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(October 1, 1973 - September 30, 1974)

LEARNING AND RETENTION OF CONCEPTS FORMED FROM UNFAMILIAR VISUAL PATTERNS

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Two experiments were conducted to investigate the learning and retention of concepts formed from novel visual stimulus materials (wave-form patterns). The purpose of the first experiment was to scale sets of wave forms as a function of difficulty, i.e., Ss were shown a prototype wave form and were asked to give same-different judgments for subsequent wave forms. On the basis of these results, sets of "simple" and "difficult" instances of

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ABSTRACT

Two experiments were conducted to investigate the learning and retention of concepts formed from novel visual stimulus materials (wave-form patterns). The purpose of the first experiment was to scale sets of wave forms as a function of difficulty, i.e., Ss were shown a prototype wave form and were asked to give same-different judgments for subsequent wave forms. On the basis of these results, sets of "simple" and "difficult" instances of concepts were chosen. In the second experiment, Ss learned four wave-form concepts with either simple or difficult instances over a four-day period and were tested for retention after periods of one, three, and ten days. The data showed significantly better performance for simple concepts, but neither group showed any performance decrement measured by the percentage of correct identifications over any of the three retention intervals. Both groups did, however, display longer decision reaction times during the retention testing. It was suggested that the results indicated a longer retrieval route for the correct responses after the passage of time.

LEARNING AND RETENTION OF CONCEPTS FORMED FROM UNFAMILIAR VISUAL PATTERNS

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This research represents an attempt to look at certain conditions of concept learning which may effect retention. In the majority of research that has examined the parameters of concept learning, there has been little effort directed toward memory processes, e.g., retention. Further, research in concept learning has been conducted such that the scattered studies of retention cannot be easily related to learning variables. More generally, research in learning has been divided into arbitrarily defined areas: problem solving, discrimination learning, pattern perception and prototype abstraction, concept learning, etc. Each of these areas has generated its own direction of research and each has employed different learning conditions and stimulus materials. This segmentation has resulted in a lack of emphasis on the commonalities of the processes involved in all types of learning, and in an inability to assess the effects on retention of many of the variables that have been examined in learning situations. Although the information processing viewpoint has diminished the arbitrary distinctions between types of learning and has provided a framework to examine the entire process from learning to retrieval, integration of previous empirical data derived from research in the different "areas" of learning has not taken place. Since the learning of new information is of little or no use if the material is not retained, it would appear that research should be directed at delineating the stimulus characteristics and conditions of acquisition common to most learning situations, and their effect on retention.

An example of the artificial distinctions between areas is concept learning and pattern perception. Concept learning is usually defined as a situation where Ss learn to make an identifying response to members of a stimulus set that are not identical. This area has emphasized the verbal "rules" used to define the concept, i.e., "red if and only if square." Almost without exception, experiments in concept learning have utilized overlearned stimuli, i.e., the stimulus objects are familiar ones (e.g., geometric shapes). Good discriminatory acuity has previously been developed along the stimulus dimensions, and category names for the dimensions already exist. Therefore, the task is the selection of an experimenter-defined classification rule (typically semantic) and the subject of investigation becomes the patterns of logical choice and inference, rather than the learning of new information and the formation of novel categorization schematas.

The research in visual pattern perception shares some basic commonalities with concept formation. It has been suggested (e.g., Mavrides & Brown, 1970) that families of visual patterns (i.e., instances that are related to one another by a number of common attributes) are stored in a structure that relates each individual stimulus to a representation of the commonalities occurring within the entire family. That is, classification of patterns involves a situation where Ss learn to make an identifying response to members of a stimulus set that are not identical, i.e., the recognition of a pattern is equivalent to knowing a concept. The development of such categories has been variously labeled as schematic concept formation (Mavrides & Brown, 1970), schema plus correction (Woodworth, 1938), and central tendency plus correction (Posner, 1968). But, in comparison to the familiar stimuli used in concept formation, research in prototype abstraction has employed novel, low meaningful stimuli like random polygons (Aiken & Brown, 1971), snowflakes and inkblots (Goldstein & Chance, 1970), two element matrix patterns (Snodgrass, 1971), and spatially represented Markov patterns generated by a computer program (Evans & Meuller, 1966).

Frequently, studies of memory have often also used low meaningful stimuli (e.g., nonsense syllables) in order to examine the associations and mechanisms involved in storing a new stimulus because attempting to study memory with familiar stimuli confounds results with previously stored memories. Therefore, unfamiliar visual patterns, similar to those employed in prototype extraction studies, were used to study memory for novel concepts or categorization schemata.

EXPERIMENT I

Numerous studies have been reported that deal with the issue of how pure psychophysical judgments are made (see Anderson & Rosenfeld, 1972). In most cases, the stimuli are simple and judgments are made on a single physical characteristic which varies along a single dimension. Of related interest is the question of how Ss make judgments of complex stimuli, (where complexity is typically defined as some function of amount of stimulus information, e.g., Newell, 1972) and here less has been done. While Experiment I was designed primarily to develop a set of stimuli scaled for complexity for use in Experiment II, the results are of some interest in their own right. Specifically, the experiment was designed to develop a set of stimuli around naturally occurring prototypes and to scale the difficulty of the exemplars of each of the prototypes. Instances of sine, square, ramp, and triangle waves were distorted by the addition of harmonic combinations and changes in frequency, and the relationship between degree of distortion and subjective difficulty was examined.

Method

Subjects.--The Ss were 58 students drawn from the introductory psychology class at the University of Denver.

Apparatus and Stimuli.--Figure 1 shows a schematic diagram of the laboratory apparatus. Stimuli were generated via auditory signals, converted to visual representations by means of a modified analog computer. Rates and sequences of stimulus presentations were controlled by a PDP-8 computer and stimuli were presented on a CRT display in a "Time-History" display format. That is, each stimulus was effectively drawn for the subject over a 5 sec period starting from left to right.

The stimuli were generated from four basic wave forms, i.e., triangle, ramp, sine, and square waves. Two examples of the stimuli are seen in Figure 2. Each basic wave form was varied in its complexity by the addition of either two or three harmonics. The matrix of harmonics, designed to yield independent stimuli, are given in Table 1. In addition to varying the harmonics combined with the wave form, two separate frequencies of presentation were utilized. The matrix of harmonics was displayed at both .5 cps and at .875 cps. Therefore, a total of 98 exemplar stimuli of each wave form were viewed. Each of the 98 were judged twice by each S, once in the first half of the experiment and once in the second. The 196 "correct" stimuli were randomly interspersed with 196 exemplars of the other wave forms, resulting in 392 stimulus presentations in each experimental session.

