	2	2	6	3	4	5	2	3
Con.	" " "	6	2	2	0	0	2	6	4	1	2	0	3
War.	" " "	6	5	5	3	2	3	6	4	2	4	5	5
Moe.	" " "	6	3	2	3	1	1	6	4	3	3	2	2
Bec.	G to L	6	1	3	2	0	0	6	5	4	4	3	5
Col.	" " "	6	5	2	2	0	0	6	4	4	3	1	0
Mel.	" " "	6	3	3	0	1	0	6	5	4	3	1	4
Lin.	" " "	6	6	3	2	3	1	6	6	5	6	3	2
McK.	" " "	6	3	2	1	0	0	6	4	4	3	1	0
Average		6.0	3.9	3.1	1.6	.9	1.0	6.0	4.3	3.4	3.6	2.0	2.6

"packs" at their first presentation. These are shown in detail in Table XVI. The final averages by the two methods are shown graphically in Figure VIII. There it is evident at a glance that the advantage of having the attention of the subject attracted to the common element in its concrete setting appears at the very beginning of the process and continues to increase until the process is interrupted by the tests. A second important fact brought out by this figure is the shrinkage which takes place in the ability of the subjects to react to new cases when they pass over from where the common element is in red (pack VI) to the tests where there is no color to aid them. The shrinkage is not great but probably real. In fact it is exactly what one would expect. It recalls the marked discrepancy found between the ability to define (Experiment E, p. 43) and the ability to react to new cases, where the common element had been given outright. It probably results from a similar cause.

The results of the present experiment may be briefly formulated as follows:

1. There is a distinct advantage in evolving concepts from concrete cases in the simple-to-complex order where the attention of the subject is attracted to the essential common element *in situ,* over the normal simple-to-complex method.

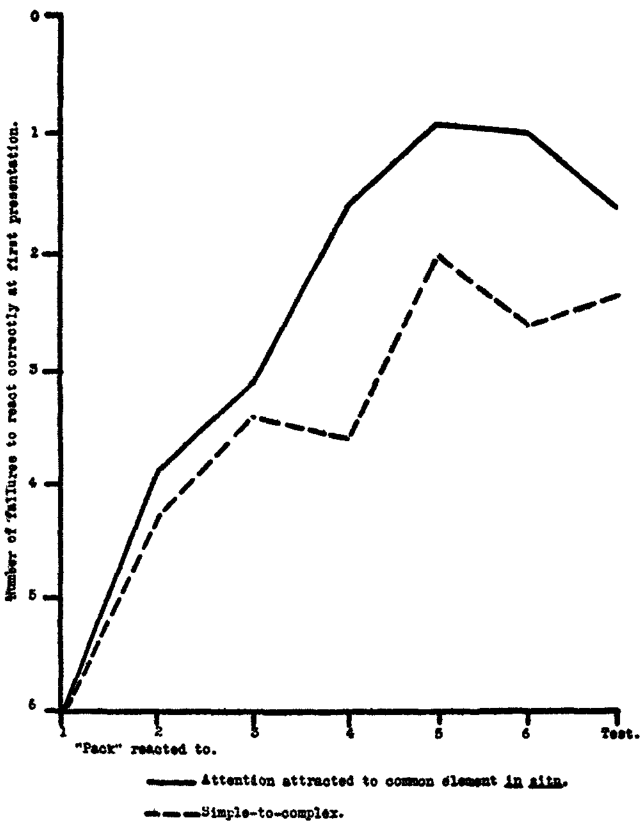


FIGURE VIII.—Showing the origin of the advantage of calling attention to the common element *in situ*, evolution series, Experiment G.

2. The advantage appears at the beginning of the process and increases continuously as far as it has been investigated.

3. There is a mild shrinkage in functional ability when the subject passes from the artificial material to normal experiences, but there still remains a substantial functional advantage in attracting attention to the common element while in its concrete setting.

As in previous chapters, the problem here investigated is only one of a group. What would be the effect of calling the subject's special attention to the red strokes as being the common element? Would the present method be improved by alternating it with normal concrete cases somewhat as in Experiment F? Would it be better in such a case to have the normal concrete case precede in the series, or follow, or both? Would the addition of the naked common element to the combination be an advantage or not? If so in what position would its advantage be greatest?

As pointed out at the end of the last chapter, the aim of the present study is attained if the general economy of the method is shown and an adequate technique indicated for the solution of the numerous problems of a related nature which it suggests.

VII

THE EFFICIENCY OF EVOLVING CONCEPTS AS A FUNCTION OF THE THOROUGHNESS OF FAMILIARITY WITH THE CONCRETE CASES

Experiment H

An important factor in all kinds of learning is the matter of thoroughness. Theorists have not been as specific in their treatment of this factor in relation to the evolution of concepts as upon some of the matters discussed in the previous chapters. There seems however to be quite a general belief that a thorough mastery of each concrete case involved in the evolutionary process will be specially conducive to efficiency in coping with new situations. This accordingly determines our problem: In the evolution of functional concepts, is it more economical to have an evolution series made up of six concrete cases each experienced moderately well, or to have half as many concrete cases each experienced twice as well?

Only a moderate variation of the general method used in the previous experiments was required in the present problem. The characters of the evolution series were rearranged so that all the "packs" were of presumably equal difficulty. This at the same time largely eliminated the simple-to-complex arrangement shown in Plate I. It was done in the following manner: If the numbers from one to six represent increasing complexities of the characters as arranged, e.g. in Series A, Plate I, the new arrangement may be conveniently represented in the following table:

	Pack I	Pack II	Pack III	Pack IV	Pack V	Pack VI
Series A	1	2	3	4	5	6
" B	2	3	4	5	6	1
" C	3	4	5	6	1	2
" D	4	5	6	1	2	3
" E	5	6	1	2	3	4
" F	6	1	2	3	4	5

A glance at the table shows that every "pack" contains one character of each of the six grades of complexity and that all are consequently of approximately equal difficulty. The other six evolution series (G to L), were rearranged in an exactly similar manner.

A second modification of the technique previously used was to make the characters in "packs" I, III and V do double service. The characters of each of these "packs" were learned as normally but also a second time in place of the characters normal to the "pack" following—II, IV and VI respectively. That is, the characters normal to "pack" I would be used both in "packs" I and II, characters normal to "pack" III would be used both in "packs" III and IV, characters normal to "pack" V would appear both in "packs" V and VI. The characters normal to "packs" II, IV, and VI of course did not appear at all. A uniform time of nine exposures was given to each "pack." Thus in evolution series G to L, 54 exposures were equally divided among six concrete cases while in series A to F, 54 exposures were equally divided among *three* concrete cases. In the first case 9 exposures were given to each concrete case which we shall regard as "moderate" familiarity, while in the second case 18 exposures or twice as many are given to each concrete case, which is regarded as "thorough" familiarity.

As usual in order to equalize any possible difference in the difficulty between the two groups of concept series, the process was reversed with half of the subjects. In this case G to L became the "thorough" series and A to F the "moderate" series. In order to equalize any difference in difficulty existent between the characters included in the "thorough" series and those excluded from it, with part of each group of subjects, the characters of "packs" II, IV and VI did double service, those of "packs" I, III, and V being excluded in this case.

