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EFFECTS OF STIMULUS COMPLEXITY, SUBJECT AGE, AND STIMULUS CODING ON SELECTIVE STIMULUS CONTROL

Abstract
Selective stimulus control refers to the functional relationships that are developed between the various stimulus elements of a discriminative stimulus and the subject’s response. A multi-element conditional discrimination problem is an effective means of studying these relationships. In the first experiment, preschool and adult subjects were presented with a series of conditional discrimination problems. They were required to respond differentially to two multi-element stimulus cards by touching one of two response circles, one red and one blue. Each problem set contained either two, four, six, or eight elements per stimulus card. The discrimination was established using an errorless training procedure and stimulus control by the individual elements was assessed by a sorting task following acquisition of each discrimination problem. During the sorting task, all elements that comprised the multi-element stimulus cards were individually presented in random order. Subjects were asked to place all elements under the response circle that they thought the element belonged to. Following stimulus control assessment of the last discrimination problem, subjects were given two additional training and stimulus control sessions with that problem to assess the effect of overtraining. Both the adults and preschool subjects showed control by proportionately fewer elements as the number of elements in successive multi-element discriminative stimuli increased. The number of elements demonstrating control in each problem set for both groups was similar. The two groups differed, however, when given overtraining on the last problem set. The preschool subjects showed no increase in the number of elements meeting stimulus control criteria when given additional training. The adults did show increased control, eventually correctly sorting all stimulus elements.

In the second experiment, preschool subjects were given multi-element conditional discrimination problems having either elements the children could label, elements the children could not reliably label, or a combination of both. The same discrimination training and stimulus control assessment procedures used in the first experiment were in the second. The results show that more elements in the labeled condition were correctly sorted than either the non-labeled or combination conditions.

The results of this study document the functional characteristics of three relevant factors in the development of selective stimulus control. In addition, the data extend the results obtained by Lovass, et al., Ray, and Hugunin and Touchette.

Keywords
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EFFECTS OF STIMULUS COMPLEXITY, SUBJECT AGE, AND STIMULUS CODING ON SELECTIVE STIMULUS CONTROL

University of New Hampshire
Ph.D. 1981

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EFFECTS OF STIMULUS COMPLEXITY,  
SUBJECT AGE, AND STIMULUS CODING ON  
SELECTIVE STIMULUS CONTROL  

BY  

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DISSERTATION  

Submitted to the University of New Hampshire  
in Partial Fulfillment of  
the Requirements for the Degree of  

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in  
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of Physical Education

Date September 8, 1981
to my son,

Chris

a very special person
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ABSTRACT

EFFECTS OF STIMULUS COMPLEXITY, SUBJECT AGE, AND STIMULUS CODING ON SELECTIVE STIMULUS CONTROL

by

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University of New Hampshire, December, 1981

Selective stimulus control refers to the functional relationships that are developed between the various stimulus elements of a discriminative stimulus and the subject's response. A multi-element conditional discrimination problem is an effective means of studying these relationships. In the first experiment, preschool and adult subjects were presented with a series of conditional discrimination problems. They were required to respond differentially to two multi-element stimulus cards by touching one of two response circles, one red and one blue. Each problem set contained either two, four, six, or eight elements per stimulus card. The discrimination was established using an errorless training procedure and stimulus control by the individual elements was assessed by a sorting task following acquisition of each discrimination problem. During the sorting task, all elements that comprised the multi-element stimulus cards were individually
presented in random order. Subjects were asked to place all elements under the response circle that they thought the element belonged to. Following stimulus control assessment of the last discrimination problem, subjects were given two additional training and stimulus control sessions with that problem to assess the effect of overtraining. Both the adults and preschool subjects showed control by proportionately fewer elements as the number of elements in successive multi-element discriminative stimuli increased. The number of elements demonstrating control in each problem set for both groups was similar. The two groups differed, however, when given overtraining on the last problem set. The preschool subjects showed no increase in the number of elements meeting stimulus control criteria when given additional training. The adults did show increased control, eventually correctly sorting all stimulus elements.

In the second experiment, preschool subjects were given multi-element conditional discrimination problems having either elements the children could label, elements the children could not reliably label, or a combination of both. The same discrimination training and stimulus control assessment procedures used in the first experiment were in the second. The results show that more elements in the labeled condition were correctly sorted than either the non-labeled or combination conditions.

The results of this study document the functional characteristics of three relevant factors in the development of
selective stimulus control. In addition, the data extend the results obtained by Lovass, et al., Ray, and Hugunin and Touchette.
I. INTRODUCTION AND LITERATURE REVIEW

When an organism responds differentially to two or more discriminative stimuli it is often assumed that the subject's responses are based upon properties of the stimulus as defined by the experimenter (e.g., wavelength of light, orientation of line). Ray and Sidman (1970), however, have pointed out that a subject's behavior often invalidates this assumption. Stimuli forming functional stimulus-response relationships need not always be those specified by the experimenter. The functional controlling stimulus may be quite different from the experimenter-defined discriminative stimulus (Underwood, 1963). A study by Reynolds (1961) is considered to be an early but important example of such a relationship.

In experiment I, two pigeons were reinforced for pecking a key illuminated with a white triangle superimposed on a red background (S+). Responding was extinguished in the presence of a white circle on a green background. Thus, the experimenter-defined discriminative stimuli were white triangle-red background versus white circle-green background. Following acquisition of the discrimination, each element (white triangle, white circle, red and green background) was presented individually during extinction. If the subject's response in the presence of the S+ stimulus compound was controlled by the stimuli as defined by the experimenter,
then each subject would have responded similarly to all of the S+ stimulus elements when presented alone. However, one subject responded maximally to the white triangle with minimal responding to red, while the second subject responded maximally to the red component. Each of the subjects' discrimination behavior was therefore under the control of only one of the two experimenter-specified elements. Reynolds argued that during training each subject had attended to only one of the two possible S+ elements. Attention refers to the functional relationships that are developed between the various stimulus elements of a discriminative stimulus and the subject's response.

