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THE EFFECTS OF TIME, DISTANCE, AND TYPE OF DISCRIMINATION ON TRANSPOSITION IN RATS[1]

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ABSTRACT. The effects of three variables on transposition were investigated: time between training and test, type of discrimination, and distance along the relevant dimension between the training and the test stimulus pairs. Two levels each of time, discrimination and distance were used in a 2x2x2 factorial design. Subjects were 80 hooded rats. The appartus was an adaptation of Munn's visual discrimination appartaus. The majority of subjects in most groups transposed the discrimination; more transposition was observed with near than with far pairs of test stimuli, and more with delayed than with immediate presentation of the test pairs of stimuli. It was found that there was reliably more transposition of the discrimination to a pair of test stimuli which were near to the original discrimination pair than to a pair which were farther away along the relevant dimension. Type and time effects did not reach a conventional level of statistical significance, although they approached it. The graphic examination of the results indicate that no significant interactions were found. The findings were interpreted according to Spence's theory of transposition. An alternative explanation in terms of adaptation level theory was also offered.

RESUMEN. La presente serie de experimentos investigó los efectos de tres variables sobre la transposición en ratas: tiempo entre el entrenamiento y la prueba, tipo de discriminación, y distancia en la dimensión relevante. Los sujetos fueron 80 ratas, en un diseño factorial 2x2x2. Se trabajó en un aparato de discriminación, adaptado de un instrumento construido por Munn. En la mayor parte de los sujetos se encontró transposición; esta fue estadisticamente mayor en los estímulos cercanos al par original; el tiempo y el tipo de discriminación no llegaron al nivel convencional de significación estadística, pero se le aproximaron. La representación gráfica de los resultados indica que no existió interacción importante entre las tres variables.

The problems of transposition have been studied for 50 years, and much work, both empirical and theoretical, has been done. The literal meaning of the word "transposition" is "change in spatial location," but the term has been used to refer also to change in temporal position. Under the influence of the Gestalt psychologists, transposition has come to refer to transfer based on "relative position" on any dimension, whether spatial, temporal, or attributive. Other investigators have used the term "stepwise phenomenon" to refer to this kind of transfer, but the term "transposition" has prevailed and is used in current research.

Transposition as a phenomenon has been investigated in discrimination learning in relation to the problems of the "effective" stimulus. When an animal learns to discriminate between two stimuli lying on the same physical dimension, what is the nature of the effective stimulus to which the response is associated? (Riley, 1958)

Operationally, the experimental demonstration of transposition involves three steps: (1) the S is trained to choose one object in preference to another, which differs from it in some physical dimension (e.g. color, size, brightness, frequency); this is called the training phase. (2) The S is then tested for one or more trials with a new pair of stimuli usually differing from each other by the same amount as the training pair, but shifted up or down the stimulus dimension; this is the test phase. (3) For transposition to be demonstrated, the S has to show the same relative preference in the test that he showed in training.

Using basically this paradigm, a large number of experiments, at least 280, have been performed during the last 50 years to study the parameters related to transposition. It has been found that transposition increases as a function of time between training and test (Stevenson & Weiss, 1955). It decreases with distance between the training and the test pair of stimuli (Kendler, 1950). Simultaneous presentation of the stimuli yields more transposition than successive presentation (Baker & Lawrence, 1951). Transposition is at least in part a function of contrast and background effects (Lawrence & DeRivera, 1954). Difficult problems produce more transposition than easy problems (Thompson, 1955). Moderate overtraining increases transposition in two-stimulus problems in both human and infrahuman subjects; prolonged overtraining, on the other hand, may reduce transposition in humans (Reese, 1968). Older children transpose more than younger children, probably due to the effect of verbal mediation (Alberts & Ehrenfreund, 1951); the effect of age on transposition has not been studied with infrahuman subjects. Two comprehensive reviews of the literature are now available: Herbert and Krantz (1965), and Reese (1968).

Table 1 presents a summary of the 23 studies published until now that have attempted to investigate the time factor in transposition.

