75-15,264

MANDRA, Douglas Arthur, 1942-
TRANSPOSITION ON THE DIMENSION OF
MEANINGFULNESS.

The University of Oklahoma, Ph.D., 1974
Psychology, experimental

Xerox University Microfilms, Ann Arbor, Michigan 48106

THE UNIVERSITY OF OKLAHOMA

GRADUATE COLLEGE

TRANSPOSITION ON THE DIMENSION OF MEANINGFULNESS

A DISSERTATION

SUBMITTED TO THE GRADUATE FACULTY

in partial fulfillment of the requirements for the

degree of

DOCTOR OF PHILOSOPHY

BY

DOUGLAS ARTHUR MANDRA

Norman, Oklahoma

1974

TRANSPOSITION ON THE DIMENSION OF MEANINGFULNESS

A DISSERTATION

APPROVED FOR THE DEPARTMENT OF PSYCHOLOGY

By

W. Jack Kanak

DISSERTATION COMMITTEE

TRANSPOSITION ON THE DIMENSION OF MEANINGFULNESS

by: Douglas Arthur Mandra

Major Professor: John C. McCullers

The primary purpose of the present experiment was to explore the extent to which transposition phenomena can be obtained using a conceptual dimension, i.e., meaningfulness (m). Adult subjects (N = 144) were trained and tested with verbal discrimination tasks conforming to the typical near and far conditions of transposition studies using perceptual dimensions. In a near condition, subjects were initially trained to select a stimulus unit having a higher m value within a pair (zero m vs. low m) and then tested with a pair of verbal units having either the previously correct low-m unit and a medium-m unit (same-near test) or a different low-m unit and a medium-m unit (different-near test). A third group received a far test after initial discrimination training involving medium-m and high-m verbal pairs. Additional variables included in the completely factorialized design were: dimensional direction (low-m to high-m vs. high-m to low-m), list form and sex.

Preliminary analyses of the mean number of relational responses revealed considerably less transposition in the same-near test condition than either the different-near or far test conditions which did not differ from each other. The overall proportions of relational responses for the different-near and far test conditions were above chance levels (i.e., 62% and 58%, respectively) and some subgroups were as high as 72%. An examination of responses made on a posttest questionnaire indicated

that over half (68%) of the subjects recognized some form of the conceptual attribute in the training lists (partially aware) but only 18% were able to identify the attribute in both training and test lists (fully aware). However, the fully aware subjects produced a significantly greater proportion of transposition responses (i.e., .77) compared to the partially aware subjects (i.e., .37).

It was concluded that the requisite condition of conceptual transposition is the conscious identification of an attribute that is common to both training and test tasks. The relationship of these data to absolute, relational, and differentiation theories was discussed; the overall pattern of results was found to be best described by the conceptions of differentiation theory.

ACKNOWLEDGMENTS

I would like to express my sincerest appreciation to Dr. John C. McCullers, Committee Chairman, for his help and encouragement during the preparation of this manuscript. I also thank him for providing the type of stimulating atmosphere that makes one feel creative.

A special debt of gratitude is also extended to Dr. N. Jack Kanak who guided me through the earlier stages of my graduate training and thus prepared me for the task at hand.

I would also like to thank the other members of my committee, Drs. Roger L. Mellgren, W. Alan Nicewander and Larry E. Toothacker, who provided helpful suggestions and criticisms.

To my wife Sheri, whose patience and understanding was a significant factor in completing my graduate training and dissertation, I will always be grateful.

Table of Contents

Manuscript to be submitted for publication

TRANSPOSITION ON THE DIMENSION OF MEANINGFULNESS

Douglas Arthur Mandra

University of Oklahoma

An examination of Reese's (1968) comprehensive review of transposition experiments as well as a search of more recent literature revealed a total lack of studies employing other than perceptual dimensions. It is rather startling to find that transposition, a conceptual task, has not been examined with stimuli differing along conceptual or symbolic dimensions. This finding, although worthy of study in its own right, is enhanced by the fact that many studies have employed subjects (_S_s) with verbal ability (e.g., Riley & McKee, 1963; Zeiler & Gardner, 1966) and a large number of experiments have been devoted to the study of symbolic behavior, i.e., mediation, in transposition phenomena (Alberts & Ehrenfreund, 1951; Kuenne, 1946; Marsh & Sherman, 1966; Reese, 1966; Spiker & Terrell, 1955; Stevenson, Iscoe, & McConnell, 1955). Transposition, as an experimental procedure, involves a minimum of two phases with the first phase consisting of differential training on two or more stimuli varying along the same dimension. The second phase involves a separate test trial in which the subject is required to make a choice among the same number of stimuli as in the initial discrimination task, but where at least one of the stimuli has been quantitatively varied along the relevant dimension.

Since previous research has involved only perceptual tasks it is not known whether a task involving more symbolic processes would reflect choice behavior in terms of the relational aspects of the stimulus situation. Relational responding occurs when _S_s' choice in the second task is based on the relationship between the stimuli learned in the first task. For example, if the positive (reinforced) stimulus in the first task is the larger of two squares, regardless of spatial dimension, then a relational response involves choosing the larger of two stimuli presented in the second task, even though both may have different absolute values than the first set of stimuli. On the other hand, if _S_ chooses the same stimulus or the stimulus physically more similar to the positive training stimulus in the second task, then _S_ is presumed to be responding to the absolute properties of the discrimination task.

By analogy, stimulus units varying along the dimension of meaningfulness (_m_) may be relevant to the above tests. For example, subjects could be trained initially to respond to one of two stimulus units having the higher _m_ value (e.g., zero _m_ versus low _m_) and then tested with a pair of units in which the previously reinforced unit (low _m_) now has a lower _m_ rating than the new unit, i.e., low _m_ versus medium _m_. In terms of traditional transposition research, this would constitute a "near" test. The inclusion of the same reinforced verbal units from the first phase in the second phase could be designated as a same-near (SN) test. The SN test may produce situational frequency cue responding (Underwood & Freund, 1970) rather than responses to _m_ values. A second type of near test could be constructed by pairing units in the low-_m_ versus medium-_m_ relationship as just described, except that different low-_m_ units would be employed than those used in the first phase. This different-near (DN) test would enable the investigation of absolute and relative responses while controlling for the differential accrual of experimental frequency units to one set (low _m_) of items but not to the other set (medium m). A third test, similar to the usual "far" test, might also be constructed by pairing medium-m and high-m units.

The purpose of the present experiment was to explore the extent to which transposition phenomena can be obtained utilizing a verbal discrimination (VD) task and the dimension of meaningfulness (m; Noble & Parker, 1960). Specifically, stimulus conditions analogous to those employed in perceptual discrimination tasks, i.e., "near" and "far" tests were used to study transpositional patterns of responding, relational and/or absolute, in human adult subjects.

The tests just described probably would not be crucial to the classical theories of transposition, i.e., relational (Köhler, 1938) and absolute (Spence, 1936, 1937). If adult Ss became aware of the conceptual dimension (meaningfulness) during initial discrimination training, then both theories would predict relational responding for both types of near and far tests. However, if secondary generalization is possible within the absolute theory, then the absolute theory might predict that Ss not consciously aware of the m dimension would respond relationally in the SN and DN tests, and absolutely in the Far test. This one possible differential prediction between the two theories would require that adult human secondary generalization gradients conform to those specified for primary generalization in a model (Spence, 1937) developed for nonverbal organisms. On the other hand, if the m dimension is not detected, the absolute theory would presumably predict responding to the previously correct stimulus in the SN-test and since no other basis for stimulus control exists in the DN- and Far-tests, chance responding should occur. Relational theory would make similar predictions in the latter tests.

Method

Subjects and Design. The Ss were 144 introductory psychology students at the University of Oklahoma who participated in the experiment in order to fulfill course requirements. Equal numbers of male and female subjects were randomly assigned to one of six treatment conditions resulting from a factorial combination of two training conditions (low- and high-meaningfulness discrimination lists) and three test conditions (Same-Near, Different-Near, and Far). In addition, half of the Ss in each training condition received one of two different lists, the remaining half received the other list. Thus, the study employed a 2 X 2 X 3 X 2 factorial design consisting of 24 cells with six Ss per cell.

List Construction. Four levels of m were obtained by assigning 96 dissyllables scaled for meaningfulness and rank ordered from high to low as follows: (1) zero-m units were defined as the 23 lowest scaled units; (2) low-m units were the 24 next higher scaled items; (3) medium-m units the next 25 units; and (4) high-m units were the highest 24 units. Within each category 16 items (5-to-8 letters) were chosen according to the following criteria: high-m units included only items with a G index of frequency (Thorndike-Lorge, 1944) of 37 or higher (13 of 16 units were A or AA) and an m range (Noble & Parker, 1960) of 7.49 to 11.72; medium-m units had a G index between 1 and 11 and a corresponding m range of 5.27 to 7.33. The 16 low-m items did not have a G rating and the m values ranged from 3.67 to 5.20. The zero-m category involved only non-word units (paralogs) with an m range of 2.50 to 3.59. The 16 items selected at each level of m are presented together with their G and m values in Table 1.

Insert Table 1 about here

From the four levels of m just described, two sets of verbal discrimination (VD) lists (eight pairs in each list) were derived for the initial learning task by pairing adjacent odd and even numbered pairs of items in Table 1. One set was composed of zero-m and low-m word pairs (List A and List B) and the other set consisted of high-m and medium-m word pairs (List C and List D). Word lists for transposition tests of the low training sets (List A and List B) were derived by pairing the same eight low-m training words with medium-m words of the same rank (SN test) and by pairing different low-m words with medium-m words of the next lower or higher rank (DN test). For example, if S was reinforced for choosing Vertex when given training pair Delpin-Vertex, then the SN test pair was Vertex-Quarry and the DN test pair was Endive-Quarry. List-B Ss trained on Tarop-Endive, with Endive correct, received Endive-Quarry for the SN test pair or Vertex-Quarry for the DN test pair depending upon treatment group. This procedure was employed to equate m level within word pairs as much as possible. Further, a Far test list was constructed by pairing the odd numbered medium-m and high-m word pairs, i.e., Quarry-Kitchen, etc. The Far test list was the same for the two Low-m training conditions and, in addition, served as the training list for one of the High-m training conditions, i.e., List C. The reverse of the above procedure was used to compose SN, DN, and Far test lists for the List-C and List-D training conditions. Further, the Far test list for the two high-*m* training conditions also served as the List-A training list.

The left-right position of the correct item was counterbalanced across four different serial orders for each training list. Test lists employed two serial orders which were different from the training lists when identical words were employed, i.e., SN test.

Procedure. Prior to learning, *S*s received standard VD learning instructions for the anticipation method and several practice trials on a memory drum using words unrelated to experimental tasks. Word pairs were presented simultaneously at a 2:2 second rate with a 4 second intertrial interval. Subjects indicated their choice of words by pressing either a left or right button, which illuminated either a left or right signal light respectively in front of *E*; a left button press indicated that the word on the left was correct and vice versa. Initial learning proceeded until *S* reached a criterion of two successive errorless trials on the total list or until 20 trials were completed. Immediately following acquisition of the first list, *S*s received one of three transposition tests: SN, DN, or Far. The *S*s were instructed to continue trying to anticipate the correct item but that feedback would not be given until the session was finished. Transposition tests for all *S*s consisted of two trials in which the eight pairs were presented at a 2:2 second rate separated by a four second intertrial interval. Following the test phase *S*s were asked a series of written and oral questions designed to determine *S*'s awareness of the experimental variables.

Results

Discrimination learning. Trials to criterion were analyzed in a 2 (Training tasks) X 3 (Transposition tests) X 2 (Sex) analysis of variance to determine comparability of initial discrimination learning for treatment conditions. (A similar analysis of numbers of errors made in reaching criterion produced essentially the same results.) In line with previous research, e.g., Ingison & Ekstrand (1970), Schulz & Hopkins (1968), Ullrich (1972), Ss learned high-m word pairs significantly faster than low-m word pairs, i.e., mean trials to criterion were 5.50 (Low m) versus 4.47 (High m), F (1,132) = 5.14, $p < .05$. However, the significant main effect appears primarily due to the slower learning of Ss in the Low-DN condition. The only other significant effect in this analysis was the Training tasks X Transposition tests interaction, F (2,132) = 4.06, $p < .05$. This interaction was further evaluated using the Newman-Keuls technique. The Low-DN group required significantly more trials to criterion ($\bar{X}$ = 6.87, SD = 6.85) than did the Low-Far ($\bar{X}$ = 4.5, SD = 2.00), High-SN ($\bar{X}$ = 4.17, SD = 4.56) or High-DN ($\bar{X}$ = 4.08, SD = 2.41) groups, all p's < .05. No other comparisons were significant.