Attention defined in this manner is very different from other definitions that have emphasized cognitive mediational processes (Kendler and Kendler, 1962), orienting responses (Sokolov, 1963), and minimal or covert attending responses (Zeaman and House, 1963). Reynolds's data were interpreted using a stimulus control definition of attention which emphasized the relationship between stimuli, responses, and maintaining reinforcer contingencies. As Skinner (1974) has indicated, "What is involved in attention is not a change of stimulus or receptors but the contingencies underlying the process of discrimination" (p. 113). It is within this operant tradition that this dissertation will study visual selective attention of preschool children that develops as a result of conditional discrimination training.

One potential advantage of using a behavioral model of
attention is that this process of stimulus control has been carefully examined using relatively simple discriminative stimuli. A number of factors (e.g., previous exposure to stimuli, reinforcement schedules, etc.) have been shown to affect stimulus control functions in predictable and systematic ways. If the development of attention to various elements of a complex discriminative stimulus is assumed to be similar to the development of stimulus control using simple discriminative stimuli, then such factors could provide a framework to help direct an analysis of the attention process.

For example, Kamin (1969) in a series of important respondent conditioning studies demonstrated the importance of stimulus pre-exposure in the later development of control by redundant stimuli. The results indicated that the pre-exposure of one element of a compound stimulus prevents the acquisition of control by the second, redundant element. This phenomenon has been called blocking. Stimulus pre-exposure has been shown to have a similar effect upon the development of selective attention during discrimination training. Johnson and Cumming (1968), using pigeons, systematically examined the effect of stimulus pre-training on later stimulus control by elements of a compound discriminative stimulus. The results showed that the degree of stimulus control exerted by elements of a stimulus compound was directly related to exposure to these elements alone. When a subject was given exposure to only one element of a stimulus compound, this element alone would control behavior
in later tests of stimulus control. As the authors suggest, "The extent to which a bird 'pays attention' to a stimulus, defined in terms of the degree of stimulus control acquired by that stimulus, is determined by how well it previously learned to discriminate that stimulus from other stimuli" (p. 157). More simply, an organism's history of exposure to various elements of a discriminative stimulus affects the probability that these elements will functionally control the subject's discriminative response.

A stimulus control approach to the study of selective attention was also used by Ray (1969). Her results strengthened the argument that the concept of attention can be defined in stimulus control terms. In this study, Ray argued not only that attention is defined by functional stimulus-response relationships, but that this relationship is a functional behavioral unit with characteristics of an operant. Thus, an established stimulus-response unit could change in probability of occurrence without altering the basic stimulus-response relationship. Like an operant, the unit's probability of occurrence is dependent upon current contingencies of reinforcement. Ray's study also suggested that the results obtained by Kamin (1968) and Johnson and Cumming (1968) depended on the fact that the additional redundant elements did not alter the initial contingencies of reinforcement. Ray developed an experimental procedure with which she established a number of stimulus-response units and demonstrated that by altering reinforcement contingencies,
the probability of the unit's occurrence may be changed, resulting in what has been called selective attention.

Ray trained Rhesus monkeys to correctly respond to two different conditional discrimination problems. The subjects were first taught a red-green color discrimination followed by a vertical-horizontal line tilt discrimination. The conditional response was a left or right key press (e.g., both keys red, press left key; both keys green, press right key; both keys vertical, press left key; both keys horizontal, press right key). Once the subjects reached 95% accuracy on both problems, the problems were combined during maintenance sessions having 30 consecutive presentations of each problem. These sessions were called "immediate history checks" and provided a measure of any change in the original stimulus-response relationships following the contingency changes outlined below.

The effect of changes in reinforcement contingencies upon the stimulus-response units were measured with two types of test sessions. Both of these used compound discriminative stimuli formed by combining the original color and line tilt elements. These compounds were either compatible with, or in conflict with the original stimulus-response relationships. A compatible compound was formed by combining stimulus elements which controlled similar responses (e.g., combining red and vertical line and required subjects to press left key). The original reinforcer contingency for both elements remained the same. A conflict compound was formed by
combining stimulus elements which controlled different (conflicting) responses (e.g., combining red and horizontal line requiring the subject to press the left key). With this compound the reinforcement contingencies were reversed for one element. The elements of both compounds were then presented individually and the discriminative response correlated with each element was determined. During these test trials the response-reinforcer contingencies were the same as during conflict compound trials (differential reinforcement).

The results of her study yielded two important findings. The first was that responding during the conflict compound was functionally related to the unchanged element alone. During the test probes only the unchanged element maintained accurate discrimination performance, the reversed element did not. For all subjects, responding to either the conflict compound or the unchanged element alone was 90-100% accurate whereas correct responding to the reversed element (responding in agreement with the reversed contingency) occurred on less than 50% of the trials. The second major result was that the behavior associated with the reversed element during test trials was either in agreement with the pre-reversal reinforcer contingencies or reflected position preferences or chance performance. Subjects did not demonstrate stimulus control in agreement with the reversed contingencies. In addition, when Ray did attempt to establish criterion accuracy with the reversed element, it required several sessions.
Ray's data suggest that stimulus-response relationships formed during acquisition of a conditional discrimination form a functional operant unit and that the probability of its occurrence depends upon current reinforcement contingencies. Thus when Ray's subjects were confronted with the conflict compound, the probability that criterion performance was being maintained by the reversed element decreased. The lowered probability would be a function of the decrease in reinforcement for responding in accord with the conflicting element's pre-reversal contingency. Thus, responding would lead to errors and non-reinforcement. Because reinforcement contingencies remained the same for the unchanged element, its probability of occurrence remained high and supported criterion accuracy. Responding during the conflict compound was not the result of a shift in an underlying attention process but rather the predictable result of a change (reduction) in the probability of reinforcement for one of the two stimulus-response units.