EXPERIMENT

The present experiment investigated the effects of three variables on transposition: A. Time between the presentation of the training stimuli (the original discrimination) and the test stimuli (the test for transposition); B. Type or dimension of transposition (size vs. brightness); C. Distance along the relevant dimension between the training and the test stimulus pairs. Each of these factors was varied in two levels: the *time* factor was varied in two ways, immediate (I) or delayed (D) presentation of the test stimuli; the *type* factor was varied in two ways: size (S) or brightness

Table 1

Studies that Investigated the Effects of time Between Training and Test in Transposition

Investigator	Time	Subjects	Effect
Adams (1937)	Varied	Rats	Undetermined
Cohen (1963)	5 min	Pigeons	Decrease
Ebel & Werboff (1966)	24 hrs	Dogs	Increase
Flory (1938)	24 hrs	Rats	No effect
Gayton (1927)	24 hrs	Rats	No effect
Gould (1963)	4 & 10 min	Adults	Increase
Johnson (1916)	24 hrs	Gamecock	No effect
Köhler (1918)	Minutes 18 hrs	Chickens	Increase
Line (1931)	Unspecified	Children	Increase
Ohtsuka (1937)	Unspecified	Monkeys	No effect
Rudel (1957)	3 hrs	Children	Increase
Rudel (1960)	3 hrs	Brain-damaged children	Increase
Sato (1934)	Unspecified	Children	Increase
Spence (1942)	24 hrs	Chimpanzees	Increase
Stevenson & Langford (1957)	24 hrs	Children	Increase
Stevenson & Weiss(1955)	10 min 24 hrs	Adults	Increase
Stevenson, Iscoe & McConnell (1955)	24 hrs	Children	Increase
Takemasa (1934)	Unspecified	Chickens	Increase
Thompson (1955)	24 hrs	Rats	Increase
Warren (1964)	24 hrs	Cats	Increase
Wohlwill (1957)	1 min	Adults	Increase
Zeiler & Lang (1966)	24 hrs	Children	Increase
Zeiler & Salten (1966)	24 hrs	Children	Increase

(B); the *distance* factor was also varied in two ways: near (N) or far (F). A summary of the design is presented in Table 2.

Although these three factors have been considered important in transposition experiments, and have been investigated separately in several experiments, they have not previously been studied in a single experiment. Insofar as possible in the present experiment all other factors were kept constant.

METHOD

Subjects. The Ss were 80 experimentally naive hooded rats, 40 males and 40 females, 90 days old at the beginning of the experiment. They were maintained in their cages with food and water always available except during the experiment; then they were placed on a 22-hour food deprivation schedule. Five males and five females were randomly assigned to each of the eight experimental groups.

Apparatus. The appartaus was an adaptation of Munn's (1950) visual discrimination apparatus. The first compartment was 45x38x39 cms. Each goal box was 25x17x30 cms. The stimuli were attached to the doors of the two goal boxes so that the animal had to push under one of them to have access to the goal box. The doors were hinged on the top, and arranged in such a way that the animal could not get out of the goal box pushing the door from inside. Wet mash food was placed in a furniture coaster in one of the goal boxes.

Table 2

Experimental Design

Treatment Groups	Time	Type	Distance
ISN	Immediate	Size	Near
ISF	Immediate	Size	Far
IBN	Immediate	Brightness	Near
IBF	Immediate	Brightness	Far
DSN	Delayed	Size	Near
DSF	Delayed	Size	Far
DBN	Delayed	Brightness	Near
DBF	Delayed	Brightness	Far

The stimuli were 23x18 cms. cards, of different brightness for the B (brightness) groups. Brightness values are presented in Table 3. For the S (size) groups the stimuli were white rings of different sizes; the width of the rings were equated for total brightness. Size values are presented in Table 4.

Aside from the stimulus cards, the entire apparatus was painted flat black, and was uniformly illuminated.

Procedure. A. Preliminary training: For familiarization with the situation the Ss were permitted to explore the apparatus individually, for three days before the experiment. Forced trials were used in order to insure equal experience with both doors. During this preliminary training, cards which were intermediate to the size or the brightness of the stimulus cards to be used during the training situation were attached to the doors.