The subjects in this experiment were scholarship students from the University High School. They ranged from 13 to 18 years of age.

The tests revealed a small but fairly consistent advantage in favor of the method of "moderate" familiarity. The results are

TABLE XVII

Showing the relative efficiency on the tests of the methods of evolving concepts respectively by "moderate" and "thorough" familiarity with the concrete cases, Experiment H.

Subject	"Thorough" method in:	In "thorough" method, characters used from "packs":	Failures to react on the tests out of a possible total of 108. "Moderate" method	"Thorough" method	Advantage of "moderate"
Hug.	Series A to F	I, III, V	61	76	+15
McC.	" " " "	" " "	59	60	+ 1
Hay.	" " " "	" " "	95	94	− 1
H. S.	" " " "	II, IV, VI	88	74	−14
Cal.	" " " "	" " "	55	83	+28
Fit.	Series G to L	I, III, V	56	71	+15
Eps.	" " " "	" " "	68	72	+ 4
Pag.	" " " "	" " "	35	77	+42
L. S.	" " " "	II, IV, VI	28	69	+41
Don.	" " " "	" " "	77	89	+12
Average			62.2	76.5	+14.3[1]
M. V.					13.9
S. D.					17.3

[1] A computation of the "unreliability" of this average shows that there is only about one chance in 220 that the true advantage for the "moderate" method would be less than zero.

shown in detail in Table XVII. Eight of the ten subjects gave a more or less decided advantage for the "moderate" method. All the subjects taken together give for the "moderate" method an average of 62.2 failures to react correctly out of a possible 108, while the "thorough" method shows an average of 76.5 failures, a difference of 14.3 points in favor of the "moderate" method.

The conditions of the experiment permit us to secure a limited view of the origin of this difference throughout the evolution series. Table XVIII shows in detail the number of failures to react at the first presentation of the various "packs." It will of course be noted that the scores in "packs" II, IV and VI of the "thorough" series are not significant because each character involved has been experienced nine times in the previous "pack" though in a different order. This accounts for the extremely small number of failures in each of these "packs." Their non-significant nature is therefore indicated by inclosing them in parentheses.

The final significant averages of the two methods are shown graphically in Figure IX. It is evident that the advantage of the "moderate" method is not a temporary matter but dates from the very beginning of the process. A second feature of interest in Figure IX is the fact that the lower or thorough curve shows

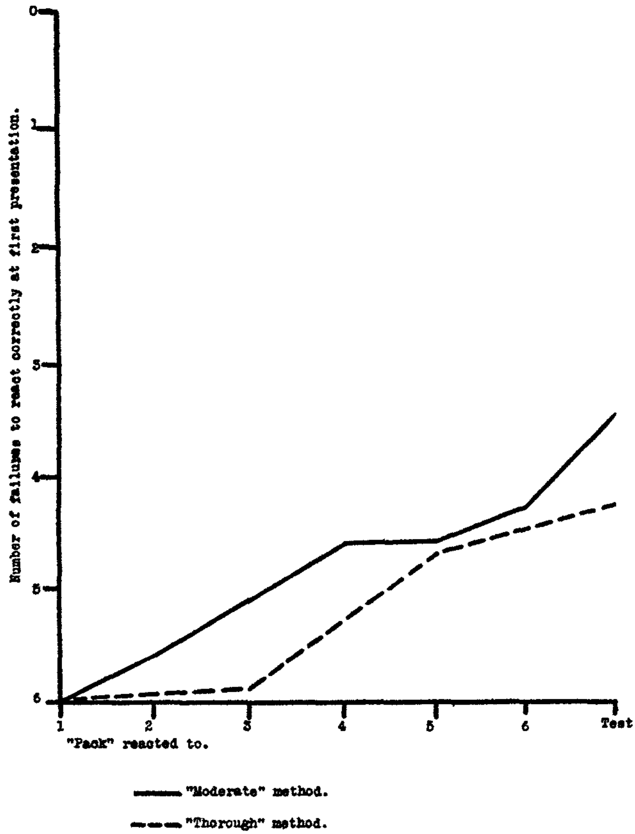


FIGURE IX.—Showing the origin of the advantage of the "moderate" method over the "thorough" method, evolution series, Experiment H.

almost no rise whatever at "pack" III after a total of eighteen exposures. This is much less than might be expected from only nine or half as many exposures. It suggests that at this stage of the process, the additional nine exposures did more harm than good, at least in terms of immediate functional efficiency.

The results of Experiment H may be summarized as follows:

1. A moderate amount of time spent upon each of six concrete cases is perceptibly more efficient in the evolution of functional concepts than twice as much time spent upon each of three concrete cases.

TABLE XVIII

Showing the comparative functional efficiency of "moderate" vs. "thorough" familiarity in reacting to the "packs" of the evolution series at first presentation, Experiment H.

The number of failures to react correctly at first presentation of "packs".

Subject	"Thorough" method in Series:	"Moderate" method I	II	III	IV	V	VI	"Thorough" method I	II	III	IV	V	VI
Hug.	A to F	6	5	3	6	6	4	6	(2)	6	(4)	6	(1)
McC.	" " "	6	6	6	5	5	5	6	(4)	6	(0)	3	(0)
Hag.	" " "	6	6	6	5	6	6	6	(5)	6	(2)	5	(4)
H. S.	" " "	6	6	6	5	5	5	6	(5)	6	(1)	6	(0)
Cal.	" " "	6	6	4	2	3	4	6	(3)	6	(0)	5	(1)
Fit.	G to L	6	6	5	4	4	4	6	(5)	6	(1)	5	(2)
Eps.	" " "	6	5	5	5	5	5	6	(4)	5	(1)	5	(1)
Pag.	" " "	6	6	5	4	4	4	6	(3)	6	(2)	4	(1)
L. S.	" " "	6	4	5	4	3	2	6	(3)	6	(0)	4	(0)
Dan.	" " "	6	6	6	6	5	4	6	(4)	6	(4)	4	(1)
Average		6.0	5.6	5.1	4.6	4.6	4.3	6.0	(3.8)	5.9	(1.5)	4.7	(1.1)

2. This superiority appears at the outset and is maintained at least through the first third of the process, as far as investigated in the present experiment.

One or two critical observations may be made at this point. In varying the thoroughness of familiarity, we have also varied the number of cases. Does this introduce the uncertainty of interpretation due to two variables? While interesting from the standpoint of logical theory, the objection is of no practical importance because the two "variables" are so rigidly related that they act essentially as a single factor.

Of more importance is the question as to why the "thorough" method should prove less efficient? The reason seems to be that the eighteen exposures of the "thorough" method carried the process of generalizing abstraction as regards the individual concrete example, farther into the region of "diminishing returns" than the nine exposures of the "moderate" method. This raises the farther question as to how early in the experience with a given concrete example, the period of "diminishing returns" sets in. Or more generally, what is the curve of the contribution of a single concrete example to generalizing abstraction, in terms of time? The writer ventures a guess that it may rise rapidly to a maximum very early after which there may be a protracted period of "diminishing returns" which may even pass into a negative value. No doubt this may differ with different material and possibly with different individuals. If the maximum is reached before the ninth exposure, the "moderate" method will triumph. If it is reached during the second nine exposures, the "thorough" method must win. This suggests a number of important problems for future investigation.