In a systematic replication and extension of Ray's paradigm, Huguenin and Touchette (1980) obtained similar results using mentally retarded adult subjects and a non-differential reinforcement test procedure during single element test trials. Eight severely retarded male subjects were taught the same color and line tilt conditional discrimination problem used by Ray. Following criterion performance (95% accuracy) on both the color and line tilt problems, the subjects were given conflict compound training sessions. As in
Ray's study, the conflict compound was produced by maintaining the original reinforcement contingencies for one element and reversing the contingency for the other. The conflict compound sessions were continued until subjects again met criterion performance. The elements of the conflict compound were then presented alone and the stimulus control by each element was assessed. Although both a differential and a non-differential reinforcement test were used, only the results of the latter will be discussed.

Unlike the differential reinforcement test used by Ray, the non-differential test provided reinforcement regardless of element displayed (color or line tilt) and the subject's subsequent response (right or left key). The percent of responses that were in agreement with the contingency associated with a particular stimulus element (e.g., press left key when both keys are green) was calculated. The results were similar to those obtained by Ray. Responding during the conflict compound was functionally related to the unchanged element. During individual element test sessions, the unchanged element demonstrated scores reflecting 100% agreement for seven of the eight subjects. This was contrasted with below 59% agreement during reversed element tests. When presented alone, the reversed element did not maintain accurate discrimination performance. As in Ray's study, errors made during single element sessions suggest that the subject's response in the reversed element was either in agreement with the pre-reversal contingency or no control was evident. The most common finding was the former.
The data support the results of Ray, and, in addition, extend the applicability to human subjects. The retarded adults selectively attended to the elements of a compound stimulus as a function of prior contingencies of reinforcement. When two visual elements are combined and one element's current reinforcement contingency conflicts with past contingencies (e.g., reversed) and the contingencies associated with the second element remain the same, the former element will be ignored. Significantly, the original stimulus-response relationship (pre-reversal) of the reversed element was not modified or changed. Thus, attention to visual stimuli in a discrimination task can be construed in the manner suggested Skinner (1974), "What is involved in attention is not a change of stimulus or receptors but the contingencies underlying the process of discrimination . . . Discrimination is a behavioral process: the contingencies, not the mind, make discriminations" (p. 117).

The studies cited above indicate that control by elements of a stimulus compound is determined, in part, by reinforcement contingencies, both past and present. Behavior is not only a function of its consequences, however. Skinner and others (e.g., Catania, 1973) have suggested that behavior is the result of what has been called the "three-term contingency." "The occasion upon which behavior occurs, the behavior itself, and its consequences are interrelated . . ." (Skinner, 1974, p. 82).

A study by Garcia and Koelling (1966) is an important
example. Using a conditioned suppression paradigm, the researchers examined the effect of four different aversive consequences (electric shock, delayed electric shock, X-ray, and lithium chloride) on the suppression of a rat's lick response during a multi-element S+. The S+ was composed of flavored water, a response (licking) activated flashing light, and auditory clicker. This stimulus condition was alternated with sessions where the subjects drank tasteless, dark, noiseless water and received no aversive consequences. The subjects quickly (within three to five sessions) learned not to lick during sessions with the S+. A stimulus control test similar to that used by Reynolds (1961) was given in order to determine which element was correlated with the subject's response suppression. The results were clear. Licking was suppressed in those subjects that were given electric shock when the flashing light or noise was present. They drank normally when given flavored water. The subjects receiving radiation or lithium chloride, however, demonstrated control by a different S+ element. Their licking was suppressed by the flavored water but normal in the presence of the flashing light or noise. Thus, in this study, selective attention to elements of the complex stimulus was dependent not only upon the type of aversive consequences (external versus internal discomfort) but also upon characteristics of the stimulus elements (exteroceptive versus gustatory).

Another important stimulus characteristic that may be
relevant in understanding selective attention to elements of a complex stimulus is the number of discrete elements that comprise the stimulus. The operant research described above has used stimuli with only two or three discrete elements. Most organisms, however, must adapt to stimuli having several discrete elements or dimensions. For example, a primary school child when learning sight words in a reading task must attend to multiple letters, including their position within a word, their spatial characteristics, etc. Thus, a relevant question is what will occur when a subject is presented with a problem having stimuli that contain more than two elements? Do all elements gain control of the subject's behavior or will the subject selectively attend to some subset of elements?

Cognitively oriented memory studies, although using substantially different procedures from typical operant discrimination problems, suggest that human subjects do utilize more than two discrete elements but that there are limits to the number of elements used. The classic study that is often cited is that of Miller (1956). Miller, studying short term memory, used a variety of verbal stimuli (e.g., digits, letters, words, etc.) and found that his subjects were able to recall 7±2 chunks or bits of information. This estimate, however, appears to be dependent upon task requirements. In a review of relevant short term memory research, Glanzer and Razel (1974) have obtained estimates that are substantially lower. They argued that the tasks used by Miller and others
(Pollack, 1953) were relatively easy, requiring little effort to maintain the material in short term memory. They re-evaluated more difficult serial learning studies using word lists of over 12 items. An estimate of the number of items in short term memory was obtained by examining the recency effect normally found with such procedures. They found that the mean number of items recalled (stored in short term memory) was 2.2 words with a range of .5 to 3.5 words. These data together (Miller, Glanzer and Razal) suggest that the number of verbal elements recalled during later tests can vary but that the number is generally greater than two and that there is a limit. The actual number of elements used by the subject appears to be dependent upon a complex relationship between task, stimulus and test characteristics.