Table 3

Brightness Values

(Reflectances, i.e. proportions of incident light reflected by surface)

Stimulus	Reflectance
A	.91
B	.57
C	.22
G	.13
H	.05

Some of these values were used by Ehrenfreund (1952), and by Chisum (1965).

B. Discrimination training: Ss were rewarded for each choice of the correct stimulus (the card with the darker stimulus in the brightness situation, or with the larger stimulus in the size situation). A noncorrection method was used in that a trial was terminated after 30 seconds in the goal box (right or left), whether the response was correct or not. Following each trial the S was returned to his home cage until every other S of that treatment condition (for instance all the Ss of the condition ISM) were given one trial. Fifteen trials a day were given to each S, all of them with the cards A-B (see Table 3) for the brightness groups, or with A'-B' (see Table 4) for the size groups. Right and left stimuli were presented following the Gellerman (1933) series. The correct stimulus was the larger or the darker of the two presented simultaneously regardless of position

Table 4

Size Values

Diameters of White Rings

Stimulus	External Diameter	Internal Diameter
A*	2.50 cms.	-
B*	3.60 cms.	2.60 cms.
C*	5.10 cms.	4.24 cms.
G*	7.50 cms.	6.92 cms.
H*	10.60 cms.	10.38 cms.

Table 5

Mean Number of Trials to Criterion

		Immediate	Delayed	Total
Size	Near	134.2	128.8	138.35
	Far	143.1	147.3	
Brightness	Near	114.8	108.3	109.57
	Far	109.6	105.6	

(right or left). Training continued until each S reached the learning criterion of ten successive errorless runs. Ss were run all days, including Saturdays and Sundays.

C. Transposition test: Each S of the (immediate) groups was run immediately after reaching the discrimination learning criterion. Each S of the D (delayed) groups was run on the following day of reaching the criterion, exactly 24 hours later. For the Ss of the N (near) condition the stimuli were B-C (or B'-C'), near in size or brightness to the training pair (A-B or A'-B'). For the Ss of the F (far) condition the stimuli were G-H (or G'-H'), far from the training stimuli. The transposition measure, as is usually the case, was the performance on the first test trial with the new pair of stimuli.

RESULTS

Table 5 presents the mean number of trials to criterion.

It can be seen that the major differences are those between the size and brightness discrimination groups. An analysis of variance showed differences between groups to the .01 level of significance. This difference will bear on the interpretation of the transposition results.

A general picture of transposition is presented in Table 6 which shows the percent of subjects in each of the eight groups making transposition responses on the first trial test.

It can be seen that a majority of subjects in most groups transposed the discrimination. The exceptions were the two groups tested immediately on the far pair of stimuli (ISF, IBF). In terms of the three parameters in this study, there appears to be more transposition with near versus far pairs of test stimuli, and tendencies toward more for the brightness versus the size discrimination, and for the delayed versus the immediate presentation of the test stimuli.

To evaluate the reliability of the differences between the several groups, the exact test for a difference between two proportions (Edwards, 1960), and Finney's (1948) and Latscha's (1953) significance tables were used. An evaluation in terms of the *distance* parameter is presented in Tables 7, 8, 9 and 10.

In Table 7 it can be seen that when the immediate test groups were compared (combining the groups without respect to type of discrimination) the near test revealed more frequent transposition responses than the far test groups. The exact test for the difference between the near and the far groups showed the difference to be significant at the .05 level.

Parallel comparisons are presented in Tables 8, 9, and 10. In Table 8 it is apparent that although the difference is in the same direction as in Table

7, it falls short of significance at the .05 level. In Tables 9 and 10, however, it can be seen that the differences are significant at the .01 and .05 level respectively. These results clearly indicate that there is reliably more transposition of the discrimination to a pair of test stimuli which are near to the original discrimination pair than to a pair which is farther away along the relevant dmension.