VIII

THE EVOLUTION OF FUNCTIONAL CONCEPTS AS RELATED TO THREE TYPES OF ABNORMAL MENTALITY

EXPERIMENT I

In the search for quantitative individual differences in the mode of evolving concepts, two general lines of procedure are open. One is to compare the performances of various normal individuals with one another and note the differences. A second way is to compare the performances of minds known to be characteristically different from the normal and from one another. The latter method was adopted in the present experiment as most likely to reveal striking individual differences if such exist. It was hoped that an experiment of this kind in which several of the higher mental processes could be conveniently measured without seriously disturbing the others, might throw some light both upon the process of generalizing abstraction on the one hand, and upon the state of some of the higher mental processes among characteristic types of insanity, on the other. The types of mental abnormality selected for the purpose were (1) constitutional inferiority, (2) dementia precox and (3) paresis.

The method employed requires little comment. It was essentially the same as that used in Experiment A (p. 9 ff.). The only exception was that in order to secure incidentally a measure of the power of retention, one week was interposed between perfecting the reaction to "pack" I and beginning work on "pack" II. At the end of the week and just before beginning work on "pack" II, a test was made to see how many of the characters of "pack" I were still retained. After this they were relearned until the score had reached the same excellence as when work was stopped a week previously i.e., a perfect score on two successive revolutions of the drum. This was done both to secure an additional measure of the retentiveness and to bring the mind into a state approximately similar to that when the work was interrupted a week previously.

Eight subjects were used in the experiment. They consisted of three constitutional inferiors, three dementia precox and two paretics.[1] They were all patients of the Wisconsin State Hospital for the Insane, at Mendota, Wisconsin. They were very carefully selected from a group of over eighty individuals who had been previously experimented on at some length in an effort to adapt the Binet-Simon tests to the determination of the extent of intellectual degeneration among the insane. The eight selected from the larger group for the present experiment were chosen upon a joint basis of tractability under experimental conditions, of furnishing relatively clear types of their respective diseases, and of an approximately equal intellectual level. The latter was determined by the very careful mental tests to which they had been subjected. The level chosen was roughly the ability to pass from thirty-five to forty of the Binet tests (Goddard's revision). Upon trial it was found impossible for paretics of this grade of general intelligence to learn the reactions required by the experiment, so a new group of paretics was secured having an intellectual ability sufficient to pass from forty-eight to fifty of the tests.[2]

The patients had all become more or less accustomed to examinations from those ordinarily given by the hospital physicians. Through having received the Binet tests, they had also become fairly accustomed to the writer in an experimental capacity. He frequently met them in the wards and in general cultivated easy friendly relations with them. All appeared to coöperate very willingly in the experiment and showed a distinct interest in its progress. The experiments were carried out in an ordinary patient's room in one of the quietest wards of the hospital. The size and lighting of the room and the position of the apparatus were very similar to those of the psychological laboratory pre-

[1] Brief case histories of these patients are given in Amer. J. of Psychol., Vol. XXVIII, pp. 419-435. A third paretic was included in the original plan, but he proved to be a poor subject and was finally excused.

[2] 51 was found to be the median number of tests passed by normal adults of about the same age and station of life. The so-called "wide range" method of testing was employed.

viously described (p. 21). Especially frequent rest periods were given the subjects to prevent fatigue.

The results in general show the insane to be distinctly inferior to normals in the formation of associations and in generalizing abstraction, but apparently fully equal in retentiveness of association once they are formed. The data concerning the formation and retention of associations with these subjects has been fully discussed elsewhere (*3*).[3] The performance of the abnormals on the tests is shown in Table XIX. The normal subjects with whom they may be compared most appropriately are those of Experiment A. The corresponding data for these latter subjects has been given (though in a divided form) in Table I (p. 23). The average of all the abnormals is 127.4 failures to react out of a possible 216 as against 74.3 for the normal subjects. Two abnormal subjects reach the mean of the normals but no normal subject does as badly as the mean of the abnormal subjects.

The superiority of the normals appears much more striking when the amount of time required to produce the respective scores is taken into consideration. This is shown in detail for the abnormal subjects in Table XX. The final averages for the normals of Experiment A have already been given on p. 30. The two sets of averages are shown graphically in Figure X. There

TABLE XIX

Showing the grade of intelligence and the number of failures to react successfully on the tests, out of a possible 216, Abnormal subjects, Experiment I.

Subject	Type of abnormality	No. Binet tests passed	No. failures to react successfully on tests
Bur.	const. inferior	37	73
Sch.	" "	38	146
Syg.	" "	35	135
Don.	dementia precox	37.5	118
Jack.	" "	40	130
Jaco.	" "	47.5	75
Har.	paresis	48	159
Sau.	"	50	183
Average			127.4

[3] In addition, the fluctuations at the threshold of recall was found to be about twice as profound with the insane as with normals.

it appears at a glance that the time consumed by the abnormals particularly in perfecting the reaction to "pack" I is many times that of the normals. The total time spent by the abnormals is nearly four times as great as that spent by the normals. The single figure expressing the ultimate efficiency of the two groups

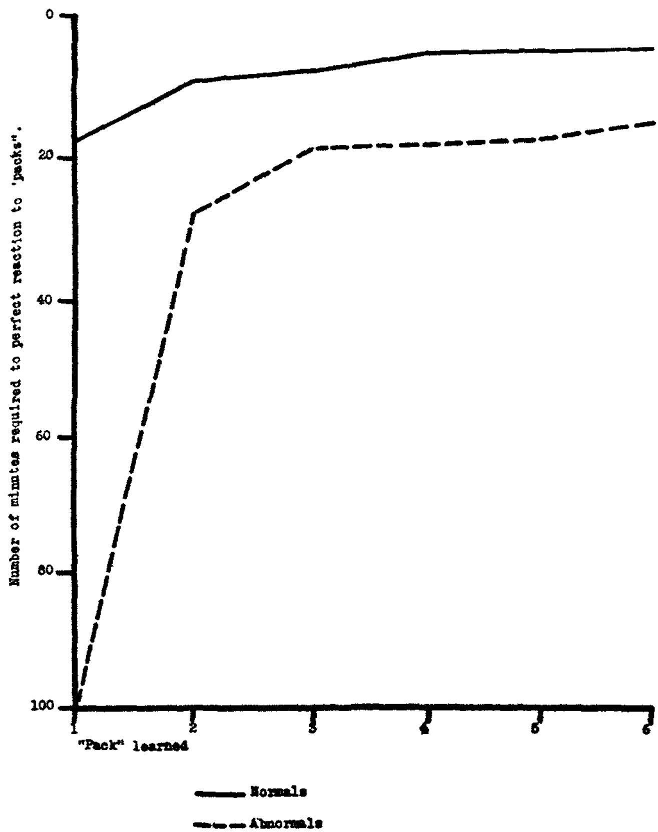


FIGURE X.—Showing the number of minutes required by the normals and the abnormals respectively in perfecting the various reactions, evolution series, Experiment I.

of subjects is the number of successful reactions on the tests per unit time spent on the evolution series. It is:

Abnormals	.45	successes per minute spent.
Normals	2.81	" " " "

or over six times as great for the normals as the abnormals.