The Role of Number of Stimulus Elements

This dissertation will explore the issue of the number of discrete elements in a discriminative stimulus used or remembered. The orientation and procedure, however, will reflect an operant, not a cognitive approach, and visual as opposed to auditory stimuli will be used. The major question concerns the development of selective attention during a conditional discrimination problem where there are multiple redundant visual cues. Of particular interest is the development of stimulus control with preschool children using a complex visual discriminatory stimulus. The cognitive verbal memory studies cited above would certainly suggest that as the number of relevant stimulus elements increases, the
discrimination behavior would be increasingly correlated with
only a subset of the potential controlling elements. A
series of discrimination studies by Lovaas and his colleagues
have provided some data relevant to this question. The study
by Lovaas, Schreibman, Koegel, and Rehm (1971) is illustra-
tive.

In this study, autistic, retarded, and normal children
were reinforced for bar pressing (FR-4) in the presence of
a multi-cue stimulus. The multi-element stimulus was com-
posed of simultaneously presented auditory, visual, and
tactile cues. After reaching a criterion level of 90%
correct responding to the S+ stimulus, each subject was inter-
mittently presented with only one of the elements comprising
the S+ and responding to each was recorded. This stimulus
control assessment procedure is, in kind, similar to that
used by Reynolds (1961) in assessing a pigeon's attention
to elements of an S+. Lovaas et al. state, "One can argue
that the child attends to (is controlled by) certain stimuli
when independent variation of these stimuli is associated
with concurrent change in the child's behavior" (p. 213).
The percent of correct bar presses (actual responses/oppor-
tunities to correctly respond) was calculated for each subject
and individual and group comparisons were made. The results
indicated that normal children learned the discrimination
more rapidly and that their responses were controlled by
all three relevant cues. Autistic and retarded children,
however, learned the discrimination more slowly and their
responses during single element trials suggested that their discrimination performance was controlled by fewer of the S+ elements. The autistic children reliably responded to only one element whereas the retarded subjects evidenced greater individual variability with subjects responding to one or more of the relevant cues. They called the autistic child's behavior "stimulus over-selectivity" and suggested that over-selectivity may explain behavior often observed with autistic children (e.g., echolalia, inappropriate affect, etc.).

In a later study by Koegel and Wilhelm (1973), similar results were obtained using a different discrimination training procedure and stimulus control test but similar groups of subjects. During this study subjects were taught to choose one of two stimulus cards (S+) presented in simultaneous discrimination format. Each card had two visual elements that comprised the S+ or S-. After each subject reached criterion performance, test trials were given in order to assess control of the choice behavior by individual elements of the stimuli. During these test trials one S+ element and one S- element were simultaneously presented as during the original discrimination training. Each S+ element was presented with each S- element and all possible S+S- element pairs were presented to each subject. The degree of stimulus control evidenced by each S+ element was expressed as the percentage of occasions each subject chose the S+ element regardless of which S- element it was paired with. No reinforcement was given during stimulus control test trials.
Individual and group data reflect results similar to Lovaas et al. (1971). Normal children acquired the discrimination rapidly and their test performances suggested control by both S+ elements. The autistic children learned the discrimination slowly and test data revealed control by only one of the two elements. Control by S- elements was not assessed.

The results of Lovaas et al. and Koegel and Wilhelm suggest that, at least for autistic children, the number of elements that comprise an S+ discriminative stimulus is an important factor in determining the number of elements that come to control a subject's response during discrimination training; that is, the breadth of selective attention. The performance of the normal subjects in both studies was controlled by all S+ elements. Consequently, if normal children are to fail to attend to all elements of a discriminative stimulus, the number required must certainly be greater than three. Although there are currently no data in the operant discrimination literature that would substantiate this hypothesis, studies using the incidental learning paradigm do provide tentative support. A recent study by Nitsch, McCarrell, Franks, and Brandsford (in Brandsford, Nitsch, and Franks, 1977) is illustrative.

These investigators requested the subjects (college students) to view a color picture taken from a magazine. The picture was of a living room. Four groups were formed: two of these groups were told to search for "hidden X's" in the picture using various scanning behavior and to report
how many were found; one group was told they were to consider the various possible acts that might be performed on, with, or to the various objects in the picture; and the last group was simply told to remember as many of the objects as they could.

All subjects were given one, one minute exposure to the picture following which all subjects were asked to verbally recall as many objects in the picture as they could. The results clearly demonstrate that normal human subjects do attend to more than three elements of a visual display although this number is affected by instruction. Instructions make certain acquisition strategies or behavior more probable than others. These results therefore reflect differences in stimulus control that arise as a result of different and highly individual learning strategies. The incidental groups (those searching for hidden X's) could only recall three to eight items. The participants in the other two groups were able to recall 25 to 32 items.

