OPTIMAL SEQUENCES OF STIMULI FOR CONCEPT ATTAINMENT IN CHILDREN OF DIFFERENT AGES

by

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ABSTRACT

Lee, Morrison, & Bavelas (unpublished manuscript, 1978) tested the proposal that wrong placements in a concept-formation task are more informative to the subject than correct placements. The authors rearranged stimulus sequences such that the stimuli on which one subject made errors would be the first stimuli to be presented to the next subject (this method of stimulus rearrangement is called an error-transformation). If incorrect placements are more informative than correct placements then this procedure should result in an improved stimulus sequence for each successive subject. That is, the concept should be attained in fewer stimuli. The results verified the prediction. The resulting stimulus sequences (e.g. the sequences for the last subjects) led to concept attainment in fewer stimuli.

The authors suggested that different groups of subjects may derive different maximally efficient stimulus sequences. In Experiment I of this thesis children of three ages (e.g. kindergarten, grade 3, and grade 6) were considered to be different subject

populations which may derive different stimulus sequences. The stimulus sequences improved (i.e. information was available within fewer stimuli near the beginning of the sequence) to an equal extent for all age groups. The kindergarten children, however, did not show any improvement in performance. Additional groups of subjects from the same three subject populations did not show any tendency to perform better on improved stimulus sequences derived from subjects of their own age. Grades 3 and 6 subjects performed best on stimulus sequences derived from all groups.

In Experiment II the effect of dimensional preference in kindergarten children on the error-transformation method was investigated. No effect was found. Chapter IV presents an analysis of the stimuli in each sequence up to the point where the concept can be attained logically (e.g. pre-LK stimuli). The pre-LK stimuli produced by error-transformations of the older children's (grades 3 and 6) stimulus sequences were almost all stimuli which eliminated only one dimension. Furthermore, they were almost all positive instances of the relevant dimension. The pre-LK stimuli of the kindergarten children in both Experiments I and II were mostly stimuli that eliminated only one dimension but stimuli that eliminated two nonrelevant dimensions were also frequent. Like pre-LK stimuli of the older groups these were almost all positive instances.

In Chapter V it is shown that almost any rearrangement of a stimulus sequence, by whatever method, will result in an informationally improved stimulus sequence. Rearrangements of stimulus sequences where stimuli are randomly assigned to be errors results in improved stimulus sequences. However, the pre-LK stimuli in stimulus sequences resulting in such rearrangements do not consist predominantly of stimuli which eliminate only one dimension, nor are they positive instances. The implications of these results for human performance are discussed.

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I. Background

There has long been a controversy over the relative informativeness of being right and being wrong. For example, Popper (1959) considered the falsification of a theory as potentially yielding a greater amount of information than the discovery of confirming evidence since the latter is compatible with an infinite number of hypotheses. Confirming evidence can be misleading since we can be "right" for the wrong reason (a false-positive). If our instruments are not faulty, and our responses are compatible with the hypotheses we hold, we cannot be "wrong" for the wrong reason (a false-negative) as long as Nature always gives correct information. In the laboratory, situations can be constructed where the experimenter plays the role of Nature and instrumentation. The experimenter can arbitrarily decide to always give correct information. Therefore false-negatives can only occur if the subjects response is incompatible with his hypothesis (i.e. he places the stimulus in a position he did not intend to). The occurrence of false-positives is not restricted. Thus, a situation is constructed where wrongs should be potentially more informative than rights since they will be misleading less often. There are many practical situations where such restrictions exist.

Concept-formation tasks constitute experimental situations such as that described above. Subjects are required to categorize stimuli in order to learn, by trial and error, the rule (or concept) which unambiguously separates the stimuli into a given number of categories. The experimenter plays the part of Nature and instrumentation when he responds as to the correctness of each placement made by the subject. In most of these experiments, and those in this study, he does not mislead the subject.

Early in the literature of concept-formation the relative informativeness of positive and negative instances (exemplars and nonexemplars, respectively) of a concept was investigated (e.g. Smoke, 1932, 1933; Hovland, 1952; Hovland & Weiss, 1953). Although the negative instances are typically more difficult for the subject to categorize (Wason & Jones, 1963; Wason, 1959, 1960, 1961; Johnson, 1972; Wason & Johnson-Laird, 1972) this is a different question than the relative informativeness of rights and wrongs. The work of Bruner and his associates (1956) during the 1940s and 1950s led to the development of several hypothesis-testing theories of concept-formation (e.g. Restle, 1962; Hunt, 1962; Trabasso & Bower, 1964, 1966, 1968; Bower & Trabasso, 1964; Erickson, 1968; Gregg & Simon, 1967; Chumbley, 1969, 1972; Wickens & Millward, 1971; Levine, 1970, 1975). That is, it was commonly assumed that the subject chose an hypothesis (or hypotheses) of what the correct ruld was and tested it ageinst the stimuli. Some of these models assumed that learning occurred only upon errors (e.g. Trabasso & Bower, 1964; Bower & Trabasso, 1964) while others considered that learning can also occur upon correct placements (e.g. Levine, 1975).

Still, these experiments in concept-formation did not address themselves specifically to the relative informativeness of errors. An unpublished study by Lee, Morrison, & Bavelas (1978) purposely set out to test the informativeness of errors in two concept-formation experiments. The simplest form of concept-formation was employed (discrimination learning). The subject categorized a stimulus set into two piles. The experimenter told the subject whether he was right or wrong after each placement. The subject continued until he had placed all the stimuli at which time the experiment was complete for him. To this point the methodology was typical of simple discrimination learning experiments. Here, Lee et al. (1978) employed a unique variation which was designed to test the informativeness of errors. Rather than presenting the same stimulus sequence to the next subject, or a stimulus sequence structured such that each successive stimulus varies in only one attribute at a time, or a stimulus sequence rearranged at random —as is typically done in concept-formation experiments—they rearranged the stimulus sequence for presentation to each subject according to a simple rule applied to the previous subject's responses. These authors made a simple assumption: if errors are more informative that correct placements then all of the stimuli on which a subject had been wrong should carry more information and would thus improve the next subject's performance if that subject were to place these stimuli first (assuming a sufficient homogeneity among the subjects with respect to responses to the stimuli). Accordingly, all a previous subject's wrongs were placed before his rights by a subsequent subject. The subjects were unaware of this error-transformation, or the existence of a previous subject.

The cascading of subjects in this way improved the performance of subsequent subjects: they required fewer stimuli to attain the correct concept. Moreover, the stimuli of one of the experiments consisted of handwritten words with the relevant concept being sex of author. Thus, the experimenter could not outline the dimensions and values in the stimulus set, let alone the relevant one (s). In another experiment (Morrison, 1979; unpublished manuscript) subjects were cascaded in a concept-formation task with these stimuli such that each subject was presented with, and placed, a previous subject's rights before his wrongs. This method, the reverse of that of Lee et al. (1978) did not improve the performance of later subjects. These three experiments indicate that errors may indeed be more informative that rights. By ensuring that stimuli likely to be placed incorrectly are categorized first, concept-formation is improved.

II. Experiment I

The error-transformation discussed above led to an improvement in concept-formation performance presumably because the concentration of high-likelihood errors near the beginning of a stimulus sequence ensures that false-positives do not mislead the subject. Incorrect hypotheses are eliminated faster, leading to concept attainment in fewer stimuli. Lee, Morrison, & Bavelas (1978) suggested that separate cascades of different populations of subjects may derive different maximally efficient stimulus sequences. Even when the number of stimuli needed to eliminate logically all incorrect hypotheses (the logical K-value, LK) is the same, the stimulus sequences may differ between subject populations in the characteristic order, or strategy involved, in eliminating hypotheses. That is, different subject populations may tend to make errors on different stimuli. The object of this experiment is to investigate this possibility.

Some work in concept-formation points toward differences in performance between subjects of various ages (Odom & Guzman, 1972; Suchman & Trabasso, 1966; Trabasso, Stave, & Eichberg, 1969; Seitz & Weir, 1971). Thus, in this experiment kindergarten, grade 3, and grade 6 children were considered to be different subject populations. Wright & Vlietstra (1975) would postulate different performances by subjects from these age groups. They would predict that the younger children would tend to pay exclusive attention to preferred dimensions. That is, after LK had been passed and the children should have attained the concept they would not respond logically but would continue to respond as if their preferred dimension were relevant. Levine (1975) has found that the younger children tend to respond illogically on the basis of response sets such as position bias or stimulus preference. All of these authors would predict poorer performance on the part of the kindergarten children because of response biases. There would not be as large a difference between the two older groups. The occurrence of illogical errors in the younger group places the error-transformation method in question since the model in the Lee, Morrison, & Bavelas (1978) study supposed that the subjects would respond logically and post-LK errors would not occur. They would predict that performance would improve within each age group (i.e. LK would reduce upon each transformation or remain the same). Furthermore, each age group would perform better on a stimulus sequence derived from a cascade of subjects of the same age. That is, each age group would perform best on its own characteristic stimulus sequence.

The first experiment was performed to identify characteristic differences in stimulus sequences between age groups, to test the effectiveness of the error-transformation with kindergarten children, and to see if each age group performs best on a stimulus sequence generated by its own age group.

Method

Subjects. The subjects were 84 children in kindergarten, grade 3, and grade 6 at Willows School in Oak Bay. The 11 female and 17 male kindergarten children ranged in age from 66 to 79 months with mean 71.07 and standard deviation 3.21. The 13 females and 15 males in grade 3 ranged in age from 101 to 117 months with mean 105.89 and standard deviation 3.58. The 11 females and 17 males in grade 6 ranged in age from 134 to 158 months with mean 142.93 and standard deviation 4.51. As the subjects participated in the experiment they entered the cell in the design whose turn had come up. Cell Sequence had previously been randomly assigned.

Stimuli. The stimuli were 16 3x5 inch, white, plasticized index cards with geometric shapes of various colours, numbers, and sizes. Each of the four dimensions (e.g. number, size, colour, form) had two values (one/two, small/large, red/green, circle/square). The stimulus deck represents all of the possible permutations of the 4 binary-valued dimensions. The large stimuli were 1" in diameter and the small stimuli were ½" in diameter. A short instruction deck of two values and two dimensions was used to explain the procedure to the subjects and to eliminate subjects who could not understand what was required of them. The two dimensions in the instruction deck were straightness (straight/crooked lines) and orientation (vertical/horizontal lines). One subject was eliminated and replaced by another subject due to her inability to categorize these stimuli.

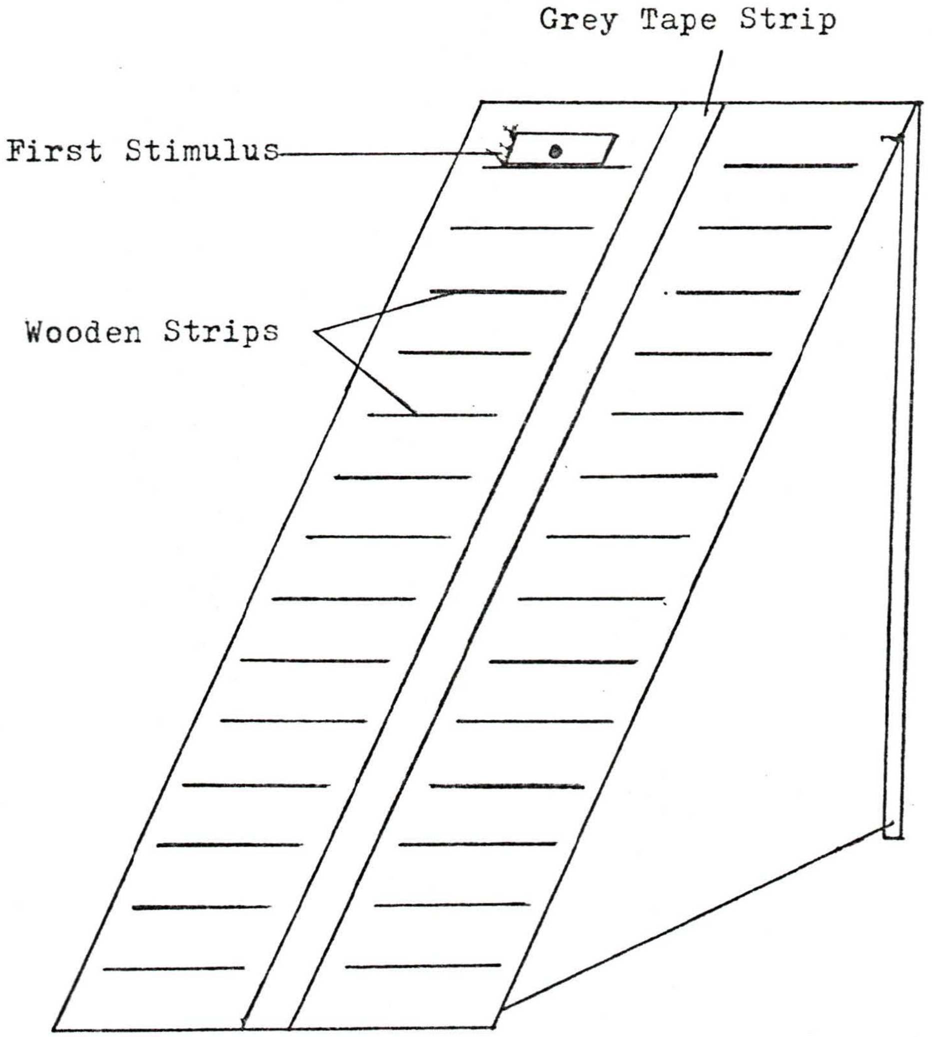
Apparatus. The apparatus involved was a board on which the subject could place the stimuli. The board was 68" tall but was at a slant when in use so that younger children could reach the top of the board. The stimuli were placed on 6" horizontal wooden strips which projected ¼" from the face of the board. There were 16 pairs of strips on the board, 16 strips on the left side and 16 on the right. The pairs were separated by

3". In addition, a 2" wide grey tape strip vertically separated the left and right sides quite clearly against the white background of the board (see Figure 1).

<u>Procedure</u>. The experimenter showed the 4 stimuli of the instruction deck to the subject and pointed out the values of each dimension. The subject was engaged in a guessing game where he tried to guess on which side of the stimulus board each card should be placed. The experimenter placed the first stimulus on the top left side of the board. The subject made his "guess" by placing the rest of the stimuli on the board, one at a time. After each placement the subject was told whether or not that was indeed where the experimenter would have placed the stimulus. If the stimulus was placed incorrectly the subject was instructed to place it in the correct position so that the stimuli on the board were at all times an accurate record of correct placements. The experimenter also asked the subject why he made his choice in order to know that the subject was attending to the dimensions of the stimuli and not to some peripheral information (e.g. that the experimenter would like all the stimuli on the left, etc.). The subject was directed to make choices which concerned only differences on the dimensions in the stimulus itself.

Figure 1.