Each stimulus trial was initiated by a warning spike, followed by a 2 sec interval, a 5 sec stimulus, and was terminated with a 4 sec response interval. The 5 sec stimulus was, as indicated previously, "drawn" on the display. No feedback was given.

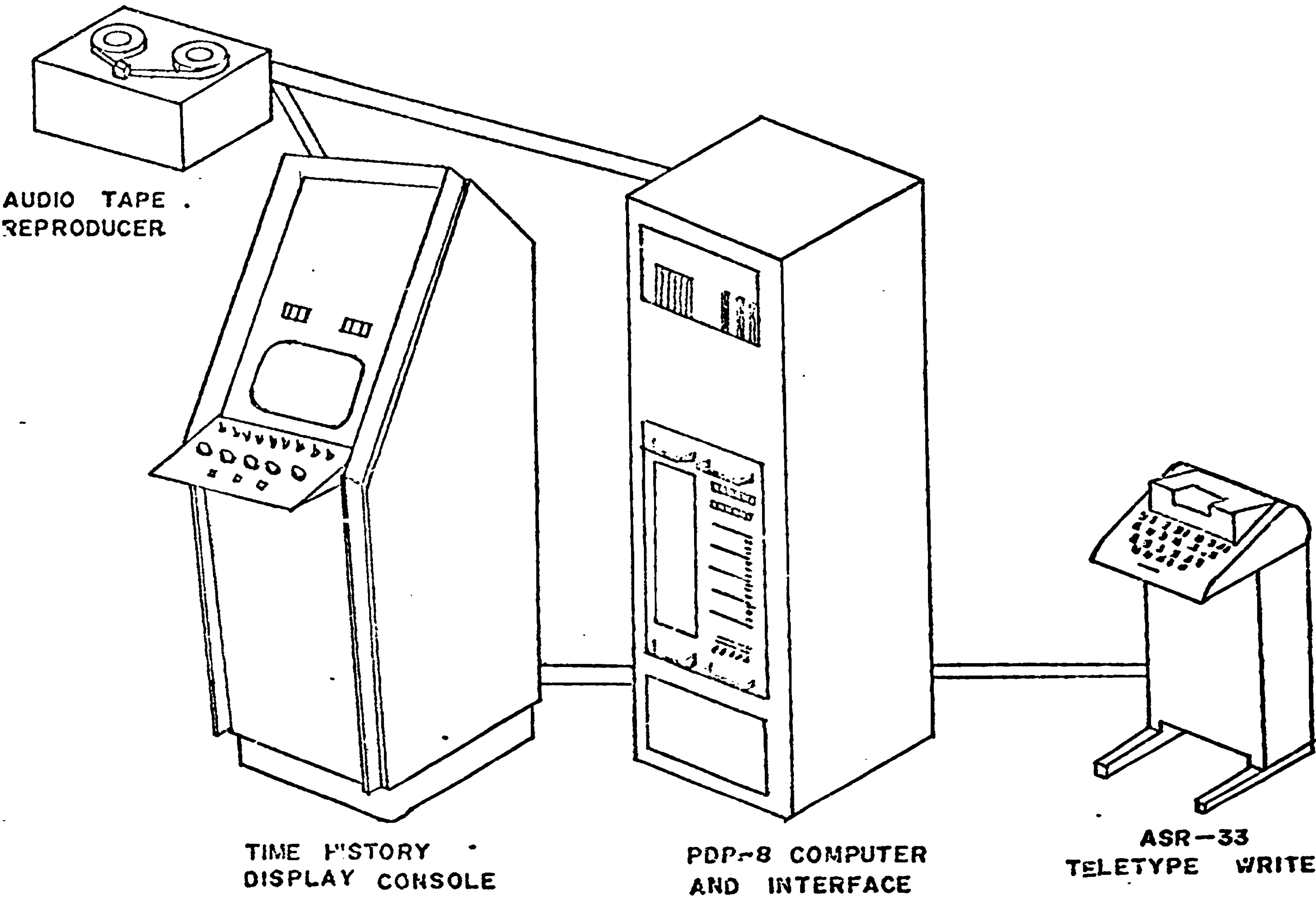
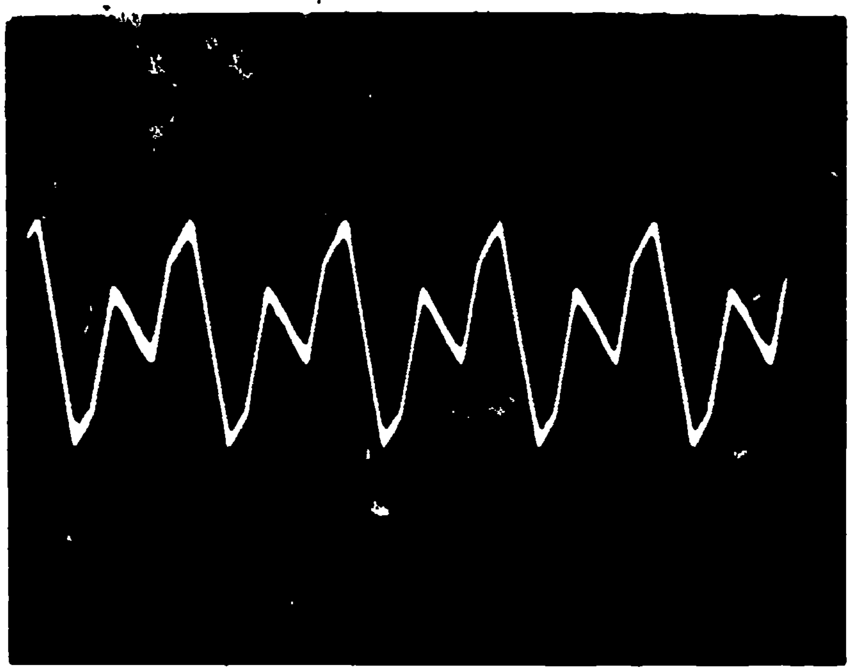
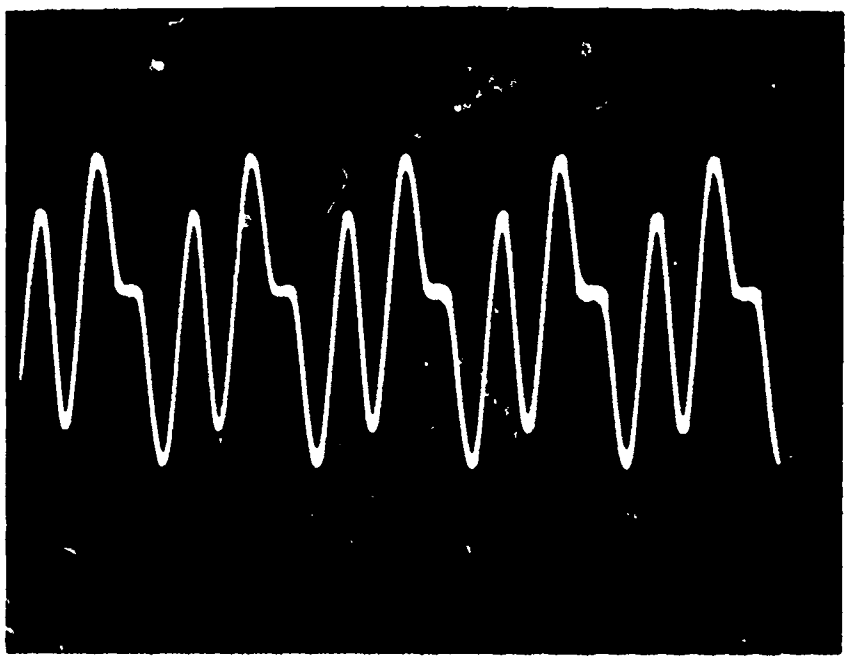