The results of Nitsch et al. (as with many of the cognitive verbal short term memory studies) are suggestive though difficult to interpret and integrate within an operant framework. They do suggest, however, that when confronted with a multi-element visual stimulus (having more than three potential elements) normal human adult subjects will attend to more than three but less than the total number of potential elements. Would subjects, given a standard operant discrimination training and stimulus control test procedures, respond in a similar manner?
The major question of this dissertation will be: What is the effect of the number of stimulus elements composing a discriminative stimulus upon the development of selective stimulus control (selective attention) when using a standard conditional discrimination paradigm? Specifically, are proportionally fewer elements attended to as the number of elements increases? As outlined above, although there is no direct support in the literature, the collective results of cognitive short term memory research, the incidental learning literature, and the operant animal and human attention studies would suggest that if subjects are presented with complex discriminative stimuli, their responses will be controlled by only a subset of the potential elements. Further, the number of elements that are functionally related to the subject's response will probably be inversely correlated with the total number of elements comprising the discriminative stimulus. That is, as the number of elements is increased over successive discrimination problems, subjects' responses will be controlled by proportionally fewer of the total possible controlling elements.

The Role of Subject Age

The second question addressed by this dissertation concerns the performance of preschool and adult subjects. Specifically, will preschool children differ substantially from adults regarding the number of elements that functionally control discrimination performance? A number of studies investigating children's learning strategies in short term
memory suggest that a difference may be found between these two groups.

Historically, cognitive research assumed that a subject's short term remembering reflected an underlying process which matured as the subject aged. This maturational process was thought to result in the older child or adult's greater memory capacity. The amount of information that could be remembered increased as the subject matured. Many of the items in standard intellectual assessment devices reflect this assumption (e.g., digit span, visual memory tasks, etc.). Recently, however, a number of investigators have questioned this assumption. The increased "capacity" of a subject's short term memory with age could also be explained by a concurrent increase in the subject's use of effective memory "strategies" (Hagen, Jongeward, and Kail, 1975). Further, increases in these effective strategies are thought to be the result of the subject's interaction with his environment (Flavell and Wellman, 1977).

For example, Flavell, Beach, and Chinsky (1966) argue that one behavior that a child learns to use during a short term memory task is mediational verbal activity. In this study the investigators used five, seven, and ten year old subjects. The subject's task was to remember which three of seven pictures were pointed to during a brief exposure period. A 15 second delay was imposed between presentation and recall. The younger subjects recalled fewer of the pictures than the older subjects. In addition, only 2 of 20 five year
olds engaged in verbal behavior during the delay whereas 17 of the 20 ten year old subjects did so. The implication is that older children had learned to engage in some meaningful verbal activity that bridges the delay and increases performance on the recall task. Younger subjects had not as yet learned the skill.

A later study by Keeney, Cannizzo, and Flavell (1967) clearly established the relationship between verbal rehearsal behavior and performance on a memory task. Using the same memory task outlined above, the investigators "instructed" the six or seven year old subjects who did not engage in verbal behavior between presentation and recall. These children were told to whisper the object's name during the delay. Following instructions the children's performance increased to a level equal to those age mates who spontaneously rehearsed. Later these children were asked to perform the memory task again. No instructions were given during these trials. The children did not whisper the names during the delay and, predictably, their performance decreased. A number of review articles (Kail and Siegel, 1977; Flavell and Wellman, 1977) have shown that young children do not use effective memory behavior (e.g., rehearsal, association, etc.) as do older children or adults.

What cognitive psychologists call encoding or retrieval strategies are classes of behavior learned because of their consequences. They increase the probability that the subject will respond successfully after delays between stimulus
presentation and recall. Adults, because of their long learning histories, have had the opportunity to acquire a rather extensive repertoire of such behavior and are presumably more facile in using it. This assumption is certainly reflected by the memory literature. Adults are generally more successful on memory tasks than young children.

Therefore, it is not unreasonable to speculate that subjects would engage in such learned behavior when confronted with a discrimination problem having multiple discrete elements. Despite differences in the mode of stimulus presentation, training, and stimulus control or recall tests, a multi-element conditional discrimination problem is similar to general short term memory problems in that: a) there are a number (greater than two) of relevant stimulus elements that could become correlated with behavior during testing, and b) both experimental procedures impose a specified delay period prior to assessing stimulus control (remembering). These similarities, particularly the latter, would suggest that some of the acquisition behavior noted with subjects in short term memory studies would be functional for those subjects given a multi-element discrimination problem. The behavior would include many of those described as memory encoding or retrieval strategies by cognitive researchers (e.g., association, verbal rehearsal, etc.). If the short term memory literature indicates that adults better utilize many of these behavior and, as a consequence remember more elements during recall, they may also do so when confronted
with multi-element discriminative stimuli. In this dissertation experiment, the adult subjects when compared to preschool subjects may demonstrate control by more of the possible stimulus elements.

Of particular interest will be how the two age groups respond to repeated stimulus control assessments during extended discrimination training (overtraining). Overtraining has been shown to have an important influence upon the development of attention to (control by) relevant dimensions of a discriminative stimulus (MacKintosh, 1974). This influence is often observed with what is called the overtraining reversal effect first documented with non-human subjects. An early study by Reid (1953) is illustrative.

In this study rats were trained to criterion accuracy on a simultaneous black-white discrimination problem using a Y maze. Following the initial discrimination training three groups of subjects were formed and given either 0, 50, or 150 further training trials (overtraining). They were then given a reversal problem where the contingencies associated with the black and white stimuli were reversed. The results were clear. The number of trials to criterion accuracy on the reversal learning problem was inversely related to the number of pre-reversal overtraining trials. Paul (1966) and Sperling (1970) have reported similar data. It has been argued that overtraining increases the subject's attention to the relevant stimulus dimensions, making the interdimensional reversal problem easier.
Similar results have been found with children. Marsh (1964), for example, presented three and four year old children with a compound discrimination problem (size and color). Only one dimension was relevant. After the subjects completed criterion training, they were given an additional 10 overtraining trials followed by an interdimensional reversal problem. As in the studies cited above, overtraining facilitated acquisition of the reversal problem, suggesting that the subjects' attention or control by the relevant stimulus dimension was increased by overtraining. These effects have been replicated in other studies using children (e.g., Tighe and Tighe, 1965).