Disregarding the differences in amount of time consumed, the number of failures to react successfully at the first presentation

TABLE XX

Showing the number of minutes required by each abnormal subject to perfect the reaction to each of the "packs" of the evolution series.

	Minutes per "pack"					
Subject	I	II	III	IV	V	VI
Bur.	89	29	7	7	9	14
Sch.	170	38	17	17	16	18
Syg.	72	18	11	13	7	12
Don.	45	12	7	7	11	8
Jack.	52	31	43	34	15	14
Jaco.	39	15	8	7	9	7
Har.	200	42	28	25	27	19
Sau.	150	32	23	25	41	22
Average	102	27	18	17	17	14.3

of the successive evolution "packs" offers us a convenient indication of the origin of the differences in efficiency found between the two groups of subjects. These data for the abnormals is

TABLE XXI

Showing the number of failures to react successfully at the first presentation of the evolution "packs," Abnormal subjects, Experiment I.

Subject	"pack" I	"pack" II	"pack" III	"pack" IV	"pack" V	"pack" VI
Bur.	12.0	12.0	4.5	3.0	4.5	4.0
Sch.	12.0	10.0	8.5	10.0	8.0	10.0
Syg.	12.0	10.5	9.0	9.5	8.0	9.5
Don.	12.0	8.0	7.0	8.0	5.5	6.0
Jack.	12.0	11.0	10.0	8.0	10.5	8.5
Jaco.	12.0	7.0	7.0	5.5	4.5	5.0
Har.	12.0	10.5	11.0	9.0	9.5	9.0
Sau.	12.0	12.0	12.0	11.0	12.0	10.0
Average.	12.0	10.1	8.6	8.0	7.75	7.6

given in Table XXI. Corresponding data for the normal subjects of Experiment A are given in Table II though in a slightly different form. The corresponding averages for the normals computed from Table II are:

"pack" I	"pack" II	"pack" III	"pack" IV	"pack" V	"pack" VI	test
12	8.7	7.6	6.3	5.5	5.0	4.1

The two sets of averages are shown in Figure XI. From these curves it is evident that the abnormals follow the same general

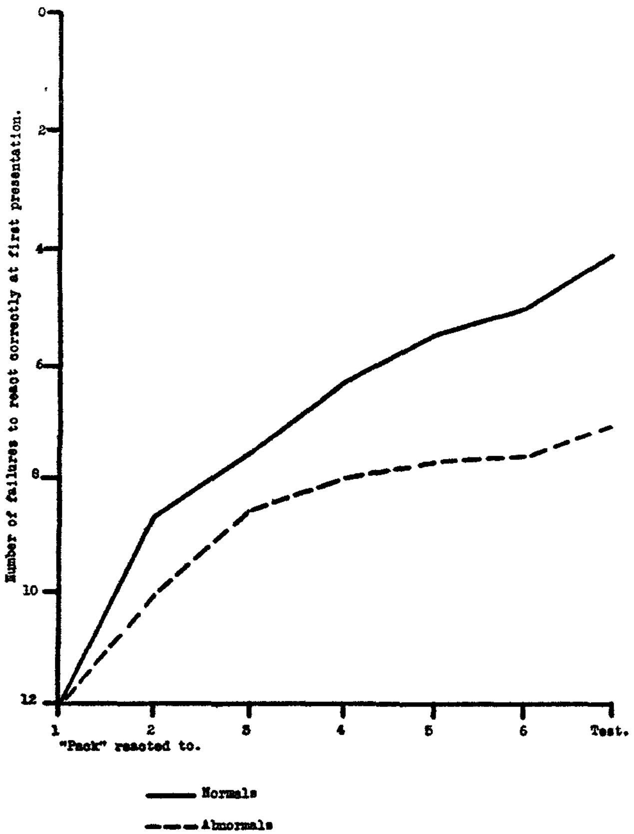


FIGURE XI.—Showing the origin of the advantage of the normals over the abnormals, evolution series, Experiment I.

course of improvement as the normals but from the very beginning there is a continuous and uniform divergence of the two curves, the normals steadily outstripping the insane.

At the conclusion of the tests the insane subjects were requested to draw on a suitable blank their idea of what a character must be in order to be called by the various names. Only a few scrawls were obtained. In general there appeared an almost total inability to define in this sense. Results obtained from normals in the previous experiments indicate in a general way that this may be one of the most striking and significant differences existing between normals and the "insane." No particular difference in this respect was discernible among the various types of abnormals included in the present study.

The results of the present experiment may be briefly formulated as follows:

1. Constitutional inferiors, dementia precox and paretics show a great disturbance in the power to form association. This disturbance is distinctly more marked with the paretics than with the other two groups.

2. Once associations are formed, however, the three types of abnormals appear to retain them as well as normals.

3. The average rate of evolving functional concepts is only about one-sixth as rapid for the abnormal group as for the normal group. The advantage of the normals appears at the beginning of the process and increases continuously as far as the experiment carries it.

4. There is an almost total lack in the abnormal group of ability to define the concept by drawing, whereas the normals ordinarily show considerable ability at about the same stage of the evolutionary process.

Of the above four conclusions, the first probably depends largely on faulty attention. If one may judge from the actions of the subjects however, there was no lack of attention in the sense of effort or will to attend. The second probably reflects a physiological condition of stability of the synaptic connections. The slow rate of evolving concepts is probably largely a function of the slow rate of forming associations though this does not account for all of it, since the disturbance is considerably greater in the former than the latter. The practical inability to define concepts which have a proven functional efficiency as contrasted with normal subjects, may be related to the great role which the subconscious plays in the abnormal mind. This last point offers perhaps the most fruitful suggestion for a future investigation.

IX

THE RELATIVE RATE OF EVOLUTION OF FUNCTIONAL CONCEPTS AT THE SEVERAL STAGES OF THE EVOLUTIONARY PROCESS

Practice-curves for various kinds of learning have long occupied the attention of experimental psychologists. The form characteristic of ordinary associative learning is well known (*5*, 575). Relatively little is known however of the characteristic course of the more complex forms of learning. A recent writer indeed found it necessary to conjecture as to the probable form of the curve for analytical learning (*15*, II, 344). It therefore becomes desirable to determine the curve for generalizing abstraction as one of the most characteristic of the more complex learning-processes. A number of lines of evidence converge upon this problem.

In the previous chapters we have shown numerous curves which purport to represent quantitatively the course of generalizing abstraction. It is obvious that for our present purpose the curve must be plotted strictly on a basis of time spent in the process. None but Figures V and VI fulfil these conditions. Owing to the peculiarities of the material employed, a composite curve from each figure suits our present purpose better. The two curves thus obtained are shown in Figure XII. In addition the curves from Figures I and III may be reduced to approximately similar conditions, in which case they resemble very closely those shown in Figure XII. So far as they go, these curves present no obvious difference from the conventional practice curve for ordinary associative learning.