Figure 1. Pictorial illustration of the equipment configuration.



Triangle waves with harmonics.



Sine waves with harmonics.

Figure 2. Examples of Wave Form "Stimuli"

Table 1

Harmonic Components Used for Stimulus Generation

for Each Wave Form

Two Harmonics per Stimulus

Matrix Presented at .5 cps and .875 cps

1 + 2*	2 + 3	3 + 4	4 + 5	5 + 6	6 + 7	7 + 8
1 + 3	2 + 4	3 + 5	4 + 6	5 + 7	6 + 8	
1 + 4	2 + 5	3 + 6	4 + 7	5 + 8		
1 + 5	2 + 6	3 + 7	4 + 8			
1 + 6	2 + 7	3 + 8				
1 + 7	2 + 8					
1 + 8						

Three Harmonics per Stimulus

Matrix Presented at .5 cps and .875 cps

1+2+3	2+3+4	3+4+5	4+5+6	5+6+7	6+7+8
1+2+4	2+3+5	3+4+6	4+5+7	5+6+8	
1+2+5	2+3+6	3+4+7	4+5+8		
1+2+6	2+3+7	3+4+8			
1+2+7	2+3+8				
1+2+8					

*The first number of each column refers to the harmonic of the basic wave form, e.g., the first harmonic of either sine, square, ramp, or triangle wave. The second and/or third number refers to an _n_th order harmonic of that same wave form which has been combined with it to produce the final stimulus.

Procedure.--*S*s were randomly assigned to one of four groups. Each group received one of the wave forms as the standard stimulus. Two of the groups had 15 *S*s (those viewing square and ramp waves) and two had 14 *S*s (those viewing triangle and sine waves). Each *S* was trained individually in an experimental session lasting approximately 70 min, with a 5 min break in the middle of the session. At the beginning of the experiment, instructions that contained a sample tape to familiarize the *S* with the equipment, the timing of the stimulus, and response intervals were given and the "standard" form was shown.

Any response occurring more than 4 sec after the stimulus offset was recorded as an incorrect response. Responses occurring during the stimulus interval were not recorded, and if the *S* failed to respond again during the response interval, an incorrect response was recorded. All responses, as well as reaction times (time lapse between stimulus offset and response) were recorded. It should be noted that at no time was the name of the wave form used nor any verbal description given. Therefore, *S*s had to formulate their own rationales for classifying stimuli in the "yes" category.

Results and Discussion

Proportion correct.--For the purpose of determining the difficulty of recognizing a stimulus as an exemplar of a particular wave form, only the number of correct responses were analyzed. There were a total of 30 judgments on each square and ramp wave stimulus and 28 judgments on each triangle and sine wave stimulus. The proportion of those responses that were correct was used as the index of difficulty. Incorrect responses and reaction times were also recorded.

Table 2 gives the proportion of correct responses for each wave form by number of harmonics and presentation frequency. The table shows that stimuli presented at .875 cps were less frequently correctly classified than stimuli presented at .5 cps. The presentation at .875 cps contained more information than the one in the .5 cps display since the entire "pattern" of the wave form had more repetitions. For example, at .5 cps, the visual configuration had 2-1/2 repetitions of the cycle, but the .875 cps presentation contained more than four repetitions.

The second conclusion that can be drawn from Table 2 is that stimuli composed of three harmonics were more difficult to classify than stimuli composed of two harmonics. That is, stimuli containing three different harmonics were less often correctly identified than stimuli having only two harmonics for each wave form. As with the presentation of the stimulus at .875 cps, more information was embedded in the stimuli containing three harmonics.

The ordering of the stimuli, then, was such that two harmonics recorded at .5 cps were the easiest, followed by three harmonics recorded at .5 cps, while two harmonics recorded at .875 cps were more difficult, and three harmonics recorded at .875 cps were the most difficult. This pattern would suggest that the manipulations producing stimulus complexity were roughly equi-

Table 2

Proportion of Correct Responses for Each Wave Form by cps of Presentation and Number of Harmonics

	.5 cps		.875 cps	
	Two Harmonics	Three Harmonics	Two Harmonics	Three Harmonics
Ramp	.53	.47	.22	.20
Sine	.45	.38	.22	.20
Triangle	.55	.52	.24	.23
Square	.37	.34	.32	.28

valent to the subjective evaluations of difficulty, i.e., difficulty increased as a function of the information value of the stimulus.

There were only slight differences in the total number of correct classifications by wave form. The most easily categorized exemplars were derived from triangle waves. The other three wave forms were very similar in the percentage of correct responses. The square wave examples, however, were more consistently identified across conditions, i.e., they produced more correct classifications at .875 cps than the other wave forms, but fewer than the other groups at .5 cps.