The above studies show that overtraining appears to have a significant effect upon the development of stimulus control by relevant dimensions in simple compound discrimination problems. But what of more complex learning problems having stimuli with more than one relevant dimension (e.g., serial learning tasks or multi-element discrimination problems)? A study reported by Masur, McIntyre, and Flavell (1973) suggests that the effect of overtraining may increase control by relevant dimensions or elements but that the effect is dependent upon the subject's age. The authors found that seven year old subjects do not appear to profit significantly from repeated learning trials and recall tests in a serial learning task (word list). The children did not come under stimulus control by more of the elements of the word list (recall measure) despite repeated exposure
and recall testing. The adult subjects used in this study did demonstrate improvement with continued exposure, however. The adults were able to recall more elements as the training-recall tests progressed. As with the reversal learning studies, overtraining resulted in control by increasingly more of the relevant stimulus elements.

Will overtraining affect control by elements of a complex discriminative stimulus in a similar manner? This dissertation will also measure the effect of repeated training-stimulus control assessment cycles (overtraining) on selective stimulus control in both children and adult subjects.

The Role of Stimulus Naming

The third question that is addressed by this dissertation concerns the effect of stimulus naming upon the development of stimulus control by elements of a complex conditioned stimulus. Specifically, are elements more likely to establish control of responding if they are individually labeled? It will be assumed that a stimulus element is labeled by a subject if he/she reliably uses a verbal name for the element. Recently, a number of operant studies using non-human subjects have demonstrated that non-linguistic labeling during discrimination training has substantial effects upon conditional discrimination performance. These studies used single element discriminative stimuli. Will response mediation predict which elements of a complex stimulus will come to be correlated with responding?
An early study by Eckerman (1970) was the first to experimentally establish an effective, overt and measurable mediation behavior in non-human subjects and to demonstrate its efficiency during discrimination learning. Prior studies (e.g., Blough, 1959) have observed what appeared to be coding or mediational behavior (e.g., stereotypic response patterns during delay periods) in non-human subjects but because of procedural or apparatus difficulties were unable to accurately measure and study the behavior. Eckerman, using pigeons, established the coding response by requiring each subject to make a specific "observing response" to the sample key. Stimulus coding was established by requiring the observing response to be made to specific areas of the sample key dependent upon the sample stimulus. For some subjects topographical separation of the observing responses' areas was large (6 inches) providing the subject with a "distinct" or differential code for each sample. For a second group topographically similar areas (0 inch separation) provided essentially a non-differential coding response. A third group, with a three inch separation between coding response areas provided an intermediate level. Eckerman employed a hue line conditional discrimination procedure.

A number of response measures (including acquisition and generalization data) were obtained and several of these provided strong support for the efficacy of response mediation behavior in conditional discrimination procedures and for their use by non-human subjects. The data clearly
indicate, for example, that the group using a differential response code acquired the conditional discrimination more quickly than either of the remaining groups. Stronger evidence, however, was obtained during experiment four. For this procedure Eckerman used only those subjects who exhibited a high level of accuracy during prior procedures (experiments 1-3). During this test the subjects were presented with a white light rather than a color sample on the display key. The previously learned observing responses were still required, however, and provided the only S+ for responding to the choice stimuli. All subjects continued to demonstrate above chance accuracy on choice performance suggesting that the observing response did establish stimulus control during earlier discrimination training.

A later study by Cohen, Looney, Brady, and Aucella (1976) provided similar evidence. Cohen et al., however, required different schedule performances rather than spatial observing responses to samples in either an identity or non-identity (conditional) match to sample task. Subjects (pigeons) were presented with samples that required the subject to key peck according to specified schedule requirements. For some subjects the schedule was the same regardless of the sample (e.g., FR 1-FR 1, FR 16-FR 16, DRL 3 sec-DRL 3 sec). For the remainder of the subjects, a differential sample schedule was required. When one sample was presented, the subjects were required to respond to an FR16 schedule requirement. The alternate sample required a
DRL 3 sec. The results were clear: accurate matching performance was most rapidly acquired when a differential "coding" observing response to each sample stimulus was required. Non-differential observing responses resulted in substantially slower acquisition which appeared to be dependent upon the difficulty of the discriminations between samples and between comparisons.

The studies cited above provide strong support for the efficiency of coding behavior in establishing stimulus control during conditional discrimination with non-human subjects. Similar results were obtained by a number of early studies examining children's discrimination performance.

Norcross and Spiker (1957), for example, gave preschool children pretraining exposure to either differential or non-differential cue words that were to be associated with stimuli (children's faces) that were to be used later in a discrimination task. The differential words were distinctive names (e.g., Jean, Peg, Jack, Pete) and the non-differential words were category labels (same, different). Following pretraining, subjects were then provided with a simple two choice simultaneous discrimination problem using either the boy pair or girl pair faces as discriminative stimuli. As would be predicted, those children having previous exposure with differential verbal labels acquired the discrimination more rapidly than those given pre-exposure to the non-differential labels or no labels at all. A later study by Norcross (1958) using phonetically similar
(non-differential) or dissimilar (differential) labels (e.g., Zim, Zam versus Wug, Kos) for discriminative stimuli (faces) provided similar results. Children having been pre-exposed to differential word cues learned the visual discrimination more quickly than those given non-differential cues.