Experiment J

A preliminary experiment designed only partly for the present purpose has an indirect bearing upon the problem. The characters in the column marked "Evolution Series" in Plate III were

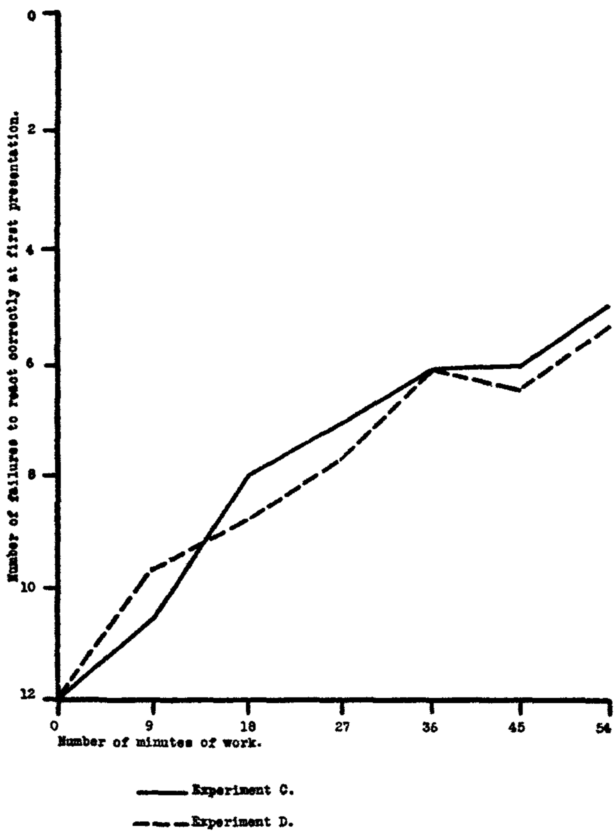
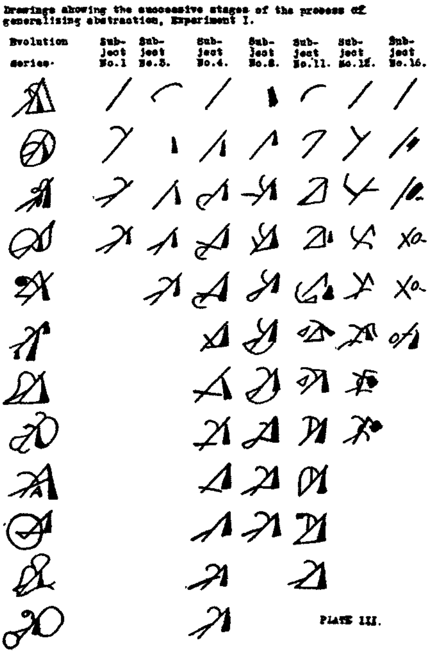


FIGURE XII.—Curves of generalizing abstraction, evolution series, Experiments C and D.

exposed to subjects in an endless series for periods of two seconds each with a blank period of two seconds between exposures. The subject was directed to find the strokes common to the various characters as quickly as possible. When he thought he had found anything, the apparatus was stopped upon the following blank space, and the subject drew what he believed he had found. The exposures were then resumed until he thought he had made another discovery when a new and more perfect drawing was made. Record was made of the number of exposures between successive drawings. A simple practice-experiment was given as a preliminary, the results of which were discarded. Sixteen Normal School students acted as subjects.



Characteristic results of the experiment are shown in Plate III. The average of all the subjects shows that it took 14 exposures to make the first discovery, 45 more to make the second discovery, 111 more for the third and 187 more for the fourth. Clearly a longer and longer time is required for each successive discovery and the increase follows a very definite law. If the successive discoveries be assumed to have equal increments of difficulty, we may obtain from these figures a kind of curve of generalizing abstraction (Figure XIII).[1]

That this systematice increase in the time required to discover the successive strokes is primarily an expression of the mind doing the abstracting rather than of the difficulty of the characters, is shown by the fact that the characters are of a fairly uniform

[1] This curve is in no strict sense comparable with those of Figures XII and XIV.

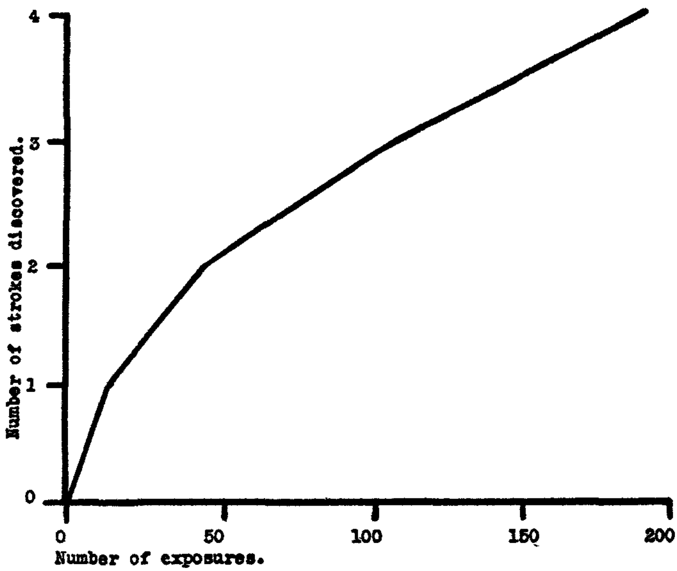


FIGURE XIII.—Curve of generalizing abstraction by the method of Experiment J.

gradation in difficulty. This in turn is shown by the distribution of variation in their order of discovery. (Table XXIII.)

TABLE XXIII

Showing the number of times that each stroke was discovered first, second, third and fourth respectively.

	1st.	2nd.	3rd.	4th.
Long diagonal stroke...............	10	6	0	0
Shaded stroke	4	6	3	3
Curved stroke	2	4	6	4
Short diagonal stroke..............	0	0	7	9

Moreover it is also clear from Table XXIII that the short diagonal stroke is, upon the whole, the most difficult one. It so happens that seven subjects discovered this stroke third, and discovered either the second or the third stroke last. Here then we have the inherent order of difficulty operating *against* the tendency in question. Yet these seven subjects give the following averages:

10, 22, 53, 86.

The tendency is still present showing clearly that the increased time required for each succeeding discovery is a function of the mind making the discovery.

Experiment K

The inadequacies of the above methods of securing a curve of generalizing abstraction are numerous. Experiment J obviously does not yield a functional measure. In addition it suffers from most of the disadvantages urged against the method of Fisher (p. 7). The method of Experiments A and D suffer from a distortion of the score owing to certain inequalities of the characters of the various "packs," the long intervals between measures, the small number of measures at each interval, the unfinished state of the curve and the necessary combination of many individual records into a single composite curve. To remedy these defects a new experiment was set up which involved the construction of an entirely new apparatus.