Additional analyses of variance were conducted with list variants substituted for the training task variable, i.e., Lists A & B (Low m) and Lists C & D (High m), in a 4 X 3 X 2 factorial design. The results demonstrated a significant effect for lists, F (3,120) = 3.93, $p < .01$. The mean trials to criterion and respective standard deviations for the two low- and two high-m list conditions were 4.72, 2.88 (List A), 6.42, 3.64 (List B), 4.56, 2.76 (List C), and 4.08, 2.57 (List D). Subjects trained on List B took more trials to achieve criterion than all other lists (p's < .05) which did not differ from one another.

Transposition tests. A relational response consisted of choosing the stimulus unit with a higher m value in a test pair for Ss in the Low-m training groups, or a unit with a lower m value for the High-m training groups.

Since there was a significant effect for Lists, the proportion of relational responses (the number of relational responses divided by the number of test pairs, i.e., 16) was analyzed with a 4 (Lists) X 3 (Test conditions) X 2 (Sex) between groups analysis of variance. The results yielded a significant difference between Test conditions, F (2,120) = 68.31, $p < .001$, and a significant interaction between Lists and Test conditions, F (6,120) = 3.85, $p < .01$. The means and standard deviations for these groups are represented in Table 2. Specific comparisons of the

---

Insert Table 2 about here

Test conditions demonstrated that Ss receiving a SN test made significantly fewer relational responses than Ss that received either the DN or Far tests (p's < .01) which did not differ from each other. In addition, the proportion of relational responses of the SN group (i.e., .15) and the DN group (i.e., .62) was significantly different from chance (Z's = 4.85 and 1.66; p's < .05 and .01, respectively). Further, the proportion of relational responses of the Far test group (i.e., .57) was at chance level (Z = 1.00, p > .05).

In light of the Lists X Test conditions interaction simple main effects tests were conducted at each level of transposition test and within each of the List conditions. As can be seen in Table 2, Lists did not produce differential transposition performance in either the SN or DN test conditions (p's > .10). However, examination of the Far test condition shows that Ss initially trained with Low-m lists and tested with higher-m verbal pairs transposed more often than Ss initially trained with High-m units and tested with lower-m verbal pairs. The finding of differential transposition responses as a function of test direction is consonant with studies employing nonconceptual dimensions, e.g., size (Stevenson & Iscoe, 1954), and pitch (Riley & McKee, 1963). Although a simple main effects analysis yielded a significant overall difference between the means, F (3,120) = 3.89, $p < .05$, specific comparisons showed the above conclusion was limited to the List-B condition ($p < .05$). However, the mean difference between List A and Lists C or D approached significance (p's < .10). Additional comparisons of the proportion of relational responses made within Low (Lists A and B) or High (Lists C and D) training sets produced the finding that these conditions did not differ from each other. Thus, the finding that List B was more difficult to learn does not appear to have affected Ss' transposition performances to any great extent. Corroborating this conclusion was a lack of relatedness between numbers of trials to criterion and numbers of relational responses (r = .002) or numbers of errors and numbers of relational responses (r = .06) for the List-B condition. Additional correlations performed on other groups revealed that acquisition performance was not related to transposition performance.

When the type of transposition test was analyzed within each of the four training (List) conditions, the following pattern was observed: significantly higher relational responding was demonstrated for the DN and Far test conditions relative to the SN test condition for Ss trained on Lists A, B, and C (all p's < .01). Further, the DN test condition produced more relational responses than the SN condition for Ss given initial training on higher meaningful VD pairs (p < .05). That is, Ss initially trained on more meaningful VD pairs (List D) were more likely to transpose on a test set including the previously reinforced stimulus than when trained on less meaningful VD pairs. However, a similarly composed list (List C) did not show the same effect, in fact, these Ss performed more like Ss trained with the lower meaningful VD pairs.

From the results described it may be concluded that transposition was demonstrated along the dimension of meaningfulness. Further support for this conclusion derives from an analysis of the verbal protocols taken after testing was completed.

Transposition as a function of awareness. An examination of the Ss responses to the posttest questionnaire revealed that comparatively fewer Ss in the low m treatment groups (58%) recognized some form of the meaningfulness attribute (i.e., familiarity, commonality, etc.) of the training list relative to high m treatment groups (78%). Examination of the discriminability of the m attribute in Training and Test lists revealed that the mean interpair differences for low m lists were 1.41 (List A) and 1.33 (List B), and for the high m lists 3.09 (List C) and 2.97 (List D). Thus, low m groups were trained on a relatively difficult discrimination task and tested on an easy discrimination task whereas the high m groups received an easy to difficult task. It appears then, that the greater difficulty of discriminating the conceptual attribute in the low m training lists may have served to reduce relational responding in those Ss receiving a Far test list in which the Low m attribute was employed.

Additional examination of verbal protocols yielded little evidence that Ss in any of the SN test conditions saw a relationship between training and test stimuli (N = 3). However, although 65% of the Ss in the SN groups did recognize some form of the m attribute in the training list, the mean proportion of relational responses was comparatively small, i.e., .15 versus .62 (DN) or .57 (Far).

When Ss were classified on the basis of their verbal protocols into either "Aware" (Ss perceived the m relationship, or some similar attribute, in both training and test conditions) or "Unaware" categories higher relational responding occurred for the aware Ss (i.e., 75%; N = 26) than for unaware Ss (i.e., 37%; N = 118). As can be seen in Table 3, this same pattern of results held when Ss were categorized in

Insert Table 3 about here

the above manner for each of three test conditions. That is, "Aware" Ss made significantly more relational responses than the "Unaware" Ss for each of the test conditions (all differences were significant, p's < .001).

Discussion

The major finding of this study was the demonstration of transposition on the conceptual dimension of meaningfulness. Significantly more relational responses were made by Ss who identified training and test stimuli as belonging to the same dimension than by Ss who could not identify the conceptual dimension. The overall proportion of relational responses for aware Ss was somewhat comparable to other two-choice simultaneous discrimination studies in which adults transposed along a physical dimension, i.e., 75% versus 81% (brightness; Johnson & Bailey, 1966) or 83% (amplitude; Fullard, Massari, Snelbecker & Love, 1973). The finding of differential responding as a function of Ss' ability to detect a common dimension between training and transfer tasks is consonant with the conceptions of the differentiation theory of discrimination learning (Tighe & Tighe, 1966, 1968). From this viewpoint, tasks which increase perceptual experience with the stimulus variables should also facilitate the abstraction of the distinguishing attributes of stimulation and thus enable the S to identify the training and test stimuli as belonging to the same continuum. Although the present experiment was not specifically designed to test these conceptualizations, the use of multiple training sets (VD word pairs) is in line with the perceptual pretraining strategy of differentiation theory, i.e., exposure to an ordered set of stimulus values.

Since relatively few Ss, i.e., 18%, were able to identify training and test stimuli as members of the same dimension, the present methodology seems to be less effective in isolating the relevant dimensional attribute as compared to the predifferentiation methodology employed by

Buss & Rabinowitz (1973) or Tighe & Tighe (1969a, 1969b). However, the failure to increase Ss sensitivity to the m dimension does not appear to be a function of either the presence of reinforcement or the use of perceptual pretraining. For example, Buss & Rabinowitz (1973, Exper. 2) found that reinforced responding during pretraining did not significantly affect transposition. Moreover, studies employing multiple training sets demonstrated a high proportion of relational responses even though perceptual pretraining was not given (Johnson & Zara, 1960; Sherman & Strunk, 1964). Inability to detect the common dimensional attribute between training and test stimuli by the unaware Ss appears to have been a function of low intrapair discriminability of the training stimuli. An additional analysis of learning difficulty made to test this possibility demonstrated that aware Ss took significantly fewer trials to learn the initial discrimination task than did the unaware Ss ($\overline{X}$ = 3.69 versus $\overline{X}$ = 5.24, respectively), $t(142) = 2.32$, $p < .025$.

From a methodological standpoint, the verbal discrimination task is similar to the perceptual discrimination task of a transposition paradigm. Unlike the latter, however, training on a verbal discrimination task seems to enhance discriminitive control by the absolute aspects of the stimuli when the positive stimulus is present in the test-pair but not when it is replaced with items of comparable m value. Supporting this conclusion is the observation of a greater proportion of absolute responses in the SN test condition relative to the response pattern of the DN test condition. The mechanism presumed to underlie the response to the absolute cue is an accrual of situational frequency to the positive stimulus. The importance of situational frequency in studies employing verbal discrimination paradigms has been repeatedly demonstrated (see Eckert & Kanak, 1974, and Wallace, 1972, for a comprehensive review of the literature). Furthermore, since choices were made without feedback, control by absolute attributes (i.e., situational frequency) in the SN test condition would be predicted by the Rule 1 strategy (always pick the most frequent alternative) of the frequency theory of verbal discrimination learning (Ekstrand, Wallace & Underwood, 1966). In contrast, however, situational frequency plays a minimal role in transposition tests employing perceptual materials. In fact, one of the most consistent findings in transposition research is that relational responding occurs in near tests.

The main purpose of the present experiment was to determine whether transposition could be obtained on conceptual dimension. Nevertheless, the possible implications of the experiment for the absolute and relational theories warrants a brief discussion. First, neither theory would have predicted the pattern of results obtained in the SN and DN test conditions: absolute and relational responding, respectively. Second, the finding of random responding in the Far test would be predicted by absolute theory if it is assumed that the test stimuli lie beyond the excitatory and inhibitory generalization gradients. But performance in the Far test conditions was not bidirectionally symmetrical (i.e., that is the high to low condition produced chance performance whereas the low to high condition produced relational response). Neither absolute nor relational theory is flexible enough to incorporate these latter findings. Thus, the present results suggest that it is possible to use a conceptual dimension in a transposition experiment but that an adequate interpretation of the data lies outside the boundaries of the classical theories.

The pattern of results obtained in the present experiment may be a function of the methodological differences between the usual verbal discrimination and transposition tasks. For example, in the usual transposition study there is normally only one pair of stimuli, presented in a spatially counterbalanced fashion. However, in the verbal discrimination task there appears to be a "list" effect which is presumably due to Ss' learning to discriminate a number of different pairs. Apparently, discrimination training on different verbal pairs increases the saliency of the absolute characteristics of the stimuli relative to the more obscure relational dimension (m). In the typical transposition study, the relational aspects (e.g., size) of the stimuli are much more salient and are more likely to increase concept learning as well as conceptual transfer.

The experimental paradigm established in the present investigation can be used to study a number of discrimination learning problems such as concept shifts, voluntary stimulus generalization, etc., which have traditionally been studied with physical dimensions. Since humans, adult or child, live in a world rich in perceptual stimulation--presumably mediated by language--the study of discrimination problems with conceptual dimensions would appear to be an interesting and feasible undertaking.

References

Alberts, E., & Ehrenfreund, D. Transposition in children as a function of age. Journal of Experimental Psychology, 1951, 41, 30-38.

Buss, J. L. & Rabinowitz, F. M. The intermediate-hue transposition of children after same-different and seriation pretraining. Journal of Experimental Child Psychology, 1973, 15, 30-46.

Eckert, E. & Kanak, N. J. Verbal discrimination learning: A review of the acquisition, transfer, and retention literature through 1972. Psychological Bulletin, 1974, 81, 582-607.

Ekstrand, B. R., Wallace, W. P., & Underwood, B. J. A frequency theory of verbal discrimination learning. Psychological Review, 1966, 73, 566-578.

Fullard, W., Massari, D. J., Snelbecker, G. E., & Love, C. Ordering preference and auditory transposition. Perceptual and Motor Skills, 1973, 36, 1072-1074.

Ingison, L. J., & Ekstrand, B. R. Effects of study time, method of presentation, word frequency, and word abstractness on verbal discrimination learning. Journal of Experimental Psychology, 1970, 85, 249-254.

Johnson, P., & Bailey, D. E. Same determinants of the use of relationships in discrimination learning. Journal of Experimental Psychology, 1966, 71, 365-372.

Johnson, R. C., & Zara, R. C. Relational learning in young children. Journal of Comparative and Physiological Psychology, 1960, 53, 594-597.

Kuenne, M. R. Experimental investigation of the relation of language to transposition behavior in young children. Journal of Experimental Psychology, 1946, 36, 471-490.

