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# EXPERIMENTAL INVESTIGATION OF THE RELATION OF LANGUAGE TO TRANSPOSITION BEHAVIOR IN YOUNG CHILDREN

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## INTRODUCTION

The phenomenon of transposition in the discrimination behavior of animals and young children has received a considerable amount of attention from psychological theorists. The Gestalt psychologists, in particular, have made much of this ability of *Ss* to transfer a learned differential response, e.g., a response to the larger of two stimuli, to a new combination of stimulus objects differing in the same property (e.g., size), and they have cited it as conclusive evidence that the response was to the relative properties of the stimulus situation.

Relational theories of transposition, as has been pointed out by others (5, 27), fall into two groups. According to one type (1, 13, 15, 20, 22) the organism perceives the relationship between the training stimuli and employs this 'relational-perception' in responding differentially to the transposed stimulus situation. Thus, Kinnaman, the earliest investigator of this problem, wrote regarding the results in his brightness experiment with monkeys: "It would appear then that if the monkey managed to choose with measurable correctness, he very likely had a general notion of a low order which might be represented by *food-always-in-the-lighter*" (15, p. 143).

The second type of relational theory conceives of the organism as responding differentially to the training stimuli as a stimulus whole. The formulations of Köhler (17, 18), and Gulliksen and Wolfle (5) fall

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into this category. Thus, Köhler, in explaining his brightness experiments, stresses the 'togetherness' of the stimuli, recognizing that this togetherness may occur independently either as *color-wholes* or as *perceived color-relations*. He regards the two processes as distinct but their functions as similar, and so he chooses to ignore the differences. In either case, the colors (brightnesses) are assumed to attain an 'inner union' in which their role "depends not upon their absolute qualities, but upon their places in the system they compose. If their places with respect to each other are held constant, but a variation is made in their absolute quality, the Gestalt and the perceived relationship will be transposed" (17, p. 221). The occurrence of transposition is then regarded as evidence of such a configural response.

Köhler has made no further attempt to elaborate his theory so as to explain the occurrences of failure of transposition which have been found under a number of experimental conditions. A configuration theory more adequate in this respect is the recent one of Gulliksen and Wolfle (5). They conceive of the animal in the discrimination situation as responding directionally to the total stimulus configuration consisting of the stimuli varying in a single dimension and presented simultaneously in a given spatial order. Thus, in the two-choice size discrimination situation, the animal learns to respond differentially (left or right) to the two configurations, small on left and large on right, small on right and large on left. They assume, further, the operation of the law of effect and generalization of the effects of the learning on the training-stimulus configuration to similar configurations. On the basis of this theoretical schema, these writers were able to deduce a number of implications which are in agreement with existing experimental data. An outstanding exception is the failure of the theory to deduce one of the most well established experimental findings concerning transposition—the tendency for it to decrease as the distance between the training and test stimuli is increased.

Contrasting sharply with these two types of relational theories of transposition phenomena is the stimulus-response theory suggested by Spence (23, 24, 25, 26). Based on principles derived from experimental studies of conditioning, his theory represents an extension of an earlier theoretical treatment of the nature of discrimination learning in animals. According to this latter formulation, discrimination learning is a cumulative process in which reinforcement strengthens the excitatory tendency or association of the positive stimulus cue to the response of approaching it as compared with the response of approaching the negative stimulus cue which receives only non-reinforcement, hence developing an opposing inhibitory tendency.

When the difference between the excitatory strengths of the two cue aspects is sufficiently large, so as always to be greater than any differences in the excitatory strengths of other stimulus aspects that may happen to be allied in their response-evoking action with one or another of the cue stimuli on a particular trial, the *S* will consistently respond to the positive stimulus; in other words, he will have learned.

In extending the theory to the problem of transposition, Spence assumes that the excitatory tendency to respond to the positive cue aspect generalizes to other members of the stimulus dimension according to the exponential function $E = Ae^{-cX^d}$, where $X$ is the distance in logarithmic units between the positive stimulus and that stimulus point under consideration on the dimension. Similarly, the inhibitory tendency to respond to the negative cue aspect is assumed to generalize to other members of the stimulus dimension according to the function $I = Be^{-kX^d}$, $X$ being the distance in logarithmic units

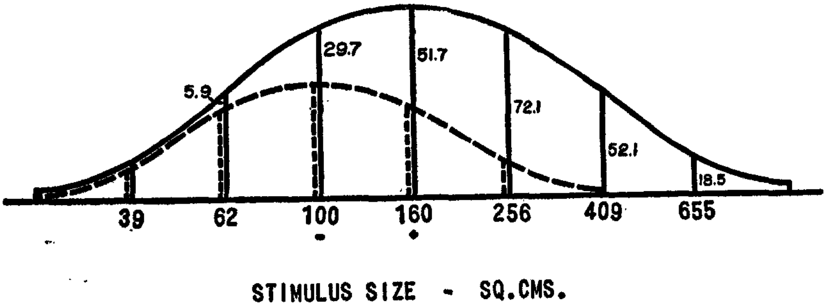


FIG. 1. Diagrammatic representation of the relations between the hypothetical generalization curves, positive and negative, after training on the stimulus combination 160(+) and 100 (−)

between the negative stimulus and that stimulus point under consideration on the dimension. The excitatory and inhibitory tendencies to respond to a stimulus cue at any point on the dimension are assumed further to summate algebraically, yielding the effective excitatory strength at that point. Which of a pair of any stimulus members of a dimension will be chosen by an organism after training on a particular pair will depend upon the magnitude of the difference in the effective excitatory strengths of the competing stimulus cues as calculated from the values of the generalization curves.

The accompanying diagram, Fig. 1, taken from one of Spence's (27) recent papers, illustrates the workings of the theory. The *S* is assumed to have been trained to choose a square of 160 sq. cm., in preference to one of 100 sq. cm. The stimulus members indicated on the base line are placed at equal intervals on a logarithmic scale, and for each of these there is calculated the effective excitatory strength, determined by summing algebraically the excitatory and inhibitory generalization values for the given member. Comparing these hypothetical effective strengths for pairs of stimuli on the dimension, one would be led to predict that transposition will occur on pairs 256 vs. 160 and 100 vs. 62, but that transposition should fail to occur in the case of stimulus pairs farther removed from the training pair.