These studies suggest that response mediated behavior, such as stimulus labeling or response coding, is associated with more rapid establishment of stimulus control in both simultaneous and conditional discrimination formats using single element stimuli. In a multi-element conditional discrimination procedure, could a subject's ability to provide a differential label for each element enhance the number of elements or determine which elements control performance? It would appear to be reasonable to assume that if previous history (Johnson and Cumming, 1968) and current contingencies (Ray, 1969; Huguenin and Touchette, 1980) affect selective stimulus control by individual elements, then so too may labeling or coding behavior.

In answering the above questions, this dissertation will employ a conditional discrimination (symbolic match-to-sample) training procedure. The procedure is similar to that used by Ray (1967) and by Huguenin and Touchette (1980). The current procedure uses more complex stimuli and the choice response will be to color rather than response position. Also, discrimination training and the selective stimulus control assessment procedures will be modified to more effectively
establish the discrimination with the preschool children and to assess stimulus control.

Young children are generally difficult to maintain on-task for long periods. In addition, they often exhibit strong position bias when confronted with a problem involving two or more spatially separate responses. Consequently a stimulus fading (errorless) teaching program similar to that used by Hively (1962) will be employed. The procedure utilizes a child's position bias by initially presenting the discriminative stimuli immediately above the respective correct response choice, then systematically fading each to a position central to the two choices. In general, rapid, errorless discrimination performance is established.
II. EXPERIMENT I

Purpose

The purpose of the first experiment was to extend the results of the preliminary investigation (Appendix B) by systematically examining the effect of the number of stimulus elements contained in a discriminative stimulus on the acquisition of stimulus control by the individual elements. Preliminary data suggested that the proportion of elements (in a multi-element problem) that control a subject's choice behavior in a conditional discrimination problem are inversely related to the total number of elements. That is, subjects will attend to proportionally fewer elements when the stimulus contains a greater number of discriminable elements.

In addition, the performance of adult (college age) subjects was compared to that of preschool children. Adults, in contrast to young children, are assumed to have extensive histories in solving multi-element problems. Would adults, therefore, show differences in the acquisition of stimulus control to the single elements as the memory literature suggests?

The effect of overtraining on selective stimulus control was also assessed with both groups. Will the number of elements that demonstrate stimulus control increase as a function of increased training? Perhaps adults and children
may initially establish control by a similar number of elements, but adults may demonstrate control by more of the elements with continued training and stimulus control assessments (Masur, McIntyre, and Flavell, 1973).

**Subjects**

The subjects that were used in this study were eight children aged 3.5 to 5.0 years and twelve nursing school students aged 18.0 to 19.0 years. The preschool children were chosen from the same center used in the preliminary study. Informal observations and teacher reports suggest age appropriate motor, perceptual, intellectual, and social skills. None of the children was described as having behavioral or emotional problems. The socioeconomic status of the children's families was middle to upper middle class.

The adult subjects were all first year nursing students enrolled in a local diploma nursing program.

**Apparatus**

All discriminative stimuli used during training and probe trials were presented using a table top format. A schematic representation of the experimental environment is contained in Appendix A. Stimulus cards were presented to each subject by placing them upon a wooden card stand which was positioned six inches from the subject's edge of the table. The stand displayed each card approximately 30° from vertical and perpendicular to the subject's midline. The
response panel was positioned directly in front of the display stand. Affixed to this panel were two circles, one blue and the other red. The circles were four inches in diameter and eight inches apart (center to center). Each child could comfortably reach both the stimulus cards and the response panel.

**Stimulus Materials**

The stimulus elements used in this study were taken from the text *Symbol Sourcebook* (Dreyfus, 1972). Selected black line drawings were photo-reproduced onto a 7x11 inch white stimulus field. The two discriminative stimulus cards contained either 2, 4, 6, or 8 stimulus elements each. Each pair was termed a problem set. Stimulus elements were positioned such that the resulting array of elements was centered within the field with each element equidistant from the surrounding elements. Each stimulus card was encased in a clear plastic sheet protector. All stimulus elements used in this study are reproduced in Appendix A. Sample stimulus cards from each problem set (2, 4, 6, and 8 elements) are included.

**General Procedure**

For preschool subjects, all test sessions were conducted in a small well lighted room at the children's day care center. Prior to the beginning of discrimination training, the experimenter met individually with each subject. This was to establish rapport with each child and to informally
assess motor, perceptual, intellectual, and social skills. Adult subjects were tested in a well lighted classroom at the nursing school. Preliminary informal assessments were not performed.

A within subjects design was used in this study. All subjects were presented with the four problem sets, one at a time, in a predetermined sequence. The sequence could not be random. During the preliminary investigation, many of the preschool subjects were either unable to respond appropriately to the selective stimulus control assessment procedure, or were unable to acquire the discrimination when given the six and eight element problems without prior exposure to the two or four element problem. Consequently, the children in this experiment were given one of two problem sequences. There were four subjects in each group. For one group, the order of problem set presentation was the 2, then 4, then 6, and finally 8 element problem. For the second group the order of presentation was 2, then 6, then 4, then 8. The inversion of the middle two conditions provided a comparison to measure possible order effects. In order to be able to unambiguously compare the two age groups, the adults in group C_0 were given the same problem set ordering. Two were given the former order while the remaining two were given the latter. The sequence of problem sets for all subjects is presented in Appendix A.

All of the preschool subjects were used during Phases I-IV. Four of these were randomly chosen for inclusion in Phase V (overtraining). Four of the twelve adult subjects
were used during all phases (I-V). This was group $C_0$. The remaining eight adult subjects were randomly assigned to one of two control groups used only during Phase V. One control group ($C_1$) was given the same three training trials-stimulus control assessment cycle during overtraining on the 8 element problem set as group $C_0$. They had no previous exposure to the other problem sets. A second group ($C_2$) was given the same number of training trials on problem set 8, but was given only one stimulus control test at the end of this period. The two adult control groups were used to assess: 1) the effect of repeated discrimination training and stimulus control testing on the initial number of elements meeting control criteria in later problems, and 2) the relative effects of repeated stimulus control assessments and stimulus exposure during overtraining on the adult discrimination performance. Similar control groups for the preschool subjects were not used for the reasons outlined above.