Köhler, W. Simple structural functions in the chimpanzees and in the chicken. In W. D. Ellis (Ed.), A source book of Gestalt psychology. New York: Harcourt, Brace, 1938.

Marsh, G., & Sherman, M. Verbal mediation of transposition as a function of age level. Journal of Experimental Child Psychology, 1966, 4, 90-98.

Noble, C. E., & Parker, G. V. C. The Montana scale of meaningfulness (M). Psychological Reports, 1960, 7, 325-331.

Reese, H. W. Verbal effects in the intermediate size transposition problem. Journal of Experimental Child Psychology, 1966, 3, 123-130.

Reese, H. W. The perception of stimulus relations: Discrimination learning and transposition. New York: Academic Press, 1968.

Riley, D. A., & McKee, J. P. Pitch and loudness discrimination in children and adults. Child Development, 1963, 34, 471-482.

Schulz, R. W., & Hopkins, R. H. Presentation mode and meaningfulness as variables in several verbal-learning tasks. Journal of Verbal Learning and Verbal Behavior, 1968, 7, 1-13.

Sherman, M., & Strunk, J. Transposition as a function of single-versus double-discrimination training. Journal of Comparative and Physiological Psychology, 1964, 58, 449-450.

Spence, K. W. The nature of discrimination learning in animals. Psychological Review, 1936, 43, 427-449.

Spence, K. W. The differential response in animals to stimuli varying within a single dimension. Psychological Review, 1937, 44, 430-444.

Spiker, C. C., and Terrell, G., Jr. Factors associated with transposition behavior of preschool children. Journal of Genetic Psychology, 1955, 86, 143-158.

Stevenson, H. W. & Iscoe, I. Overtraining and transposition in children. Journal of Experimental Psychology, 1954, 47, 251-255.

Stevenson, H. W., Iscoe, I., and McConnell, C. A developmental study of transposition. Journal of Experimental Psychology, 1955, 49, 278-280.

Thorndike, E. L., & Lorge, I. The teacher's wordbook of 30,000 words. New York: Columbia University, Teachers College, Bureau of Publications, 1944.

Tighe, L. S., & Tighe, T. J. Discrimination learning: Two views in historical perspective. Psychological Bulletin, 1966, 66, 353-370.

Tighe, T. J., & Tighe, L. S. Differentiation theory and concept shift behavior. Psychological Bulletin, 1968, 70, 756-761.

Tighe, T. J., & Tighe, L. S. Perceptual variables in the transposition behavior of children. Journal of Experimental Child Psychology, 1969, 7, 566-577. (a)

Tighe, T. J., & Tighe, L. S. Facilitation of transposition and reversal learning in children by prior perceptual training. Journal of Experimental Psychology, 1969, 8, 366-374. (b)

Ullrich, J. R. Re-pairing, number of alternatives, and meaningfulness in verbal discrimination learning. Journal of Experimental Psychology, 1972, 96, 201-203.

Underwood, B. J., & Freund, J. S. Retention of a verbal discrimination. Journal of Experimental Psychology, 1970, 84, 1-14.

Wallace, W. P. Verbal discrimination. In C. P. Duncan & L. B. Sechrest (Eds.), Human memory: Festschrift for Benton J. Underwood. New York: Appleton-Century-Crofts, 1972.

Zeiler, M., & Gardner, A. M. Intermediate size discrimination in seven- and eight-year-old children. Journal of Experimental Psychology, 1966, 71, 203-207.

Table 1

Word Pools for Verbal Discrimination Learning Conditions and Transposition Tests

Meaningfulness level											
High m	G[a]	M[b]	Medium m	G	M	Low m	G	M	Zero m	G	M
Kitchen	AA	11.72	Quarry	11	7.33	Vertex	-	5.26	Delpin	-	3.59
Money	AA	10.87	Mallet	3	7.27	Endive	-	5.26	Tarop	-	3.54
Garment	40	9.96	Zenith	4	7.15	Lozenge	-	5.24	Kupod	-	3.46
Heaven	AA	9.94	Pigment	4	7.15	Argon	-	4.96	Kaysen	-	3.41
Dinner	AA	9.93	Lichens	7	6.64	Femur	-	4.87	Balap	-	3.35
Wagon	A	9.90	Pallet	2	6.42	Nimbus	-	4.74	Gojey	-	3.26
Office	AA	9.77	Ordeal	5	6.17	Stoma	-	4.51	Brugen	-	3.23
Insect	40	9.56	Yeoman	11	6.11	Grapnel	-	4.33	Quipson	-	3.20
Jewel	41	9.33	Sequence	6	6.09	Jetsam	-	4.26	Sagrole	-	3.06
Village	AA	9.11	Quota	3	6.04	Davit	-	4.25	Goken	-	2.98
Captain	AA	8.57	Tartan	1	5.58	Carom	-	4.22	Volvap	-	2.96
Hunger	37	8.35	Pallor	2	5.68	Bodkin	-	3.99	Zumap	-	2.87
Leader	AA	7.94	Bodice	2	5.65	Matrix	-	3.97	Polef	-	2.69
Uncle	AA	7.82	Naphtha	1	5.34	Gamin	-	3.90	Nostaw	-	2.64
Quarter	AA	7.76	Tankard	1	5.34	Widgeon	-	3.86	Meardon	-	2.56
Region	A	7.49	Rampart	4	5.27	Flotsam	-	3.67	Neglan	-	2.50

[a]Frequency value taken from Thorndike-Lorge (1944).

[b]Mean meaningfulness quantified by the method of average frequency of continued written associations in 60 seconds (Noble & Parker, 1960).

Table 2

Means and Standard Deviations of the Proportion of Transposition Responses for Experimental Conditions

Training List	Transposition Test					
	SN		DN		Far	
Low m	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
A	.09[a]	.21	.72	.14	.65	.27
B	.16	.23	.54	.13	.70	.26
High m						
C	.05	.04	.66	.19	.49	.17
D	.30	.35	.56	.18	.45	.19

Note. Maximum number of relational responses = 16.

[a] *N* = 12 for each subgroup.

Table 3

Proportion of Relational Responses
by Dimensional Awareness

	Transposition Test		
Group	SN	DN	Far
Aware	.69	.77	.81
N	3	14	9
Unaware	.12	.55	.45
N	45	34	39

Note. Maximum number of relational responses = 16.

APPENDIX A

Prospectus

The history of research into transposition phenomena reveals some of the diversity and often highly contrasting views in the broader field of psychology. Some of the earlier issues were concerned with the ontological status of relations as well as the problem of defining the basic units of perceived experience. Later, interest in reducing perceived relations into "mental" elements shifted to: how learning in one situation influences learning in new situations (viz., transfer). At one time considerable research was focused on what the transposition experiment demonstrates; the resulting theoretical speculations differed not only with regard to, "what is learned," but also, "how learning takes place." It is remarkable that, given the relatively long history of research,[1] the question, "what are the variables responsible for establishing control of S's response in the transposition experiment," is as of yet unanswered (Stevenson, 1970; Zeiler, 1974).

Successful resolution of the question does not seem to lie within the approaches taken by the classical perceptual theorists, e.g., Gestalt and American Configurationists, nor by the single (S-R)- or two (S-r-s-R)-stage mediational models of the learning theorists.

One purpose of the present article was to examine transposition data in terms of early relational (Gestalt) and absolute (single stage) theories, pointing out important weaknesses in both of these theoretical positions. This discussion will then be followed by an examination of a more successful theory of transposition posited by Spence (1937). The attempt here is not to provide a balanced critique--weighing both pros and cons--rather, to provide some data which focuses on the shortcomings of an assumption of the theory which is crucial to prediction in a transposition experiment (i.e., summation hypothesis).

Contrasting with the classical theories are two recent perceptual approaches, Ratio Theory (Zeiler, 1963, 1966a) and Differentiation Theory (Gibson & Gibson, 1955; Tighe & Tighe, 1966, 1968) which show considerably more promise. However, Ratio Theory, in its current stage of development is not presently able to handle the numerous situational variables affecting performance in the discrimination task, e.g., asymmetrical tests (Riley, 1968; Zeiler, 1966a, 1967). Since Ratio Theory has been adequately treated elsewhere (e.g., Hebert & Krantz, 1965; Reese, 1968; Riley, 1968) it was excluded from the present review.

Differentiation Theory, which has been successful in explaining other discrimination phenomena, e.g., shift behavior (Tighe & Tighe, 1966, 1968b, 1972), has only recently been applied to transposition phenomena (Tighe & Tighe, 1969a, 1969b). Because of the sparcity of theoretical and empirical work on this issue (cf. Stevenson, 1972), a second purpose of this article is to examine Differentiation Theory and methodology as it applies to transposition phenomena, i.e., two- and three-choice discrimination problems and multiple training sets. Following a brief description of the transposition paradigm, this review will proceed from a consideration of the early theories, to Spence's absolute model, and conclude with an examination of differentiation theory.

Definition

Transposition, as an experimental procedure, involves a minimum of two phases, the first consisting of discriminative training on two or more stimuli varying along the same dimension. The next phase involves a test for transfer in which the subject(_S_) is presented the same number of stimuli as in the initial discrimination task, but with at least one of the stimuli quantitatively varied along the relevant dimension. A transposition response is defined in the above situation as a choice response to the relative properties of the stimuli. That is, if _S_ was trained to select the larger square of a set, 1 sq. in. _vs_. 2 sq. in., then when presented the set, 2 sq. in. _vs_. 4 sq. in., the _S_ would also choose the larger stimulus. On the other hand, if _S_ chose the previously rewarded stimulus or one which is most similar to it, then _S_ is presumed to be responding to the absolute properties of the stimuli.

Early Theories

The Gestalt analysis of discrimination performance, as tested by the transposition paradigm, emphasizes the role of perceptual factors within the stimulus set and the non-continuity of learning; what is learned in the discrimination task is a relationship (Klüver, 1931, 1933; Köhler, 1938). Thus, during the second test phase of the experiment, subjects (_Ss_) would be expected to choose a stimulus object in terms of that relationship.

Alternatively, behaviorists have traditionally minimized the role of perceptual factors and consciousness in their explanatory efforts (e.g., Watson, 1913; 1919), focusing instead, upon responses and their controlling operations. From the standpoint of the behaviorist, "what is learned" is a response, gradually conditioned to the absolute properties of the stimuli (Hull, 1930). Initially, prediction of _Ss_' response during testing seemed straightforward: if the test set included the previously rewarded (positive) stimulus, the organism should select that object. Contrary to this prediction, Ss were found to consistently avoid the positive cue and select on the basis of the relational cue. This finding was demonstrated in a number of studies for a variety of infrahuman species and across several physical dimensions: chickens--size dimension, Bingham (1913, 1922), brightness dimension, Köhler (1938); rabbits--brightness dimension, Washburn & Abbott (1912); monkeys--loudness, Klüver (1933); rats--size dimension, Gulliksen (1932, 1936), brightness dimension, Helson (1927). Gestalt psychologists as well as American Configurationists (e.g., Gulliksen & Wolfle, 1938a, 1938b) have interpreted this finding as support for their respective definitions of the controlling stimulus in the transposition experiment.

Spence's Model

The Gestalt position remained unchallenged until Spence (1936, 1937) proposed a theory of discrimination learning that could account for the transfer of discrimination habits in situations where relational and other stimulus-response theories had difficulty. For example, several studies had shown that when S was given a stimulus set during testing further removed along the physical dimension while maintaining the same intraset ratio as the initial discrimination task, i.e., training set 1 sq. in. vs. 2 sq. in., test set 4 sq. in. vs. 8 sq. in., control by the relational cue diminishes (Gulliksen, 1932; Klüver, 1933; Spence, 1937). That is, Ss chose the stimulus most like the training stimulus (distance effect). (See Spence, 1936, 1937, 1942 for a more detailed description of the absolute theory.) The Gestalt and other relational positions would not predict differential responding as a function of the distance between the training and test sets.

For over three decades Spence's theory (1936, 1937) of discrimination learning and its extensions (Spence, 1942) have provided much of the impetus for the systematic study of transposition phenomena. Although the initial form of the theory was proposed to account for the behavior of infrahuman organisms, serious consideration had been given to its applicability to a much broader range of tasks and variety of organisms, e.g., non-mediating human Ss, (Kuenne, 1946). However, recent theory and empirical data have challenged some of the assumptions of Spence's theory, most notably the summation hypothesis, and consequently questioned the adequacy of the theory to account for transposition phenomena. Recent attempts to modify the theory (Spence, 1960; Spiker, 1970, 1971) have not dealt specifically with the transposition problem and so the criticisms remain. The next section will review several tests of the summation hypothesis which demonstrate the inadequacy of this hypothesis in accounting for discrimination learning and transposition.