The results in terms of the parameter *type* of discrimination (size vs. brightness) indicate that the differences associated with type of discrimination were not reliable, although in three of the four situations there were slightly more transposition responses for size than for brightness.

Table 6

Percent of Transposition Responses

		Immediate	Delayed
Size	Near	90	90
	Far	40	60
Brightness	Near	80	90
	Far	40	70

Table 7

Frequencies of Near vs. Far Transposition (T) and No Transposition (NT) Responses in the Immediate (I) Groups

	T	NT	Totals
Near (Size and Brightness)	17	3	20
Far (Size and Brightness)	8	12	20
	25	15	40

$P < .005$

Table 8

Frequencies of Near vs. Far Transposition (T) and No Transposition (NT) Responses in the Delayed (D) Groups

	T	NT	Totals
Near (Size and Brightness)	18	2	20
Far (Size and Brightness)	13	7	20
	31	9	

$P > .05$

Table 9

Frequencies of Near vs. Far Transposition (T) and No Transposition (NT) Responses in the Size (S) Groups

	T	NT	Totals
Near (Size and Brightness)	18	2	20
Far (Size and Brightness)	10	10	20
	28	12	

$P < .01$

The results in terms of the parameter *time* (immediate vs. delayed presentation of the test stimuli) indicate that the differences associated with different time intervals between training and test for transposition were not reliable although they were in the direction of more transposition for the greater delay groups in all comparisons. More transposition has been found in previous research for delays in testing, and there is no reason to doubt the effect.

Concerning possible *interactions* between the three parameters, the results are presented graphically in Figures 1, 2, and 3. The percent of transposition is presented as a function of type in Figure 1, as a function of distance in Figure 2, and as a function of time in Figure 3.

Examination of these graphs reveals little evidence of interaction effects. Although the lines are not parallel (indicating zero interaction), the divergence is not large enough to indicate significant interactions in any case. In four of the graphs (Figures 2 and 3) the divergence represents the difference due to the performance of only one animal in the group. In the two graphs of Figure 1 the divergence is due to the performance of two animals.

DISCUSSION

Most previous studies of transposition have involved only one parameter. A few have involved two parameters. The present investigation studied

Table 10

Frequencies of Near vs. Far Transposition (T) and No Transposition (NT) Responses in the Brightness (B) Groups

	T	NT	Totals
Near (Immediate and Delayed)	17	3	20
Far (Immediate and Delayed)	11	9	20
	28	12	40

$P < .05$

transposition as a function of three parameters: (1) type of discrimination (size or brightness); (2) time interval between training and test for transposition (immediate vs. delayed); (3) distance between the original discrimination stimulus pair and the test pairs (near vs. far).

The findings of this study are basically in accord with the findings of previous ones (with one or two parameters). In the present study, differences associated with type of discrimination and time interval between training and test were not large enough to be statistically reliable, although they were in the expected direction.

The exact test for proportions, used to analyze the data of the present study, requires the use of large *N*'s, and each group in the present investigation was composed of 10 subjects. Failure to find significant differences where previous studies have found them can be explained partially by the relatively small *N*'s.

However, other factors also influenced the results. It was observed that animals developed position habits that were hard to break. In the Gellerman series used for the presentation of the stimuli it was possible to see that the animals first learned a position habit to the right or to the left, and only later "paid attention" to the stimuli. The experimental situation used in the present investigation demanded that the S push the panel (or door) to have access to the goal box. and this did guarantee that the animal saw the stimulus. The action of other factors, such as the odor of the food, can be ruled out considering the large number of trials required to learn the discrimination, more than 100 trials in almost all cases. If the subjects had been following the odor of food, they should have reached the learning criterion very quickly. Each goal box was cleaned often, and the particles of food were removed.

In previous investigations more transposition has been found in brightness discrimination than in size discrimination, although this parameter has never been systematically investigated in one study. In the present case, more transposition was found with size than with brightness, although the results did not reach a conventional level of statistical significance.