Previous findings in prototype abstraction have indicated that Ss can become increasingly sensitive to attributes of novel stimuli that define schema families in the absence of external feedback (e.g., Dansereau & Brown, 1974; Rankin & Evans, 1968). The present experiment found no evidence for improved discrimination over trials. However, in most of the experiments reporting facilitation, the two stimuli were simultaneously presented, and same-different judgments were made. In the present experiment, Ss "matched" from memory and did not have repeated exposure to the prototype. Therefore, it is less than surprising that about half of the Ss responded correctly more often in the first block of 25 trials than they did on the average of all of the trials.

Decision criteria.--A logical hypothesis is that Ss' definition of the criterion or the Ss' abstraction from the exemplars of the prototype determined which stimuli were classified as members of a set. That is, since none of the stimuli were identical to the prototype, Ss made some judgments on which elements of the prototype were to be used as the decision criterion.

Therefore, all of the Ss were asked on a postexperimental questionnaire how they had classified the stimuli. There seemed to be three types of classification "methods," occurring about equally in all four groups. Most Ss responded to the question by drawing the abstracted pattern which was usually similar to the standard. The graphic representation of the pattern was occasionally accompanied by an explanation; for example, "up, then down, then up." Another method of categorizing the stimuli was verbal labeling or descriptions, like "sharpness," "roundness," "mountains rather than boxes." The third method was to abstract the number of times the pattern was repeated. That is, some Ss said that every time the pattern occurred "two times and a partial" it was the same as the prototype.

The Ss' decision criterion was inspected and it was decided whether or not the criterion was one that would produce correct classifications. This could be done with little reliability, since many of the criteria were either too vague or appeared to be contradictory. However, those employing classification criterion with characteristics discrepant from the prototype had lower total number correct than those who appeared to have the correct classification criterion, although some overlap was noted. On the other hand, while the number of correct responses averaged around 50%, one S who was dropped from the experiment had a markedly higher percentage correct (96.8%). Upon examination, he correctly identified the category as "square waves" and was an engineering student, to whom the stimuli were not novel. In sum, then, it seems apparent that illustrating the correct prototype for the pattern does not insure that the essential features will be abstracted as the classification criterion.

EXPERIMENT II

It has been assumed that a concept, once learned, is not forgotten. Consequently, long-term memory for concepts has not received much empirical attention. However, as has been emphasized before, the nature of the task used in traditional concept learning dictates that Ss isolate a common element or dimension that has a semantic label. But the learning of a concept, at least in the colloquial sense, does not necessarily imply learning a definitive set of characteristics. For example, one is hard pressed to give a single attribute or set of attributes that would include all criminals. Rather, repeated exposure to exemplars of the concept enrich and broaden the class of characteristics in a manner such that many subtle characteristics can no longer be verbalized. The present experiment, then, examined long-term memory for concepts learned in a manner more closely approximating the "real world." That is, the stimuli were novel and did not contain a single defining set of attributes that could be easily verbalized--the concept was defined by some general pictorial prototype.

In addition to examining the long-term retention of concepts formed from unfamiliar visual patterns, the study also examined the variables of sequence of learning the concepts and stimulus discriminality. Sequence of learning was defined as the order of learning a multiconcept problem, i.e., the concepts could either be learned simultaneously or successively. It was hypothesized that when a concept is learned singly, rather than with several others, the task at any given time is less difficult. There are fewer attributes relevant at any time and attention may be focused only on those attributes. That is, the information overload is less since blocks of the information may be processed sequentially rather than simultaneously.

The other variable examined in this experiment was the stimulus characteristic of discriminability or difficulty in identifying the exemplar as a member of a stimulus set. Specifically, it was hypothesized that the more complex exemplars would decrease the speed of learning, as it does in concept learning tasks utilizing familiar stimuli (Uhl, 1966). Similarly, Posner, Goldsmith, and Welton (1967) showed that the rate at which Ss learned to classify patterns was an inverse function of the amount of distortion of the instances from their respective prototype. It was also of interest to see whether any decrement in learning produced by the complex stimuli would be overcome with practice, an effect noted with traditional concept identification tasks (Bourne, 1967).

The study, then, examined the effect of sequence of learning on both learning and retention, and of the difficulty in identifying a stimulus as an exemplar of a concept.

Method

Subjects.--The Ss were 28 students at the University of Denver obtained from the Career Placements Office. The Ss were paid $3.00 per session and 1¢ for every correct response.

Apparatus.--The equipment was the same as that used in the previous experiment.

Stimuli.--A sample of 25 complex and 25 simple stimuli was selected from the 98 exemplars of each stimulus. The simple stimuli were selected from the range of stimuli that had the highest accuracy scores in Experiment I and the complex stimuli from the range of the lowest accuracy scores. Since a stimulus was viewed twice by each S, once in the first half of the experiment and once in the second half, the reliability of the judgment could be determined. The stimuli with the least amount of variation in the two judgments were selected. If the stimuli otherwise appeared equally appropriate, a random selection procedure was used to determine the final sets of 25 stimuli.

An experimental session consisted of 200 trials, in which each of 100 stimuli were viewed twice. Each of the four wave forms occurred equally often and in a random order that was varied from day to day, i.e., 50 exemplars of each wave form were seen every day.

Procedure.--A 2 X 2 factorial design was used. One-half of the Ss learned all four concepts simultaneously, i.e., Ss responded to all four categories on each of the first four days of the experiment. The other half of the Ss learned the concepts successively in an additive manner. On Day 1, a single concept was learned, and all other exemplars were "incorrect" or in the "no" category. On Day 2, Ss responded to a new concept as well as the one responded to on the previous day. Similarly, on Day 3, Ss responded to three categories, and by the fourth day of learning, Ss were utilizing all four response categories. The sequence of exemplars was intermixed, but Ss learned a single new response at a time, and had only a single new set of discriminations to make on each day. One-half the simultaneous group and one-half of the additive group learned the four concepts from the set of difficult exemplars, while the other half learned the concepts from the set of simple exemplars.

Days 1 through 4 comprised the learning phase. On Days 5, 8, and 15, all Ss were tested with the same 200 stimuli containing instances of all of the four categories in the absence of feedback. The Ss were tested on the same level of exemplar difficulty they were trained on, i.e., Ss trained on simple stimuli were tested on simple stimuli.