The Apparatus



If after going through the instruction deck twice the subject could not correctly place the stimuli according to the orientation of lines he was dropped from the experiment. Otherwise, he was shown examples of the stimuli in the test deck. On the example cards each value and dimension was represented and the subject had to be able to identify each verbally (e.g. one, big, red, circle, etc.) or be able to indicate each upon a verbal prod. The subject was then engaged in the same kind of guessing game as he played with the instruction deck. However, this time he was not allowed to ask the experimenter questions nor did the experimenter respond other than indicating the correctness of each placement according to the relevant dimension of size. Once each stimulus from the test deck had been placed the trial was over for that subject. Each trial was the same except for the sequence in which the test deck stimuli were presented to the subject, the sequence depending on the errors made by the previous subject.

The first subject in each yoked group of four subjects was presented with the same test deck sequence of stimuli which had been constructed to require the maximum number of stimuli to isolate logically the relevant dimension (see Table I). This number of stimuli is

Table I.

Original Stimulus Sequence

1. one small red circle
2. two large green squares
3. two small red circles
4. one large green square
5. one small green circle
6. two small green circles
7. two large red squares
8. one large red square
9. one small red square
10. two large green circles
11. two large red circles
12. one large green circle
13. one small green square
14. two small red squares
15. two small green squares
16. one large red circle

called the logical K-value (LK) which was 9 in this case[1]. The relevant dimension was always size. The placing of the first stimulus (which was the same for all subjects) on the left effectively made that stimulus and its value (small) a positive instance. In each yoked foursome the first subject's wrong placements were presented to the second subject, in order, before the correct placements. The third subject received the second subject's wrongs before his rights. The fourth subject received such an error-transformation of the third subject's responses (see Table II). Each subject except the first of each yoked foursome was presented witha stimulus sequence which had been transformed on the basis of the previous subject's performance. A cascade of subjects yoked together in this manner constituted a group who responded individually to the same set of stimuli but whose arrangement had been changed several times. There were 12 such groups in this experiment (see Figure 2); four for each age group. Each of the stimulus sequences presented to the final subject in each group was presented to additional groups of subjects from each age level. This produced 9 groups of 4 subjects each. These groups were compared to see if subjects perform best on the stimulus sequences derived by their own group.

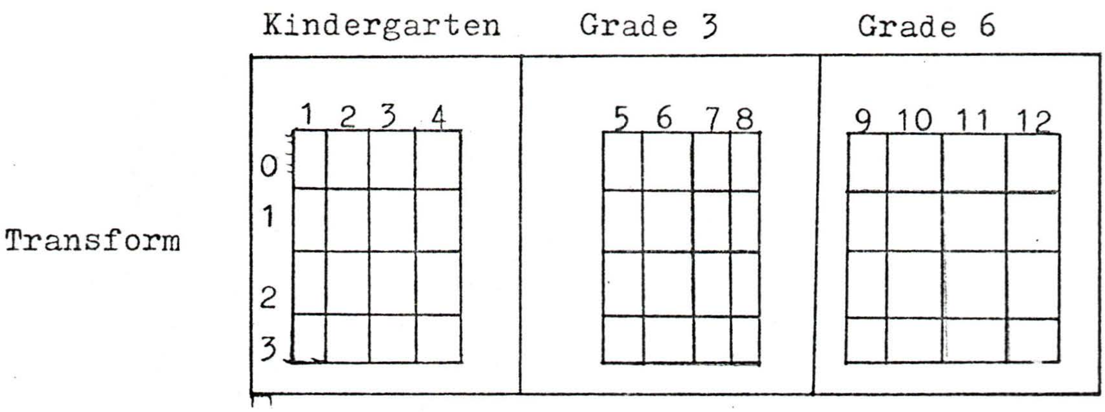
Table II.

Stimulus Sequences at each Transform

Subject Level	Stimulus Sequence
Transform 0	Original sequence
Transform 1	First transformed sequence
Transform 2	Second transformed sequence
Transform 3	Third transformed sequence

Figure 2.

Experimental Design



Stimulus from Transform 3

Age	Kindergarten	Grade 3	Grade 6
Kindergarten	21	22	23
Grade 3	24	25	26
Grade 6	27	28	29

<u>Hypotheses</u>. The main hypotheses of this experiment were:

1. Differences in derived stimulus sequences shall exist between age groups. These differences shall be reflected by different LK values or, given identical LK, differences in the stimulus sequences (e.g. different orders of elimination of nonrelevant dimensions).
2. Within each age group the value of LK shall reduce significantly with the transform, level. If LK does not reduce significantly there should be evidence of interference with the error-transformation process, such as failure to respond logically and response bias.
3. Subjects should produce a lower LK stimulus sequence when presented with a stimulus sequence which has been derived from the responses of subjects of their own age.

Results

Trend analyses showed LK to reduce significantly with transform. Linear components were significant for all age groups ($27.60 \geq F(1,15) \geq 10.25$, $p < .001$) and accounted for the largest proportion of the variance (e.g. 52.6% to 70.3%). Quadratic components were also significant for all age groups ($5.37 \leq F(1,15) \leq 34.32$, $.001 \leq p \leq .035$) but accounted for a much smaller share of the variance (e.g. 10.2% to 20.0%). A rather interesting result, explained below, was the significant cubic components for the kindergarten and grade 3 children ($F(1,15)=20.00$, $p < .001$; $F(1,15)=9.60$, $p < .009$) although the variance accounted for was small (e.g. 11.7% to 5.2%). The cubic component for the grade 6 group also approached significance ($F(1,15)=4.23$, $p < .058$) with a similar amount of variance accounted for (e.g. 8.1%). There were no differences across age groups in LK ($F(2,45)=1.33$, $p > .05$, Per.Var.=0.97%) but the transform effect was significant in a two-way, transform by age group, ANOVA ($F(4,45)=56.29$, $p < .000$, Per.Var.=82.05%). In these results a fifth level (transform 4) was included. After the last subject in each group (transform 3) had responded the LK for the sequence presented to the next subject (transform 4) was determined and included in the analysis.

The LK is a measure of the improvement of the stimulus sequence according to a logical analysis. It is a structural characteristic of the stimulus sequence and is not a measure of a subject's performance. An additional measure not originally planned but common in the literature was applied. This measure is commonly called the trial of the last error (TLE: the number of the last error in the sequence) but will here be called the performance K-value (PK) to emphasize its predicted close relationship with LK if subjects benefit from an improved stimulus sequence. If subjects do benefit from an improved stimulus sequence then PK should reduce along with LK. Trend analyses showed the kindergarten and grade 3 groups not to improve with transform but a significant linear component in the grade 6 group did exist ($\underline{F}(1,12)=13.097$, $p<.004$, Per. Var.=46.1%). A two-way, transform by age group, ANOVA showed significant differences between transform ($\underline{F}(3,36)=6.54$, $p<.001$, Per. Var.=27.66%) and between age groups ($\underline{F}(2,36)=4.80$, $p<.014$, Per. Var.=13.54%). Tukey's test showed significant differences between grade 6 and kindergarten ($q(3,36)=5.44$, $p<.01$); grade 3 and kindergarten ($q(3,36)=4.12$, $p<.05$); but not between grade 3 and grade 6 ($q(3,36)=1.60$, $p>.05$).

Pearson product moment correlations between LK and PK were significant for grades 3 and 6 ($r=0.55$, $p<.02$;

and $r=0.56$, $p < .01$, respectively) but not for the kindergarten group ($r=0.40$, $p > .05$). The means and standard deviations of LK and PK are presented in Table III for each age group. Figures 3, 4, and 5 outline graphically the relationship between LK and PK for the three age groups and show the trend for each parameter. Clearly, the improved stimulus sequence of the older groups is accompanied by an improvement in subjects' performance. The improvement in the stimulus sequence of the kindergarten children is not accompanied by an improvement in performance.

A two-way ANOVA showed no difference between the LKs resulting from the transform 3 stimulus sequence presented to the original group of subjects for each age level and the second group of subjects of the same age for each age level ($\underline{F}(1,18)=2.18$, $p > .05$, Per.Var.= 9.09%). The difference between same-age groups for PK was also nonsignificant ($\underline{F}(1,18)=2.26$, $p > .05$, Per.Var.= 9.13%). This attests to the reliability of the LK and PK measures and the transform method. None of the age groups performed better on the stimulus sequences generated by subjects their own age according to LK ($\underline{F}(2,18)=0.18$, $p > .05$, Per.Var.=1.19%). However, there was a significant sequence effect according to PK ($\underline{F}(2,27)=$

Table III.

Means and Standard Deviations

LK:

Transform	Kindergarten		Grade 3		Grade 6	
	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
0	9.0	0	9.0	0	9.0	0
1	4.5	1.3	5.5	.58	5.0	1.8
2	4.25	.5	5.0	.82	4.75	1.71
3	4.25	.5	4.5	1.0	4.5	1.73
4	3.75	.58	4.0	0	3.5	.58

PK:

Transform	Kindergarten		Grade 3		Grade 6	
	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
0	11.25	2.63	9.0	0	11.0	2.83
1	12.75	2.06	5.25	5.12	6.25	3.59
2	5.5	4.04	3.5	2.38	4.5	1.92
3	8.25	4.99	5.75	5.56	4.5	1.73

Note: since the transform 4 level is predicted there is no PK measure.

Figure 3.

Graph of Transform vs Mean K-values for Kindergarten

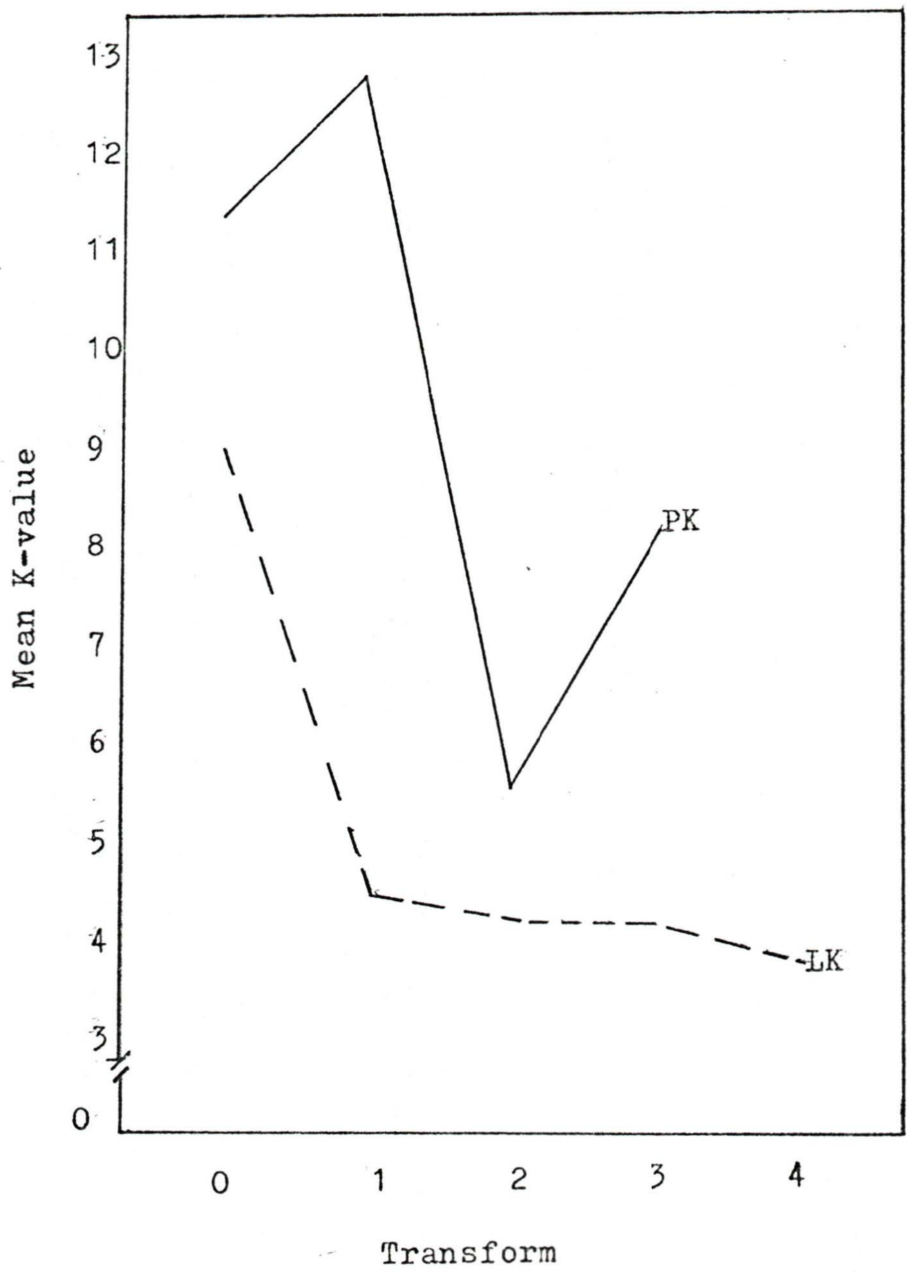


Figure 4.