Spence's Summation Hypothesis

The summation hypothesis states that an interaction (algebraic summation) of excitatory and inhibitory gradients, produced by the effects of reward and non-reward upon discriminally different values of the same physical dimension, results in a specific "effective reaction potential" or net E for all values on the continuum. Effective reaction potential is presumed to mediate both discrimination learning as well as choice performance in subsequent transposition tests (Spence, 1937). Verification of the theoretical mechanisms underlying the summation hypothesis proposed by Spence can be accomplished by contrasting post-discrimination gradients (PDG) with a control gradient (i.e., gradient of stimulus generalization; GSG), and by studying choice performance in the transposition experiment. A PDG is typically produced by first training an organism to differentially respond to two stimuli lying on a relevant dimension then testing for generalization to other values of that same dimension. The level of response to each of the test stimuli is used to form a generalization gradient (Hanson, 1959).

The research reviewed in the following sections is intended to provide a critique of several predictions made by the summation hypothesis. Other reviews of this topic with similar interests are either limited to some particular methodology (Allen, Capehart & Hebert, 1969) or do not include the more recent investigations in this very active research area (e.g., Hebert & Krantz, 1965). The first series of studies apply PDG methodology to examine three specific types of interacting gradients: (a) Excitatory-Inhibitory, (b) Excitatory-Excitatory, (c) Inhibitory-Inhibitory, followed by (d) tasks in which only one gradient is presumed to exist, i.e., errorless discrimination tasks. A final section will be devoted to research involving transposition paradigms which employ multiple excitatory and inhibitory gradients, i.e., multiple learning sets or separation of training and test sets.

The main point of this review is to show that even if <u>E</u> or <u>I</u> gradients exist (of which there is some doubt--see errorless discrimination below) and have their theorized shapes, they do not algebraically summate. If this latter conclusion is correct, then the transposition phenomena the theory was initially proposed to account for, i.e., distance effect, must be a function of some other (unexplained) mechanism(s).

Post Discrimination Gradients

Excitatory-inhibitory summation. Hanson (1959) studied the interaction of excitatory and inhibitory gradients by training pigeons to respond to a positive stimulus (S^+) wavelength, i.e., 550 mμ, and on randomly alternated trials, separate groups received one of the following non-reinforced stimuli (S^-): 555, 560, 570 or 590 mμ. A control group received only the S^+ during training and all groups were given a post-discrimination test involving wavelengths ranging from 480 to 620 mμ, at 10 mμ steps. Two important results were obtained (for present discussion): The modal responses for all groups were displaced to the left (peak shift) of the S^+ (away from the S^-); the amount of displacement being related to the proximity of the S^+ to the S^-. That is, more distant values produced smaller PDG shifts than less distant values. Secondly, the PDG's revealed that smaller distances between S^+ and the S^- did not predict a reduction in response rate. The peak shift can be derived from the summation hypothesis since values on the S^- side of a bilaterally symmetrical gradient would have less net E than values on the opposite side. However, the maximum height of the empirical gradients should diminish as S^- approaches S^+ due to a progressively increasing subtractive effect of S^-. As previously noted smaller distances between S^+ and S^- did not decrease response rate. Thus, the I gradient did not interact with the E gradient in the predicted manner.

The peak shift phenomenon was partly replicated by Doll and Thomas (1967) employing similar methodology and human Ss. Subjects were first trained on an S^+ (530 mμ) wavelength and were given depending on experimental group, one of the following S^-'s 540-, 550- or 590-mμ. All groups were given generalization testing. The modal responses for the 540 and 550 S^- groups were shifted away from the S^- relative to the control group lending further support to the summation hypothesis. However, overall support for Spence's model is somewhat lessened by the additional finding that a group whose S^- was more proximal to the S^+ (i.e., 530 S^- gp), displayed less of a peak shift than a group in which the S^- was comparatively more distal to the S^+ (i.e., 550 S^- gp).

Excitatory-excitatory summation. The following studies examine the ability of the summation hypothesis to predict behavior when the organisms are trained with more than one S^+ (Kalish & Guttman, 1959; Malone, 1974; Thomas & Williams, 1963) or when several S^-'s are present (Hanson, 1961) during discrimination training. Kalish and Guttman (1959) trained pigeons to three values which were close together with regard to spectral wavelength (i.e., 530, 540, 550), to test the hypothesis that a small separation would produce maximal summation of E gradients. However, the authors thought their data were best interpreted as demonstrating three separate gradients instead of a theoretically predicted supra-gradient. Thomas and Williams (1963) found somewhat similar results using more widely spaced stimuli. Control groups were given two S^+'s, i.e., 540 and 580 mμ, whereas an experimental group received a S^-, 560 mμ, along with the two S^+'s. Contrary to theory, the summation of positive habits did not occur as evidenced by the bimodal PDG's of the control groups. Other data critical of the notion that positive gradients summate derives from the lower overall response rate of the controls relative to the experimental group. Malone (1974) tested the prediction that the slope of a steady-state generalization gradient would flatten and overall responding to all stimuli would increase with increasing numbers of excitatory gradients. Pigeons were maintained throughout the experiment on two separate reinforcement schedules: when S^+ (90° vertical line) was present a variable-interval (VI) 1-min. schedule was in effect and a VI 3-min. schedule was used for six other line orientations (60°, 54°, 42°, 18°, 6°) which were initially presented with S^+, one at a time. Subsequent training involved each _S_ receiving a different presentation order of three conditions: (a) S^+ (90°) _vs_. 6°; (b) S^+ (90°) _vs_. 30°, 6° and (c) S^+ (90°) _vs_. 54°, 34°, 6°. The interacting gradient model of Spence was not supported in that an increase or decrease in number of orientation stimuli did not affect the gradient slope or absolute response rates.

Inhibitory-inhibitory summation. Hanson (1961) trained one group of _Ss_ to an intermediate wavelength (550 mμ) in a three-stimulus problem. The PDG of this group compared to a control group receiving training only to the S^+, was higher at the S^+ point. If Spence (1942) were correct in assuming that _I_ gradients algebraically summate, then the experimental _Ss_ should have had a lower empirical gradient than the control _Ss_.

Errorless discrimination. The successful establishment of a discrimination without any responding to S^- (errors) was first demonstrated by Terrace (1963) using a "fading in" technique. In a typical demonstration of errorless discrimination, the _S_ is initially trained to respond to a positive cue, then, in the presence of the S^+, S^- is introduced in as unobstrusive manner as possible gradually becoming more salient, over trials. When compared to a conventional discrimination learning group and a control group given no additional discrimination learning, Terrace (1964) did not find the usual peak shift on subsequent PDG tests, even though the conventionally trained group did display the usual peak shift. Further, both the errorless discrimination and the conventional discrimination groups displayed an elevated PDG relative to the control group. The "fading in" technique was cleverly used by Cole, Dent, Eguchi, Fujii, and Johnson (1964) to train three-year-old children in a transposition experiment. In the presence of S^+, a straight line (S^-) was introduced and over the course of 30 trials it was gradually transformed into a square somewhat smaller (1.6:1 area ratio) than the S^+. If it can be assumed that an _I_ gradient did not develop, Spence's model would predict absolute responding, that is, the stimulus most similar in size to the S^+ would elicit the most net _E_. The _S_s tended to choose a relational response on a test set near to the original training set. Reese (1968) has suggested that the Cole et al data could have occurred due to _S_'s failing to notice a difference between training and test set ratios. This argument is weakened since Rudel (1958) and Zeiler (1966a), also found relational responding on a near test when _S_s were trained and tested on stimuli with smaller area ratio's, i.e., 1.5:1 and 1.4:1 respectively.

The failure to find a peak shift in the PDG of _S_s learning a discrimination task without the occurrence of errors as well as relational responding in a transposition experiment when absolute responding is predicted calls into question the traditional view of discrimination learning as dependent upon extinction of a negative response tendency.

Transposition Paradigms

Multiple training sets: two choice. Studies employing multiple training sets have added a unique dimension to the problem of accounting for transposition by the summation hypothesis. If a single 2-choice discrimination task involves the interaction of two independently formed gradients, S_1^+ and S_1^-, then the learning to criterion of two discrete discrimination problems, having the same basis for solution, would involve the formation of four interacting gradients, $S_1^+ - S_1^-$ and $S_2^+ - S_2^-$. The problem of predicting discrimination performance is twofold: how do multiple sets of gradients interact, and secondly, what is the effective summation range. However, based on the initial form of the model (Spence, 1936, 1937) and its extension to the three-choice task (Spence, 1942), the behavioral consequences of multiple training sets would logically depend upon specific features of the task: (a) number of sets, (b) training set similarity, and (c) similarity between training and test sets. What does not seem apparent is how the theory and logical extensions can account for differential responding apparently due to an interaction of training methods, tests methods and number of choices in the discrimination task.

Johnson and Zara (1960) studied the effects number of discrimination training sets (one versus two) had on similar and dissimilar preference tests. One group of four-year-old children was trained to select the largest of two squares for two discrete training sets (i.e., 1 *vs*. 2 and 3 *vs*. 4).[2] The training sets were randomly alternated and each set had an area size ratio of 2.6:1.[3] A control group was trained on set, 3 *vs*. 4, with the same reward contingencies in force. Following training, _S_s from both groups were given one of three transposition tests: similar or near test (4 _vs_. 5), intermediate test (5 _vs_. 6) and a dissimilar or far test (6 _vs_. 7). The single training _S_s chose the larger of two squares in the near test approximately 80% of the time, but as similarity between training and test sets decreased the number of relational choices decreased, i.e., 5 _vs_. 6 = 55%, 6 _vs_. 7 = 52%. However, the multiple training group displayed near perfect relational responding for all test sets. This latter finding is discordant with the summation hypothesis which predicts a decline in relational responding on a far test relative to the control group. Sherman and Strunk (1964) replicated these results demonstrating the reliability of the effect. Not all studies have shown clear superiority of multiple training set methodology in producing response to the relational cue in the transposition experiment. For example, Sherman (1966) conducted a series of four experiments, using three- and four-year-old children, to study the effects different types of multiple training (e.g., pretraining, multiple dimensions, etc.) had on control of choice responses. The major finding of Sherman's study seems to be that although multiple training did not increase relational responding within experiments, the overall probability was significantly greater than chance. It appears that a high degree of relational responding for all groups diminished the effects of the multiple training variable. Since testing was not also accomplished with more dissimilar sets, differential predictions cannot be made.

It should be noted that the relevance of a study for the summation hypothesis is, in part, contingent upon the use of appropriate subjects (Kuenne, 1946; Spence, 1937). In the multiple training studies just mentioned, care was taken to select children who either could not articulate the basis for solution prior to training, or the ability to articulate the relevant concept was taken into account during analysis (not all agree with the presumed success of these attempts, e.g., Riley, 1968, p. 97).

Multiple training sets: three choice. Additional problems for the summation hypothesis derive from the demonstrations that three-choice multiple discrimination training sets produce a high degree of relational responding when inarticulate Ss are given "far" tests (Beaty and Weir, 1966; Caron, 1966a, 1966b; Gonzalez and Ross, 1958). The diminution of control by the absolute aspects of the stimulus, as test and training set dissimilarity increases, is in contrast to the many single three-choice studies showing opposite effects (e.g., Reese, 1961, 1962; Stevenson & Bitterman, 1955). Gonzalez and Ross (1958) trained three- to five-year-old children to the intermediate stimulus of two 3-choice discrimination tasks which were widely spaced, i.e., 1-2-3 and 11-12-13, and then tested within the range of the training set, i.e., 6-7-8. Although the intraset discriminability was relatively low (1.3:1), multiple training Ss chose the relational cue 73% of the time, significantly higher than the 20% of a single set control group which trained on 1-2-3 and was tested on 6-7-8. The pattern of these results was repeated by Beaty and Weir (1966) who found 80% and 0% first trial relational choices for range and control groups, respectively. Caron (1966a), using a 1.8:1 area ratio for his stimuli and similar Ss, also found a predominance of relational control in a range condition, i.e., 61%. Beaty and Weir point out (1966, p. 340) that since the test set was located at equal size-ratio distances from both training sets transposition could be predicted on the basis of overlapping generalization gradients. On the other hand, these same studies show that when test sets extend beyond the training range, i.e., training sets 1-2-3, 7-8-9 and test set is 10-11-12, multiple training results in a predominance of absolute responding. In the example just described, Caron (Reese, 1968, p. 77) found that only 55% of the choices were relational and when training sets were more similar, i.e., 1-2-3, 4-5-6, an equally distant test set (7-8-9) produced very little relational control, i.e., 28%. Zeiler and Paalberg (1964a) used a slightly more discriminable training set (2:1) and also found little evidence for relational control (26% and 17%) when highly similar multiple training sets were compared to a single set condition (16%). Using a similar experimental design and college Ss, Zeiler and Paalberg (1964b) demonstrated a much greater response to the relational cue when training sets ranged over a greater physical distance: sets 1-3-5, 3-5-7 and 2-4-6, 3-5-7 and controls 1-3-5 or 2-4-6, yielded 100%, 50% and 50% relational responses when tested with set 5-7-9. The only apparent difference between the two latter multiple groups is the total range of values delimited by the training sets.