If, however, despite the lack of a statistically significant difference in this experiment as far as type of discrimination, there is actually a reliable difference in amount of transposition, such a difference may be explained in terms of the relative difficulty of the types of discrimination problems. Using this kind of reasoning Thompson (1955) has demonstrated that difficult problems produce more transposition than easy problems. In the present experiment the size discrimination was more difficult to learn than the brightness discrimination as was shown by the significant difference in number of trials required to reach criterion.

Perhaps one of the most important findings of the present study was the apparent lack of significant interactions between the three factors investigated in the experiment. Of course, any statements about interaction effects in the present experiment must be very tentative because they would, in ffect, be based upon "proving the null hypothesis." There may be several possible reasons, including the size of the *N*'s, for the apparent lack of interaction effects in this experiment even if the three factors are not mutually independent. This is a matter which should be further investigated.

Finally, although the present study is not primarily addressed to theoretical issues, it does have some theoretical implications. Spence's theory (1936 a, b; 1937 a, b; 1942) predicts that there should be a decrement of transposition with increased distance between training and test pairs of stimuli. Relational theories have difficulty with this prediction. The confirmation of the distance effect in the present experiment lends further evidence for the acceptance of Spence's theory, at least for the type of subjects and conditions involved in this study.

An alternative theoretical explanation, based on James' (1953), and Zeiler's (1966) adaptation level theory, could also explain the results. Zeiler's theory is an adaptation level formulation, based on Helson's concepts, and it is capable of integrating the data of transposition in intermediate-size problems. In his experimental study transposition predominated at one step but not beyond. This distance effect is similar to the effect obtained in the present study. Zeiler relates the distance effect to AL concepts and to stimulus similarity.

Zeiler refers to his theory as a "ratio" theory, but the use of the label could lead to confusion with Riley's (1958) ratio theory. The model was proposed specifically to deal with the intermediate-size transposition problem. The theory has three basic assumptions: the subject learns during training to respond to the ratio of the positive stimulus to the adaptation level; this ratio is the "positive training ratio." The second assumption is that the subject responds on the first test trial to the test stimulus ratio that is most similar to the positive training ratio, unless the ratios of all test stimuli are either larger than or smaller than the positive training ratio. The third assumption is that the AL on test trials is determined by the test-stimulus magnitudes and the training AL.

The distance effect, found in the present experiment, can be explained in Zeiler's theory as follows: as the difference between the ratio of the training to the test pairs of stimuli increases, the amount of transposition responses would decrease. In the near condition the AL should move in such a way that the ratio of the larger of the two test stimuli to the new AL would be more similar to the training ratio, whereas in the far condition the ratio for the smaller of the two test stimuli to the AL would be more