While insufficient knowledge as to the nature of the variation of generalization curves from individual to individual precludes the possibility of making specific deductions as to the exact results to be expected from individual *S*s at each point on the stimulus dimension, nevertheless the theory does lead to certain more general implications which are experimentally testable. One of these, that the amount of transfer will be less the farther removed the test pair from the original training pair, is of particular importance for the present investigation.

## Statement of the Problem

The present study takes its point of departure from the theoretical formulation of transposition phenomena proposed by Spence. This theory was developed in relation to the behavior of nonarticulate organisms and is assumed to represent the underlying mechanisms (variables and laws) operating in infrahuman subjects and possibly in human *S*s prior to the advent of verbal processes. In the case of an organism possessing verbal responses, however, behavior in discrimination situations presumably becomes cued to some extent to such words as 'bigger,' 'longer,' 'brighter,' etc. Observation and phenomenological reports suggest that verbal processes dominate such behavior in the case of the human adult. The relational theories originally proposed by the early American experimenters provide excellent examples of the recognition of the role of verbal processes in the human *S*. In line with the existing tendency to anthropomorphize, these writers projected their own processes into their animal *S*s, although they usually acknowledged that such abstractions could function only as 'more general notions,' whatever that might mean.

As a basis for an attempt to extend our understanding of discrimination behavior and the phenomenon of transposition in human *S*s, *the working hypothesis is here adopted that the mechanisms assumed by Spence to underlie this behavior in animals are also operative in the young child, and that with the development in older children of the capacity to employ verbal responses in such behavior situations, a shift occurs to the verbal type of control.*

According to this assumption, the child who has not yet learned the terms 'bigger' or 'smaller,' or who has not yet learned to control his overt behavior by means of such verbal responses or their implicit equivalents in a size discrimination problem, would learn the discrimination in much the same way as the animal *S*. Transfer of the learned response to another set of stimuli differing from the training set only with respect to size, would depend upon the generalization of excitation and inhibition from the positive and negative members of the training pair, respectively, to these other members of the size dimension. With increasing distance on the continuum of the test stimuli from the training pair, the differential effects of generalization would be expected to decrease until a point is eventually reached at which the difference would be too small to produce a differential response to the test stimuli. Non-cue factors would then be decisive and should produce a response which, except in the case of an original size preference, would be unrelated to the size aspect of the stimuli. A group of nonverbal *S*s would, in such a case, be expected to respond in a manner consistent with original training only a chance number of times.[1]

The child whose discrimination behavior is controlled by verbalization of the cue aspect of the stimulus situation should, on the other hand, generalize equally well to all other pairs of test stimuli differing from the training stimuli in the same dimension. For example, if he learns to respond to the 'smaller' of a stimulus pair during training and is then tested on a new stimulus pair also maintaining the relationship 'smaller-larger,' it is expected that he will abstract the relationship in the new pair and respond on the basis of it to the smaller stimulus of the pair, whatever the distance of the test stimuli from the training stimuli. His choice behavior, in other words, will be controlled by some such verbal response as 'always in the smaller'.

Studies of transposition of response in children thus far reported in the literature consistently show that transposition occurs in a large proportion of cases, but they have employed only test stimuli near to the original training pair. Transposition would be expected under this condition whether the child used verbal responses effectively or not: in the first instance through generalization on a verbal basis; in the second, through generalization on a simple conditioning basis. Thus, the findings are not critical so far as the present hypothesis is concerned. Evidence for or against it can be obtained only on transposition tests with stimuli that are at a considerable distance from the training pair. This investigation attempts to provide such evidence.

[1] The size dimension has been used for illustrative purposes, but any other stimulus continuum such as brightness, weight, etc., would be equally applicable.

In the absence of a measure of the extent to which the child employs the type of verbal concepts demanded by the theory, mental age has been taken as a rough indicator of the degree to which verbal or symbolic responses control behavior. *The implications of our working hypothesis are, then, that (mentally) very young children trained in a discrimination situation and in whom, presumably, verbal mechanisms are not highly developed, will respond on the distant transposition test in a chance manner, not in a manner consistent with training, while (mentally) older children, in whom the verbal-type mechanism is presumably well established, will exhibit transposition, that is, will respond in the distant test situation in a manner consistent with the original training.* It is probable that intermediate age groups will, as groups, fall somewhere between these two extremes, for some individuals will still be in the nonverbal stage, some will have progressed to the verbal level, while still others might possibly be in a stage of transition.

## Review of Previous Studies

Comparatively few transposition experiments have employed child *Ss*, and none has treated the variables under consideration in the present study, namely: 1, the relation of the choice to the distance of the two test stimuli from the training pair on the stimulus dimension, and 2, the relation of choice to verbal development. Köhler (18), Frank (3), Klüver (16) and Jackson *et al.* (12) have demonstrated the predominance in children of relative choices on critical tests with stimuli one step [2] distant from the training pair on a size, brightness, or weight dimension, even under the condition of over-training. Other transposition experiments with children (7, 8, 9, 10, 11) have employed conditions irrelevant to the present problem.

In the animal field, a number of investigators have studied the relation of transposition to the distance of the test stimuli from the training stimuli on a single dimension. Gulliksen (4) and Flory (2) working with white rats, and Klüver (16) and Spence (25) working with chimpanzees, have consistently found that, in the size dimension, as the distance between the training and test stimuli increases from one to five steps, the frequency of relative choices decreases from a significantly high toward a chance level. Kendler (14), employing hooded rats, conducted a similar experiment in the brightness dimension through four step intervals. She found a progressive decrease in the relative choice through the first three steps, but a rise or

[2] 'Step,' a term introduced by Kendler (14), refers to the distance on the stimulus dimension of the test stimuli from the training stimuli, such that the members of the test set have the same relation to the corresponding members of the training set, as the members of the training set have to each other. One step interval is represented by the distance between a training pair 10 vs. 5, for example, and a test pair 20 vs. 10.

leveling off thereafter, depending on whether training was to the brighter or duller stimulus. Thus, the findings with respect to the distance variable in transposition experiments with animals tend to be in line with the theory based on conditioning principles.