The range of training values variable appears to offer a unifying explanation regarding the effects of multiple training sets. In young children lacking the ability to express the basis for solution in a three-choice discrimination task, relational responding is predominately controlled by the total range of training stimuli and not by the spatial relationships between training and test series. Support for this hypothesis derives from those multiple training studies showing relational responding when total training set is large--in absolute values--and independent of spatial position of the test set, i.e., within or outside of range: (1) within, .34-34.4 sq. in. = 61%, Caron (cited by Reese, 1968, p. 77), 1-23.3 sq. in. = 73%, Gonzalez and Ross (1958), 2.9-50.9 sq. in. = 80%, Beaty and Weir (1966), and (2) outside tests, .34-34.4 sq. in. = 55%, Caron (1966). Additional support for the hypothesis is obtained from a comparison of those multiple training conditions which show that a relatively narrow range of training values produces very little relational control and, often, are not very different from control conditions: (1) multiple training = 1-3.71 sq. in. vs. control = 2.2-3.7, 14% and 0% respectively, Beaty and Weir (1966), (2) control = 1-1.69 sq. in., 20% Gonzalez and Ross (1958), (3) multiple training = .34-5.90 sq. in., 28%, Caron (cited by Reese, 1968, p. 77), (4) multiple training = 2.9-21.6 and 4.0-21.6, 26% and 17%, respectively vs. control = 5.6-21.6, 16%, Zeiler and Paalberg (1964b).

An extension to the methodology employing discrete 2-stimulus learning sets utilizes a greater range and number of training values: subsequent tests involve both novel values within the training range or recombinations with different spatial characteristics. Lawrence and DeRivera (1954) trained rats to jump right or left using lighter (i.e., 1, 2, or 3) or darker (i.e., 5, 6, or 7) shades of grey on the top half of a standard brightness value (i.e., 4). Initial training consisted of left jumps for a 1/4 stimulus and right jumps for a 7/4 stimulus. Following criterion, four remaining sets were added to the initial set: 2/4, 3/4, 5/4, 6/4; requiring the same responses. Finally, Ss were presented different spatial orientations of training stimuli (i.e., 4/1, 4/2, etc.) and 18 additional combinations in which nine sets had lighter tops (e.g., 1/2, etc.) and nine sets had darker tops (e.g., 2/1, etc.). Summing the theoretical positive gradients, results in 16 combinations in which there are opposing definitions of the stimulus. For example, absolute theory predicts right and left responses for 4/2, 4/6 respectively, but a relational definition would predict left and right jumps, respectively. The results clearly supported a relational definition in 12 sets, an absolute definition in the remaining two sets.

Several other investigators have applied Lawrence and DeRivera's definition of the stimulus to study the effects multiple of training sets transposition phenomena using humans (Johnson & Bailey, 1966; Morris & Tempone, 1969; Porter, 1969). The results of the studies employing human Ss have not entirely supported Lawrence and DeRivera, but several important differences in methodology are evident. Johnson and Bailey (1966) studied one, two or three multiple training sets within several methods of presentation and age levels. Following training, four test trials were given in which the spatial relationships of the training stimuli were reversed (e.g., 1/4 to 4/1, etc.) allowing the testing of opposite definitions of the stimulus, absolute or relational. Multiple training sets increased relational responding for college Ss compared to fourth grade and kindergarten Ss (82%, 70% and 68% respectively). Although, the number of training sets did not significantly increase relational responding, the overall relational responding was high for simultaneously presented stimuli (78%) but slightly lower for successive groups (69%). Additional support for relational aspects of the task controlling choice behavior derives from the fact that only 75 of 540 Ss (14%) responded to absolute stimuli on the first, and on two of the next three test trials. Using a similar experimental design, Porter (1969) found only slight support for relational definition of the stimuli. Porter's Ss were fourth graders who were given 12 test sets; six test sets were similar to those used by Johnson and Bailey and an additional six employed other brightness value combinations (i.e., 2/1, 3/1, 3/2, 5/6, 5/7, 6/7). In addition, training and test cycles were repeated. The major finding of Porter's study was that neither relational nor absolute aspects controlled Ss' choices in trial one, as evidenced by the small (total N = 40) and relatively equal numbers of Ss who could be categorized in predominately absolute (less than two relational responses), i.e., 16 Ss, or predominately relational (nine or more relational responses), i.e., 13 Ss. However, this pattern changed on trial two; 23 Ss could be classified as relational but only 11 Ss were categorized as absolute responders. The remaining Ss were apparently controlled by both stimulus aspects. Some caution must be exercised when interpreting these results since the brightness values used were based on a subjective scale. Thus, the Ss in this experiment may have received a difficult brightness discrimination problem. This explanation seems plausible since others (cf. Mackintosh, 1965) have pointed out that the effect of increasing the difficulty of a discrimination problem is to increase responsiveness to irrelevant cues, and consequently increase the probability that Ss will respond to both relative and absolute properties of the stimuli. The reduction of absolute control observed in trial two may well be a result of the additional training on multiple sets.

One additional difference of importance between Lawrence and DeRivera (1954) and both Johnson and Bailey (1966) and Porter (1969) is that the latter two studies did not use a pre-training phase. The importance of this difference can be evaluated in a study by Morris and Tempone (1969) who pre-trained first and third grade children with a relatively easy brightness discrimination task (1/4 and 7/4). After criterion had been met, all Ss were given four additional problems requiring the same type of solution (2/4, 3/4, 5/4, 6/4) giving a total of six problems for the second phase. Upon completion of the training phase, each S was given one presentation of 24 different test sets (the combinations were identical to Lawrence and DeRivera, 1954). Unlike Lawrence and DeRivera's subjects (rats), third grade Ss chose the relational stimulus consistently. Of the 16 tests making opposing theoretical predictions, the third grade Ss used the relational aspect of the stimulus significantly more often than the absolute aspects and significantly more than the first grade Ss who performed at chance for all tests. An additional finding of significance is that the 11 Ss verbalizing the relevant relationships of the stimuli (three first-grade plus eight third-grade Ss) chose the relational stimulus 78% of the time, whereas the remaining 13 non-verbalizers (nine first-grade plus four third-grade) responded at chance.

Although the relational aspects of the stimuli seem to adequately predict choice performance of the third graders, the chance responding of the first grade Ss is somewhat puzzling in light of previous research. Johnson and Bailey's Ss were in kindergarten (N = 180) but chose the relational aspects of the stimuli in 68% of the overall conditions and

75% when the successive discrimination task data are excluded from analysis. A mediation hypothesis would be plausible for the Morris and Tempone data but not when Johnson and Bailey's results are also considered. A closer look at the stimulus materials for both studies reveals a possible explanation for these apparently discrepant results. When the physical values (% reflectance of light) of both studies are converted into ratios, the seven training sets of Johnson and Bailey's study have larger absolute differences between variable and standard stimuli (i.e., .22/1.0, .37/1.0, .56/1.0, 1.44/1.0, 2.03/1.0, 2.63/1.0) than similarly ordered training sets of the Morris and Tempone study (i.e., .31/1.0, .52/1.0, .58/1.0, 1.12/1.0, 1.58/1.0, 2.07/1.0); the smaller the difference between standard and variable stimulus values, the harder the discrimination. It was suggested previously that increasing difficulty of a discrimination task (Mackintosh, 1965) also increases the learning of both types of cues, relative and absolute. It seems that from these data a modification is warranted: younger Ss (first grade) will learn proportionately more of both types of cues than older Ss (third grade). Support for the later conclusion may be inferred from a study of Osler and Kofsky (1965) who found that in a discrimination task varying form, size, and color, four- and six-year-old Ss responded more frequently to the irrelevant dimensions and position cues than did eight-year-olds. Lastly, pretraining on an easy task seems to facilitate control by the relational cue when "verbal" Ss are given a difficult discrimination task.

Summary

Of the two types of experiments reviewed, PDG and transposition, the former provides a purer test of the summation hypothesis. Unlike the PDG paradigm, transposition experiments typically include a second stimulus during testing a procedure which may actually alter the underlying theoretical gradients. Indeed, Zeiler (1966a) has presented some impressive data suggesting that S's response may not only be related to training variables, but to the stimulus values of the test set as well. Most of the support (i.e., peak shifts of the PDG) for the summation hypothesis derives from studies experimentally manipulating E and I gradients. On the other hand those studies attempting to manipulate E and I gradients separately have met with scant success. These findings generalize across several species (i.e., pigeons and humans) and hold for several physical dimensions (hue, line orientation and size).

One of the strong points of Spence's theory is that it can predict the distance effect (i.e., absolute responding on far tests but relational responding on near tests) in transposition experiments. Failure to demonstrate a distance effect by linguistically competent subjects would not be particularly damaging to the theory since it was primarily designed for infrahuman organisms and inarticulate children. However, the data of the multiple training set studies was obtained from the theoretically appropriate subject population. Hence, the finding of relational responding on far tests as a function of multiple training sets is unfavorable to the summation hypothesis. When studies supportive of the summation hypothesis were carefully examined with regard to the total range of values used in training and test sets, it was found that a narrow range produced absolute responding whereas a wide range produced relational responding. This latter finding cannot be predicted by the summation hypothesis. The overall conclusion of the results produced by the PDG and Transposition studies is that the summation hypothesis is empirically sterile. Further, the data discussed call into question the following assumptions of the summation hypothesis: that (a) gradients interact and (b) the shape of E and I gradients is bilaterally symmetrical.

Differentiation Theory

It is clear from the foregoing analysis as well as other recent discussions of transposition phenomena (Kalish, 1969, p. 256; Stevenson, 1970, Pp. 886-887) that situational variables are important in determining choice performance in transposition. A fairly recent theory of discrimination learning that shares this view is differentiation theory (Gibson & Gibson, 1955; Tighe & Tighe, 1966). A major assumption of differentiation theory is that discrimination learning occurs as a result of perceptual learning; that is, the organism learns to distinguish various aspects of the stimuli which already exist but which it has not yet responded to, rather than adding associations or response-produced-cues to stimuli. Implicit in this assumption is the notion that some organisms may be insensitive to differences in stimuli at the beginning of training due to developmental and/or individual differences in perception. However, conditions which foster perceptual learning increase the organism's ability to detect and subsequently utilize such variables or differences. Differentiation theory, then, places a great deal of importance on the role stimulus variables play in discrimination learning relative to the sensitivity of the subject, and also on the types of manipulations of training conditions which affect sensitivity, e.g., manner of stimulus exposure (Tighe & Tighe, 1966). Although the theory has had considerable success in accounting for shift behavior (Tighe & Tighe, 1972), it has only recently been applied to transposition (Buss & Rabinowitz, 1973; Tighe & Tighe, 1969a, 1969b). A brief review will be made of the research which permits an evaluation of the theory's ability to deal with transposition phenomena.

Two-Choice Tasks

Predifferentiation experiment. Pretraining methodology requires that Ss make non-reinforced same-different judgments to successively presented stimulus objects which vary along the dimensions (e.g., size or brightness, etc.) to appear in subsequent discrimination tasks. Tighe and Tighe (1969a) assume that the pretraining task as described promotes differentiation of the task stimuli and that facilitation of discrimination following such treatment is due to an increase in S's sensitivity to the distinguishing features of the task. Two experiments were performed to account for the data of previous studies of reversal shift problems which demonstrated that pretraining on three or four stimulus values facilitated reversal shift performance but not when two stimulus values are specified (Tighe & Tighe, 1968a, 1968b). First grade Ss were pretrained (same-different methodology) on a two-value height discrimination task using easy or more difficult discrimination sets, and other Ss were given either a three-value, continuous variation, or control (no pretraining) treatment conditions. Following the pretraining phase, Ss were given discrimination training on the same dimension using 1.4:1 height ratio, followed by 10 presentations of a "far" transposition test. All groups learned the training task at the same speed. The control and two-value pretraining conditions produced an equivocal number of relational responses, which were less than the three-value and continuous variation conditions which did not differ from each other. The same pattern of results was observed in all groups for frequency of S categorized as "transposers" (8 of 10 relational responses).