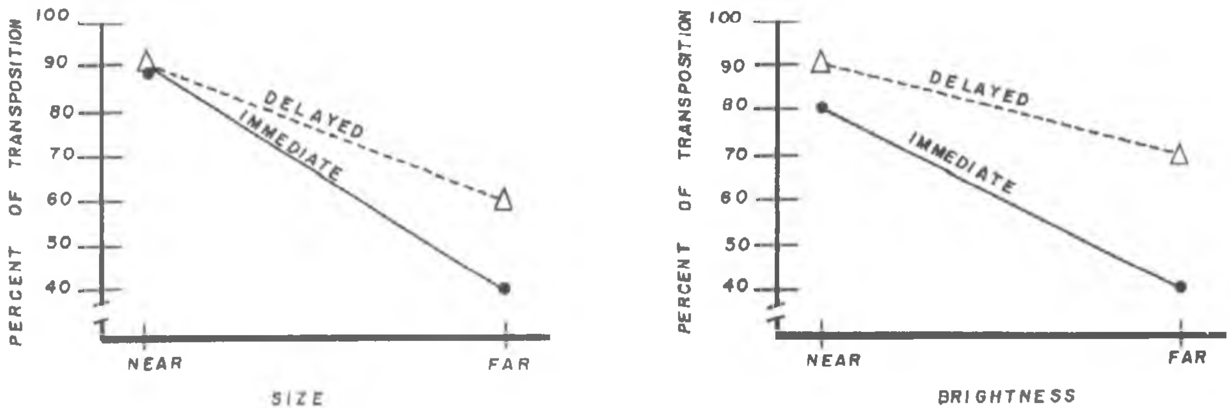

FIGURE 1. INTERACTIONS AS FUNCTION OF TYPE

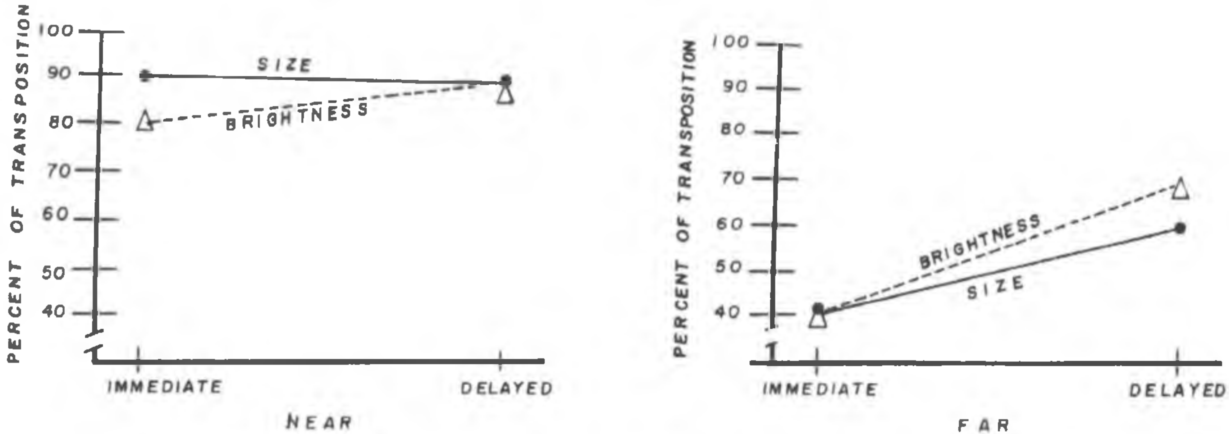

FIGURE 2. INTERACTIONS AS FUNCTION OF DISTANCE

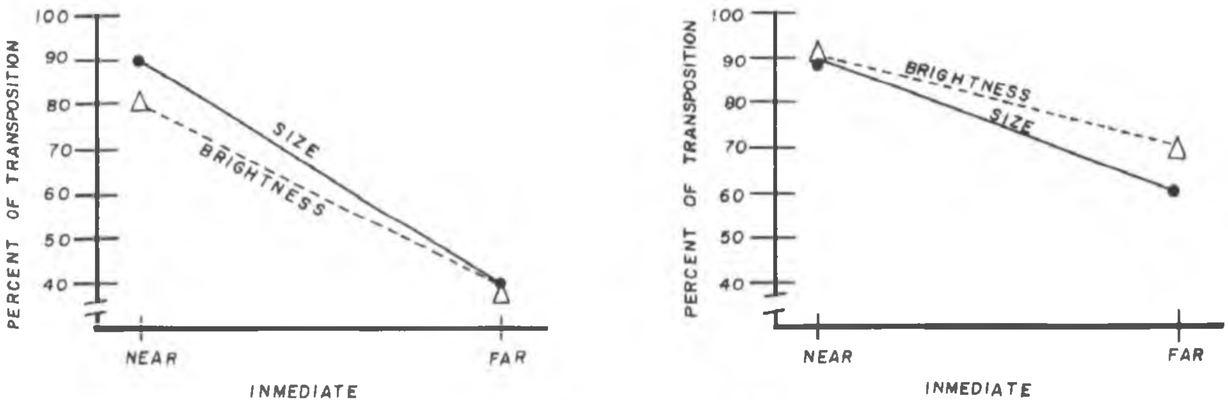

FIGURE 3. INTERACTIONS AS FUNCTION OF TIME

similar to the training ratio than the ratio of the larger test stimuli. The distance effect would be predicted in this way.

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FOOTNOTES

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