Results and Discussion

The proportion of correct responses over each of the days of learning and retention for the four groups may be seen in Figure 3. The data were analyzed by a two between (simple vs complex exemplars, and simultaneous vs successive learning) and one within (days) analysis of variance. The days of learning (Days 1-4) were analyzed separately from a comparison of learning and retention (Days 4, 5, 8, and 15).

The analysis of the four days of learning revealed a signi-

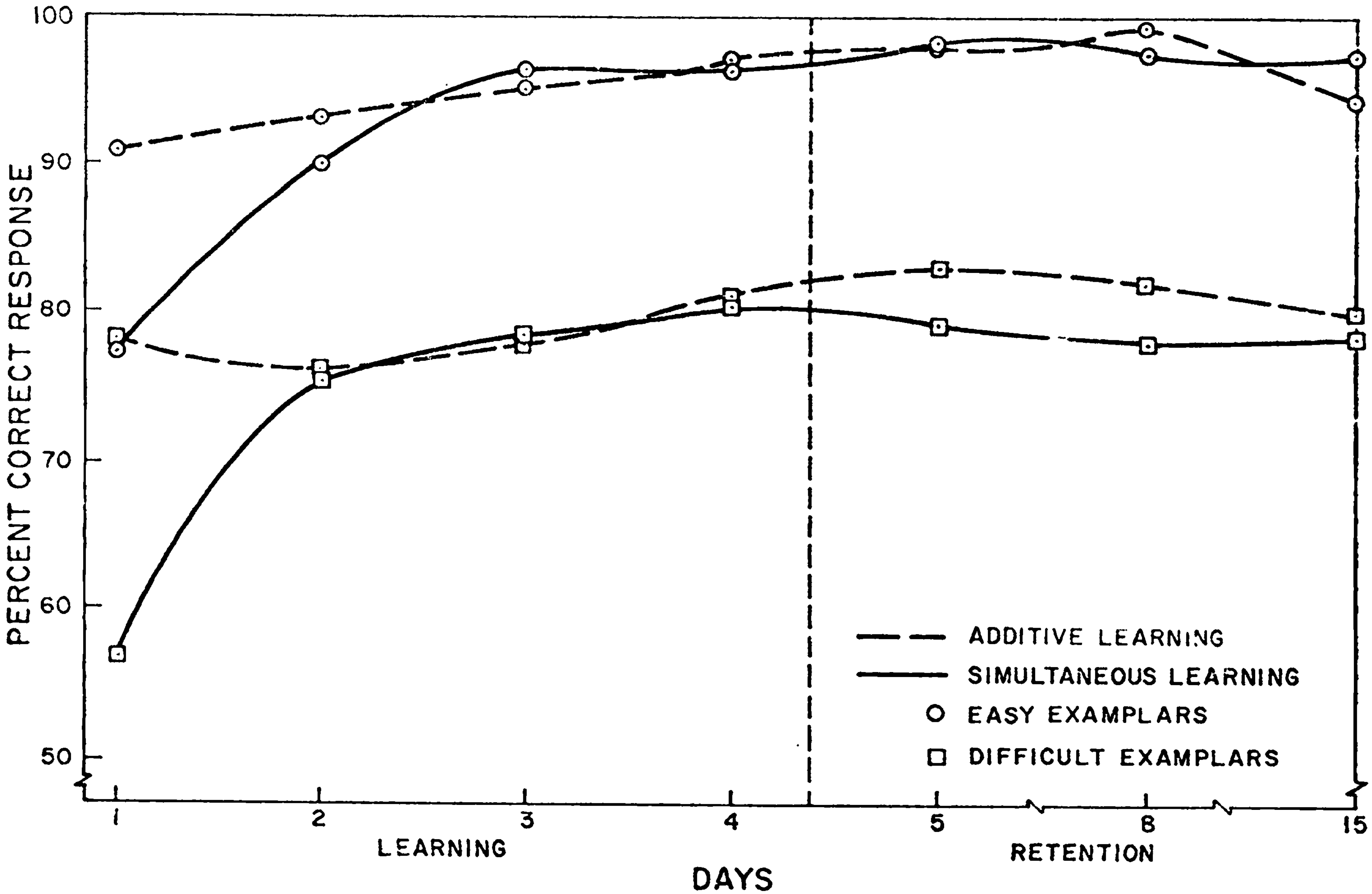


Figure 3. Percentage of correct responses during learning and retention for groups learning the concepts simultaneously and additively with either simple or complex exemplars.

ficant main effect of exemplar difficulty, $F(1, 24) = 58.78$, $p < .01$, a main effect of days, $F(3, 72) = 2.91$, $p < .05$, and a significant days X method of learning interaction, $F(3, 72) = 2.96$, $p < .05$.

The significant main effect of exemplar difficulty is apparent in the figure. The groups learning the concepts from the more difficult exemplars started at a lower level and attained a lower final level of performance than the groups learning the concepts with the less difficult exemplars, but the rate of learning for both groups was approximately the same. This result confirms the prediction that utilizing stimuli not easily identified as an exemplar of a concept impairs learning.

However, the similarity of the rates of learning among all of the groups contrasts with the different rates of learning for different levels of stimulus complexity found in studies of classification of patterns and multivariate concept learning. Specifically, Posner, Goldsmith, and Welton (1967) found that more distorted exemplars of a pattern concept resulted in a slower rate of learning as measured by trials to criterion. A slower rate of learning with the addition of relevant information (Walker & Bourne, 1961), and irrelevant information, (Bourne & Restle, 1959) has been found in multivariate concept learning. The data from the present experiment give no indication that the initially poorer performance produced by the groups learning with the difficult exemplars would ever be overcome. This result may be due to the use of stimulation that precludes clear rules for categorization, e.g., when very complex stimuli are utilized and no rule is available to classify them, performance may be permanently inferior regardless of the amount of practice.

The second important effect seen in Figure 3 is the difference in the learning curves resulting from the simultaneous and additive methods of concept formation, noted as days X method of learning interaction. The groups learning the concepts simultaneously showed a typical learning curve, whereas the groups learning the concepts additively showed about the same performance on each of the four days including the first. Since the additive groups learn the same amount of new information on each of the days, the result is hardly surprising. However, the performance on the last day of learning is almost identical for the two methods. Therefore, there appears to be no difference in final level of learning between the simultaneous and additive methods of learning.