The second experiment was designed to test the efforts of various training procedures on transposition: One group of Ss was given a simultaneous presentation of both training and test pairs--during the test phase. A second group of Ss received an alternating presentation of training and test pairs and a control group was tested in the usual manner. All groups learned the task at an equal rate but differed on the transposition test. The simultaneous group made significantly more relational responses ($\overline{X} = 9.9$) than either the alternating or control groups ($\overline{X}$'s = 7.5 and 5.6, respectively). Taking the results of both experiments together, there seems to be support for the notion that identification of training and test stimuli as belonging on the same continuum is a critical factor in transposition. In experiment I, this was accomplished by pretraining Ss with three-values or continuous dimensional variation and in experiment II the simultaneous group did better than either of the other groups. In the situations just mentioned, Ss had experience with ordering the stimuli along a dimension and presumably such experience increased Ss' sensitivity to the continuum relating both training and test stimuli.

Additional support for the latter suggestion derives from several studies showing that transposition will occur on a dimension that Ss have little or no difficulty ordering values (e.g., amplitude) but not on a dimension (frequency) in which the Ss have difficulty in ordering values (Riley & McKee, 1963; Riley, McKee, Bell & Schwartz, 1973; Riley, McKee, & Hadley, 1964). Fullard, Massori, Snelbecker, & Love (1973) were not able to show unequivocal support for the effects of pretraining on transposition. Prior to training Ss were given a preference task, which requested them to order stimuli varying on both amplitude and frequency dimensions. Either dimension could be selected. Subjects were given discrimination training on either a preferred or non-preferred dimension which was followed by a "near" test. Analysis of both proportion of first trials responses as well as choices for 10-test trials demonstrated the usual finding that Ss transposed more on an amplitude dimension than on a frequency dimension ($\bar{X}$'s 8.0 and 5.97, respectively), thus replicating the Riley studies. However, first trial responses failed to demonstrate an increase in transposition for both dimensions when Ss were trained with a preferred dimension. In fact, Ss preferring to order the frequency dimension produced significantly fewer relational responses on that dimension (44%) compared to Ss given a non-preferred dimension (e.g., amplitude, 80%). This latter finding conflicts with the findings of Smiley and Weir (1966) who trained Ss with a shift task using a similar procedure but employing different dimensions, i.e., color or form, and kindergarten Ss. The Ss in the latter study who were trained with a "preferred" dimension demonstrated significantly more reversal shifts than Ss who were trained with a non-preferred dimension. Johnson and White (1967) pretrained six- and seven-year-old children to order stimuli on a dimension and then divided these Ss by performance into high or low. The high performers made significantly fewer errors on a reversal task than low performers. Apparently Ss with more highly developed concepts of dimensionality are more likely to make less errors on a reversal shift.

Verbalization. A number of studies have relied upon the concept of verbal mediation to explain developmental differences in transposition (Kuenne, 1946; Alberts & Ehrenfreund, 1951) and reversal learning (Kendler & Kendler, 1962). That is, as children mature they become more likely to employ covert verbal mediating responses, rather than the absolute properties of stimuli, in discrimination problems. The verbal mediation hypothesis has been typically studied using the following methodologies: one type studies a range of age levels (Caron, 1967; Marsh & Sherman, 1966; Marshall, 1966) or employs a subject population presumed to be deficient in linguistic ability, i.e., retardates, (Zeiler, 1974) and psychotics (Hagen, Winesburg & Wolf, 1968), and still another type attempts to provide various kinds of labels during training (McKee & Riley, 1962; Potts, 1968; Reese, 1966; Tighe & Tighe, 1969b). The role verbalization plays in transposition phenomena, as suggested by Reese (1968) is one in which facilitation of transposition may occur by mediating a perceptual response which identifies or calls attention to the relevant dimension.

Differentiation theory also de-emphasizes the role of verbalization in the development of discrimination behavior, suggesting instead, that dimensional control in transposition is mediated by increasing Ss' sensitivity to the stimulus variables. Tighe and Tighe (1969b) studied the role of verbalization in both transposition and reversal learning using two pretraining groups and a condition for controlling for non-specific sources of transfer. A perceptual pretraining condition employed same-different judgments to two successively presented stimuli which varied along the dimension which appeared on a subsequent discrimination task. A second pretraining group involved verbal label training as well as same-different predifferentiation training. Following discrimination training one-half of each group was given either a reversal task or a transposition task. The results for both problems were similar, in that pretraining tasks facilitated both reversal learning and increased relational responding relative to a control condition. In addition, neither pretraining condition nor the initial discrimination learning condition were significantly different within experimental groups. The mean number of relational responses for the perceptual pretraining, perceptual-verbal pretraining, and control groups were 18.5, 16.8, and 13.7, respectively. It can be seen that higher relational responses were due to perceptual pretraining increasing Ss' ability to detect the relevant dimension-reward relations. A major problem for these data is the equivocal performance of verbal labeling and perceptual training groups. The additional cue of labeling was expected to facilitate relational responding more than mere perceptual training. An earlier study by Whitman (1965) found very similar results using perceptual, verbal, and no-pretraining conditions. Subjects in this study (three, four, and five years) were given a three-choice pretraining task in which they were required to select the middle sized stimulus of three triangles and then were rewarded for selecting the middle size of three boxes in a subsequent discrimination task. Choice performance was obtained for two test sets both distant from the training set. The major finding was that the two older groups produced significantly more relational responses than the youngest group but did not differ from each other. Secondly, the perceptual and verbal pretraining groups performed about the same during initial discrimination learning but both produced more transposition than the no-pretraining group.

Three-Choice Tasks

Another study relevant to differentiation theory predictions was conducted by Buss and Rabinowitz (1973) using a three choice discrimination task and hue dimension. Also of interest in this study was a comparison between two types of perceptual pretraining procedures, same-different and seriation pretraining. As previously noted, same-different pretraining involves S judging whether a variable stimulus is the same or different from a standard. Seriation pretraining involves the ordering of three or more stimuli along some physical dimension. Seriation pretraining Ss ($\overline{X}$ = 8.2 yrs.) were given a set of seven hues (i.e., Set A = middle blue-green) then trained and tested with values from the same range of stimuli. Another seriation pretraining condition involved training Ss on one set (i.e., A) and testing on a different set (i.e., Set B = green-green yellow) or Ss were pretrained on set B then trained on set A. Finally, a no-pretraining control received discrimination training only on set A. All Ss received both near and distant transposition tests. Examination of training trials revealed no significant differences across experimental conditions. The major finding of this study was that seriation-pretraining Ss did better than control Ss, and that only the control Ss displayed reduced responding (significant) on the distant test. In a follow up study, the effects of using reward vs. no reward, and two types of perceptual pretraining were factorially combined and evaluated under near and far test conditions. A reliable and significant finding was that seriation pretraining produced faster learning than same-different pretraining as evidenced by the large differences in number of trials to criterion for both conditions, i.e., $\overline{X}$'s = 1.08 and 5.68, respectively. Unlike previous studies, only seriation pretraining produced a high flat gradient of relational responding across test conditions. The same-different and control conditions displayed a significant reduction in relational responding compared to the seriation pretraining condition. The occurrence of a distance effect for the same-different group is in sharp contrast with other data obtained for similarly trained Ss (Tighe & Tighe, 1969). However, several differences between the methodology of Buss and Rabinowitz and Tighe and Tighe seems to have been critical in producing their results. The distance effect in the same-different group may have been due to the difference in number of judgments made per stimulus. In Buss and Rabinowitz, three or six judgments were made for seven values, whereas Tighe and Tighe used eight judgments of three values. Tighe and Tighe (1968) demonstrated that 8 or 12 judgments per value on a 4-value pretraining task facilitates reversal but not four judgments per value. In another study, Tighe and Tighe (1968) found that giving 8 judgments on either 3- or 4-stimulus values per dimension, but not two, facilitated reversal. Whitman's (1965) Ss were pretrained with 12 separate sets of three stimulus values; both pretrained groups produced more relational responses than a control. In addition to the number of judgments per value and number of values presented simultaneously during pretraining, the dimensionality of the stimuli also appears to interact in a complex way with task methodology. In the Tighe and Tighe, and Whitman studies Ss received stereometric stimuli during training whereas, Buss and Rabinowitz Ss received planeometric stimuli. The importance of dimensionality can be easily seen from the studies of Stevenson and McBee (1958) and Dornbush and Winnick (1966) which demonstrated that sterometric stimuli are learned better or more easily in a discrimination task than planeometric stimuli.

Extensions

In an earlier discussion of multiple training sets, it was suggested that the range of training stimulus values was related to choice performance in a transposition experiment. The major finding of interest for differentiation theory is that larger ranges of training values facilitated relational responding when compared to smaller training set ranges. Both relational and absolute theories would have difficulty in predicting the range variable effect. For example, relational theories would presumably predict a flat gradient of responding for all training and test situations, contrary to the data (Caron; cited by Reese, 1968, p. 77). As discussed earlier, the summation hypothesis would have difficulty in generating the appropriate gradients needed to predict choice behavior following multiple discrimination training. However, differentiation theory suggests that any procedure that increases Ss' sensitivity to information in a stimulus array, should also increase the Ss' ability to use that information. Since identification of test and training stimuli as belonging to the same dimension has been found to be an important factor in producing relational responding (e.g., Riley et al, 1967), it would seem that multiple training tasks which include test set stimuli within the training set range should also facilitate relational responding as such studies have shown (e.g., Gonzalez & Ross, 1958). Further, increasing the training set range should also facilitate relational responding since generalization between stimuli is greatly reduced due to decrease in similarity, but at the same time information about the dimension is increased due to inclusion of an ordered set of stimuli demarcating the continuum.

Conclusions

Differentiation theory has been applied to both two- and three-choice discrimination tasks in which pretraining and multiple training set tasks were employed. On the whole, studies employing a predifferentiation methodology offer strong support for the application of differentiation theory to two- and three-choice problems. Specifically, the notion that an increased sensitivity to the perceptual information within the stimulus variables was supported in the available studies, despite Buss & Rabinowitz (1973, Exper. 2). It appears that after appropriate training, Ss are able to identify training and test stimuli as belonging on the same continuum and consequently produce more transposition. The findings of Tighe & Tighe (1969b) and Whitman (1965) further suggest that perceptual variables play a more important role than verbal factors in producing transposition. It may well be that in those studies using verbal pretraining, the facilitation of transposition (e.g., Potts, 1968) may reflect the verbal mediation of a perceptual response which identifies or calls attention to the relevant dimension.

Although the scope of the theory, as it applies to transposition, is rather narrow at this time, it is apparently due to a lack of empirical research employing the appropriate theoretical strategy. Nevertheless, in the situations described traditional theories have difficulty in predicting the empirical results. Thus, it remains to be seen whether differentiation theory is merely a complementary theory or whether it can eventually offer a systematic interpretation of what is learned in the transposition experiment.

References

Alberts, E., & Ehrenfreund, D. Transposition in children as a function of age. Journal of Experimental Psychology, 1951, 41, 30-38.

Allen, D., Capehart, J., & Hébert, J. Spence's theory of discrimination learning: A re-evaluation. The Psychological Record, 1969, 19, 443-456.

Beaty, W. E. & Weir, M. W. Children's performance on the intermediate-size transposition problem as a function of two different training procedures. Journal of Experimental Child Psychology, 1966, 4, 332-340.

Bingham, H. C. Size and form perception in Gallus Domesticus. Journal of Animal Behavior, 1913, 3, 65-113.

Bingham, H. C. Visual perception in the chick. Behavioral Monographs, 1922, 4 (No. 20), 1-104.

Buss, J. L. & Rabinowitz, F. M. The intermediate-hue transposition of children after same-different and seriation pretraining. Journal of Experimental Child Psychology, 1973, 15, 30-46.

Caron, A. J. Far transposition of intermediate size in preverbal children. Journal of Experimental Child Psychology, 1966, 3, 296-311.

Caron, A. J. Intermediate transposition at an extreme distance in preschool children. Journal of Experimental Child Psychology, 1967, 5, 186-207.