Graph of Transform vs Mean K-values for Grade 3

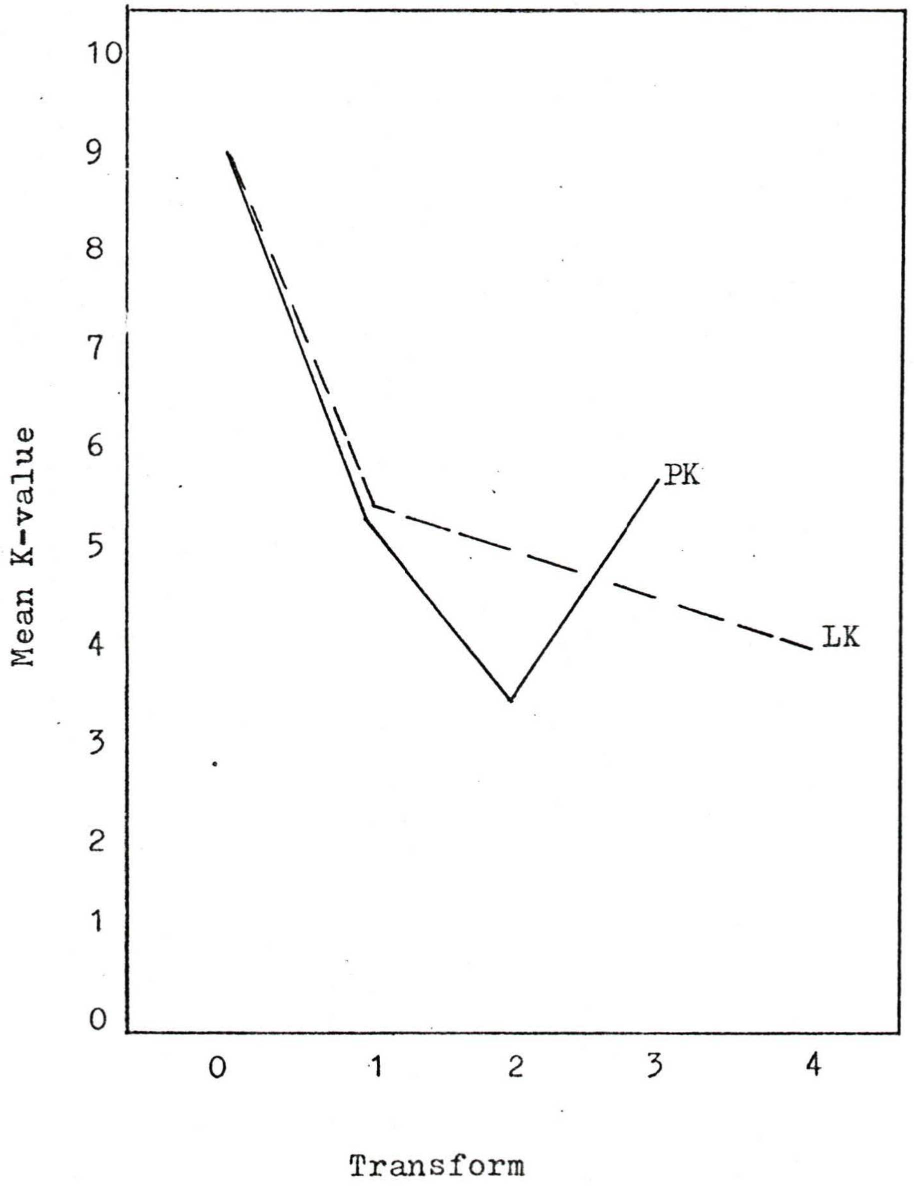
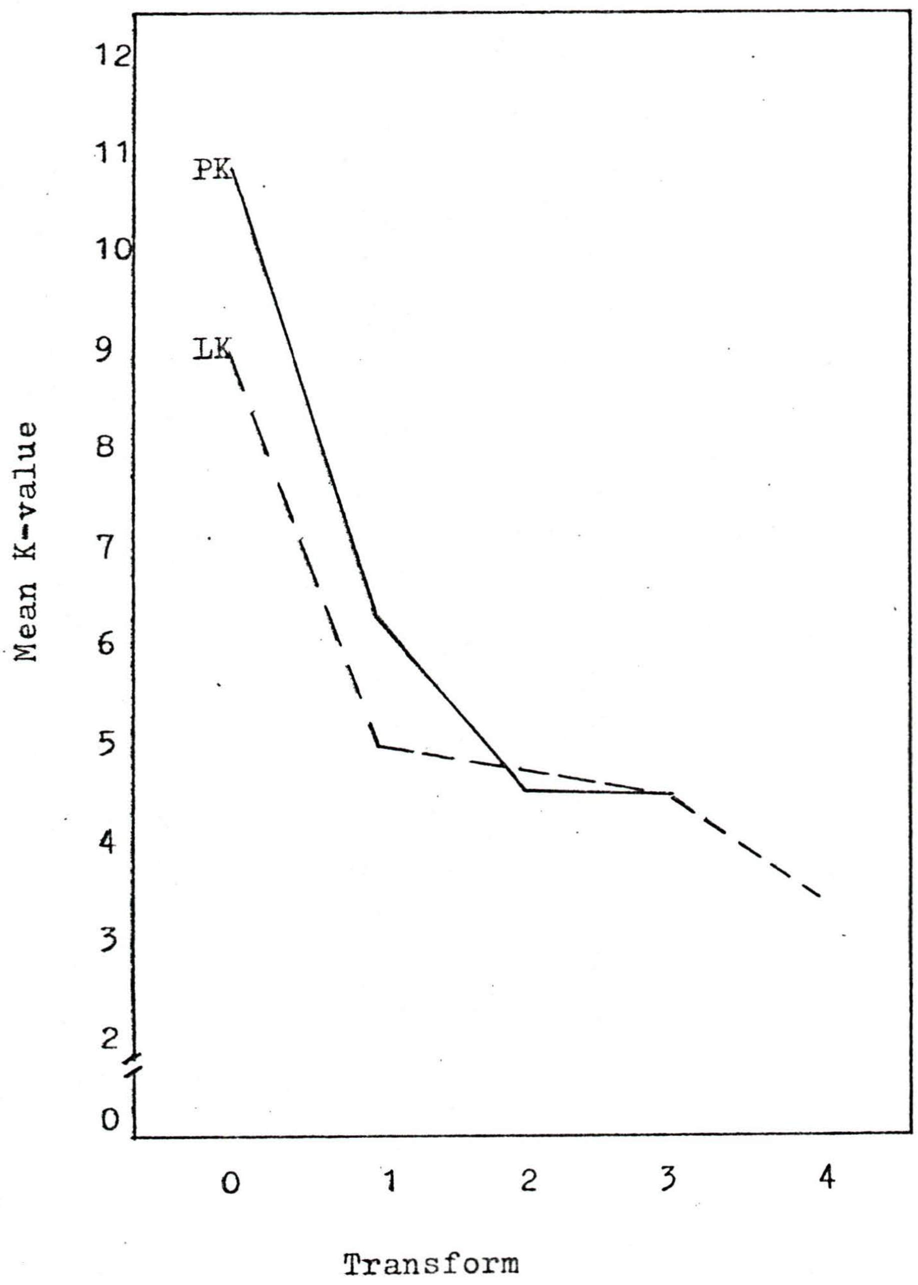


Figure 5.

Graph of Transform vs Mean K-values for Grade 6



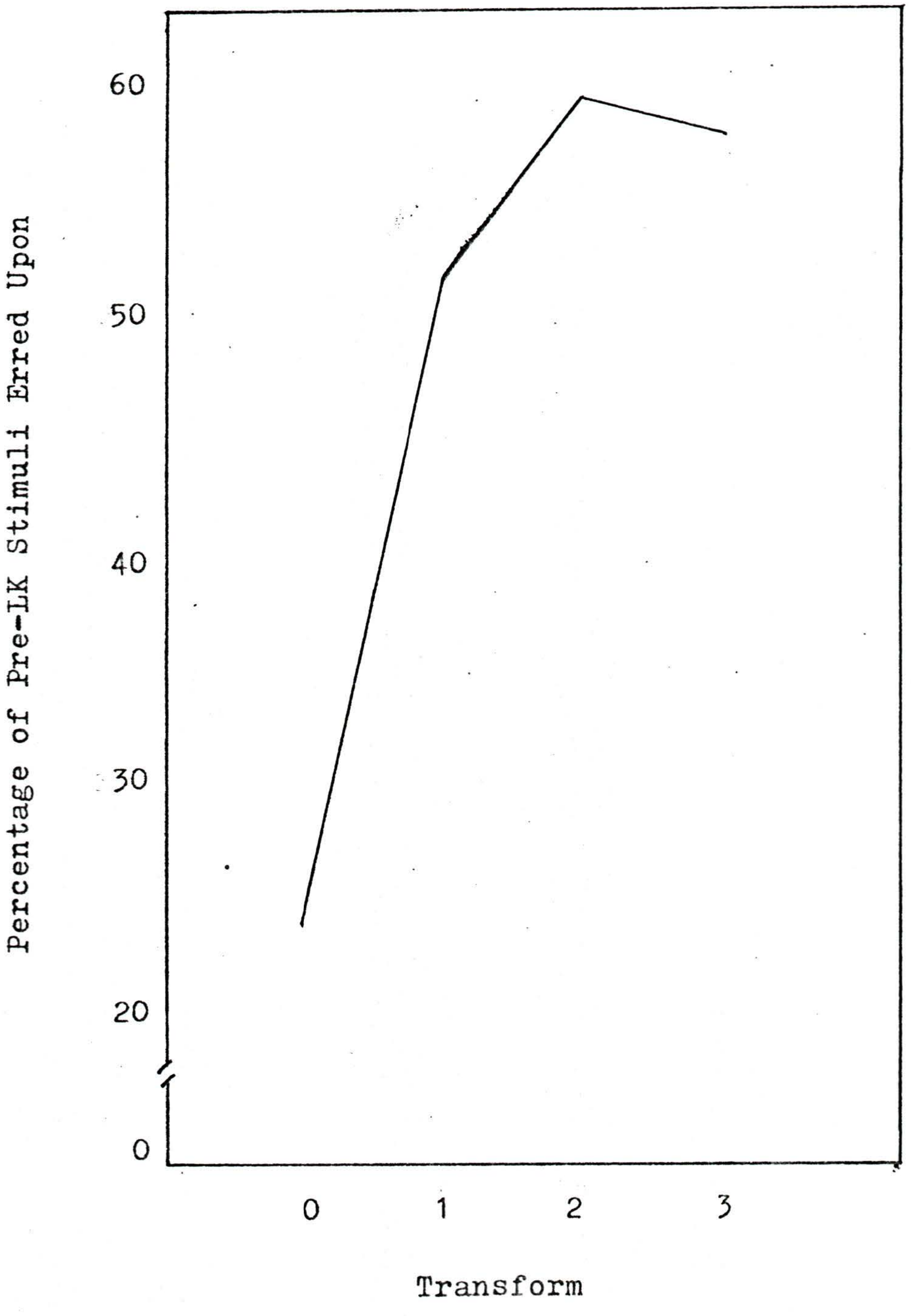
7.47, $p < .003$, Per.Var.=29.73%). Tukey's test showed that both the grade 3 ($q(3,27)=4.55$, $p < .01$) and grade 6 groups ($q(3,27)=4.85$, $p < .01$) differed significantly from the kindergarten group but not from each other ($q(3,27)=0.30$, $p > .05$). The older children perform best on all stimulus sequences.

A significant difference did not exist between age groups on the nonrelevant dimension eliminated first ($X^2=8.82$, df=4, $p > .05$). Both the kindergarten and grade 6 children tended to eliminate the number dimension first (e.g.62% and 56%, respectively). It should be noted that this tendency to eliminate a certain dimension first is not the same as dimensional dominance. Post-LK errors were very rare for the grade 3 and grade 6 groups ($\bar{X}=0.375$ and 0.875 errors, respectively). Only one of the ten kindergarten subjects who made post-LK errors responded according to a position bias. A dimensional response bias was not demonstrated by any of these subjects.

The percentage of pre-LK stimuli on which subjects made errors increased with transform level. The effect was significant by trend analysis for the linear component ($\underline{F}(1,44)=8.44$, $p < .006$). Proportion of variance accounted for was 79.2%. This relationship, which may

Figure 6.

Graph of Transform vs Percentage of Pre-LK Stimuli on Which Subjects Made Errors



reflect the elimination of redundant information, is illustrated graphically in Figure 6. One mistake was made in transforming the stimulus sequences during the experiment (e.g. subject 13, stimulus 0111). A stimulus was recorded as an error and transformed accordingly, resulting in a rise in LK. This stimulus was actually correctly placed. Since the effect of this mistake was contrary to the hypothesis of this experiment (i.e. it contributed to a rise in LK) it was ignored.

Discussion

The error-transformation method clearly improves the stimulus sequence by the logical measure, LK. Lee et al.'s (1978) results are upheld within each age group, including kindergarten, but there are no differences between these age groups on LK. Neither are there any differences in the stimuli except for the slight tendency for some subjects to eliminate a particular dimension first. The difference was not strong enough to be significant. The difference between groups on PK follows the split proposed by both Wright & Vlietstra (1975) and Levine (1975). The reason for this division is not clear. The method employed in this experiment does not allow an unambiguous separation of response biases. Furthermore, the instructions to the subject and the guidance through the instruction deck tended to preclude response biases of the type Levine (1975) was suggesting. Regardless of the reason for the illogical responding by kindergarten children the surprising thing is that the error-transformation improved the stimulus sequence anyways. Moreover, this improvement in logical structure of the stimulus sequence did not result in improved performance. The responses of the kindergarten children did not hamper the reduction of LK but did not improve PK.

The type of post-LK errors the kindergarten children make should be investigated further. Tests should be made to determine the contribution of response sets. That the error-transformation method seems to withstand illogical errors should also be investigated. Two hints of the secret underlying this robustness can be found in the present results. First, the significant cubic components of the LK trends. This slight effect arises from the finding that LK can, and does, rise. This result is contrary to the model proposed by Lee, Morrison, & Bavelas (1978). Their prediction is that LK will fall or remain the same. A scrutiny of the present results shows that LK can rise but only under stringent conditions. If a post-LK error occurs on a stimulus which is redundant to a pre-LK stimulus and few enough errors are made so that on the next error-transformation this stimulus becomes a pre-LK stimulus, then LK will rise by one. For example, suppose an error is made on the post-LK stimulus, one small red square. The pre-LK stimulus, two large green circles, which is completely redundant (since the relationship between dimensions is the same) to this post-LK stimulus,is also erred upon. Few enough errors are made so that on the next error-transformation both of these stimuli become pre-LK stimuli. The LK now rises by one. All of the rises in LK happen in this way. Furthermore, as LK decreases it becomes more difficult for a post-LK stimulus to become a pre-LK stimulus since there is less room at the top. The importance of this resistance to a rise in LK by the mechanics of the method is simply the attention that it did draw to the mechanics of the method. Is the method so robust that the characteristics of errors, logical or illogical, are superficial? Is it simply enough that errors occur? If the illogical errors of the kindergarten children do not affect the effectiveness of the method, will a transformed stimulus sequence on which errors occur at random, improve?

Second, the relationship between transform level and proportion of pre-LK stimuli which were errors, depicted in Figure 6, drew attention to the pre-LK stimuli. This rise in the proportion of errors on the pre-LK stimuli begs the question: Why are the stimuli being transformed to the beginning of the stimulus sequence more susceptible to errors? Lee et al. (1978) predicted that errors would tend to occur earlier in the stimulus sequence and intended for this to occur. The specific purpose of the error-transformation method was to take advantage of the fact that subjects tend to make errors on the same stimuli. The question still is —why? More detailed analysis of pre-LK stimuli is required. It is possible that these stimuli lead to errors because the subject is led to an erroneous placement by Levine's (1975) subset-sampling and working-hypothesis rule or by Richard, Lépine, & Rounet's (1969) majority rule. These questions led to more detailed analyses of the pre-LK stimuli later in this thesis. The two rules mentioned above are subsequently explained in detail.

III. Experiment II

The results of Experiment I left open the problem of illogical responses by the kindergarten children. It was not clear whether these illogical responses were caused by dimensional preference, other response sets, or were just random events. Levine (1975) has found that kindergarten children rarely entertain dimensional hypotheses in concept-formation tasks. Other results suggest a strong potential interference by dimensional preference. The present experiment retained the instructions and initial guidance through the instruction deck used in Experiment I. This should have again effectively eliminated the occurrence of the types of response bias proposed by Levine (1975). The experimental procedure was the same but the test deck used replaced the salient dimension of colour by a more innocuous one (e.g. pattern: presence or absence of a cross). Dimensional preference, rather than other response sets, is thus the more likely cause of any change in results from Experiment I.