## Experiment

### *A. Subjects*

Thirty-eight children from the preschools of the University of Iowa and 18 children from the kindergarten of the Horace Mann Public School in Iowa City were *S*s in this experiment. They were selected on the basis of mental age scores within the range three to six years, and intelligence quotients of average or higher. In all, 12 who had from 140 to 630 training trials left school

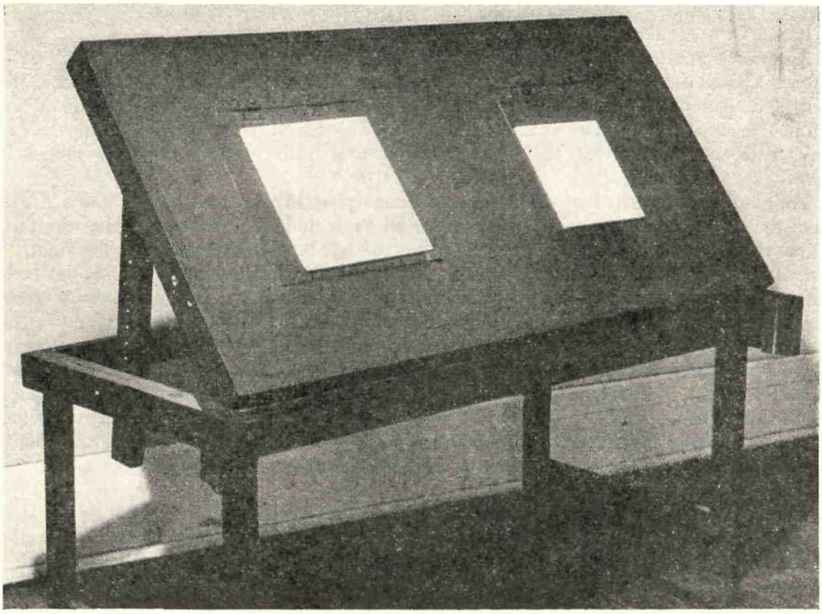

Fig. 2. Photograph of the apparatus with the training stimuli in position

before they reached the learning criterion. Those who completed the study ranged in CA at the start of the experiment from 30 to 70 months, in MA from 36 to 83 months, and in IQ from 89 to 151.

Mental age and intelligence scores were obtained for all *S*s on the New Revised Stanford-Binet Tests of Intelligence, Form L, within six months preceding the first day of training. With two exceptions, the investigator administered the tests. On the basis of the scores the children within each of the mental age levels 3, 4, 5 and 6 years, were divided into pairs matched for MA and IQ, and for sex whenever possible. One member of each pair was randomly assigned to one test group and the other automatically fell into the alternate group.

### *B. Apparatus*

The apparatus, shown in Fig. 2, consisted of a stand 22 in. in height, on which rested a panel inclined at a 60-degree angle. Two 10-in. square openings were cut 10 in. apart in the panel, and covered with hinged lids. Behind these openings boxes were constructed. A thin strip of metal ⅜ in. wide was attached to the lower edge of the lid of each box to hold the stimuli in place. The metal extended over the inner edge of the lids and was bent slightly to form tabs for opening the boxes. Locks invisible to the *S* and manipulated from behind the apparatus were arranged so that the lid under the negative stimulus was always locked. Notched blocks of wood attached to the front legs of the table held a pressed wood screen in place between trials. A large variety of colorful toys, one of which was hidden each trial in the box on which the positive stimulus lay, served to motivate the child. The entire apparatus was painted flat black.

Stimuli were white-enameled ¼-in. pressed wood squares with the areas 2.0, 3.6, 21.0, 37.8 and 68.0 sq. in. These will be referred to by the numbers 1, 2, 5, 6 and 7, respectively. Numbers 3 and 4 are omitted to emphasize the links needed to complete the stimulus series whose successive members have areas maintaining the ratio 1.8:1 between them. A duplicate of stimulus 6, the positive training stimulus, was used for transposition tests as a control over responses on the near test to some specific characteristic (other than size) of the original training stimulus.

## *C. Experimental Procedure*

*Training series.*—The procedure was identical for both experimental groups. *Ss* were trained to choose the box with the smaller of the two stimuli, 6 and 7. Fig. 2 shows these stimuli in position. In the event of a correct response, the box opened and a toy was found inside, while in the event of an incorrect response, the box was found to be locked. The *S* was never permitted to try both boxes. Toys were collected in a cardboard box which the child held on his lap.

Training began on the first day with a preliminary set of two trials during which *E* demonstrated the response. Instructions, uniform for all *Ss*, included no mention of the stimuli. On the first trial, the positive stimulus appeared on the left box, the negative on the right. The positions were reversed on the second trial. Following the demonstration the regular training session was begun. In no case was the preliminary series repeated. Any spontaneous verbalization of the cue aspect of the stimuli was recorded throughout the experiment.

Ten trials were presented the *S* each school day. On odd-numbered days the position of the positive stimulus for the 10 trials was LRLLRLRRLR. The order on even-numbered days was RLLRLRLRRL. Training was continued until the *S* chose the positive stimulus on at least the last nine of the 10 trials. In instances in which a child responded nine consecutive times on the basis of position, *E*, on the ninth trial, indicated the correct box, saying, "Look! This box opens!" Trials were then given with the positive stimulus on the nonpreferred side until the child chose correctly once.

If, after 450 standard training trials, the *S* showed no indication of approaching the learning criterion, he was given at the start of the next session, five to 10 trials in which no stimuli were present, followed immediately by the regular training trials. Five trials without stimuli were given after 470 and 490 trials if learning still had not occurred. After 500 trials, the daily session opened with 10 trials in which the positive stimulus was presented alone. This series was followed immediately by 10 regular trials. Single stimulus presentation was continued on alternate days until there was evidence of learning.