Cole, R. E., Dent, H. E., Eguchi, P. E., Fujii, K. K., & Johnson, R. C. Transposition with minimal errors during training trials. Journal of Experimental Child Psychology, 1964, 1, 355-359.

Doll, T. J. & Thomas, D. R. Effects of discrimination training on stimulus generalization for human subjects. Journal of Experimental Psychology, 1967, 75, 508-512.

Dornbush, R. L., & Winnick, W. A. The relative effectiveness of stereometric and pattern stimuli in discrimination learning in children. Psychonomic Science, 1966, 5, 301-302.

Fullard, W., Massari, D. J., Snelbecker, G. E., & Love, C. Ordering preference and auditory transposition. Perceptual and Motor Skills, 1973, 36, 1072-1074.

Gibson, J. J., & Gibson, E. J. Perceptual learning: Differentiation or enrichment? Psychological Review, 1955, 62, 32-41.

Gonzales, R. C. & Ross, S. The basis of solution by preverbal children of the intermediate size problem. American Journal of Psychology, 1958, 71, 742-746.

Gulliksen, H. Studies of transfer of response: I. Relative versus absolute factors in the discrimination of size by the white rat. Journal of Genetic Psychology, 1932, 40, 37-51.

Gulliksen, H. The relationship between degree of original learning and degree of transfer. Psychometrika, 1936, 1, 37-43.

Gulliksen, H., & Wolfle, D. L. A theory of learning and transfer. I. Psychometrika, 1938, 3, 137-149. (a)

Gulliksen, H., & Wolfle, D. L. A theory of learning and transfer. II. Psychometrika, 1938, 3, 225-251. (b)

Hagen, W. J., Winsberg, B. G., & Wolff, P. Cognitive linguistic deficients in psychotic children. Child Development, 1968, 39, 1103-1117.

Hanson, H. M. Effects of discrimination training of stimulus generalization. Journal of Experimental Psychology, 1958, 58, 321-334.

Hanson, H. M. Stimulus generalization following three stimulus discrimination training. Journal of Comparative and Physiological Psychology, 1961, 54, 181-185.

Hébert, J. A., & Krantz, D. L. Transposition: A re-evaluation. Psychological Bulletin, 1965, 63, 244-257.

Helson, H. Insight in the white rat. Journal of Experimental Psychology, 1927, 10, 378-396.

Hull, C. L. Knowledge and purpose as habit mechanisms. Psychological Review, 1930, 37, 511-525.

Johnson, P., & Bailey, D. E. Some determinants of the use of relationships in discrimination learning. Journal of Experimental Psychology, 1966, 71, 365-372.

Johnson, P. J., & White, R. M., Jr. Concept of dimensionality and reversal shift performance in children. Journal of Experimental Child Psychology, 1967, 5, 223-227.

Johnson, R. C., & Zara, R. C. Relational learning in young children. Journal of Comparative and Physiological Psychology, 1960, 53, 594-597.

Kalish, H. I. Stimulus generalization. In M. H. Marx (Ed.), Learning: Processes, New York: The Macmillan Company, 1969, Pp. 207-297.

Kalish, H. I., & Guttman, N. Stimulus generalization after training on three stimuli: A test of the summation hypothesis. Journal of Experimental Psychology, 1959, 57, 268-272.

Kendler, H. H., & Kendler, T. S. Vertical and horizontal processes in problem solving. Psychological Review, 1962, 69, 1-16.

Kinnamon, K. J. Mental life of two Macacus rhesus monkeys in captivity. American Journal of Psychology, 1902, 13, 98-148, 173-218.

Klüver, H. The equivalance of stimuli in the behavior of monkeys. Journal of Genetic Psychology, 1931, 39, 3-27.

Klüver, H. Behavior mechanisms in monkeys, Chicago: University of Chicago Press, 1933.

Köhler, W. Simple structural functions in the chimpanzees and in the chicken. In W. D. Ellis, A source book of Gestalt psychology. New York: Harcourt, Brace, 1938.

Kuenne, M. R. Experimental investigation of the relation of language to transposition behavior in young children. Journal of Experimental Psychology, 1946, 36, 471-490.

Lawrence, D. H., & DeRivera, J. Evidence for relational discrimination. Journal of Comparative and Physiological Psychology, 1954, 47, 465-471.

McKee, J. P., & Riley, D. A. Auditory transposition in six-year old children. Child Development, 1962, 33, 469-476.

Mackintosh, N. J. Selective attention in animal discrimination learning. Psychological Bulletin, 1965, 64, 124-150.

Malone, J. C. The effect of number of stimuli on the steady-state generalization gradient: A test of the summation hypothesis. Journal of Experimental Psychology, 1974, 102, 729-732.

Marsh, G., & Sherman, M. Verbal mediation of transposition as a function of age level. Journal of Experimental Child Psychology, 1966, 4, 90-98.

Marshall, H. R. Transposition in children as a function of age and knowledge. _Journal of Genetic Psychology_, 1966, _108_, 65-69.

Morris, L. A., & Tempone, V. Relational responding by elementary school children to transposition tasks. _Child Development_, 1969, _40_, 1203-1212.

Osler, S. F., & Kofsky, E. Stimulus uncertainty as a variable in the development of conceptual ability. _Journal of Experimental Child Psychology_, 1965, _2_, 264-279.

Porter, W. L. Absolute vs. relational responding in children. _Journal of Experimental Child Psychology_, 1969, _7_, 485-491.

Potts, M. The effects of a morphological cue and of distinctive verbal labels on the transposition responses of three-, four- and five-year olds. _Journal of Experimental Child Psychology_, 1968, _6_, 75-86.

Reese, H. W. Transposition in the intermediate-size problem by preschool children. _Child Development_, 1961, _32_, 311-314.

Reese, H. W. The distance effect in transposition in the intermediate size problem. _Journal of Comparative and Physiological Psychology_, 1962, _55_, 528-531.

Reese, H. W. Verbal effects in the intermediate size transposition problem. _Journal of Experimental Child Psychology_, 1966, _3_, 123-130.

Reese, H. W. _The perception of stimulus relations: Discrimination learning and transposition_. New York: Academic Press, 1968.

Riley, D. A. _Discrimination learning_. Boston: Allyn and Bacon, Inc., 1968.

Riley, D. A., & McKee, J. P. Pitch and loudness discrimination in children and adults. Child Development, 1963, 34, 471-482.

Riley, D. A., McKee, J. P., Bell, D. D., & Schwartz, C. R. Auditory discrimination in children: The effect of relative and absolute instructions on retention and transfer. Journal of Experimental Psychology, 1967, 73, 581-588.

Riley, D. A., McKee, J. P., & Hadley, R. W. Prediction of auditory discrimination learning and transposition from children's auditory ordering ability. Journal of Experimental Psychology, 1964, 67, 324-329.

Rudel, R. G. Transposition of response to size in children. Journal of Comparative and Physiological Psychology, 1958, 51, 386-390.

Sherman, M. B. The effect of variations in size of training stimuli on relational responding in young children. Unpublished doctoral dissertation, University of California, Berkeley, 1966.

Sherman, M., & Strunk, J. Transposition as a function of single- versus double-discrimination training. Journal of Comparative and Physiological Psychology, 1964, 58, 449-450.

Smiley, S. S., & Weir, M. W. Row of dimensional dominance in reversal and nonreversal shift behavior. Journal of Experimental Child Psychology, 1966, 4, 296-307.

Spence, K. W. The nature of discrimination learning in animals. Psychological Review, 1936, 43, 427-449.

Spence, K. W. The differential response in animals to stimuli varying within a single dimension. Psychological Review, 1937, 44, 430-444.

Spence, K. W. The basis of solution by chimpanzees of the intermediate-size problem. Journal of Experimental Psychology, 1942, 31, 257-271.

Spence, K. W. Behavior theory and learning: Selected papers. Englewood Cliffs, N.J.: Prentice Hall, 1960.

Spiker, C. C. An extension of Hull-Spence discrimination learning theory. Psychological Review, 1970, 77, 496-515.

Spiker, C. C. Application of Hull-Spence theory to the discrimination learning of children. In H. W. Reese (Ed.), Advances in child development and behavior (Vol. 6). New York: Academic Press, 1971.

Stevenson, H. W. Learning in children. In P. Mussen (Ed.), Carmichael's Manual of Child Psychology (Vol. 1). New York: John Wiley and Sons, Inc., 1970, Pp. 849-939.

Stevenson, H. W. Children's learning. New York: Appleton-Century-Crofts, 1972.

Stevenson, H. W., & Bitterman, M. E. The distance-effect in the transposition of intermediate size by children. American Journal of Psychology, 1955, 68, 274-279.

Stevenson, H. W., & McBee, G. The learning of object and pattern discriminations by children. Journal of Comparative Physiological Psychology, 1958, 51, 752-754.

Terrace, H. S. Discrimination learning with and without "errors." Journal of the Experimental Analysis of Behavior, 1963, 6, 1-27.

Terrace, H. S. Wavelength generalization after discrimination learning with and without errors. Science, 1964, 144, 78-80.

Thomas, D. R., & Williams, J. L. A further study of the stimulus generalization following three-stimulus discrimination training. Journal of the Experimental Analysis of Behavior, 1963, 6, 171-176.

Tighe, L. S., & Tighe, T. J. Discrimination learning: Two views in historical perspective. Psychological Bulletin, 1966, 66, 353-370.

Tighe, L. S., & Tighe, T. J. Transfer from perceptual pretraining as a function of number of stimulus values per dimension. Psychonomic Science, 1968, 12, 135-136.

Tighe, T. J., & Tighe, L. S. Perceptual learning in the discrimination processes of children: An analysis of five variables in perceptual pretraining. Journal of Experimental Psychology, 1968, 77, 125-134. (a)

Tighe, T. J., & Tighe, L. S. Differentiation theory and concept shift behavior. Psychological Bulletin, 1968, 70, 756-761. (b)

Tighe, T. J., & Tighe, L. S. Perceptual variables in the transposition behavior of children. Journal of Experimental Child Psychology, 1969, 7, 566-577. (a)

Tighe, T. J., & Tighe, L. S. Facilitation of transposition and reversal learning in children by prior perceptual training. Journal of Experimental Psychology, 1969, 8, 366-374. (b)

Tighe, T. J., & Tighe, L. S. Stimulus control in children's learning. In A. D. Pick (Ed.), Minnesota Symposia on Child Psychology (Vol. 6). The University of Minnesota Press, Minnesota, 1972, 128-157.

Washburn, M. F., & Abbot, E. Experiments on the brightness value of red for the light adapted eye of the rabbit. Journal of Animal Behavior, 1912, 2, 145-180.

Watson, J. B. Psychology as the behaviorist views it. Psychological Review, 1913, 20, 158-177.

Watson, J. B. Psychology from the standpoint of a behaviorist. Philadelphia: Lippincott, 1919, 177.

Whitman, T. L. Transposition in children under three treatment conditions. Unpublished master's thesis, University of Illinois, 1965.

Zeiler, M. D. New dimensions of the intermediate size problem. Neither absolute nor relational response. Journal of Experimental Psychology, 1963, 66, 588-593. (a)

Zeiler, M. D. The ratio theory of intermediate size discrimination. Psychological Review, 1963, 70, 516-533. (b)

Zeiler, M. D. The stimulus in the intermediate size problem. Psychological Review, 1966, 73, 257-261. (a)

Zeiler, M. D. Solution of the two-stimulus transposition problem by four- and five-year old children. Journal of Experimental Psychology, 1966, 71, 576-579. (b)

Zeiler, M. D. Stimulus definition and choice. In L. P. Lipsitt and C. C. Spiker (Eds.), Advances in child development and behavior (Vol. 3). New York: Academic Press, 1967, Pp. 125-156.

Zeiler, M. D., Simultaneous discrimination: Two separate types of control. Journal of Experimental Psychology, 1974, 102, 941-947.

Zeiler, M. D., & Paalberg, J. The effect of two training sets on transposition in adults. Psychonomic Science, 1964, 1, 85-86. (a)

Zeiler, M. D., & Paalberg, J. Transposition in children with two discriminations in training. Unpublished manuscript, Wellesley College, 1964. (b) Cited by H. W. Reese, The perception of stimulus relations: Discrimination learning and transposition. New York: Academic Press, 1968, p. 80.

Footnotes

[1]It is generally (Hebert & Krantz, 1965; Reese, 1968; Riley, 1968; Spence, 1968) agreed that the first experimental study of transposition was by Kinnamon (1902).