One reliable finding in concept-formation tasks has been that when dominant dimensions are relevant, problem solution is facilitated, whereas when nondominant dimensions are relevant, problem solution is delayed (Mitler & Harris, 1969; Crane & Ross, 1967; Suchman & Trabasso, 1966; Odom & Mumbauer, 1971). In developmental studies the youngest subjects often do as well as the older subjects when the relevant dimension is the more salient one. Young subject's performance under these conditions has been found to equal or surpass that of older subjects under conditions in which the less salient dimension is relevant to solution (Odom & Mumbauer, 1971). However, other researchers have found that in young children performance is hampered when salient cues are irrelevant, but no strong facilitation results when they are relevant (McGurk, 1972; Koenigsberg, 1973; Maccoby & Konrad, 1967).

Odom & Guzman (1972) found younger children to be dominant on colour and the older children more predisposed towards form. Size has been found to remain at a roughly constant low level of preference for children varying in development from preschool to grade 3 (Siegel & Vance, 1969). In this experiment the relevant dimension was again size so that performance was not unecessarily hampered. The pattern dimension which replaced colour should not be salient to kindergarten children since it is a decentralized dimension (i.e. contains information concentrated at various points in the stimulus), like form, and does not pervade the entire stimulus like colour. Younger children probably do not have a preference for decentralized stimuli.

Method

Subjects. The subjects were 16 kindergarten children from the same school as the subjects in Experiment I but who had not participated in that experiment. The 11 males and 5 females ranged in age from 66 to 76 months with a mean of 70.1 and standard deviation 3.40.

Stimuli. The stimuli were identical to those used in Experiment I except the colour dimension was replaced by a pattern dimension with two values (e.g. presence or absence of a cross).

Apparatus. The apparatus in this experiment was identical to the apparatus in Experiment I.

Procedure. The procedure in this experiment was identical to that used in Experiment I.

Hypotheses. There are two main hypotheses in this experiment:

1. Since the illogical errors made by the kindergarten

children in Experiment I had no effect on LK it is expected that LK in this experiment would be comparable to LK in Experiment I.

2. Since the salient nonrelevant dimension of colour had been removed PK should decrease with LK if stimulus preference had interfered in the performance of kindergarten subjects in Experiment I.

Results

The kindergarten children tended to eliminate the number dimension first (f=9), then form (f=5), and lastly colour (f=2) in Experiment I. In this experiment form tended to be eliminated first (f=10), then number (f=4), and lastly pattern (f=2). There seems to be no reason why the children should have preferred to eliminate number first in Experiment I and form first in this experiment. Although this is not a measure of stimulus preference there is a clear difference in the dimension which is eliminated first. This tendency had no effect on LK which shows a significant linear trend ($\underline{F}(1,15)=24.01$, $p<.001$, Per.Var.=53.6%), dropping from an initial mean of 9.0 to 3.75. A two-way, transform by stimulus deck, ANOVA showed a significant transform effect on LK ($\underline{F}(4,30)=25.92$, $p<.000$, Per.Var.=76.23%) but no difference in the stimulus decks used ($\underline{F}(1,30)=1.14$, $p>.05$, Per.Var.=0.84%). A trend analysis of PK showed no significant components. A two-way, transform by stimulus deck, ANOVA showed no significant effects for either transform or stimulus deck used ($\underline{F}(3,24)=1.72$, $p>.05$; $\underline{F}(1,24)=0.008$, $p>.05$). Means and standard deviations for LK and PK are shown in Table IV for the kindergarten children in Experiment I and Experiment II. Figure 7 illustrates graphically the trends in LK and PK for the children in this experiment. The pearson correlation between LK and PK, as in Experiment I, was not significant ($\underline{r}=0.19$, $p>.05$).

The post-LK errors in this experiment were comparable to those in Experiment I ($\overline{X}=2.0$ and 1.875, respectively). As in Experiment I no response set of any kind was found to be prevalent. However, as noted earlier, the data in these experiments are not particularly amenable to bias-finding analyses. The proportion of pre-LK stimuli on which subjects made errors increased with transform in a fashion comparable to that in Experiment I. Trend analysis showed a significant linear component ($\underline{F}(1,12)=7.41$, $p<.019$,

Table IV.

Means and Standard Deviations

LK:

Transform	Experiment I		Experiment II	
	$\bar{X}$	SD	$\bar{X}$	SD
0	9.0	0	9.0	0
1	4.5	1.29	5.5	2.65
2	4.25	.50	5.0	1.83
3	4.25	.50	4.25	.96
4	3.75	.58	3.75	.50

PK:

Transform	Experiment I		Experiment II	
	$\bar{X}$	SD	$\bar{X}$	SD
0	11.25	2.63	10.25	5.5
1	12.75	2.06	8.5	3.87
2	5.5	4.04	12.75	5.19
3	8.25	4.99	6.75	1.5

Note: Since transform 4 is a predicted level there are no measures for PK.

Figure 7.

Graph of Transform vs Mean K-values

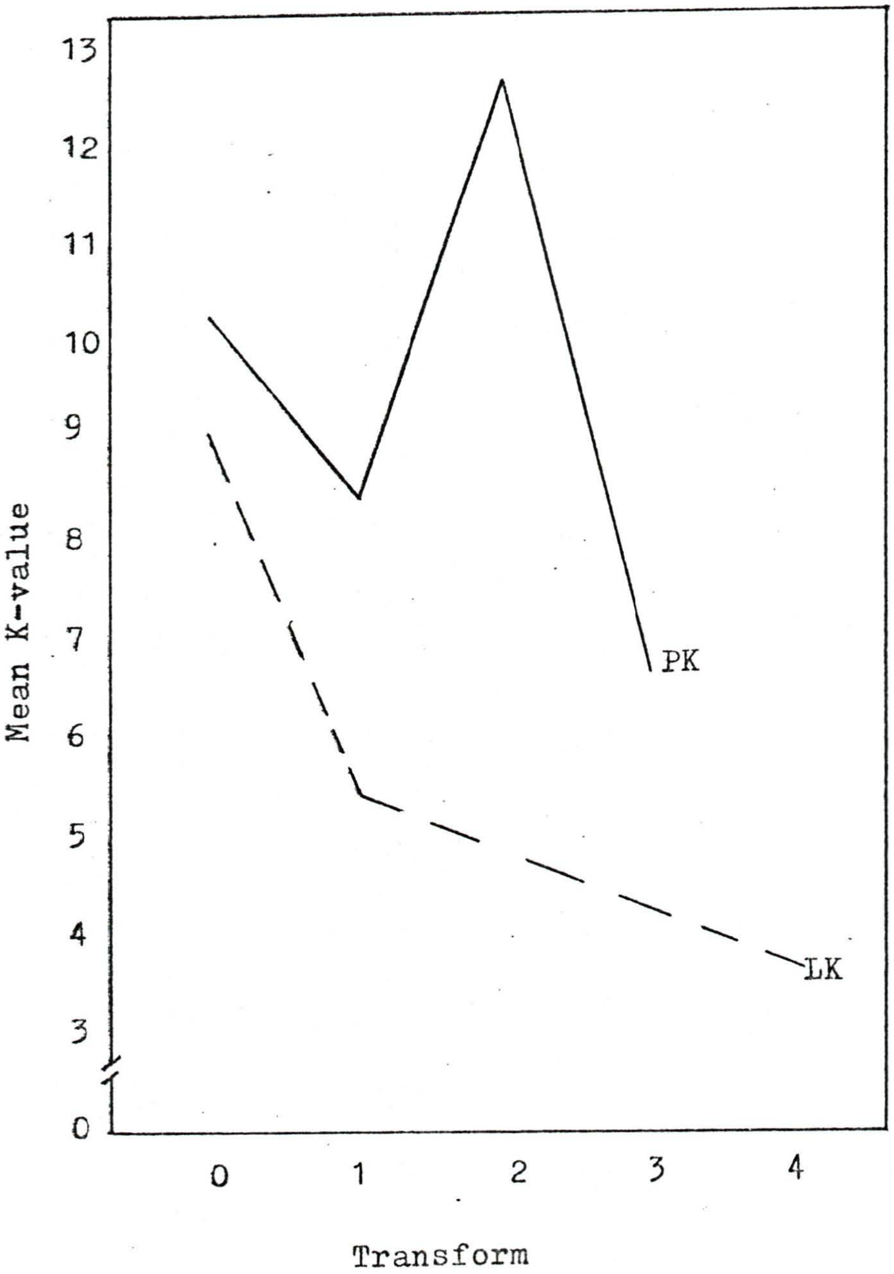
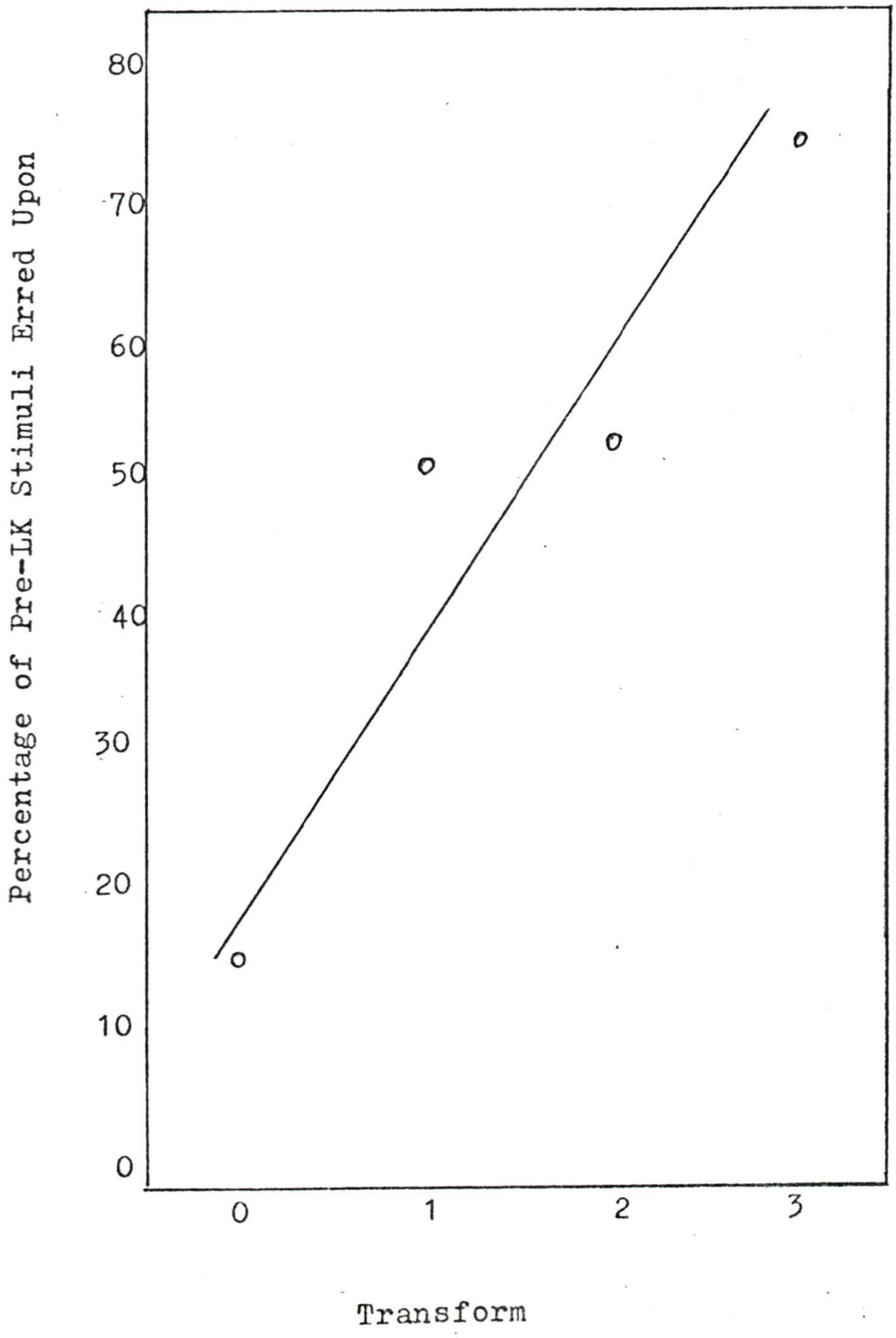


Figure 8.

Graph of Transform vs Percentage of Pre-LK Stimuli on Which Subjects Made Errors



Per.Var.=59.4%). Figure 8 illustrates this relationship graphically.

Discussion

Although a difference exists between the subjects in this experiment and kindergarten children in Experiment I on the preference of which dimension to eliminate first there was no difference in the effect on LK. Performance of subjects did not improve despite the improved stimulus sequence. The change in the stimulus deck had no effect on LK, PK, or percentage of pre-LK stimuli which were errors. It would seem that dimensional preference had little effect on the error-transformation method, at least under the circumstances in these two experiments.

IV. The Pre-LK Stimuli

In the present research dimensional and response biases have not proven to be fruitful leads. Two lines of investigation were proposed in the discussion of Experiment I: the mechanics of the method regardless of errors characteristic of human subjects and an investigation of the pre-LK stimuli. This chapter engages in an analysis of the latter.

Figure 6 in Experiment I depicted the increasing proportion of pre-LK stimuli which were errors with successive transform levels. The same relationship between pre-LK stimuli and transform level is evident in Figure 8 in Experiment II. It was suggested earlier that these stimuli may have been more susceptible to error because subjects followed Levine's (1975) subset-sampling and working-hypothesis rule or Richard et al.'s (1969) majority rule. Consider the following stimulus which is represented in digital form, 0000. Each digit represents a dimension while the numerical value within each digit indicates the value along that dimension. Suppose the first digit represents the relevant dimension. If this stimulus was the initial correctly placed stimulus then Levine's (1975) rule would predict that subjects would place the stimulus

0001 correctly 75% of the time. This prediction arises because 3 of 4 dimensional hypotheses would lead to a correct placement. Majority rule would predict correct placement by all subjects. That assumes the subject evaluates his options and makes the placement most likely to pay off. These two stimuli are confounded on three dimensions. This is analogous to what Levine (1975) terms a 3-1 shift in his simultaneous discrimination learning task. In this thesis 0000 is the digital representation of the first stimulus presented to all subjects and is, thus, the positive focus stimulus. All stimuli which eliminate one dimension will be called one-dimension eliminators (1DEs) and are similar to the stimuli labeled as a 3-1 shift in Levine's (1975) simultaneous discrimination learning task. A stimulus which eliminates two dimensions will be called a two-dimension eliminator (2DE, e.g. 0011 and 0101); 1000 and 0111 are the two three-dimension eliminators (3DEs); and 1111 is the only zero-dimension eliminator (0DE).

Both of the above two rules predict the same direction for the subject's response but a different rate for this response. Stimuli which would be commonly placed incorrectly by these rules would be those on which most of the dimensional values were opposite to that of the relevant dimension (remember that the relation between the dimensional values had been set by the focus stimulus). The stimuli which meet this criterion are the 3DEs. The 2DEs do not meet this criterion but would be placed incorrectly half the time according to both rules since they are the same on two dimensions and different on two. Therefore, according to these rules, the stimuli transferred to the beginning of the stimulus sequences by the error-transformation method should be predominantly 3DEs and 2DEs. That is, the bulk of the pre-LK stimuli in the final stimulus sequences of all groups should be 3DEs and 2DEs.