A comparison of the last day of learning and the three retention days was done to assess differences in performance resulting from the retention interval. The analysis showed the same main effect of exemplar difficulty seen in the days of learning, $\underline{F}(1, 24) = 48.93$, $\underline{p} < .01$, and a significant days X method of learning interaction, $\underline{F}(3, 72) = 2.79$, $\underline{p} < .05$.

Again, looking at Figure 3, no deterioration in performance is seen over the retention days. Therefore, in this classification task, there is no significant change in performance after a one, three, or ten-day delay. However, the significant interaction between days and method of learning indicates an average superiority of retention for the groups learning the concepts additively.

In addition to correct responses, decision latencies can sometimes prove informative in this type of task. However, analyses of decision latencies here are complex for several reasons, not the least of which involves the fact that there is a ceiling effect in the "simple" groups. There were, however, several interesting trends. First, the latencies for correct response to simple and complex stimuli were not equal. Second, latencies tended to increase during retention testing, the increase being most pronounced for incorrect responses (see Appendix 1).

GENERAL DISCUSSION

This study is somewhat similar to one done by Posner and Keele (1970). To investigate the retention of pattern schemata, two groups of Ss learned four concepts. The stimulus examples were statistically distorted instances of a prototype pattern. One group of Ss were tested immediately on transfer patterns, previously learned patterns, and the pattern prototype, and one group was tested on these patterns after a one-week delay. The results showed evidence of forgetting after the one-week delay in recognition of previously seen patterns, with the deterioration being most pronounced on the first block of trials.

Posner and Keele (1968) reasoned that high distortion instances of the concept produce knowledge about the variability around the schema prototype and a "looser" concept, while low distortion instances produce knowledge about the prototype, itself, resulting in a "tighter" concept. They showed that learning concepts from high distortion instances and low distortion instances produce differential performance on transfer tasks. A parallel can be drawn between the "high distortion" instances in the Posner and Keele studies and the difficult exemplars in the present study. Specifically, Posner and Keele define the amount of distortion as the amount of statistical distance from the central tendency, while Experiment I ascertained the average amount of perceived distance from the standard prototype. Further, the amount of perceived distance coincided with the amount of additional noise added to the standard, i.e., the mathematical distance from the standard. Therefore, the difficult stimuli in the present study are more distorted or are more distant from the standard judged both by physical and subjective measures.

If the analogy between the stimuli used by Posner and Keele and those used in the present study is correct, the discrepancies between the results of the studies are instructive. Posner and Keele (1970) found a significant decrement in performance after a one-week delay on previously viewed patterns, the decrement being the most pronounced in the first block of trials. Further, no differences in response time between the group tested immediately and those tested after one week were reported. The pattern of results in the present study are diametrically opposed, i.e., no significant decrement in performance was found in any of the retention trials, but the latency to respond did increase (see Appendix 1).

There are several fundamental methodological differences between the two studies. Posner and Keele utilized a total of either three or four examples of four concepts, and _Ss_ had unlimited exposure to the exemplars. Therefore, the familiarity with any given exemplar was probably much higher than in the present study where exposure was paced and 100 different exemplars were seen. If any memorization did occur, the decrement in performance after the retention interval would be the expected result. Further, if the exemplar were retrievable directly from memory, i.e., no decision need be made at the time, the DRT would not necessarily increase. Posner, Goldsmith, and Welton (1967) indicated that with the levels of distortion utilized in the Posner _et al._ (1970) study, that verbal labeling did occur. It seems probable that retrieval of a verbal label might represent a different and perhaps more efficient process than retrieval of a pictorial schema. The present study appears to preclude memorization, and represents a straight concept for classification by pictorial prototype rather than semantic rules.

Finally, the present stimuli are naturally occurring prototypes and exemplars, and may be subject to different critical rules and defining characteristics than the prototype and categories defined by probabilities and statistical rules, which may involve some sort of "averaging" rather than selection of certain attributes.

Whether these studies represent different retrieval processes should be elucidated by the use of transfer studies with the present stimuli in a manner similar to Posner and Keele (1968) and more extensive examination of the role of verbal labels with both sets of concepts (see Appendix 2).

Several general conclusions can be drawn from the data presented here. First, while performance to concepts learned with simple exemplars is superior to performance with more complex exemplars, the rates of learning are similar. Second, although terminal learning levels are approximately the same with additive and successive methods, retention is better when the concepts are learned in an additive fashion. Finally, it seems that the methodology used here is useful for future studies of memory since there was no loss after up to ten days subsequent to original learning.

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APPENDIX 1

In the present experiment, the latency to respond represents the time required to process the information and to reach a decision. Consequently, the latencies will be referred to as decision response times (DRTs) to distinguish them from the reaction time measures often used in situations requiring rapid responses.

Several problems were encountered in analyzing the DRTs. Most important, correct and incorrect DRTs probably reflect different cognitive processes, and correct DRTs are typically shorter and show less variance. Consequently, correct and incorrect DRTs are most appropriately analyzed separately. However, the frequency with which incorrect DRTs occurred varied and was often very low, i.e., in some groups almost all of the responses were correct. Therefore, no statistical analysis was conducted on the DRT data. Figure 4 shows the DRTs for both correct and incorrect responses by exemplar complexity for the groups learning the concepts simultaneously, while Figure 5 shows the comparable data for the groups learning the concepts in an additive manner. As is typically found, the correct DRTs were substantially lower and never overlapped with the incorrect DRTs. Moreover, the correct DRTs appeared to be stable while the incorrect DRTs were quite labile.

The incorrect DRTs for the groups using simple stimuli and complex stimuli show very different curves. Much of the differ-