*Test series.*—Twenty-four hours after reaching the learning criterion the *S* was given a transposition test of 10 trials, during which all choices were rewarded. Group I was tested on the stimulus pair 5 vs. 6, while Group II was tested on the pair 1 vs. 2. If the child was not in school on the day after reaching the criterion, he was given training trials on his first day back. If he was able to choose the correct stimulus on five trials in five, he was given a 24-hour interval and then tested for transposition. If he failed on one of the five training trials, he was presented a total of 10 regular training trials that day and every day thereafter until he again reached the original criterion of nine consecutive correct choices in 10 trials. He was then given a 24-hour interval before the transposition series.

On the day following the first transposition series, 10 trials were presented with the training stimuli. If the child reached the original learning criterion, he was given a 24-hour interval and then presented with the other pair of test stimuli. For this test, Group I had the stimulus pair 1 vs. 2, while Group II had the pair 5 vs. 6. If, on the other hand, the child failed to reach the criterion, he was given 10 trials each day until he could reach it. As before, a transposition test was given after a 24-hour interval.

*Elicitation of verbalization.*—Following the final transposition test trial on the last day of the experiment, the screen was placed in position and the child was asked how he knew which box to open. If there was no response, the training blocks were placed in position, the screen was removed, and the *S* was asked how he knew which block to choose. If there was still no response he was asked how the blocks differed.

It was recognized, of course, that failure of the child to verbalize the size aspect aloud does not indicate that he also failed to verbalize internally; nor does failure to state a generalization in response to questioning indicate a similar failure during the course of the experiment. Furthermore, verbalizing at the conclusion of the experiment gives no cue as to the time the child actually formulated his generalization. On the other hand, the occurrence of spontaneous verbalization aloud is evidence of the presence of a verbal mechanism at least at that time. Verbalization in response to questioning indicates capacity for such a process and the possibility that it did occur during the learning period.

## D. *Results*

The various data obtained on the 44 *S*s divided into four mental age levels are presented in Tables I to IV. The first column of each

TABLE I

LEARNING AND TEST DATA FOR SUBJECTS AT THE THREE-YEAR LEVEL

| Subjects | CA Mos. | MA Mos. | IQ | No. Trials | No. 'Smaller' Responses in 10 Trials | |
|---|---|---|---|---|---|---|
| | | | | | Near Test | Far Test |
| Group I (*S*s given near test first) | | | | | | |
| 1 | 34 | 36 | 107 | 590 | 9 | 6 |
| 2 | 43 | 38 | 89 | 320 | 9 | 4 |
| 3 | 40 | 42 | 105 | 190 | 10 | 6 |
| 4 | 30 | 44 | 148 | 40 | 10 | 4 |
| Group II (*S*s given far test first) | | | | | | |
| 5 | 37 | 37 | 100 | 540 | 7 | 5 |
| 6 | 40 | 42 | 105 | 170 | 10 | 5 |
| 7 | 39 | 46 | 119 | 500 | 10 | 5 |
| Means | 37.6 | 40.7 | 110.4 | 335.7 | 9.3 | 5.0 |
| Medians | 39 | 42 | 105 | 320 | 9.5 | 5.0 |

table identifies the *S* by number, and the next three contain data on CA, MA, and IQ, respectively, for each individual. The fifth column gives the total number of standard trials required to attain the criterion of learning in the discrimination situation. Finally, the last two columns show the number of responses consistent with the original training made in the 10 trials on the near test and the 10 trials on the far test. Each of the tables has been divided into an upper and lower part. The former includes those *S*s (Group I) who were given the near test first; the latter, those *S*s (Group II) who had the far test first. At the bottom of each table appear the

TABLE II

LEARNING AND TEST DATA FOR SUBJECTS AT THE FOUR-YEAR LEVEL

| Subjects | CA Mos. | MA Mos. | IQ | No. Trials | No. 'Smaller' Responses in 10 Trials | |
|---|---|---|---|---|---|---|
| | | | | | Near Test | Far Test |
| Group I (*Ss* given near test first) | | | | | | |
| 8 | 43 | 48 | 112 | 360 | 9 | 7 |
| 9 | 41 | 53 | 129 | 40 | 10 | 5 |
| 10 | 59 | 58 | 98 | 90 | 1 | 5 |
| 11 | 41 | 58 | 142 | 400 | 10 | 10 |
| 12 | 45 | 59 | 131 | 230 | 10 | 4 |
| 13 | 44 | 59 | 133 | 170 | 10 | 10 |
| Group II (*Ss* given far test first) | | | | | | |
| 14 | 52 | 54 | 104 | 90 | 10 | 3 |
| 15 | 42 | 56 | 134 | 190 | 10 | 6 |
| 16 | 37 | 56 | 151 | 380 | 0 | 10 |
| 17 | 39 | 58 | 149 | 176* | 1 | 6 |
| 18 | 46 | 59 | 128 | 380 | 10 | 6 |
| Means | 44.5 | 56.2 | 128.3 | 227.8 | 7.4 | 6.5 |
| Medians | 43 | 58 | 131 | 190 | 10 | 6 |

* On one training day, only six trials were given for reasons beyond *E*'s control.

TABLE III

LEARNING AND TEST DATA FOR SUBJECTS AT THE FIVE-YEAR LEVEL

| Subjects | CA Mos. | MA Mos. | IQ | No. Trials | No. 'Smaller' Responses in 10 Trials | |
|---|---|---|---|---|---|---|
| | | | | | Near Test | Far Test |
| Group I (*Ss* given near test first) | | | | | | |
| 19 | 61 | 60 | 98 | 290 | 10 | 10 |
| 20 | 64 | 65 | 102 | 270 | 10 | 7 |
| 21 | 65 | 65 | 100 | 50 | 10 | 8 |
| 22 | 68 | 66 | 97 | 160 | 10 | 4 |
| 23 | 66 | 70 | 106 | 110 | 10 | 2 |
| 24 | 62 | 70 | 113 | 200 | 10 | 10 |
| Group II (*Ss* given far test first) | | | | | | |
| 25 | 63 | 65 | 103 | 200 | 10 | 7 |
| 26 | 64 | 65 | 102 | 210 | 10 | 9 |
| 27 | 62 | 66 | 107 | 30 | 10 | 10 |
| 28 | 67 | 67 | 100 | 250 | 10 | 10 |
| 29 | 65 | 70 | 108 | 310 | 10 | 8 |
| 30 | 63 | 71 | 113 | 220 | 10 | 9 |
| Means | 64.2 | 66.7 | 104.1 | 191.7 | 10 | 7.8 |
| Medians | 64 | 66 | 102.5 | 205 | 10 | 8 |