An analysis of the third and fourth transform levels showed no difference in the distribution of pre-LK stimuli over eliminator-type so the two levels were combined. Table V lists the proportion of pre-LK stimuli according to eliminator-type for each age level in Experiment I and for the subjects in Experiment II. There are clear differences between age groups in the distribution of pre-LK stimuli over eliminator-type. The number of pre-LK stimuli is roughly constant over age groups (e.g. this is LK, total N for each group ranged from 24 to 26 stimuli). The two older groups

Table V.

Distribution of Pre-LK Stimuli Over Eliminator Type

Dimensions Eliminated	K1	3	6	K2	K	3&6
3	0	0	0	8.3	4.2	0
2	37.5	7.7	20.8	37.5	37.5	14.3
1	62.5	88.5	75.0	50.0	56.2	81.7
0	0	3.8	4.2	4.2	2.1	4.0

Note: K1 represents the kindergarten group in Experiment I; K2 represents the subjects in Experiment II; K represents the average of the two kindergarten groups; and 3&6 represents the average of the two older groups.

Percentage of 1DEs that are positive instances:

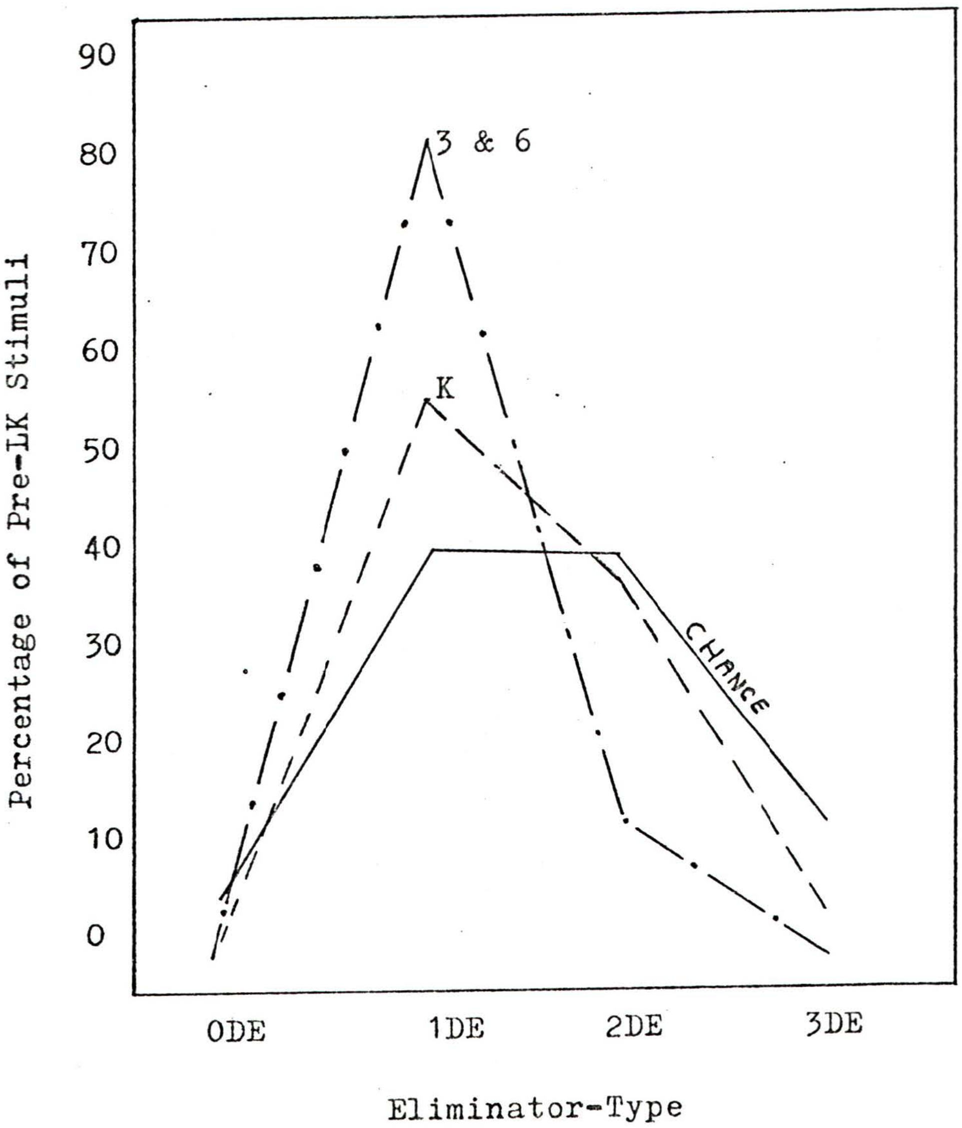
K1	3	6	K2	K	3&6
86.7	95.7	94.4	83.3	85.0	95.1

tend to have predominantly 1DEs. The two younger groups have a greater proportion of 2DEs although 1DEs still represent the largest share. Three-dimension eliminators, contrary to prediction, are absent in the two older groups and nearly so in the younger groups. The eliminator-types are not equally likely to end up near the top by chance. Of the 15 stimuli placed by the subject two are 3DEs, six are 2DEs, six are 1DEs, and only one is a ODE. In percentages the distribution over eliminator-type is 6.7%, 40.0%, 40.0%, and 13.3% for eliminator-types 3DE to ODE, respectively. Figure 9 illustrates graphically the distribution for each group and chance expectation. Neither the majority rule or Levine's rule is upheld. Furthermore, the kindergarten groups differ from the older groups (X^2=10.02, df=3, $p < .02$) but neither the kindergarten groups (X^2=3.33, df=3, $p > .05$) nor the older groups differ from each other (X^2=1.75, df=2, $p > .05$).

One fact fairly jumped out when this analysis was performed: almost all of the pre-LK 1DEs were positive instances. Table IV shows the percentages of 1DEs that were positive instances (e.g. 0001 is positive and 1110 is negative). These results show that the kindergarten children average 85% positive

Figure 9.

Distribution of Pre-LK Stimuli Over Eliminator-Type



1DEs and the two older groups 95.1% positive 1DEs. There were no significant differences between age groups (X^2=2.11, df=3, $p > .05$).

One further test of the two response rules was made. The first stimulus placed by each subject (except the first of each group who placed 1111 by design) was recorded over the distribution of eliminator-types for both Experiment I and Experiment II (N=84, excluding the 16 first subjects of each group). Since this is the first placement by the subject he had no information on the relevance of any dimension. Both response rules predict 50% correct placements for 2DEs. Levine's (1975) rule predicts 75% and Richard et al.'s (1969) rule predicts 100% for 1DEs. Based on 11 responses 72.7% of the 2DEs were placed <u>incorrectly</u>! Based on 73 responses 75.3% of the 1DEs were placed <u>incorrectly</u>! Both rules are again rejected.

Neither Levine's (1975) nor Richard et al.'s (1969) rule accounts for the subjects' responses in these two experiments. One point may be worth noting. In Levine's (1975) experiments the subject was encouraged to make as many correct responses as possible. There was no such encouragement in these experiments. The subject was merely told to guess the correct rule by making appropriate placements. The question now is what was the subject doing. The simplest explanation is that he was isolating one dimension at a time, against the focus stimulus, and purposely testing this dimension. That is, he would make what he thought was an appropriate placement according to the one dimension that differed from the focus stimulus, and would tend to be wrong. For example, given 0001, he would make a placement according to the fourth digit. Notably, negative instances (such as 1110, the stimulus redundant to 0001) are almost completely absent from pre-LK stimuli regardless of age level. This result is in keeping with all the literature which demonstrates subjects' aversion to negative instances unless prodded into using them. The error-transformation method seems to produce a stimulus sequence which is amenable to a positive, conservative-focussing strategy of problem-solving (Bruner, Goodnow, & Austin, 1956). This is an efficient strategy which leads to the elimination of one nonrelevant dimension per trial, so that LK should equal the number of dimensions involved.

V. Machine-Produced Stimulus Sequences

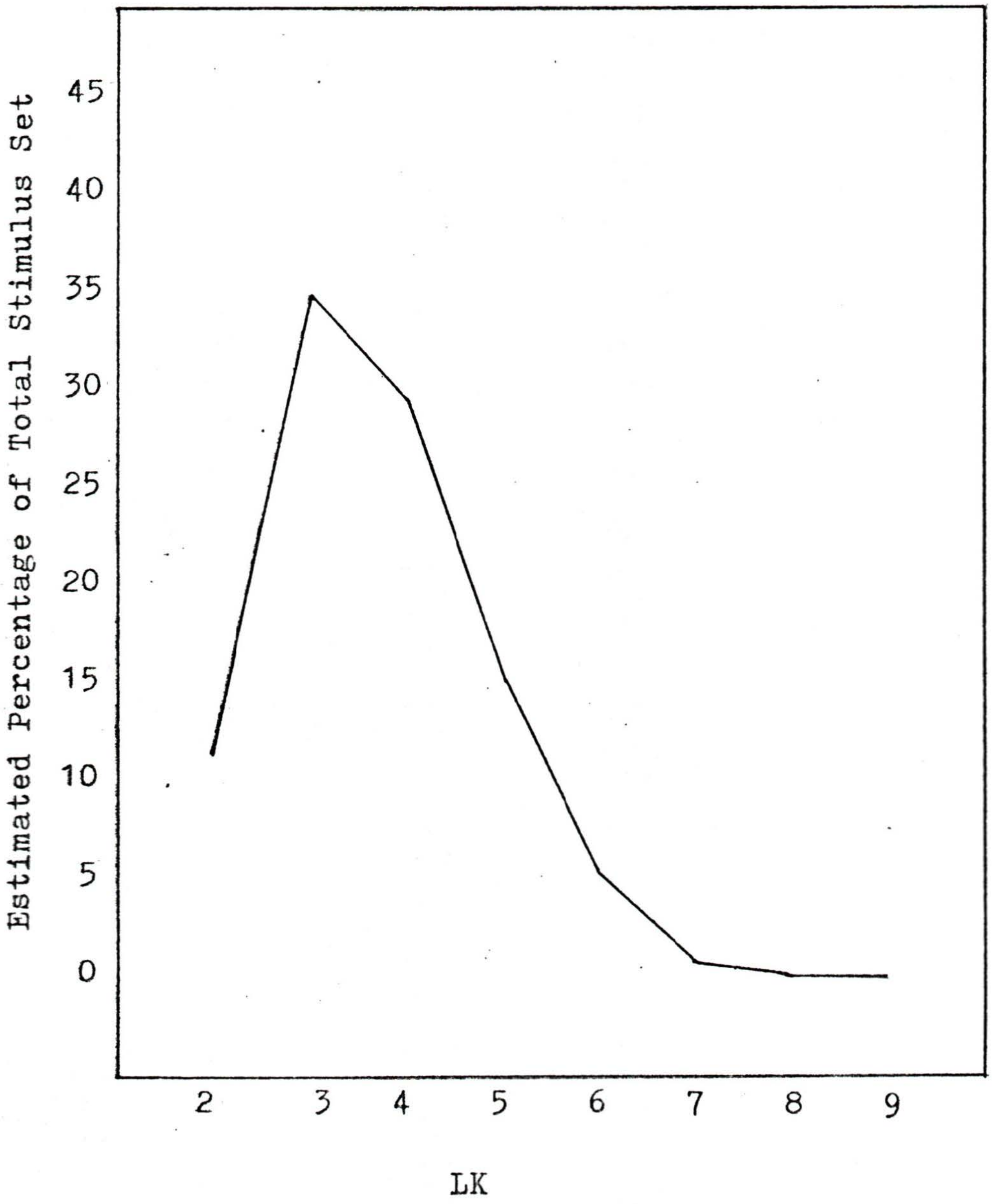
The reduction of LK in spite of the illogical responses by the kindergarten children drew attention to the mechanics of the error-transformation method. Given than the original stimulus sequence was at the maximum LK, as in Experiments I and II, would any change to the stimulus sequence result in a reduced LK? The frequency distribution of stimulus sequences over the range of LK was estimated to determine if the observed reduction in LK was, in part, a regression to the mean.

A stimulus deck with four, two-value dimensions contains 16 unique permutations of the various dimensions and values (i.e. there are 16 stimulus cards). Since the first stimulus is always the same there are 15 factorial possible arrangements of the remaining 15 stimuli. Each of these sequences yields a unique LK given a particular relevant dimension. A computer programme (DISTR) was written to estimate the frequency distribution of a stimulus set of any size over its possible range of LK values[2]. For a stimulus set of four binary dimensions LK can range from a minimum of 2 (i.e. since a 3DE stimulus eliminates all nonrelevant dimensions at one time LK would be 2 if this were the first card placed by the subject) to a maximum of 9. The DISTR programme estimates the percentage of the total frequency for each value of LK, 2 to 9 to be 13.54%, 35.15%, 29.0%, 15.05%, 5.26%, 1.6%, 0.4%, and 0.02%, respectively. Figure 10 illustrates this distribution as a frequency polygon. Clearly, the distribution is quite skewed and the effects we have observed may be, in part, a regression to the mean. The mean of this distribution is 3.698, quite close to the mean LK of all subject groups (e.g. 3.75). It is likely that any change to a stimulus sequence of LK=9 would result in a reduced LK. In addition, the skewedness of the distribution may invalidate the ANOVA transform effects due to ANOVA's assumption of an underlying normal distribution.

If any change to a high LK stimulus sequence is likely to result in a reduced LK, would an error-transformation reduce the LK of stimulus sequences where errors were determined, not by subjects' performance, but by random assignment? An underlined sentence in the discussion of Experiment I posed this question earlier. The error-transformation was performed on stimulus sequences where stimuli were

Figure 10

Graph of the Distribution of Stimulus Sequences Over LK for the Four Binary Dimension Case



randomly assigned to be errors in the following way. Figure 11 lists the 15 stimuli placed by the subject following the stimulus 0000 in the same order as originally presented to the subjects in Experiments I and II (LK=9). Each stimulus was determined to be correct by consulting a column of random numbers in Steven's (1949) Table of 105,000 Random Decimal Digits. Each of the top 15 numbers of a column were assigned to a stimulus. If the number was odd the stimulus was said to have been placed correctly. If the number was even the stimulus was said to have been placed incorrectly. Each stimulus had a 50% chance of being wrong. The errors were then transformed and the altered stimulus sequence is shown in the right column in Figure 11. The LK is 5, a reduction of 4. A stimulus sequence resulting from an error-transformation in this way is called a machine-generated stimulus sequence.

It is important to note that false-positives and false-negatives occur in this kind of error-transformation. This is not the case in the subject-generated stimulus sequences where false-negatives do not occur. This fact, however, did not hamper the reduction of LK by an error-transformation. A number of columns of random

Figure 11.

The Production of a Machine-Generated Stimulus Sequence

Original Sequence	Response	Transformed Sequence
0000	-----	0000
1111	+	0010
1000	+	1010
0111	+	0101
0010	-	1110
1010	-	1100
1101	+	1001
0101	-	0100
0001	+	1111
1110	-	1000
1100	-	0111
0110	+	1101
0011	+	0001
1001	-	0110
1011	+	0011
0100	-	1011

Note: The second digit represents the relevant dimension.