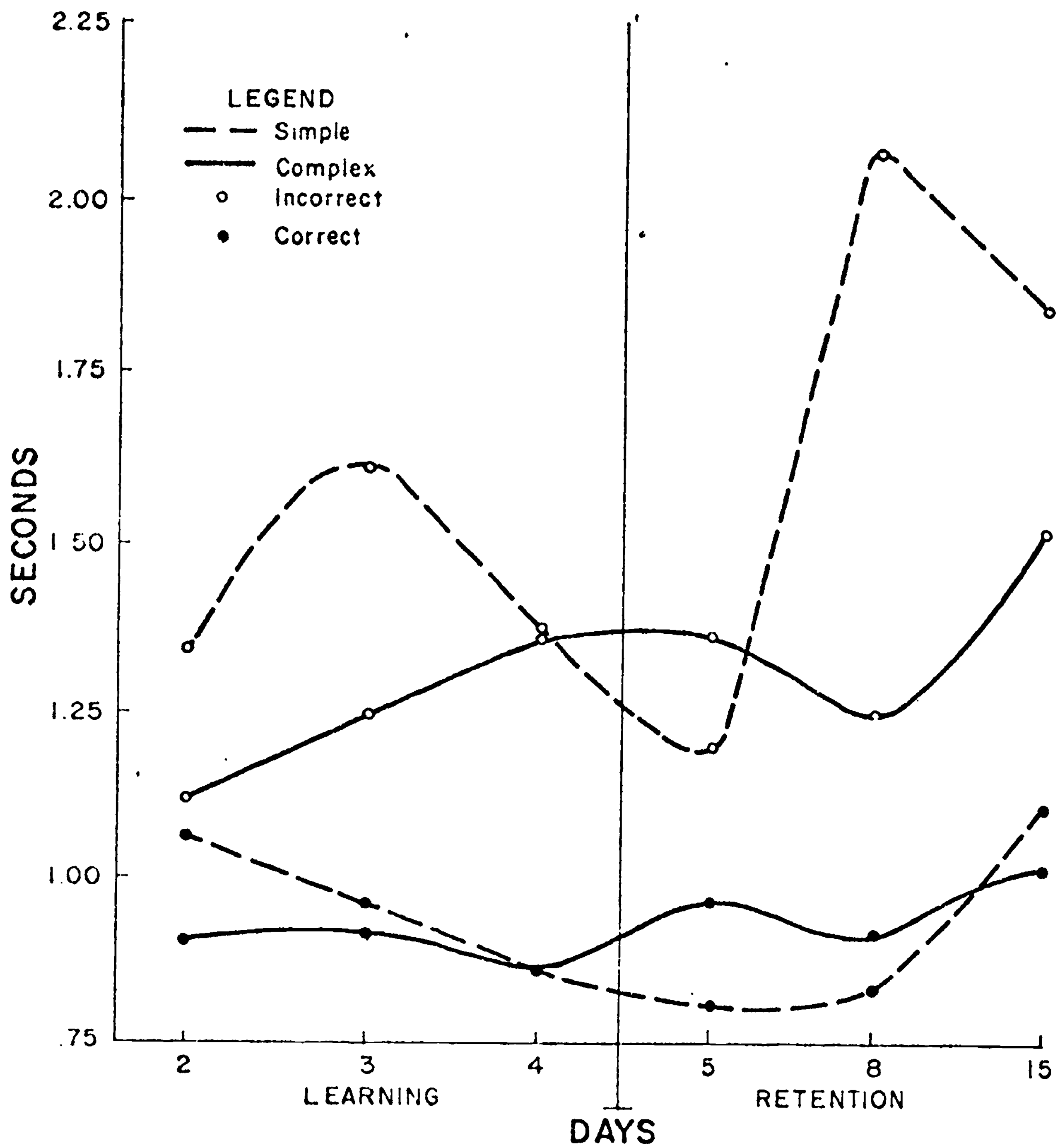

Figure 4. Decision reaction time for both correct and incorrect responses for groups learning the concepts simultaneously with either simple or complex exemplars.

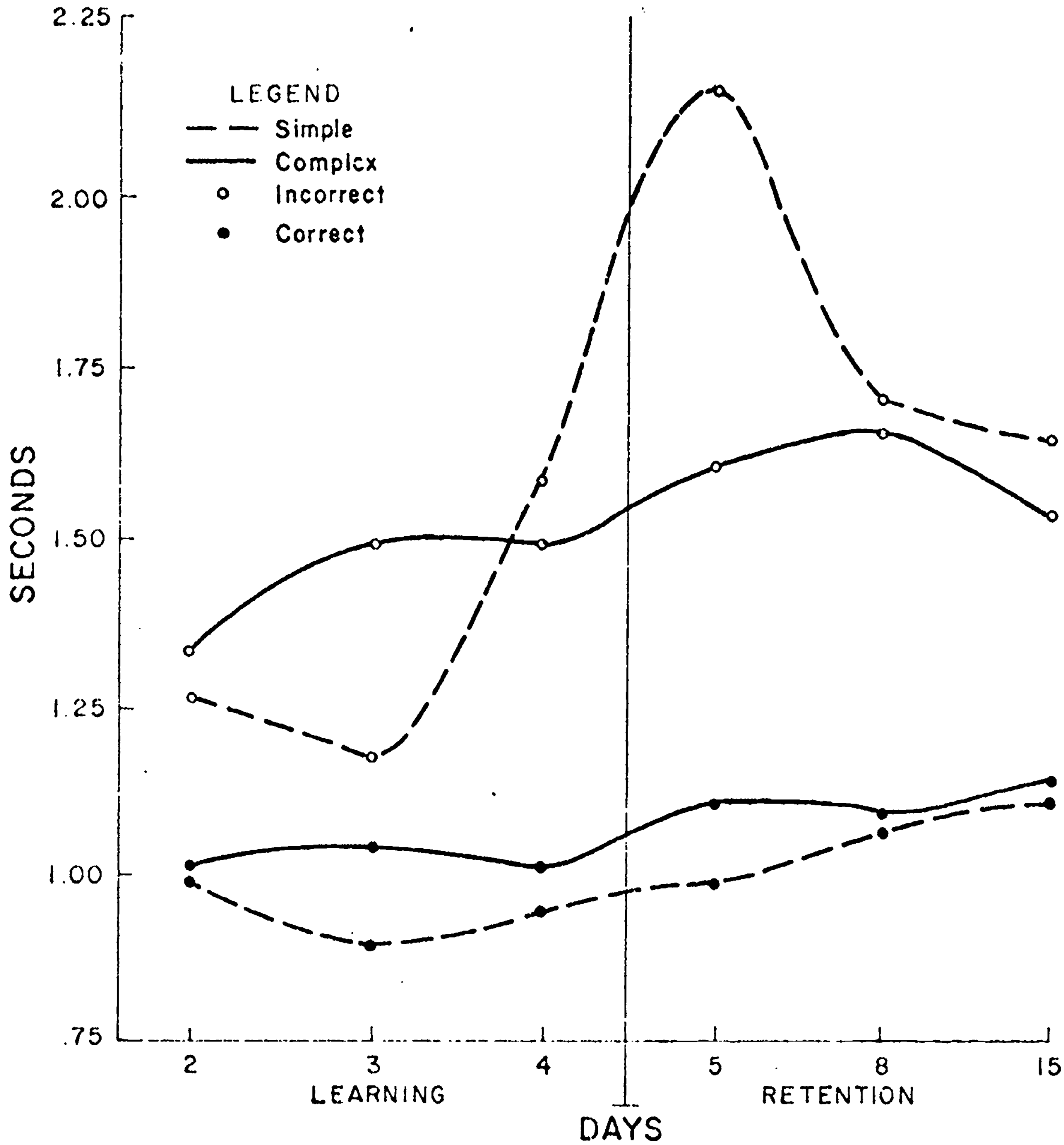

Figure 5. Decision reaction time for both correct and incorrect responses for groups learning the concepts additively with either simple or complex exemplars.

ence may be attributed to the extreme variance resulting from the low frequency of occurrence of incorrect responses in the groups using the simple stimuli.