TABLE IV

LEARNING AND TEST DATA FOR SUBJECTS AT THE SIX-YEAR LEVEL

| Subjects | CA Mos. | MA Mos. | IQ | No. Trials | No. 'Smaller' Responses in 10 Trials | |
|---|---|---|---|---|---|---|
| | | | | | Near Test | Far Test |
| Group I (*Ss* given near test first) | | | | | | |
| 31 | 60 | 72 | 120 | 50 | 10 | 10 |
| 32 | 67 | 74 | 111 | 130 | 10 | 9 |
| 33 | 70 | 75 | 107 | 130 | 10 | 10 |
| 34 | 61 | 77 | 126 | 100 | 10 | 10 |
| 35 | 61 | 78 | 128 | 190 | 10 | 10 |
| 36 | 67 | 81 | 121 | 10 | 10 | 10 |
| 37 | 64 | 83 | 130 | 50 | 10 | 10 |
| Group II (*Ss* given far test first) | | | | | | |
| 38 | 63 | 72 | 115 | 40 | 10 | 10 |
| 39 | 66 | 73 | 111 | 60 | 10 | 10 |
| 40 | 68 | 74 | 109 | 20 | 10 | 10 |
| 41 | 65 | 75 | 116 | 10 | 10 | 10 |
| 42 | 67 | 78 | 117 | 80 | 10 | 10 |
| 43 | 68 | 80 | 118 | 10 | 10 | 10 |
| 44 | 63 | 80 | 127 | 120 | 10 | 10 |
| Means | 65.0 | 76.6 | 118.3 | 71.4 | 10 | 9.9 |
| Medians | 65.5 | 76.0 | 117.5 | 55 | 10 | 10 |

means and medians of these various measures for each mental age group.

*Learning.*—An examination of the data showing the number of trials to reach the learning criterion of nine consecutive correct choices in 10 reveals that the individual *S*s ranged from 10 to 590 trials. There is evident a marked tendency for the low scores (fast learning) to be concentrated at the older age levels and the high scores (slow learning) to be found at the younger age levels. Both measures of central tendency for the four age groups reveal a decrease in the number of trials with increasing age, the means showing a consistent downward trend and the medians a single inversion between ages four and five. Further support for this relation between speed of learning and mental age is provided by the product-moment coefficient of correlation of − .62 found between these variables. For a significant relationship at the one-tenth of one percent level with this number of cases, a coefficient of only .47 is needed. Speed of learning is also highly correlated with chronological age as shown by the *r* of − .55 between these two measures.

In addition to the regular training trials, special trials ranging in number from 2 to 199 were given to eight three- and four-year-old

*S*s and one five-year-old in an attempt to modify position habits. In line with the plan described in Section C, three three-year-old *S*s—Nos. 1, 5, and 7—were given 5 to 20 trials without the stimuli present, and *S*s 1 and 5 also received single-stimulus trials numbering 15 and 10, respectively. These data serve to add to the evidence that the problem was relatively much more difficult for the young *S*s than for the older ones.

The majority of *S*s, 28 in all, spontaneously commented on the size of the stimuli at some time during learning. Of these, nine mentioned the size aspect for the first time on the day they reached the criterion, or the day just preceding it, and 12 others verbalized the concept on one of these two days in addition to some earlier day or days. A number of other children talked about the 'big block' or 'little block' but never reached the learning criterion.

*Relearning.*—Only three *S*s of the 44 required more than the minimum of 10 trials to reach the learning criterion the second time.[3] Two of these three, *S*s 8 and 22, met the criterion after 20 trials. Both, it is interesting to note, were among the three *S*s who at no time during the experiment verbalized the size aspect of the stimuli. *S* 30 took 40 trials to relearn the discrimination, but the conditions in this case were exceptional in that a period of over three weeks elapsed between the first transposition test and the start of the relearning. With no other *S* was the interval greater than four days.

*Transposition tests.*—The results of the near transposition test show that with very few exceptions the children tended to respond in a manner consistent with the original training, that is, to choose the smaller stimulus. Thus, if we select a score of 9 or more such responses in 10 as a significant one (a score of 9 would be expected on a chance basis only 10 times in 1024), it will be seen that there were only four *S*s in all who did not choose the smaller stimulus a statistically significant number of times, that is, did not demonstrate transposition. One of these, *S* 5, was in the three-year-old group, while the other three, *S*s 10, 16, and 17, were in the four-year-old group. The results for these latter three *S*s on the near transposition test were quite different from those of the other children, their responses being predominantly (beyond chance) to the absolute stimulus cue.[4]

[3] The relearning series, it will be recalled, came at least 24 hours after the first transposition test.

[4] The results for these individuals are discussed in some detail in the original thesis, deposited in the library of the State University of Iowa. The behavior of *S*s 10 and 16 are not necessarily contrary to the proposed theory. Both appear to have learned the discrimination on a nonverbal basis. Their responses on the near test could possibly be explained as resulting from very narrow generalization curves. Such an assumption would require that the responses on the far test be random, which is in line with the experimental results. The absolute choice of *S* 17 on the near test, after transposing on the far test, is contrary to the theoretical expectation.

The findings of the far transposition tests present a somewhat different picture from those of the near test, particularly in the case of the younger *Ss*. Thus, none of the *Ss* at the three-year-level behaved on this test in a manner consistent with original training. Rather, all seven responded to the two stimuli in more or less chance fashion, as may be seen from the data in the last column of Table I. The percent of *Ss* responding a statistically significant number of times (nine or more) to the smaller stimulus on this far test increased at each of the subsequent age levels. Thus, 27.3 percent (three *Ss*) of the four-year-old group, 50 percent (six *Ss*) of the five-year-old group, and 100 percent (14 *Ss*) of the six-year-old group chose in accord with their original training in nine or more of the 10 far test trials.