+ means a correct placement, - an incorrect one digits equal to the number of subjects in an age group in Experiment I (e.g. 16) were used to produce machine-generated stimulus sequences where the probability of error was 0.5 (Pe=.5). Trend analysis showed significant linear and quadratic components ($\underline{F}(1,15)=41.068$, $p<.001$, Per.Var.=61.03%; and $\underline{F}(1,15)=10.38$, $p<.005$, Per.Var.= 16.11%, respectively). Neither the inclusion of falso-negatives nor distribution of errors at random hampers the reduction of LK. However, it must be stressed that LK is a logical measure of the efficiency of a stimulus sequence. There has been no indication that the inclusion of false-negatives and the random assignment of errors would not hamper the performance of human subjects. That is, PK has not been shown to be reduced on machine-generated stimulus sequences.

How many errors must occur for the error-transformation to reduce LK? More machine-generated stimulus sequences were produced by error-transformations. The probability of error was varied so that for one group it was 10% (e.g. group 1, Pe=.1); for a second group 30% (e.g. group 3, Pe=.3); for group 5, 50% (e.g. Pe=.5, this group had already been run above); for group 7, 70% (e.g. Pe=.7); and for group 9, 90% (e.g. Pe=.9). The groups were numbered to reflect their levels of probability-of-error (i.e. there were no groups 2, 4, 6, or 8). The actual rates of error occurrence closely matched the assigned probabilities: e.g. for groups 1 to 9, respectively, 0.113, 0.292, 0.463, 0.675, and 0.892. Table VI lists the means and standard deviations of LK for each probability group at each transform level. Figure 12 illustrates graphically the relationship between transform level and LK for all probability groups (e.g. the curve is numbered for each group). Groups 1 to 7 result in LKs equivalent to stimulus sequences generated by human subjects (e.g. $\overline{X}$=3.813). Group 9 resulted in a reduced LK but not to the same extent as the other groups (e.g. $\overline{X}$=6.0). Trend analyses show all groups to yield significant linear components ($25.44 \leq \underline{F}(1,15) \leq 126.15$, $p < .001$, $38.28\% \leq$ Per.Var. $\leq 88.34\%$). Groups 1 to 5 yielded significant quadratic components ($10.84 \leq \underline{F}(1,15) \leq 21.80$, $.001 \leq p \leq .007$, $14.85\% \leq$ Per.Var. $\leq 32.8\%$). No other components were significant. A two-way, transform by probability-of-error level, ANOVA showed a significant transform effect ($\underline{F}(4,75)=61.66$, $p < .000$, Per.Var.=58.25%), a significant probability-of-error level effect ($\underline{F}(4,75)= 16.25$, $p < .000$, Per.Var.=15.36%), and a significant interaction ($\underline{F}(16,75)=2.30$, $p < .008$, Per.Var.=8.68%).

Table VI.

Means and Standard Deviations for Machine-Generated Stimulus Sequences

Means: Group

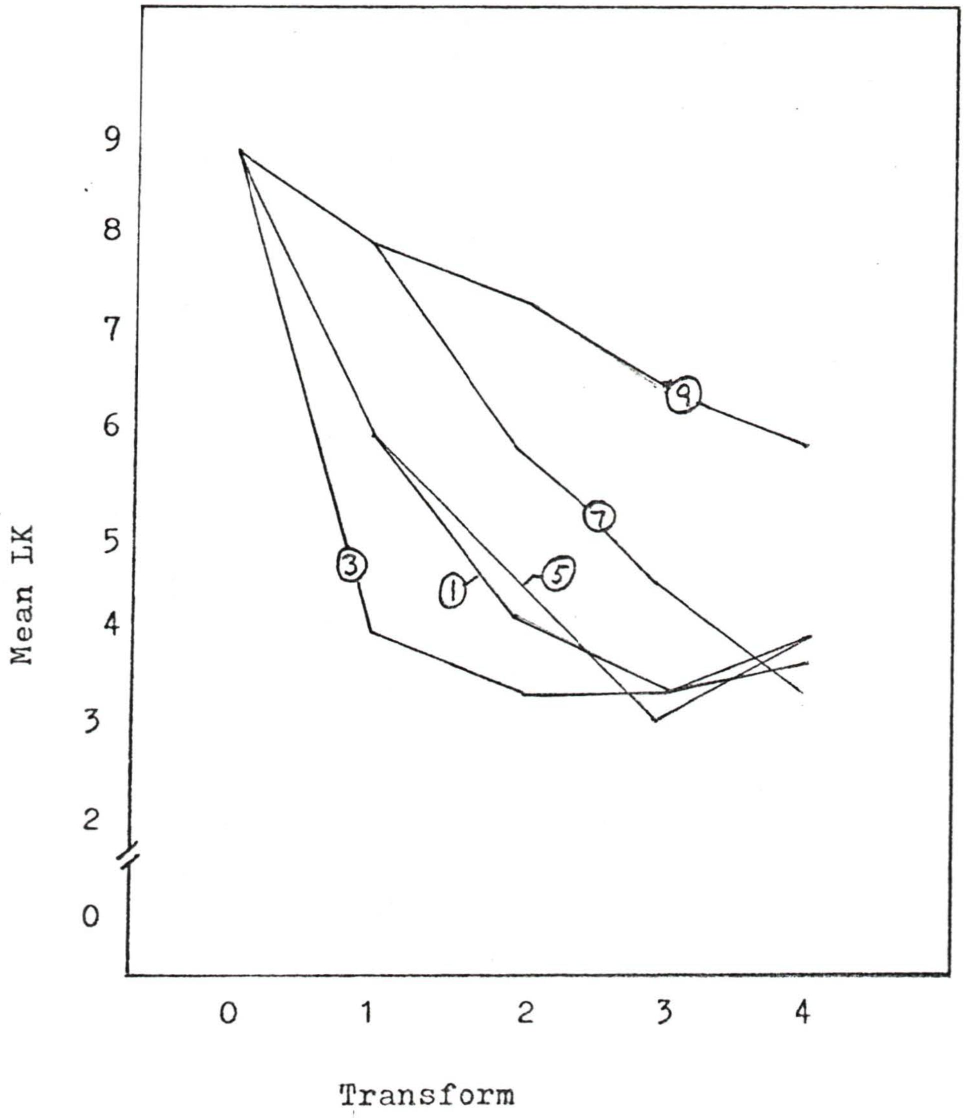
Transform	1	3	5	7	9
0	9.0	9.0	9.0	9.0	9.0
1	6.0	4.0	6.0	8.0	8.0
2	4.25	3.5	4.5	6.0	7.5
3	3.5	3.5	3.25	4.5	6.5
4	3.75	4.0	4.0	3.5	6.0

Standard Deviations:

Transform	1	3	5	7	9
0	0	0	0	0	0
1	2.16	1.41	1.41	.82	.82
2	1.5	1.73	1.73	.82	.58
3	1.0	1.29	.96	1.29	1.0
4	.5	1.41	1.41	.58	1.41

Figure 12.

Graph of Transform vs Mean LK for Pe=.1 to Pe=.9



Tukey's tests showed all the significant differences to be between groups 1 to 7 and group 9 ($1.2 \leq q(5,75) \leq 2.6$, $p < .01$) and between group 3 and group 7 ($q(5,75) = 1.4$, $p < .01$). Clearly, the error-transformation method will reduce the LK of a stimulus sequence even if the responses are random, and over a wide range of probability of error.

The improvement of a stimulus sequence may not be wholly attributable to the distribution of stimulus sequences over the range of LK. Earlier in this chapter it was pointed out that PK had not yet been shown to be reduced by an error-transformation in machine-generated stimulus sequences. The specifically human contribution to the improvement of a stimulus sequence may lie in the specific stimuli on which subjects make errors. Thus, there may be differences between subject-generated and machine-generated stimulus sequences in the characteristics of the pre-LK stimuli, on which most errors are made. If such differences exist there may be a difference in the performance of human subjects on subject-generated and machine-generated stimulus sequences of equal LK.

It was not feasible in this thesis to run more subjects to investigate possible differences in PK that may result from the two types of stimulus sequences.

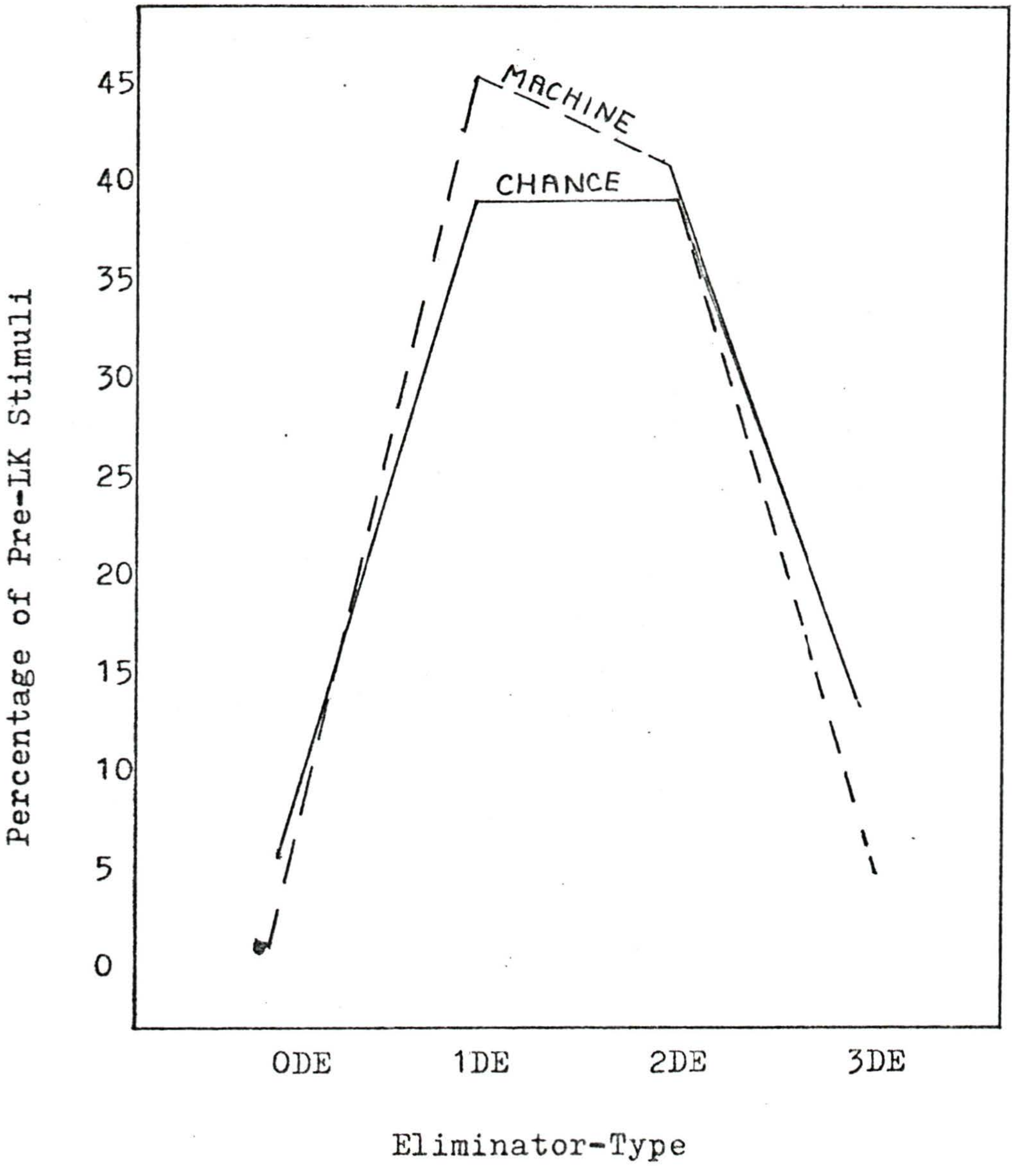
However, the existence of differences in the pre-LK stimuli was probed. Two analyses were performed on the subject-generated stimulus sequences in Chapter IV: the distribution of pre-LK stimuli over eliminator-type and the proportion of 1DEs in the pre-LK stimuli that are positive instances of the relevant dimension. Both of these analyses were applied to the machine-generated stimulus sequences for transform 3 and transform 4.

Group 9 was not included in the analysis since LK for this group did not reduce to a value comparable to the other probability groups or the subject groups in the number of error-transformations performed. Moreover, the number of pre-LK stimuli was almost double that of other groups. The distribution of pre-LK stimuli over eliminator-type does not differ significantly from chance for the machine-generated groups (X^2=6.28, df=3, $p > .05$). The percentage of pre-LK stimuli for each type of eliminator was: 3DE=8.0%, 2DE=42.0%, 1DE=46.6%, and ODE=3.4%. These distributions are illustrated graphically in Figure 13.

A significant difference does exist between the two subject groups (e.g. kindergarten and grades 3 and 6) and the machine-generated stimulus sequences (X^2=22.81, df=6, $p < .001$). It is particularly notable that the

Figure 13.

Distribution of Pre-LK Stimuli Over Eliminator-Type



distribution of the kindergarten children is much closer to that of the machine-generated distribution than is that of the older children (remember that PK did not improve with kindergarten children). In terms of the distribution of pre-LK stimuli over eliminator-type the machine-generated stimulus sequences are much closer to chance than the subject-generated stimulus sequences.

A comparison was made between the machine and subject-generated stimulus sequences on the proportion of pre-LK 1DEs that were positive instances. For the subject groups these proportions were very high (e.g. 85% and 95.1%) but for the machine groups the proportion was near chance expectation (e.g. 58.5%). In Chapter IV it was shown that these differences between subject groups were not significant. The differences between subject groups and machine groups, however, were significant (X^2=17.39, df=4, $p < .002$).

Finally, the proportion of pre-LK stimuli on which errors were made was determined for the machine-generated stimulus sequences. Recall that for subject-generated stimulus sequences the proportion of errors tended to rise with transform level (e.g. see Figures 6 and 8). There was no such indication for the machine-generated stimulus sequences (e.g. 0.54, 0.45, 0.48, and

0.30, respectively for transforms 0 to 3).

In this chapter we have seen that any change in a high LK stimulus sequence is likely to reduce LK. Indeed, the transformation of stimuli where errors were assigned at random resulted in a reduced LK. However, differences exist between the pre-LK stimuli of subject and machine-generated stimulus sequences. These differences may be reflected in differences in PK between human subjects who are presented with machine-generated stimulus sequences and those presented with subject-generated stimulus sequences of equal LK.