In the simultaneous condition, the correct DRTs for the complex stimulus group is consistently higher than for the sample stimulus groups. This may reflect an increase in time needed to process the greater amount of information contained in the complex display. In the successive groups, however, the groups using simple stimuli had higher DRTs during the learning days than the complex stimulus group, while the average DRT for the complex stimulus groups was slightly higher during the retention testing.

In comparing correct responses from Figures 4 and 5, it is apparent that the DRTs for all groups in the simultaneous conditions tended to be longer than for the additive groups. Longer DRTs would be expected on the first days of learning in the simultaneous conditions since more information was processed. However, the DRTs remained higher on the final days of learning and during retention. Contrary to what might have been expected, the DRTs for the additive conditions decreased over days of learning with accompanying decrease in the simultaneous conditions. It is possible that learning several concepts simultaneously alters the method of encoding, and more variables are examined before a decision is reached. In keeping with the hypothesis, it will be remembered that the successive conditions not only had shorter DRTs, but also generally had a higher percentage correct during learning and retention. The longer processing time may possibly indicate the decision criteria are less distinct when formed for several concepts simultaneously. However, both the percent correct, as well as the DRTs, indicate that learning similar concepts in an additive fashion enhances both learning and retention.

There was a strong trend for DRT to increase after a retention interval. The mean DRT for the last three days of training was always shorter than for the three days of retention testing. Specifically, correct DRTs pooled over the difficulty variable for the groups learning the concept simultaneously was .98 sec during learning, but 1.09 sec during retention. For the additive groups, the correct DRTs were almost identical (.92 sec in learning vs .94 sec in retention). The biggest differences were found in the incorrect DRTs, i.e., for the simultaneous groups, the mean was 1.37 sec in learning vs 1.54 sec in retention, and the means were 1.34 sec in learning vs 1.54 sec in retention for the additive group. Therefore, although no deterioration was noted after the retention interval, the time to process the information did increase. The increase was more pronounced with the incorrect DRTs. This pattern of results indicates that although information is well retained, the time to access the information is longer after a retention interval, and while the retrieval of correct schemata is only slightly slower, the incorrect processing time increases sharply.

APPENDIX 2

A small pilot study was done to examine differences in transfer tasks resulting from learning the concepts with complex instances and simple instances. Posner and Keele (1968) reasoned that high distortion instances of a concept (complex stimuli) produce knowledge about variability around a prototype and a "looser" concept, while low distortion instances produce knowledge about the prototype itself, resulting in a "tighter" concept. They found that learning concepts from high distortion instances increased the amount of transfer to new, more highly distorted instances. This pilot was an attempt to examine transfer after learning with both high distortion exemplars and with low distortion exemplars.

Method

Subjects.--The *Ss* were 18 students at the University of Denver, acquired through the Career Placements Office. They were paid $3.00 per session and a bonus of 1¢ for every correct response.

Procedure.--There were four groups of *Ss* organized in a balanced factorial design. Training on Day 1 involved the presentation of all exemplars (i.e., simultaneous condition) of either the "simple" or "complex" exemplars with feedback. Day 2 was a "testing" session without feedback. Five *Ss* experienced "simple" exemplars on Day 1 and these same stimuli on Day 2 (Group S-S). Four Ss were treated in the same way except that the complex exemplars were used (C-C). Three Ss were trained with the "simple" exemplars and tested on the complex (Group S-C), while four other Ss were trained with the "complex" exemplars and tested with the "simple" (Group C-S). All other particulars of the procedure were identical to Experiment II.

Results and Discussion

Percentage Correct.--As seen in Table 3, both of the groups with the same exemplars Days 1 and 2 showed an increment in the percent of correct responses on the testing day. The increment confirms the trend seen in Experiment II for improved performance in the absence of feedback after initial learning. The improvement, however, was more dramatic after a single day of learning than after several, and suggests that the number of trials needed to produce additional learning in the absence of feedback may be quite small. That is, initial feedback produces learning about the prototype. Once information about the prototype has been abstracted, learning continues even without feedback. All of the Ss in both groups showed improved performance on the testing day. Further, as seen in Table 3, the percentage of improvement was greater for the group learning the concepts from more complex stimuli. The percentage correct was 19.3% higher for the complex stimuli group on the testing day, but only 5.7% better in the simple exemplar group. Since neither group approached asymptotic level, it is possible

Table 3

Percentage of Correct Responses During the Training and Testing Days

	Simple	Complex
Simple	79.6 (Day 1)	84.0 (Day 1)
	85.3 (Day 2)	77.2 (Day 2)
Complex	45.5 (Day 1)	60.0 (Day 1)
	46.5 (Day 2)	79.3 (Day 2)

that prototypes that included knowledge about the variability may produce a better basis for continued learning in the absence of feedback.

The group trained on complex exemplars and transferred to simple exemplars showed approximately the same performance during both phases. Considering the improvement shown by the nontransferred groups, it must be concluded that the shift in stimulus complexity was disruptive to performance. The disruption, however, was not nearly as large as that seen in the group trained on simple exemplars and tested on complex ones. This group actually showed a 6.8% decrement in performance. Although the nature of the study precludes anything but tentative speculation, it would appear that neither training on complex exemplars nor on simple exemplars facilitate the identification of instances of the concept from the other complexity level. At least learning a "looser" concept from the high variability instances does not disrupt performance to the extent that learning low variability does. Therefore, although the "direction" of the shift was different for the two groups, these preliminary findings do contradict the findings of Posner and Keele (1968).

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