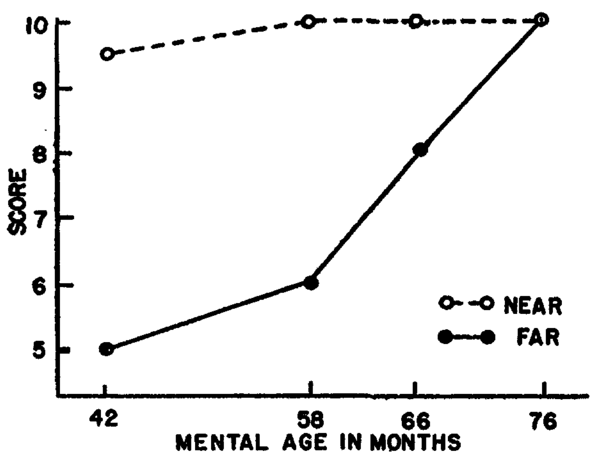


FIG. 3. Graphic representation of the relation between mental age and median scores on near and far transposition tests

The differences in the results for the two transposition tests are also revealed by the measures of central tendency included at the bottom of Tables I to IV. Fig. 3 brings together in graphic form the median near and far transposition scores made by *Ss* at various age levels. The number of transposition responses in 10 trials appears on the ordinate, while the median mental age in months for each of the four groups is plotted on the abscissa. Inspection of the almost horizontal near test curve reveals that all four age groups showed transposition to a very high degree. The far curve, on the other hand, begins at chance (5) for the youngest group and rises to 10 for the oldest group, with the intermediate age groups falling at 6 and 8.

We turn now to the consideration of the relation of these experimental facts to the theoretical formulation elaborated at the beginning of this paper. It will be recalled that the implications of this theory were that the far transposition test would reveal significant differences between children of different age levels, whereas the near transposition test would not. In the first instance the theoretical expectation was that at some point in the age range, presumably at a very young level, the responses of the *Ss* on the far transposition test would approximate a chance result. At an older age, on the other hand, presumably when the stage of verbal abstraction and control of behavior is attained, the response of the child on this far test would be highly consistent with the direction of original training.

That the results of the experiment were in agreement with these theoretical expectations is readily apparent. The children of different age levels showed little, if any, difference in the near transposition test. In the far transposition test, however, the three-year-olds responded in a purely chance manner, while the six-year-olds showed practically 100 percent transposition. There now remains the task of ascertaining the degree of confidence we may have that these differences did not arise purely by accident.

Because of the nature of the data, for example, the skewed character of the distributions of the transposition scores and the inequality of the variances at different age levels, it was not possible to apply analysis of variance, or to apply in most instances, the usual *t*-test of significance between means. The main theoretical implications may, nevertheless, be tested for significance in the following manner. If we set up the null hypothesis with respect to differences on the two tests, near and far, for both the three- and six-year mental age groups, then our theory would require that the experimental results for the three-year-old group would lead to the rejection of the null hypothesis of no difference between the two tests at this age, while the results for the six-year mental age group would lead to acceptance of that hypothesis.

In the case of the three-year-old group, we can apply the *t*-test for differences in the means of related measures (21). The resulting *t* is 8.25, which far exceeds the value of 5.96 required for a significant difference at the one-tenth of one percent level. From this we would be led, as our theory demands, to reject the hypothesis that there is no difference in the results on the two tests for this age group.

Unfortunately, a similar statistical test of the differences between the near and far transposition scores for the six-year-old group cannot be made because of the almost complete lack of variability in these test scores. The nature of the results is such, however, that one can readily accept the null hypothesis that no difference exists. All *Ss* but one responded 10 times on both tests to the smaller stimulus and, in the case of the single exception, the transposition scores were 10 on the near test and 9 on the far. Thus, there are 13 cases of zero difference and a single case of a difference of 1. The probability that one would obtain on the basis of chance 13 instances of zero in 14 is extremely remote.

As was true at the six-year level, the distributions of transposition scores at the intermediate ages four and five do not justify the assumptions of normality and homogeneous variability that are necessarily made in applying the *t*-test for differences between means. There are too few *S*s to permit a chi-square test of independence on these two groups alone, but by combining the three- with the four-year group and the five- with the six-year one, the application of that test is made possible. We are interested in testing the hypothesis that there is no relationship between mental age and the occurrence of transposition (score of 9 or 10 in 10 trials) in the far test situation. The resulting chi-square, corrected for continuity by Yates' method, is 13.1, which, for one degree of freedom, exceeds the value required for significance at the one-tenth of one percent level. The hypothesis can, therefore, be rejected even if some reservation is made for the relatively small number of *S*s. Further evidence against the hypothesis of no relation between mental age and far transposition scores is furnished by the product-moment correlation of .66 obtained between these variables for the 44 *S*s This coefficient is far in excess of the value .47 required for significance at the one-tenth of one percent level.

A chi-square test of independence could not be applied to the near transposition measures to test their relationship to mental age, because the data fail to satisfy the requirement that there be a theoretical (expected) frequency of at least five in each of the cells of the contingency table. The correlational approach is likewise not applicable to these results, for the transposition scores show almost no variability. Examination of the data, however, should make one extremely hesitant about rejecting the null hypothesis of the relation between mental age and near transposition.[5]

*Verbalization.*—An analysis of the recorded verbalizations of the stimulus cue suggested the classification of the *S*s into four mutually exclusive categories—A, B, C and D. A includes those *S*s who at no time, either spontaneously or in response to questioning, verbalized the size aspect. In category B are those who did spontaneously

[5] Analysis of transposition scores based on only the first test trial gave results which corroborate those for 10 test trials. No significant differences were found between the different mental age groups on the near transposition test, whereas the percent of *S*s who transposed on the far test increased from 14.3 percent for the three-year-old group to 100 percent for the six-year-olds. The four- and five-year-old groups fell in between these values, with 72.7 of the former and 86.7 percent of the latter showing transposition. Application of the chi-square test of independence permits one to reject, at a confidence level between two and five percent, the hypothesis of no difference in the percent of transposition for the four groups.

mention the size variable at least once at any time during the experiment, but who failed to state the relation of size to the success or failure of choice behavior. Typical verbalizations of *S*s in this group are: "This one is big and this one is little." "What a nice little block!" "This time I'll take the big one." *S*s in the third class, *C*, verbalized the general principle of solution, but only in response to questioning at the conclusion of the experiment. Many of these individuals also mentioned the size of the stimuli during the training or transposition trials, but in no instance did they express generalizations at that time. Examples of replies judged as adequate generalizations are: "It's (toy) always in the little one," or "The big one doesn't open." Category D includes those children who verbally generalized with respect to the size aspect of the stimuli at some time prior to the routine questioning at the conclusion of the experiment. All except three of these *S*s repeated the principle in reply to the experimenter's questions following the last 10 trials.