[2]Unless otherwise noted, it can be assumed that all stimuli lie on the same physical dimension, and numbers identify the relative position of a value in a particular series.

[3]Ratios will be used to designate the proportionate increase in value of an ordered set of stimuli.

Appendix B

Instructions

Verbal Discrimination Instructions

In the window of the machine pairs of words will appear at the rate of one pair every two seconds. One of the words of each pair has been designated as correct, the other as wrong by the experimenter. There is a way to be correct every time. Each pair will be exposed twice for two seconds each time before a new pair appears. Your task is to learn to recognize the correct item during the first exposure, and indicate your choice of which item is correct by pushing the appropriate button in front of you. For example, if you think the item on the right-hand side is the correct one, push the button on the right (ask S to push button). If you think the left item is the correct one, push the left button. During the second exposure the correct word will be underlined to inform you if your selection was correct. Do not push the buttons during this time.

There are eight different pairs. Each complete run through the eight pairs constitutes a trial. A series of small stars will appear in the window between trials to alert you to the trial to follow. The eight pairs will be arranged differently on each trial, so that, the position of the correct word will be on the right side on some trials and on other trials, it will be on the left side. You should not try to use either position of the pair in the trial or left-right position of the words to help you learn. In any case, the correct word in each pair will be correct from trial to trial.

Your first trial will be a study trial, that is, all eight pairs will be presented for you to study silently. After the study trial, we will begin and you should select the word you think is correct during the first exposure of each pair. We will continue until you make no mistakes on the eight pairs for two consecutive trials or until I tell you to stop. Remember, after the study trial, begin to select the correct item when the pair appears again without underlining. Do not push the buttons when the underlined pair appears. Again I would like to remind you that it is possible to be correct every time. Here is an example:

Strong Painting

Strong <u>Painting</u>

Are there any questions?

<u>Transposition Test Instructions</u>

You will now be shown eight new pairs of words, different from the ones you have just learned, and as before, one of the two words in each pair is correct and the other is wrong. Choose the item you think is correct as you did before, that is, simply select the item you think is correct by pushing the appropriate button. Unlike the first task, however, you will not be shown the correct items (the underlined word), there will be a blank instead--nor will you be given an initial study trial. Even though I do not show you the correct item, you should still find it possible to be correct every time. Since you are not given the underlined words, you will have to make a judgment as to which item you think should be correct. In other words, select the item you think I would pick. Continue until I tell you to stop. I will let you know how many you got right after I stop you. Are there any questions?

Appendix C

Posttest Questionnaire

Written

1. In the last task how did you know which word to select?
2. Did you use the same strategy for all items in the first list?
3. Did you do anything differently for the second list?
4. What do you think this experiment was about?

Oral

1. Did you notice anything peculiar about the items in the first task, i.e., was there anything about the items within a pair that you recognized?
2. (If yes to question #1) Was the characteristic that you recognized only in the correct, incorrect or both items?
3. How about the second task, were any of these items peculiar?
4. Did the second task have anything to do with the first task? Was there any logic that seemed to connect the two tasks?

Appendix D

Raw Data

List A

Same-Near Condition

Males			Females		
Trials	Errors	Relational Responses	Trials	Errors	Relational Responses
6	12	1	3	1	2
2	0	1	4	4	0
4	2	0	3	2	12
2	0	0	7	3	1
6	3	0	10	18	0
4	1	1	3	2	0
$\overline{X}$ = 4.00	3.33	.50	5.00	5.00	2.50
SD = 1.79	4.56	.55	2.89	6.45	4.72

Different-Near Condition

4	2	14	7	7	14
3	1	8	3	2	14
2	0	12	3	3	13
6	8	9	14	11	12
5	7	12	14	18	10
4	1	12	5	7	8
$\overline{X}$ = 4.00	3.17	11.17	7.67	8.00	11.83
SD = 1.41	3.43	2.23	5.12	5.58	2.40

Far Condition

4	4	8	3	2	8
3	1	11	2	0	16
3	1	10	4	2	15
5	5	16	6	12	2
2	0	7	7	4	8
5	5	8	4	4	15
$\overline{X}$ = 3.37	2.67	10.00	4.33	4.00	10.67
SD = 1.21	2.25	3.29	1.86	4.19	5.57

List B

Same-Near Condition

3	4	1	4	3	4
13	20	10	7	8	0
3	1	1	4	3	0
8	21	8	10	16	0
8	10	7	6	6	1
5	4	0	5	4	0
$\bar{X}$ = 6.67	10.00	4.33	6.00	6.67	.83
SD = 3.83	8.65	4.32	2.28	4.97	1.60

Different-Near Condition

18	28	7	12	15	11
12	24	12	7	8	8
3	1	7	9	14	6
2	0	7	12	11	7
6	5	9	6	6	8
4	4	9	4	1	12
$\bar{X}$ = 7.50	20.67	8.50	8.33	9.16	8.62
SD = 6.25	12.34	1.97	3.27	5.27	2.34

Far Condition

2	0	14	5	5	14
9	12	14	5	6	9
7	3	2	3	3	10
9	10	6	4	4	15
3	1	10	6	8	16
4	2	11	3	2	14
$\bar{X}$ = 5.67	4.67	9.50	4.33	4.67	13.00
SD = 3.08	5.05	4.72	1.21	2.16	2.83

List C

Same-Near Condition

8	7	2	3	1	0
4	3	1	3	2	1
2	0	0	3	1	0
3	1	0	4	1	0
3	1	0	3	1	0
11	11	0	2	0	6
$\overline{X}$ = 7.33	3.83	.50	3.00	1.00	1.17
SD = 3.54	4.31	.84	.63	.63	2.40

Different-Near Condition

8	14	10	9	19	8
3	1	15	9	12	14
2	0	15	4	2	9
2	0	8	4	2	12
7	15	6	5	3	7
7	8	9	3	1	10
$\overline{X}$ = 4.83	6.33	10.50	5.67	6.50	10.00
SD = 2.79	7.00	3.73	2.66	7.34	2.61

Far Condition

2	0	8	3	2	10
12	13	6	13	17	4
4	3	7	4	6	11
3	2	7	3	1	6
2	0	6	2	0	13
2	0	4	2	0	6
$\overline{X}$ = 4.17	3.00	6.33	4.50	4.33	8.33
SD = 3.92	5.06	1.37	4.23	6.59	3.50

List D

Same-Near Condition

4	2	0	5	5	10
4	5	0	2	0	15
4	4	0	6	4	0
3	2	3	4	2	0
6	7	14	3	3	8
3	1	2	7	10	5
$\overline{X}$ = 4.00	3.50	3.16	4.50	4.00	6.33
SD = 1.09	2.26	5.46	1.87	3.41	5.89

Different-Near Condition

2	0	9	4	4	7
2	0	8	4	5	5
2	0	7	2	0	10
2	0	11	3	1	13
2	0	6	2	0	13
7	6	12	3	1	6
$\overline{X}$ = 2.83	1.00	8.83	3.00	1.83	9.00
SD = 2.04	2.45	2.32	.89	2.14	3.52

Far Condition

9	6	3	2	0	6
6	5	10	3	1	6
3	3	7	9	15	12
4	3	9	14	18	10
3	1	10	3	2	4
2	0	6	3	2	3
$\overline{X}$ = 4.50	3.00	7.50	5.67	6.33	6.83
SD = 2.59	2.28	2.74	4.80	7.97	3.49

Appendix E

Summary Tables of the Analyses of Variance

Summary of the 2 X 3 X 2 Analysis of Variance
on Trials to Criterion

Source	df	MS	F	p
Training Tasks (A)	1	45.57	5.14	< .05
Test Conditions (B)	2	7.13	.80	> .10
Sex (C)	1	11.88	1.34	> .10
A X B	2	36.02	4.06	< .05
A X C	1	.18	.02	> .10
B X C	2	8.74	.98	> .10
A X B X C	2	11.92	1.34	> .10
Error	132	8.86		

Summary of the 2 X 3 X 2 Analysis of Variance
on Errors to Criterion

Source	df	MS	F	p
Training Tasks (A)	1	180.01	5.74	< .05
Test Conditions (B)	2	37.55	1.19	> .10
Sex (C)	1	12.84	.41	> .10
A X B	2	53.47	1.71	> .10
A X C	1	.03	.001	> .10
B X C	2	20.88	.67	> .10
A X B X C	2	7.52	.24	> .10
Error	132	31.35		

Summary of the 4 X 3 X 2 Analysis of Variance
on Trials to Criterion

Source	df	MS	F	p
Lists (A)	3	37.31	3.93	< .01
Test Conditions (B)	2	10.55	1.11	> .10
Sex (C)	1	7.11	0.75	> .10
A X B	6	15.11	1.59	> .10
A X C	3	10.24	1.08	> .10
B X C	2	8.42	0.89	> .10
A X B X C	6	3.75	0.39	> .10
Error	120	9.51		

Summary of the 4 X 3 X 2 Analysis of Variance
on Errors to Criterion

Source	df	MS	F	p
Lists (A)	3	127.78	4.22	< .01
Test Conditions (B)	2	36.19	1.19	> .10
Sex (C)	1	11.11	0.36	> .10
A X B	6	48.62	1.61	> .10
A X C	3	31.35	1.04	> .10
B X C	2	22.11	0.73	> .10
A X B X C	6	6.24	0.21	> .10
Error	120	30.25		

Summary of the 4 X 3 X 2 Analysis of Variance on Proportions of Relational Responses

Source	*df*	*MS*	*F*	*p*
Lists (A)	3	.052	1.13	> .10
Test Conditions (B)	2	3.159	68.31	< .01
Sex (C)	1	.061	1.33	> .10
A X B	6	.178	3.85	< .01
A X C	3	.008	0.16	> .10
B X C	2	.009	0.19	> .10
A X B X C	6	.065	1.40	> .10
Error	120	.046		

Summary of the Simple Main Effects Analysis of Variance on Proportions of Relational Responses

Source	*df*	*MS*	*F*	*p*
A (Lists)	3	.052	1.13	> .10
A at b_1 (SN test)	3	.138	2.29	> .10
A at b_2 (DN test)	3	.088	1.91	> .10
A at b_3 (Far test)	3	.179	3.89	< .05
B (Test Conditions)	2	3.159	68.31	< .01
B at a_1 (List A)	2	1.401	30.47	< .01
B at a_2 (List B)	2	.924	20.08	< .01
B at a_3 (List C)	2	1.168	25.40	< .01
B at a_4 (List D)	2	.205	4.46	< .05
Error	120	.046		

Appendix F

Summary of A Posteriori Comparisons

Summary of the Newman-Keuls Test of Differences
Between Means for Trials to Criterion

	$\overline{X}_1$	$\overline{X}_2$	$\overline{X}_3$	$\overline{X}_4$	$\overline{X}_5$	$\overline{X}_6$
$\overline{X}_1$ (High-DN) = 4.08	--	.09	.42	1.09	1.34	2.79*
$\overline{X}_2$ (High-SN) = 4.17		--	.33	1.00	1.25	2.70*
$\overline{X}_3$ (Low-Far) = 4.50			--	.67	.92	2.37*
$\overline{X}_4$ (High-Far) = 5.17				--	.25	1.70
$\overline{X}_5$ (Low-SN) = 5.42					--	1.45
$\overline{X}_6$ (Low-DN) = 6.87						--

*$p < .05$

Summary of Newman-Keuls Test of Differences
Between Means of List Conditions for
Far Test

	List D	List C	List A	List B
$\overline{X}$ (D) = .4479[a]	------	.0417	.1979	.2552*
$\overline{X}$ (C) = .4896		------	.1562	.2135*
$\overline{X}$ (A) = .6458			------	.0573

[a]Proportion of relational responses.

*$p < .05$.

Summary of Newman-Keuls Test of Differences
Between Means of Test Conditions

List A

	SN	Far	DN
X (SN) = .0938	----	.5520**	.6249**
X (Far) = .6458		----	.0729
X (DN) = .7187			----

** $p < .01$.

List B

	SN	DN	Far
X (SN) = .1615	----	.3750**	.5416**
X (DN) = .5365		----	.1666
X (Far) = .7031			----

** $p < .01$.

List C

	SN	Far	DN
X (SN) = .0521	----	.4375**	.6042**
X (Far) = .4896		----	.1667
X (DN) = .6562			----

**p < .01.

List D

	SN	Far	DN
X (SN) = .3000	----	.1479	.2573*
X (Far) = .4479		----	.1094
X (DN) = .5573			----

*p < .05.