VI. Discussion and Conclusions

The LK of a stimulus sequence can be reduced by placing stimuli at random (e.g. by machine-generated random response patterns) and transferring the errors to the beginning of the stimulus sequence. The PK of such a stimulus sequence has not yet been measured. There is no difference to a computer between the machine-generated and subject-generated stimulus sequences. There may be differences, however, to a human subject. The emphasis on positive 1DEs found in subject-generated stimulus sequences may reflect a cognitive process. Furthermore, the tendency of the older subjects to concentrate on 1DEs almost to the exclusion of other eliminator-types, together with the close relationship between LK and PK for these groups suggests the conjecture that human subjects will perform better on a subject-generated stimulus sequence than on a machine-generated stimulus sequence of equal LK. This test remains to be made. The complexity of the stimuli and of the relevant concept may be of critical importance. The kindergarten children derived stimulus sequences which were more like machine-generated stimulus sequences in terms of the distribution of pre-LK stimuli over eliminator-type. However, the grade 6 subjects performed as well on these stimulus sequences in terms of PK as they did on other stimulus sequences in Experiment I. Human subjects may be able to utilize machine-generated stimulus sequences on simple stimulus sets and concepts where they need not invoke the efficient positive, conservative-focussing strategy. With more complex concepts and stimulus sets such a strategy may be necessary. In that event, machine-generated stimulus sequences would not improve performance.

Consider the distribution of stimulus sequences over LK. One could jump to the conclusion that the selection of a conservative-focussing strategy which solves a discrimination problem in the n-dimensions in the stimulus set is an artifact due to the skewedness of the distribution. This conclusion would be wrong since the stimulus sequences representing a conservative-focussing strategy are only one small subset of the stimulus sequences which have an LK equal to n dimensions. An interesting question to pursue is how many of the LK equals-number-of-dimensions stimulus sequences are positive 1DE instances, predominantly? Even more intriguing would be the construction of a computer programme which could restructure the stimulus sequence for a given subject on the basis of his own previous errors. This kind of symbiotic relationship may lead to a cheap, quick method of teaching humans complex concepts. It is necessary, therefore, to investigate the differences in performance of humans between subject-generated and machine-generated stimulus sequences. The error-transformation effect must also be tested on more complex concepts involving more than one relevant dimension. Finally, the effect of dimensional preference and other response sets, not on LK but on the characteristics of the pre-LK stimuli, should be investigated.

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VIII. Footnotes

1. The formula to derive the maximum LK for a stimulus set of any size is:

$$LK_{max} = v^{d-1} + 1$$

where: v is the number of values

d is the number of dimensions

2. The DISTR programme was written by Mr. Tom Allen of the University of Victoria Statistics Laboratory. Complete details of this programme can be found in Appendix E along with an explanation of the algorithm, courtesy of Mr. Allen.

IX. Appendix A

Raw Data

The stimuli are listed in the order they were presented to the subjects. The stimuli are in digital form. The first digit represents the dimension number: zero means 1 and one means 2. The second digit represents the relevant dimension size: zero means small and one means large. The third digit represents the dimension colour (for Experiment II this dimension is pattern): zero means red (cross absent) and one means green (cross present). The last digit represents the dimension form: zero means circle and one means square. The first stimulus (0000) was the same for all subjects and was placed for them. It is not included. The 15 stimuli placed by the subject are listed in the order he placed them. If he made an error this is indicated by a - beside the stimulus.

The number at the top of each column is the subject number. The first digit represents the transform level (0,1,2,3). The remaining digits represent the group number. Groups 1-4 are kindergarten, 5-8 are grade 3, 9-12 are grade 6, and 13-16 are the subjects from Experiment II. Groups 21-23 are the kindergarten subjects who responded again to stimulus sequences presented to the transform 3 subjects in Experiment I. Group 21 received the sequences from groups 1-4, group 22 received the sequences from groups 5-8, and group 23 received the sequences from groups 9-12. Groups 24-26 are the grade 3 subjects who received the transform 3 stimulus sequences again (i.e. the same stimulus sequences as presented to groups 21-23). Group 24 received the sequences from groups 1-4, group 25 from groups 5-8, group 26 from groups 9-12. Finally, groups 27-29 were the grade 6 subjects such that group 27 received the sequences from groups 1-4, group 28 from groups 5-8, and group 29 from groups 9-12. S02 thus represents the original subject in group 2. S213 represents the subject receiving the second transformed sequence in group 13.

Raw Data

S01	S11	S21	S31
1111	1000 -	1000 -	1000
1000 -	0010 -	0010 -	0010
0111	1010	1100 -	1100
0010 -	1100 -	1001 -	1001 -
1010 -	1001 -	1111 -	1111
1101	1111 -	0110	0110 -
0101	0111	1010	1010
0001	1101	0111	0111
1110	0101	1101	1101
1100 -	0001	0101	0101 -
0110	1110	0001	0001 -
0011	0110 -	1110	1110
1001 -	0011	0011	0011
1011	1011	1011	1011 -
0100	0100	0100	0100

S02	S12	S22	S32
1111	1010	0001 -	0001
1000	0101	1000 -	1000
0111	0001 -	1110	1110
0010	1111	1100	1100 -
1010 -	1000 -	0110	0110
1101	0111	0011	0011
0101 -	0010	1010	1010
0001 -	1101	0101	0101
1110	1110 -	1111	1111
1100	1100 -	0111	0111
0110	0110 -	0010	0010
0011	0011 -	1101	1101
1001	1001	1001	1001
1011	1011	1011	1011
0100	0100	0100	0100

S03		S13		S23		S33	
1111		0101		0001	-	0001	
1000		0001	-	0111		0111	
0111		1100		1010		1010	-
0010		0011		1110		1110	
1010		1111		0110		0110	-
1101		1000		1011		1011	
0101	-	0111	-	0101		0101	
0001	-	0010		1100		1100	-
1110		1010	-	0011		0011	
1100	-	1101		1111		1111	
0110		1110	-	1000		1000	
0011	-	0110	-	0010		0010	
1001		1001		1101		1101	
1011		1011	-	1001		1001	
0100		0100		0100		0100	

S04		S14		S24		S34	
1111		1000	-	1000	-	1000	-
1000	-	0001	-	0001	-	0001	-
0111		1111		0010	-	0010	-
0010		0111		1110	-	1110	
1010		0010	-	1111	-	1111	
1101		1010		0111		1100	
0101		1101		1010		0111	
0001	-	0101		1101		1010	
1110		1110	-	0101		1101	
1100		1100		1100	-	0101	
0110		0110		0110		0110	
0011		0011		0011		0011	
1001		1001		1001		1001	
1011		1011		1011		1011	
0100		0100		0100		0100	

S05	S15	S25	S35
1111	0010 -	0010 -	0010
1000	0001 -	0001 -	0001 -
0001	1111	1111	1000
0010 -	1000	1000 -	1111
1010	0111	0111	0111
1101	1010	1010	1010
0101	1101	1101	1101
0001 -	0101	0101	0101
1110	1110	1110	1110
1100	1100	1100	1100
0110	0110	0110	0110
0011	0011	0011	0011
1001	1001	1001	1001
1011	1011	1011	1011
0100	0100	0100	0100

S06	S16	S26	S36
1111	0001	0001	1000 -
1000	1111	1111	0001 -
0111	1000	1000 -	1111
0010	0111	0111	0111
1010	0010	0010	0010 -
1101	1010	1010	1010
0101	1101	1101	1101
0001 -	0101	0101	0101
1110	1110	1110	1110 -
1100	1100	1100	1100 -
0110	0110	0110	0110 -
0011	0011	0011	0011
1001	1001	1001	1001 -
1011	1011	1011	1011
0100	0100	0100	0100

S07	S17	S27	S37
1111	0001 -	0001 -	0001 -
1000	1111	0010	1000 -
0111	1000	1111	0010 -
0010	0111	1000 -	1111
1010	0010 -	0111	0111
1101	1010	1010	1010
0101	1101	1101	1101
0001 -	0101	0101	0101
111-	1110	1110	1110
1100	1100	1100	1100
0110	0110	0110	0110
0011	0011	0011	0011
1001	1001	1001	1001
1011	1011	1011	1011
0100	0100	0100	0100

S08	S18	S28	S38
1111	0010 -	0010	0010 -
1000	0001 -	0001	0001
0111	1111	1010	1010
0010 -	1000	0110	0110
1010	0111	1111	1111
1101	1010 -	1000	1000
0101	1101	0111	0111
0001 -	0101	1101	1101
1110	1110	0101	0101
1100	1100	1110	1110
0110	0110 -	1100	1100
0011	0011	0011	0011
1001	1001	1001	1001
1011	1011	1011	1011
0100	0100	0100	0100

S09	S19	S29	S39
1111	0001	1000 -	1000 -
1000	1111	0010 -	0010 -
0111	1000 -	1010	0001 -
0010	0111	0001 -	1010
1010	0010 -	1111	1111
1101	1010 -	0111	0111
0101	1101	1101	1101
0001 -	0101	0101	0101 -
1110	1110	1110	1110
1100	1100	1100	1100
0110	0110	0110	0110
0011	0011	0011	0011
1001	1001	1001	1001
1011	1011	1011	1011
0100	0100	0100	0100

S010	S110	S210	S310
1111	1010 -	1010 -	1010 -
1000	0001 -	0001 -	0001 -
0111	1111 -	1111	1111
0010	1000 -	1000	1000
1010 -	0111	1101	1101
1101	0010	1110	1110
0101	1101 -	1100	1100
0001 -	0101	0111	0111
1110	1110 -	0010	0010
1100	1100 -	0101	0101
0110	0110	0110	0110
0011	0011	0011	0011
1001	1001	1001	1001
1011	1011	1011	1011
0100	0100	0100	0100

S011	S111	S211	S311
1111	0010 -	0010	0001 -
1000	0001 -	0001 -	0010 -
0111	1110	1110	1110
0010 -	1100	1100	1100
1010	1111	1111	1111
1101	1000	1000	1000 -
0101	0111	0111	0111
0001 -	1010	1010	1010
1110 -	1101	1101	1101
1100 -	0101	0101	0101
0110	0110	0110	0110
0011	0011	0011	0011
1001	1001	1001	1001
1011	1011	1011	1011
0100	0100	0100	0100

S012	S112	S212	S312
1111	1000 -	1000 -	1000
1000 -	0001 -	0001 -	0001
0111	1100 -	1100 -	1100 -
0010	0110	0110	1011
1010	1001	1001	0110
1101	1011	1011 -	1001
0101	1111	1111	1111
0001 -	0111	0111	0111
1110	0010	0010	0010
1100 -	1010	1010	1010
1110 -	1101	1101	1101
0011	0101	0101	0101
1001 -	1110	1110	1110
1011 -	0011	0011	0011
0100	0100	0100	0100

S013	S113	S213	S313
1111	0001 -	0001 -	0001 -
1000	1001 -	1001	1111
0111	1011	1011	1001 -
0010	1111	1111 -	1011 -
1010	1000	1000	1000 -
1101	0111	0111	0111
0101	0010	0010	0010
0001 -	1010	1010	1010
1110	1101	1101	1101
1100	0101	0101	0101
0110	1110	1110	1110
0011	1100	1100	1100
1001 -	0110	0110	0110
1011 -	0011	0011	0011
0100	0100	0100	0100

S014	S114	S214	S314
1111	0001 -	0001 -	0001 -
1000	1111	1110	0010 -
0111	1000	1111	1010
0010	0111	1000	0101 -
1010	0010	0111	1100
1101	1010	0010 -	0110
0101	1101	1010 -	0100
0001 -	0101	1101	1110
1110	1110 -	0101 -	1111
1100	1100	1100 -	1000
0110	0110	0110 -	0111
0011	0011	0011	1101
1001	1001	1001	0011
1011	1011	1011	1001
0100	0100	0100 -	1011

S015	S115	S215	S315
1111	1000 -	1000	0001 -
1000 -	1111	0001 -	0111
0111	0111	1111	1110
0010	0010	0111 -	1100 -
1010	1010	0010	0110 -
1101	1101	1010	1011 -
0101	0101	1101	1000 -
0001	0001 -	0101	1111
1110	1110	1110 -	0010
1100	1100	1100 -	1010
0110	0110	0110 -	1101
0011	0011	0011	0101
1001	1001	1001	0011
1011	1011	1011 -	1001
0100	0100	0100	0100

S016	S116	S216	S316
1111	1010 -	1010 -	1010 -
1000	0001 -	0001 -	0001 -
0111	1100 -	1100 -	1100 -
0010	0110	1111	0110
1010 -	1001	0101	1000 -
1101	1111 -	0110 -	1110
0101	1000	1001	1011 -
0001 -	0111	1000 -	1111
1110	0010	0111	0101
1100 -	1101	0010	1001
0110 -	0101 -	1101	0111
0011	1110	1110 -	0010
1001 -	0011	0011	1101
1011	1011	1011 -	0011
0100	0100	0100	0100

S021	S121	S221	S321
1000 -	0001 -	0001 -	1000 -
0010 -	1000 -	0111	0001 -
1100	1110 -	1010 -	0010
1001 -	1100 -	1110 -	1110
1111	0110 -	0110 -	1111
0110 -	0011	1011 -	1100
1010	1010	0101 -	0111 -
0111	0101	1100 -	1010
1101	1111	0011	1101
0101 -	0111 -	1111	0101
0001	0010 -	1000	0110
1110	1101	0010 -	0011
0011	1001	1101	1001
1011 -	1011	1001	1011
0100	0100	0100	0100

S022	S122	S222	S322
0010	1000 -	0001 -	0010
0001 -	0001	1000 -	0001 -
1000	1111	0010 -	1010 -
1111	0111	1111 -	0110 -
0111	0010 -	0111 -	1111
1010 -	1010 -	1010 -	1000
1101	1101	1101	0111
0101 -	0101	0101	1101
1110 -	1110 -	1110	0101
1100	1100	1100	1110
0110	0110	0110	1100
0011	0011	0011	0011
1001	1001	1001	1001
1011	1011	1011	1011
0100	0100	0100	0100

S023	S123	S223	S323
1000 -	1010 -	0001 -	1000 -
0010 -	0001 -	0010 -	0001 -
0001	1111 -	1110	1100
1010	1000 -	1100	1011 -
1111 -	1101	1111	0110
0111	1110	1000 -	1001 -
1101	1100	0111 -	1111
0101	0111	1010	0111
1110 -	0010	1101	0010
1100	0101	0101 -	1010
0110	0110	0110	1101
0011 -	0011	0011 -	0101
1001	1001	1001	1110
1011	1011	1011	0011 -
0100 -	0100	0100	0100

S024	S124	S224	S324
1000	0001 -	0001 -	1000 -
0010	1000 -	0111	0001
1100 -	1110	1010	0010 -
1001	1100 -	1110	1110
1111	0110	0110	1111
0110	0011	1011	1100
1010	1010	0101	0111
0111	0101	1100	1010
1101	1111	0011	1110
0101	0111	1111	0101
0001	0010	1000	0110
1110	1101	0010	0011
0011	1001	1101	1001
1011	1011	1001	1011
0100	0100	0100	0100