The number and percent of *S*s at each age level who fall in the four verbalization categories are shown in Table V. It is apparent

TABLE V

Number and Percent of Subjects at Each Age Level in the Four Verbalization Categories

| Category | Mental Age | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 3 | | 4 | | 5 | | 6 | |
| | *N* | % | *N* | % | *N* | % | *N* | % |
| A | 0 | 0 | 2 | 18.2 | 1 | 8.3 | 0 | 0 |
| B | 7 | 100.0 | 2 | 18.2 | 1 | 8.3 | 0 | 0 |
| C | 0 | 0 | 4 | 36.4 | 5 | 41.7 | 5 | 35.7 |
| D | 0 | 0 | 3 | 27.3 | 5 | 41.7 | 9 | 64.3 |

that the three- and four-year-old children tend to be in the non-generalizing groups (A and B) while the five- and six-year-old children are predominantly in the generalizing ones. A chi-square test of the null hypothesis of no relationship between mental age and classification in the combined A-B or combined C-D categories yields a corrected chi-square of 12.22, permitting the rejection of the hypothesis at the one-tenth of one percent level of confidence. This result lends support to our proposed use of mental age as an indicator of the ability to make verbal generalizations in such situations.

Table VI indicates the median transposition scores in 10 trials for *S*s in the four verbalization categories, and the median number of trials to learn the discrimination originally. It is evident that *S*s who failed to verbalize the size aspect of the stimuli explicitly, or who merely noted the size without stating the relationship of the size aspect to the solution of the problem, behaved differently on the far transposition test from *Ss* who did formulate and state the relationship. On the near test, responses were similar from group to group.

It is possible to test the significance of the apparent relationship by using the chi-square test of independence. The obtained corrected chi-square of 18.37 permits us to reject at the one-tenth of one percent level the hypothesis of no relationship between the occurrence of transposition (a score of 9 or 10 in 10 trials) in the far test and the tendency to verbalize the solution of the discrimination problem. As in previous applications of this test, a chi-square of only 10.83 is needed for significance at this level for one degree of freedom. The

TABLE VI

Median Transposition Scores for Subjects in the Four Verbalization Categories

| Category | $N$ | Median Trials | Median Transposition Responses (10 trials) | |
|---|---|---|---|---|
| | | | Near Test | Far Test |
| A | 3 | 176.0 | 9.0 | 6.0 |
| B | 10 | 250.0 | 10.0 | 5.0 |
| C | 14 | 100.0 | 10.0 | 10.0 |
| D | 17 | 130.0 | 10.0 | 10.0 |

chi-square test is not applicable to the near transposition data for the reason before discussed, of too small theoretical frequencies in the non-transposing categories. There seems to be no occasion for doubting, however, that the null hypothesis is tenable for the relation between near transposition and tendency to verbalize the principle.

Analysis of individual data with respect to the relation of verbalization to the phenomenon of transposition suggests the possibility that there are several verbal stages. There appears to be one stage in which the child verbally identifies the stimuli as 'little' and 'big,' but he fails to verbalize the relation of size to the success or failure of his choice responses. This occurred predominantly in the younger *Ss* and was associated in every case with chance performance on the far transposition test series. There is another stage—presumably a later one because of its much greater incidence in older *Ss*—in which the child states aloud or to himself that the little stimulus always leads to success and the big one to failure. The occurrence out loud of such verbal behavior in the learning or transposition series invariably was followed by transposition on the far test, regardless of the mental age of the child. In contrast, 43 percent of those who made such verbalizations only upon questioning at the conclusion of the experiment transposed on the far series with this consistency. In the case of three *Ss* who had failed to transpose in the far test and a few seconds later, upon questioning, verbalized the principle, there seemed to be no apparent recognition of the discrepancy between this verbal formulation of the solution and their failure to act in a manner consistent with it in the immediately preceding test trials.

While the data on verbalization are not sufficiently clear-cut to permit any definite conclusions, there is, however, the suggestion that there are at least two developmental stages so far as the relation of verbal responses to overt choice behavior is concerned. In the first, the child is able to make differential verbal responses to appropriate aspects of the situation, but this verbalization does not control or influence his overt choice behavior. Later, such verbalizations gain control and dominate choice behavior.

## Summary and Conclusions

Taking its point of departure from a theoretical formulation of discrimination learning based on the findings of conditioning experiments, this study hypothesizes that the simple mechanisms mediating transposition of response in infrahuman organisms are identical with those responsible for similar behavior in children in the preverbal stage of development. With the acquisition of verbal processes, however, and the transition to behavior dominated by such processes, it is hypothesized that the child's responses in the discrimination-learning situation become keyed to words relating to the cue aspect of the stimuli. Implications of this theory are that the preverbal child, like the animal *S*, will transpose consistently on test stimuli near on the dimension to the training pair, but will show only chance response on transposition tests with distant stimuli. The verbal child, on the other hand, would be expected to show transposition on both far and near stimulus tests.

As an empirical test of the proposed hypothesis, an experiment was conducted in which mental age was used as a rough indicator of verbal level. *Ss* were 44 Iowa City preschool and kindergarten children distributed over the mental age range three to six years and divided into two matched groups at each year level. Both groups were trained to select the smaller of a pair of squares whose areas were 37.8 and 68.0 sq. in. They were tested in counter-balanced order after learning, with two pairs of still smaller stimuli (21.0 vs. 37.8 sq. in., and 2.0 vs. 3.6 sq. in.). All spontaneous verbalizations of the size aspect of the stimuli were recorded throughout the experiment, and attempts were made at the conclusion, through questioning, to elicit verbalization of the general principle of solution.