The new apparatus was built very much after the plan of the one used in the previous experiments. Instead of holding a small number of cards, the drum bore a long band which hung suspended from it and upon this an indefinitely large number of characters could be attached. The band of white oilcloth, two inches wide, was placed with the rough side toward the subject. Small spurs on one edge of the drum engaged eyelets in the band to insure accurate movements. The characters of Plate I were photographed, printed on a matt surface in exactly the same size as the originals and glued to the band at proper intervals. They were put on by "packs" in the order I to XII. The order of characters within each "pack" was determined by chance except that two characters by the same name should not be too close together at the joining of two consecutive "packs." The 144 characters required a band over twelve feet long. The apparatus was elevated so that the band when joined at the ends and suspended from the drum, just cleared the floor. A screen of gray cardboard was built in front of it. This had a small square hole cut just on a level with the subject's eyes so as to expose a single character. Suitable guides were provided to keep the characters close to the aperature and to prevent vibrations while being viewed. The shifts from one character to the next were practically instantaneous as in the previous experiments and the exposures were likewise five seconds each.

The subject was instructed to learn as quickly as possible the names of the characters which would appear at the "window," so that he could pronounce them at sight. He was told plainly that there were several "families" of characters, that the members of each "family" bore a certain family resemblance and also bore the same name.[2] It was explained that he would be prompted in the middle of each exposure, that he was to repeat the name when prompted, and that he was to attempt to name the characters for himself as soon as he had any indication as to what the name might be. It was pointed out that errors were not considered in the score but success only, and that on the long run reactions to even faint suggestions would materially improve the score. The results were recorded much as in the previous experiments only on a large special blank prepared for the purpose.

By the above technique, every one of the 144 characters was seen before the first was exposed a second time. This consumed twelve minutes of vigorous mental activity. It thus came about that when the characters began returning they were not recognized individually at all. Consequently very little or no learning of the individual characters took place and the improvement in the score was due almost entirely to the progress of generalizing abstraction. By taking the average score for a period of twelve minutes we have 144 judgments which gives us a very reliable indication of the status of the process for the period. The difficulty of the material from point to point on the curve is not only uniform but identical. We may carry the process to any desired degree of perfection. And we not only can secure a reliable curve of generalizing abstraction from a single person but also for any single one of the twelve individual concepts evolved by that person.

Eight subjects in all were used in the various forms of this experiment. Their records appear in Table XXIV. The first

[2] We here departed from our policy of avoiding deliberate abstraction in order to escape any unnecessary delay at the beginning of the learning which might of itself produce the "initial plateau," to be mentioned presently.

TABLE XXIV

Showing the average number of successful reactions per "pack" for each successive period, Experiment K.

Subject	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XV	XVI
Cha.	1/6	1 3/4	4 1/6	6 1/3	8	9 1/4	10	10 5/12	10 5/6	11	10 5/6	11 1/4				
Bes.	1/6	1 1/4	4	7 5/12	8	10 1/2	10 2/3	10 3/4	10 11/12	11 1/6	11 1/6	11 5/12	11 7/12			
Lap.	1/6	1	1 1/6	5/6	2/3	1	1 1/3	1 1/3	2 7/12	3	5 7/12	6 7/12	7 1/4	8 1/2	8 2/3	9
Kin.	1/3	1	2 2/3	5 1/3	8 1/3	8 5/6	10 1/3	11 2/3	11 5/6	12						
Pil.	1/6	1 1/6	3 1/2	4	6 5/6	8 1/3	8 5/6	9 1/2	9 1/6	9						
Wil.	1/6	5/6	5 1/3	7 1/2	10	11	10 1/2	11 2/3	11 2/3	11 2/3						
Coa.	2/3	1 1/6	2 1/4	4 1/6	6 2/3	9 1/6	8 5/6	9 1/2	9 5/6	9 5/6	10 2/3	10 1/2	10 2/3			
Pea.	1/6	1/3	2/3	2 1/3	2 1/3	3 1/3	5	5 1/3	6 1/2	7 1/6	8 1/6					

four subjects did the experiment exactly as described above. Subject Pil. did it the same except that drawings and introspections were taken at frequent intervals. Subject Wil. had a practice experiment on some other material of the same type before making the present record. The last two subjects (Coa. and Pea.), did the experiment using only the first 72 of the characters used with the others, i.e. only the characters of "packs" I to VI. In this case the characters were somewhat smaller than the originals, they were glossy, and the subjects were not told anything about the "family" resemblances. The results for the first three subjects are by 12-minute periods, for the rest by six-minute periods. Three characteristic curves from this table are shown in Figure XIV.

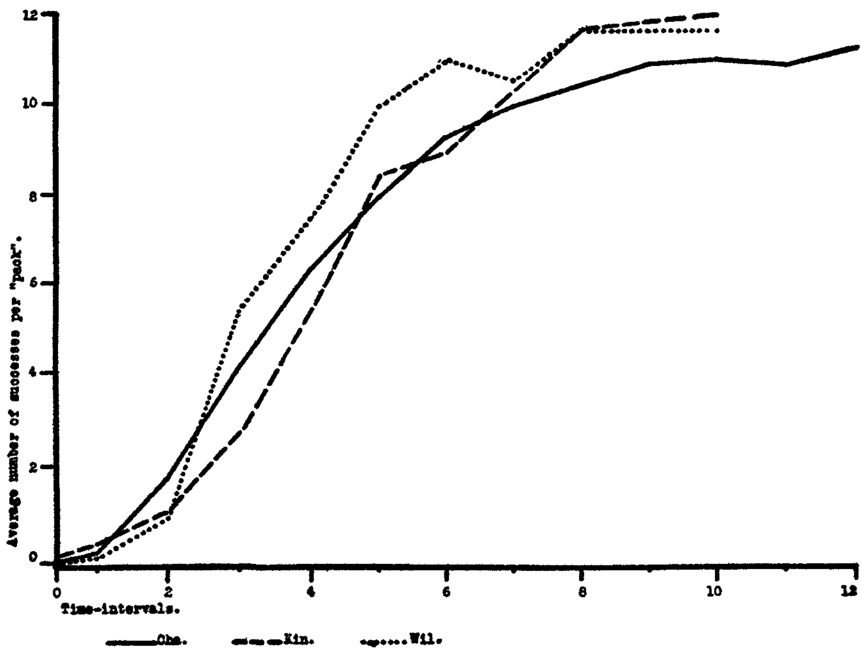


FIGURE XIV.—Showing typical (composite) curves of generalizing abstraction, Experiment K. Time-intervals for subject Cha. were twelve minutes; those for the others, six minutes.

Even to a casual observation these curves present a marked contrast to the curves hitherto examined, as well as to the conventional curves of learning. Without exception all eight subjects begin with a period of slow learning which increases rapidly until at an efficiency near one-fourth it reaches a maximum. After this its rate gradually decreases until as perfection is approached its advance becomes very slow indeed. It is also interesting to note what a variety of conditions yields this type of curve. It seems to matter not whether the subject knows at the beginning that he must isolate certain common elements, whether there has been preliminary practice, whether definitions are required, whether learning is fast or slow, or whether the curve is plotted by six or twelve minute periods. There is in all cases a brief initial plateau, then a rapid rise, followed by a protracted period of slower and slower learning.