S025	S125	S225	S325
0010	1000 -	0001 -	0010 -
0001 -	0001 -	1000 -	0001 -
1000 -	1111	0010 -	1010 -
1111	0111	1111	0110
0111	0010 -	0111	1111
1010	1010 -	1010	1000
1101	1101	1101	0111
0101	0101	0101	1101
1110	1110 -	1110	0101
1100 -	1100 -	1100	1110
0110	0110 -	0110	1100
0011	0011	0011	0011
1001 -	1001	1001	1001
1011 -	1011	1011	1011
0100	0100	0100	0100

S026	S126	S226	S326
1000	1010 -	0001 -	1000 -
0010 -	0001 -	0010 -	0001 -
0001 -	1111	1110 -	1100 -
1010	1000	1100	1011
1111	1101	1111	0110
0111	1110	1000	1001
1101	1100	0111 -	1111
0101	0111	1010	0111
1110	0010	1101	0010
1100	0101	0101	1010
0110	0110	0110	1101
0011	0011	0011	0101
1001	1001	1001	1110
1011	1011	1011	0011
0100	0100	0100	0100

S027	S127	S227	S327
1000 -	0001 -	0001 -	1000 -
0010 -	1000 -	0111	0001 -
1100 -	1110	1010 -	0010 -
1001	1100	1110 -	1110 -
1111	0110	0110	1111
0110	0011	1011	1100
1010	1010	0101	0111
0111	0101	1100	1010
1101	1111	0011	1101
0101	0111	1111	0101 -
0001	0010	1000	0110
1110	1101	0010	0011
0011	1001	1101	1001
1011	1011	1011	1011
0100	0100	0100	0100

S028	S128	S228	S328
0010 -	1000 -	0001 -	0010
0001 -	0001 -	1000 -	0001
1000	1111	0010 -	1010 -
1111	0111	1111	0110
0111	0010	0111	1111
1010	1010	1010	1000
1101	1101	1101	0111
0101	0101	0101	1101
1110	1110 -	1110	0101
1100	1100 -	1100	1110
0110	0110 -	0110	1100
0011	0011	0011	0011
1001	1001	1001	1001
1011	1011	1011	1011
0100	0100 -	0100	0100

S029	S129	S229	S329
1000 -	1010	0001 -	1000
0010 -	0001 -	0010 -	0001
0001 -	1111	1110	1100
1010 -	1000	1100	1011
1111	1101	1111	0110
0111	1110	1000 -	1001
1101	1100	0111	1111
0101	0111	1010	0111
1110	0010	1101	0010
1100	0101	0101	1010
0110	0110	0110	1101
0011	0011	0011	0101
1001	1001	1001	1110
1011	1011	1011	0011
0100	0100	0100	0100

X. Appendix B

Experimental Instructions

There was no specific word-for-word set of instructions in the experiments reported in this thesis. The instructions were in general the same but did vary from subject to subject in terms of specific words, intonation, and emphasis depending on how the subject was reacting. For example, if at a particular point a subject looked confused more time and redundancy would be used. If the subject was nervous more time would be taken and a more playful manner adopted by the experimenter (E) to relax the subject. The instructions typically went something like this:

I have some cards I'd like to show you (E sets the 4 cards of the practice deck out in 2 rows, 2 columns). Take a look at the lines on these cards. They are all different aren't they? But sometimes they are a little like each other. These two point different ways but are both crooked, and these two point different ways but are both straight. These two both point up but one is crooked and one is straight, and these two both point sideways but one is straight and one is crooked. Right? Good. Now, we're going to play a little game with these cards. I'm going to take one of these cards (E takes the straight, vertical line) and put it on one side of this board (E puts the card on the top, left side of the board). Notice that this board has two sides (E demonstrates). One on the left and one on the right. I have put the card on this side of the board. Now, you have to guess where I would put the next card. (S places the next card) OK. Why do you think I would put that card there? (S says because E put the other card on the other side). Yes, that's right but I'm thinking of another reason, something about the lines. You've put that card there which is right. That's where I would put it. But the cards are on different sides now. That means that the line on that card is different from the line on the first card. What's different about the lines? Good. Now where would I put this card? (This continues until S can place the cards correctly and E concentrates S's attention on the stimulus, not position, etc.). If S cannot place the cards correctly after two attempts he does not enter the experiment. In 100 Ss this happened once.

These cards weren't too hard for you, were they? (this statement is intoned more like an obvious statement to make the S feel that he has done very well). I have some other cards I want you to look at. They're a little different. They don't have lines, they have shapes. (E shows the same 6 examples of the test deck to all subjects). What do I have on this card? Good. And this one? Good. And this one? Is it the same as this one? (E points out differences along each dimension as they appear, e.g. red-green, small-large, etc.). Now, we're going to play the same kind of game with these cards as we did with the first ones. I'm going to put this card here (E places 0000 on top left left) and I want you to put the rest of the cards, one at a time as I give them to you, on the board on the side that you think that I would put them on. OK. Where do you think I would put this one? ... (S places the cards on the board, one at a time, while E tells him if he was right or wrong each time. If S was wrong E says that was a good guess but he would have put the card on the other side. S then moves the card into the correct position).

XI. Appendix C

Source Tables: Trend Analyses Over Transform

1. Experiment I

a) Kindergarten, LK

Source	SS	df	MS	F	P
Within Cells	7.500	15	0.500		
linear	50.625	1	50.625	101.250	.001
quadratic	17.161	1	17.161	34.321	.001
cubic	10.000	1	10.000	20.000	.001
quartic	0.514	1	0.514	1.029	.327

b) Grade 3, LK

Source	SS	df	MS	F	P
Within Cells	6.000	15	0.400		
linear	48.400	1	48.400	121.000	.000
quadratic	10.286	1	10.286	25.714	.001
cubic	3.600	1	3.600	9.000	.009
quartic	0.514	1	0.514	1.286	.286

c) Grade 6, LK

Source	SS	df	MS	F	P
Within Cells	28.750	15	1.917		
linear	52.900	1	52.900	27.600	.001
quadratic	10.286	1	10.286	5.366	.035
cubic	8.100	1	8.100	4.226	.058
quartic	0.514	1	0.514	o.268	.612

d) Kindergarten, PK

Source	SS	df	MS	F	P
Within Cells	157.250	12	13.104		
linear	52.812	1	52.812	4.030	.068
quadratic	1.562	1	1.562	0.119	.736
cubic	70.312	1	70.312	5.366	.039

e) Grade 3, PK

Source	SS	df	MS	F	P
Within Cells	188.500	12	15.708		
linear	26.450	1	26.450	1.684	.219
quadratic	36.000	1	36.000	2.292	.156
cubic	0.800	1	0.800	0.051	.825

f) Grade 6, PK

Source	SS	df	MS	F	P
Within Cells	82.750	12	6.896		
linear	90.312	1	90.312	13.097	.004
quadratic	22.562	1	22.562	3.272	.096
cubic	0.312	1	0.312	0.045	.835

g) All groups, Proportion of Pre-LK Stimuli Erred Upon

Source	SS	df	MS	F	P
Within Cells	38415.488	44	873.079		
linear	7370.422	1	7370.422	8.442	.000
quadratic	2581.336	1	2581.336	2.957	.093
cubic	60.001	1	60.001	0.069	.794

2. Experiment II

a) Kindergarten, LK

Source	SS	df	MS	F	P
Within Cells	34.500	15	2.300		
linear	55.225	1	55.225	24.011	.001
quadratic	9.446	1	9.446	4.107	.061
cubic	3.025	1	3.025	1.315	.269
quartic	0.804	1	0.804	0.349	.563

b) Kindergarten, PK

Source	SS	df	MS	F	P
Within Cells	223.250	12	18.604		
linear	7.812	1	7.812	0.420	.529
quadratic	18.063	1	18.063	0.971	.344
cubic	52.812	1	52.812	2.839	.118

c) Kindergarten, Proportion of Pre-LK Stimuli Erred Upon

Source	SS	df	MS	F	P
Within Cells	9632.980	12	802.748		
linear	5951.258	1	5951.258	7.414	.019
quadratic	156.248	1	156.248	0.195	.667
cubic	551.251	1	551.251	0.687	.423

3. Chapter V

a) Group 1, Pe=.1, LK

Source	SS	df	MS	F	P
Within Cells	24.500	15	1.633		
linear	67.600	1	67.600	41.388	.001
quadratic	16.071	1	16.071	9.840	.007
cubic	0.025	1	0.025	0.015	.903
quartic	0.004	1	0.004	0.002	.963

b) Group 3, Pe=.3, LK

Source	SS	df	MS	F	P
Within Cells	26.000	15	1.733		
linear	44.100	1	44.100	25.442	.001
quadratic	37.786	1	37.786	21.799	.001
cubic	6.400	1	6.400	3.692	.074
quartic	0.914	1	0.914	0.527	.479

c) Group 5, Pe=.5, LK

Source	SS	df	MS	F	P
Within Cells	23.750	15	1.583		
linear	65.025	1	65.025	41.068	.001
quadratic	17.161	1	17.161	10.838	.005
cubic	0.100	1	0.100	0.063	.805
quartic	0.514	1	0.514	0.325	.577

d) Group 7, Pe=.7

Source	SS	df	MS	F	P
Within Cells	10.000	15	0.667		
linear	84.100	1	84.100	126.150	.001
quadratic	0.071	1	0.071	0.107	.748
cubic	0.900	1	0.900	1.350	.263
quartic	0.129	1	0.129	0.193	.663

e) Group 9, Pe=.9

Source	SS	df	MS	F	P
Within Cells	12.000	15	0.800		
linear	22.500	1	22.500	28.125	.001
quadratic	0.071	1	0.071	0.089	.769
cubic	0	1	0	0	1.0
quartic	0.229	1	0.229	0.286	.601

XII. Appendix D

Source Tables, ANOVA

1. Experiment I

a) Two-way, Transform by Grade (5x3), LK

Source	df	SS	MS	F	P
Transform	4	211.40	52.85	56.29	.000
Grade	2	2.50	1.25	1.33	.274
T x G	8	1.50	0.19	0.20	.989
Error	45	42.25	0.94		
Total	59	257.65			

b) Two-way, Transform by Grade (4 x 3), PK

Source	df	SS	MS	F	P
Transform	3	233.42	77.81	6.55	.001
Grade	2	114.29	57.15	4.80	.014
T x G	6	67.71	11.29	0.95	.474
Error	36	428.50	11.90		
Total	47	843.92			

c) Two-way, Grade by Sequence (3 x 3), LK

Source	df	SS	MS	F	P
Grade	2	0.18	0.08	0.18	.836
Sequence	2	0.18	0.83	0.18	.836
G x S	4	1.78	0.29	0.63	.645
Error	27	12.50	0.46		
Total	35	14.00			

d) Two-way, Grade by Sequence (3 x 3), PK

Source	df	SS	MS	F	P
Grade	2	221.18	110.58	7.47	.003
Sequence	2	4.67	2.33	0.16	.855
G x S	4	118.67	29.67	2.01	.122
Error	27	399.51	14.80		
Total	35	744.00			

e) Two-way, Same-Age by Grade (2 x 3), LK

Source	df	SS	MS	F	P
Same-Age	1	0.67	0.67	2.18	.157
Grade	2	0.58	0.29	0.96	.404
SA x G	2	0.58	0.29	0.96	.404
Error	18	5.50	0.31		
Total	23	7.33			

f) Two-way, Same-Age by Grade (2 x 3), PK

Source	df	SS	MS	F	P
Same-Age	1	48.18	48.18	2.26	.150
Grade	2	91.58	45.79	2.15	.146
SA x G	2	4.08	2.04	0.10	.909
Error	18	384.00	21.33		
Total	23	527.83			

2. Experiment II.

a) Two-way, Transform by Stimulus Deck (5 x 2), LK

Source	df	SS	MS	F	P
Transform	4	145.15	36.29	25.92	.000
Stim. Deck	1	1.60	1.60	1.14	.294
T x SD	4	1.65	0.41	0.30	.879
Error	30	42.00	1.40		
Total	39	190.40			

b) Two-way, Transform by Stimulus Deck (4 x 2), PK

Source	df	SS	MS	F	P
Transform	3	55.75	18.58	1.72	.341
Stim. Deck	1	0.13	0.13	0.01	.930
T x SD	3	147.63	49.21	3.10	.045
Error	24	380.50	15.85		
Total	31	584.00			

3. Chapter V.

a) Two-way, Transform by Probability-of-Error-Level (5 x 5), LK

Source	df	SS	MS	F	P
Transform	4	316.54	79.14	66.66	.000
Prob. of E.L.	4	83.44	20.86	16.26	.000
T x PEL	16	47.16	2.95	2.30	.008
Error	75	96.25	1.28		
Total	99	543.39			

XIII. Appendix E

The DISTR Programme

Given a stimulus set of d dimensions (ND) and v values (BASE) the DISTR programme will take a random sample (number of iterations NI) of stimulus sequences from the total possible set. For each stimulus sequence in the random sample DISTR calculates LK. The programme then prints the frequencies for each value in the LK range (the distribution vector DIST) and also the percentage of the total sample accounted for by each value of LK. The programme is:

```
 DISTR [0]
 DISTR; ND; BASE; NI; LIM; DIST; I; T.
1. ND←□ , Op□← 'NO. DIGITS?'
2. BASE ←□, Op□ ←'BASE?'
3. NI←□ ,Op□←'NO. ITERATIONS?'
4. LIM←BASE*ND-1
5. DIST←LIMp0
6. I←1
7. LOOP: T←(NDpBASE)⊤ LIM? - 1 + BASE * ND
8. DIST [T]←DIST [ T←(∧ ≠ ∨\  T [(ND-1)p1;] ≠1 0 ↓T)⍳1] +1
9. →(NI≧ I←I + 1)/ LOOP
10.        "
11. 'DISTRIBUTION:',5 0 ⍕ DIST
12. 'PERCENTAGES:', 5 1 ⍕ 100 x DIST   NI
```

The algorithm works as follows:

1. input number of digits (ND)
2. input base (BASE)
3. input number of iterations (NI)
4. set limit (LIM) to $BASE^{ND-1}$
5. set distribution vector (DIST) to LIM zeros
6. set counter (I) to 1. The counter will be incremented until < NI
7. set T to LIM sequences of random digits between 0 and BASE such that digit 0 + digit 1 $BASE^1$ + digit 2 $BASE^2$ + ... + digit ND $BASE^{ND}$ is between 1 and $BASE^{ND-1}$, for each sequence.
8. This statement is best explained pictorially:

	0	110	
	1	011	Take the first column and
If T=	1	101	compare to the rest (using ǂ
	0	010	operation). The ǂ function
	0	101	returns the following:
	0	001	0 ǂ 0→0
	1	001	0 ǂ 1→1
	1	110	1 ǂ 0→1

	LK=5		1 ǂ 1→0

The result is:

110
100
010
010
101
001
110
001

Then do an OR scan. This means that going down a column, change all digits to ones after the first 1 is encountered. The result is:

110
110
110
110
111
111
111
111

Find the first row of ones. The index is LK by the programme. Since the initial 000 stimulus is not involved in the programme 1 must be added to each value of the LK range printed by the programme. The actual LK of the above sequence is 6.

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