Analysis of the results revealed a highly significant relationship between mental age and the occurrence of far transposition, and a low relationship between mental age and near transposition. The median number of responses on the far transposition test increased with age from 50 percent at mental age three years to 100 percent at six years. The corresponding value for the near transposition test was 90 percent or above at all four age levels.

With regard to verbalization, *S*s tended to fall into four categories: 1, failure to verbalize the size aspect of the problem; 2, verbal identification of the size difference between the stimuli without explicit association of size with the success or failure of choice behavior; 3, verbalization of the principle of solution in response to questioning at the conclusion of the experiment; and 4, verbalization of the principle spontaneously during training or transposition trials. *S*s in the first two categories were significantly younger in mental age than those in the last two. No *S* in the first two categories transposed on the far test, while 73 percent of the individuals in the last two categories transposed. Analysis of the individual data suggests the possibility of two developmental stages so far as the relation of verbal responses to overt choice behavior is concerned.

On the whole, the experimental results were found to be in close accord with the proposed hypothesis.

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References

1. Bingham, H. C. Visual perception in the chick. *Behav. Monogr.*, 1922, 4, No. 20, 1–104.
2. Flory, R. M. A study of the factors determining discrimination of size by the white rat. Unpublished Master's thesis, Univ. Va., 1938.
3. Frank, Helene. Untersuchung über Sehgrössenkonstanz bei Kindern. *Psychol. Forsch.*, 1926, 7, 137–145.
4. Gulliksen, H. Studies of transfer of response: I. Relative versus absolute factors in the discrimination of size by the white rat. *J. genet. Psychol.*, 1932, 40, 37–51.
5. Gulliksen, H., & Wolfle, D. L. A theory of learning and transfer. *Psychometrika*, 1938, 3, 127–149, 225–251.
6. Gulliksen, H., & Wolfle, D. L. Correction of an error in 'A theory of learning and transfer.' *Psychometrika*, 1939, 4, 178.
7. Jackson, T. A. Studies in the transposition of learning by children. III. Transpositional response as a function of the number of transposed dimensions. *J. exp. Psychol.*, 1939, 25, 116–124.
8. Jackson, T. A., & Dominguez, K. Studies in the transposition of learning by children. II. Relative vs. absolute choice with multi-dimensional stimuli. *J. exp. Psychol.*, 1939, 24, 630–639.
9. Jackson, T. A., & Eckhardt, M. E. Studies in the transposition of learning by children. V. The number of stimuli in the training series as a factor in generalization. *J. exp. Psychol.*, 1940, 27, 303–312.

10. JACKSON, T. A., & JEROME, E. A. Studies in the transposition of learning by children. IV. A preliminary study of patternedness in discrimination learning. *J. exp. Psychol.*, 1940, **26**, 432–439.
11. JACKSON, T. A., & JEROME, E. A. Studies in the transposition of learning by children. VI. Simultaneous vs. successive presentation of the stimuli to bright and dull children. *J. exp. Psychol.*, 1943, **33**, 431–439.
12. JACKSON, T. A., STONEX, E., LANE, E., & DOMINGUEZ, K. Studies in the transposition of learning by children. I. Relative vs. absolute response as a function of amount of training. *J. exp. Psychol.*, 1938, **23**, 578–600.
13. JOHNSON, H. M. Visual pattern discrimination in the vertebrates. *J. Anim. Behav.*, 1914, **4**, 319–339, 340–361; 1916, **6**, 169–188.
14. KENDLER, SYLVIA T. S. Experimental investigation of the effect of difference between training and test stimuli on the amount of transposition. Unpublished Doctor's dissertation, State Univ. Ia., 1943.
15. KINNAMAN, A. J. Mental life of two *Macacus rhesus* monkeys in captivity. *Amer. J. Psychol.*, 1902, **13**, 98–148, 173–218.
16. KLÜVER, H. *Behavior mechanisms in monkeys.* Chicago: Univ. of Chicago Press, 1933.
17. KÖHLER, W. *Gestalt psychology.* New York: Horace Liveright, 1929.
18. KÖHLER, W. Simple structural functions in the chimpanzee and in the chicken. In: W. D. ELLIS, *A source book of Gestalt psychology.* New York: Harcourt, Brace and Co., 1938. Pp. 217–227.
19. KOFFKA, K. *The growth of the mind.* (2nd ed., rev.) New York: Harcourt, Brace and Co., 1928.
20. LASHLEY, K. S. The mechanism of vision. XV. Preliminary studies of the rat's capacity for detail vision. *J. gen. Psychol.*, 1938, **18**, 123–193.
21. LINDQUIST, E. F. *Statistical analysis in educational research.* New York: Houghton Mifflin Co., 1940.
22. PERKINS, F. T., & WHEELER, R. H. Configural learning in the goldfish. *Comp. Psychol. Monogr.*, 1930, **7**, No. 31, 1–50.
23. SPENCE, K. W. The nature of discrimination learning in animals. *Psychol. Rev.*, 1936, **43**, 427–449.
24. SPENCE, K. W. Analysis of formation of visual discrimination habits in chimpanzee. *J. comp. Psychol.*, 1937, **23**, 77–100.
25. SPENCE, K. W. The differential response in animals to stimuli varying within a single dimension. *Psychol. Rev.*, 1937, **44**, 430–444.
26. SPENCE, K. W. Failure of transposition in size-discrimination of chimpanzees. *Amer. J. Psychol.*, 1941, **54**, 223–229.
27. SPENCE, K. W. The basis of solution by chimpanzees of the intermediate size problem. *J. exp. Psychol.*, 1942, **31**, 257–271.
28. WARDEN, C. J., & ROWLEY, JEAN B. The discrimination of absolute versus relative brightness in the ring dove, *Turtur risorius*. *J. comp. Psychol.*, 1929, **9**, 317–337.