But the ultimate curve of generalizing abstraction has not yet been reached. This is the curve of the evolution of a *single* concept. As suggested above, the flexibility of our technique enables us to secure this with ease by retabulating the data from which the figures of Table XXIV were secured. It will be remembered that the latter are really composite results from twelve individual concepts. The curves of individual concepts thus obtained, while showing characteristic differences from any found thus far, agree in the main with the curves which they make in combination. They differ in the more bold and striking manner of their emphasis of the peculiarities noted in the latter. In general the initial plateau tends to be more absolute, and when the break comes it is apt to be more abrupt. The period of diminishing returns is usually present but not in every case. Typical results from such a retabulation of the data for subject Cha. are shown in Figure XV (cf. the corresponding composite curve for this subject, Figure XIV).

Conclusions

We may formulate the results of our investigation of the curve of generalizing abstraction as follows:

1. The average functional improvement of a group of relatively homogeneous concepts all of which are evolved simultaneously, begins with an initial plateau or brief period of positive

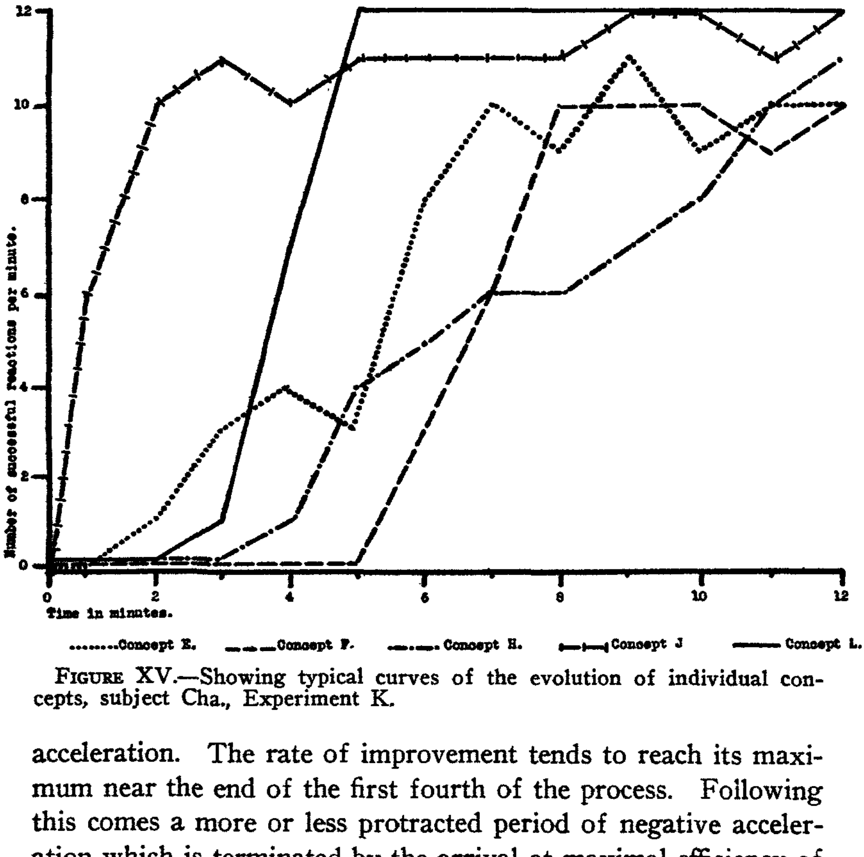


FIGURE XV.—Showing typical curves of the evolution of individual concepts, subject Cha., Experiment K.

acceleration. The rate of improvement tends to reach its maximum near the end of the first fourth of the process. Following this comes a more or less protracted period of negative acceleration which is terminated by the arrival at maximal efficiency of the concepts.

2. The functional improvement of the *individual* concept follows the same general course as the composite curve. The initial plateau is apt to be somewhat more protracted and absolute and the change from this to a period of rapid improvement tends to be much more abrupt (*13*, 51; *15*, II, 342 ff). The period of negative acceleration may be much abbreviated or entirely lacking, though with material of considerable difficulty it may be greatly extended.

The above statements clearly apply only to concepts evolved under conditions very similar to those of Experiment K. All methods agree as to the concluding period of diminishing returns. It is impossible to tell whether the initial plateau exists under the conditions of Experiments A to D. It probably could not appear in the results there even if it did, owing among other things to the fact that no point is located on the curve soon enough to show it. While both experiments duplicate important natural life processes, they are sufficiently different to make it unnecessary to assume the presence of the initial plateau in the latter process even if invariably present in the former.

The relative novelty of the initial plateau among learning curves makes it of interest to speculate as to its cause. The most probable explanation seems to be that in the compound process of generalizing-abstraction (*12*, 8) the abstraction (seeing the object in parts) must take place to a certain extent before generalization can begin[3] and that the score reflects only the progress of the latter process. Trial and error would also undoubtedly contribute to the same end.

The period of diminishing returns probably results from a multiplicity of causes. One is that chance hits upon significant elements must grow progressively less as the undiscovered significant elements grow less. A second factor is probably that when a concept is evolved to the extent of affording means for coping with some of the new situations presenting themselves, effort will largely cease on the successful occasions, which will progressively diminish the total amount of effort given to the process.

[3] This is indicated by a number of introspections obtained at the end of the process in our experiments. See Moore, op. cit., p. 120.

X

QUALITATIVE ASPECTS OF THE EVOLUTION OF CONCEPTS

Experiment L

We have already seen as an incidental product of Experiment I, (Plate III), what might be called serial cross sections of the concept throughout its process of evolution. The limitations of that form of experimentation have been pointed out. It was thought desirable therefore to secure similar cross sectional views from a more normal process of concept evolution. A very convenient means was immediately at hand in the technique used in the experiments described in the past chapters, particularly Experiments B and K.

In the first part of the present experiment the general technique of Experiment B was followed. But instead of limiting the evolution series to six "packs" as previously, it was extended to include all twelve "packs" (Plate I). At the conclusion of the learning of the second "pack," the subject was given a blank containing the names of the various concepts and asked to draw with as much care as possible, the strokes which a character must have in order to be called by the respective names. Four university students served as subjects in this part of the experiment. A typical series of such drawings are shown in Plate IV. Two other subjects repeated the experiment according to the general technique of Experiment K. They were called on for drawings usually every six minutes throughout the process. No difference was discernable between the drawings obtained by the two latter methods despite the differences in the form of their respective curves of learning.

In examining the drawings obtained for all three methods perhaps the most striking characteristic is the extremely gradual way in which the concepts come into existence. This is particularly true of the concepts evolved by the more natural methods (Plate

PLATE IV.—Showing serial cross sections of the evolution of twelve concepts in parallel, Experiment L.

IV). It is true that in some cases (Series D) where the common element is very simple, it may be almost or quite perfect at its first appearance. In such cases however it is apt to be accompanied by certain excess or non-essential characteristics. But again where the common element is seemingly very simple it may come to consciousness only in the most halting and gradual manner (Series C). The evolution of a rather complicated concept is shown in Series F and perhaps even better, by Series H.

A second interesting characteristic shown by this investigation is a tendency to transmute an essentially erroneous first notion of a concept by almost imperceptible degrees into its true form. This also is admirably illustrated by Series H, and many other examples are scattered through the records of the various subjects. The subsequent transformations are not unlike the transformations which the common philosophical and religious concepts have undergone in the history of thought.

The third and most important fact which emerges from the examination of the cross-sectional views of the concepts in the course of evolution is the enormous role of "trial and error" in the process (*9*, 80). This appears clearly by all three methods. It is shown in an objective way by the continual appearance of false strokes which disappear again after a more or less protracted existence. This objective evidence is confirmed in a certain sense by introspective accounts given by the subjects at the conclusion of the process. The present writer is strongly of the opinion however, that this *conscious* trial and error so revealed is largely spurious. It is believed that this deliberate seeking of the common element which appears in a gross way in the work of Moore, Grünbaum, Fisher, in our own Experiment J, somewhat less in Experiment K and to a slight extent in the other experiments, is largely an artifact resulting from experimental technique, so far as the *spontaneous* process of generalizing abstraction is concerned. The following brief analysis of certain inner aspects of the process may serve to make clear our notion of the real nature of the trial and error element.

1. Let us suppose that we have a concept evolution series in which each case is experienced until the reaction is perfected before passing on to the next. Let the various characteristics of the first situation be represented by the letters *a, b, c, d* and the required reaction by *m*. Now in perfecting the reaction, associative bonds must be set up between *m* and the situation *a b c d*. Certain parts of the situation will become focal in consciousness because they have greater attention values than other parts. Let *a* be the focal characteristic, *b* the secondary characteristic, *c* and *d* marginal characteristics. Accordingly a major bond will extend from *a* to *m*, a secondary bond from *b* to *m*, and minimal bonds from *c* to *m* and from *d* to *m*. But since there is nothing to indicate which characteristics of the situation are the really significant ones, the distribution of the various bonds must be largely a matter of chance.

2. At the next situation which requires the reaction *m*, the result will vary greatly according to whether the significant element in the *m*-series, turns out to be *a, b* or *c*. Suppose it is *a*. Then we may represent the new case by *a e f g*. In this case

the major bond from *a* to *m* will function, the reaction *m* will take place more or less promptly, and the bond from *a* to *m* will be strengthened by use. The process in this case is most simple. The chance trial has proven a success.

3. The opposite extreme is found where the significant element of the *m*-series turns out to be *c*. In this case we may represent the new situation by *c e f g*. The bond from *c* to *m* is subliminal. Associations must therefore be established between *m* and *c e f g* before the reaction can be perfected. No doubt the process will be somewhat complicated by the previous set of major bonds leading to *m*, which may be expected to have certain inhibiting influences upon the formation of other bonds (5, 580). But as before the bonds when finally formed may be expected to consist of one major bond and other bonds of rapidly decreasing strengths. Again also the attention values of the various characteristics of the new situation will be the dominating factors in determining the strength of the various bonds. But will the attention values be purely chance in this second case? It seems likely that they will not be entirely so. The bond from *c* to *m* even though subliminal may reasonably be expected to have a certain amount of tendency to attract attention to *c*. Obviously the stronger the original bond between *c* and *m*, the greater will be this tendency. Such an action if real, would greatly facilitate the process.

If the bond between *c* and *m* in the second case is still subliminal after the reaction is perfected, the process must be repeated until the subliminal bonds accumulate and become liminal, providing chance does not step in to suddenly shorten the process by putting *c* into a position of special attentional advantage.

4. Once more let us suppose that *c* is the significant element of the *m*-series in the first situation, and that the second situation is *a o h i*, *o* being here the significant element and requiring the *p*-reaction. The major bond $a \rightarrow m$ formed in the first situation will produce the false reaction *m*, with attendant unpleasantness and tendency to weaken the bond. In case a bond $o \rightarrow p$ has also been previously formed, a rivalry will ensue between the reactions *m* and *p*, with strong tendencies to mutual inhibition. The ex-

perimental results indicate that often a prolonged alternation of the two reactions will develop, the *m*-reaction each time resulting in unpleasantness. At length it will give place to the *p*-reaction, though often with unexpected relapses.

5. A third situation appears where the major bond is still between *m* and the irrelevant *a*, and where the new case contains both *a* and *c*, as *a c e f*. Here *a* will produce the reaction *m*, *accidentally* correct, and the spurious bond from *a* to *m* will be strengthened by use as in (2). Sooner or later it must of course encounter situations like (3) and (4) in which the $a \rightarrow m$ bond must be destroyed. The difficulties and inhibitions there described presumably will then take place in an aggravated form.

There thus appears a large element of trial and error in the process but not in the conscious or deliberate sense that this expression is often understood.

XI

SUMMARY

We may now briefly summarize the results obtained by the various experiments described in the preceding pages.

1. Evolving concepts by proceeding from the simple to the complex in the evolution series yields a substantial advantage over proceeding from the complex to the simple, where the activity in each succeeding case is continued until the reaction is just established. But by this method much more time is spent upon the simple cases of the simple-to-complex method than upon the corresponding cases of the complex-to-simple method. When the disproportion is partially reduced, the advantage of the simple-to-complex method is somewhat decreased; and when the disproportion is completely eliminated, the advantage of the simple-to-complex method is completely eliminated also. This fact, together with the shape of the two curves throughout the evolutionary process, indicates that the simpler characters are much more efficient in the evolution of concepts than the complex ones. There appears to be no advantage in the simple-to-complex order merely as such.

2. Concepts given to the subject directly, the common element concerned never being experienced in its concrete setting, shows about the same functional efficiency as concepts evolved from the concrete. The ability to define however is about twice as great with the former method. The power to define is thus in some cases at least a very inadequate index of the functional value of a concept.

3. A combination of abstract presentation and concrete examples yields a distinctly greater functional efficiency than either method alone.

4. During the evolution of concepts, mildly attracting attention to the common element *in situ* considerably increases the efficiency of the process. The increase is continuous from the

beginning of the process as far as it was investigated. But when the transition is made from the artificial evolution-material to that of the normal test-material the advantage is perceptibly decreased.

5. Moderate familiarity with each member of an evolution series comprising a number of concrete cases is perceptibly more efficient than twice as thorough familiarity with half as many cases. This advantage appears at the very beginning and persists at least through the first third of the process, i.e. as far as investigated.

6. Constitutional inferiors, dementia precox subjects and peretics average only about one sixth as rapid progress in evolving functional concepts as normals. The ability to define the concepts was very much poorer than that of the normals of the same functional level, it being almost totally lacking. The ability to form associations was greatly impaired, though associations once formed seem to be as permanent as with normals.

7. The curve of the evolution of concepts begins with an initial period of positive acceleration which goes on to a maximum rate after which a period of negative acceleration sets in which continues to the end of the process.

8. The individual concepts usually come into consciousness very gradually. Erroneous first impressions are either discarded or transmuted into the correct form by a continuous development. Trial and error plays, if not a dominating, at least a very great rôle in the process.

9. A considerable number of quantitative problems involved in the evolution of concepts may be conveniently investigated by slight modification of the general technique employed with the various experiments described in the present study.

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