**Phase I: Element Labeling**

Each element's label was documented by presenting to all subjects the potential stimulus elements centered on individual 3x5 inch index cards and requesting that the subject name or label each. Specific verbal instructions are included in Appendix A. Three sessions were used during which all elements were presented individually and in random order. The response panel was removed during these sessions and each card was placed directly in front of each subject. The
subjects could pick up or handle the card but the proper orientation of the card was maintained. If subjects failed to respond within 10 seconds or they said they did not know what the picture was, they were asked to guess. The label given each element during the sessions was recorded.

An element was scored as having a functional label if that element was given the same label during successive test trials and no other element in the stimulus pool was consistently given the same label. An element was thought to have a non-functional label if the element was given a different label on one or more trials or if more than one element in the stimulus pool was given the same label. A sample of labels given by the preschool subjects for each category is included in Appendix A.

For each subject, elements that met labeling criteria for that subject were then randomly assigned to one of four problem sets. Each set contained two multi-element stimulus cards. A set was composed of either two, four, six, or eight elements per discriminative stimulus card. A sample of each problem set is included in Appendix A. Placement of an element within a particular stimulus array was random. The only restriction was that elements within a common class (e.g., car, truck, motorcycle = transportation or vehicle) were randomly divided between the two stimulus cards. The elements used in each problem set were individually chosen for each subject. No stimulus configuration, including the specific elements used within a problem set, was duplicated for any two subjects.
Phase I was given to each subject only once, prior to any discrimination training.

**Phase II: Establishment of the Conditional Discrimination**

Both the children and the adult subjects were initially trained using the same teaching procedure outlined in the preliminary investigation. Each subject was instructed that he/she was to learn which color (red or blue) was associated with each stimulus ($S_1$ and $S_2$). Specific instructions are found in Appendix A.

The children received tokens (pennies) that were exchanged for a small 10 to 25 cent toy at the end of the session. Each child chose the toy that he/she would work for prior to beginning each session. The adult subjects received course credit for their participation in the study.

As in the preliminary investigation, for the first few training trials of each problem set, the stimulus cards were presented to the subject directly above the correct color choice for each discriminative stimulus. Each stimulus ($S_1$ and $S_2$) was presented individually and in random order. The cards were faded over successive trials to a position that was equidistant between the two response choices. During these fading trials, an incorrect response initiated a correction procedure: the same stimulus was presented on the next trial with its display position moved closer to the correct response panel. A correct response would re-initiate the movement of the stimulus toward the center display position. Criteria for completion of this phase of the training
procedure were met when both of the stimulus cards were pre­sented centered between the two response choices and the subject responded correctly to five random presentations of each. Each stimulus presentation was separated by a 5 to 7 second intertrial interval during which data were re­corded and the stimulus cards changed. A schematic presenta­tion of the fading procedure can be found in Appendix A.

Phase III: Maintenance of Discrimination

Following the completion of Phase II each subject was given an additional 50 training trials prior to selective stimulus control assessment. Each stimulus card (S₁ and S₂) was presented 25 times in random order. The only restriction on the order of presentation was that S₁ and S₂ could not be presented more than three times in a row. As in Phase II each trial was separated by a 5 to 7 second intertrial inter­val during which the subject's response was recorded, the token and verbal praise administered (adults received the verbal praise alone), and the next stimulus card chosen. The correction procedure was still in effect. A sample data sheet and stimulus presentation schedule is in Appendix A. During test sessions the data sheet was positioned behind the display stand in order to conceal the data. Phases II and III were generally completed within one training session.

Phase IV: Assessing Selective Stimulus Control

Selective stimulus control was assessed during the next training session. The intersession interval was generally
23.5 hours. Prior to beginning the stimulus control assess-
ment, each subject was given a 10 trial baseline exposure
to the stimulus cards ($S_1$ and $S_2$). This baseline was to
check if performance was disrupted by the intersession in-
terval. If subjects exhibited 90% correct responding during
baseline, stimulus control testing was begun. If not,
baseline was continued until this criterion was established.

Once the baseline criterion was reached, each subject
was given a sorting task. This task was used to measure
each stimulus element's control of correct choice behavior.
The stimulus display stand and response panel were moved
approximately 12 inches closer to the experimenter so as
to allow subjects space in which to sort the cards. (Refer
to the schematic of the experimental environment in Appendix
A.)

For this task each of the elements that comprised the
multi-element training cards were individually affixed to a
white 3x5 inch index card. Each card was presented indivi-
dually to each subject and in a random order. The card
was displayed so that it was equidistant between both re-
sponse circles. Each subject was asked to place all the
elements that were associated with the blue or red circles
beneath their respective circles. Specific instructions
are presented in Appendix A. The subjects were not required
to place them in piles or to order them in any way. They
simply had to place each card in the area immediately be-
neath each response circle. A total of ten sorting trials
were given for each discrimination problem. The placement of each element was recorded after each trial. Each element was number coded and the color of the circle beneath which it was placed was recorded. (Refer to the data sheet sample in Appendix A.) A stimulus element was assumed to have established a functional stimulus control relationship if the element was correctly sorted in eight of the ten trials. All subjects were repeatedly cycled through Phases II, III, and IV for each problem set.

Phase V: Overtraining

Following stimulus control assessment of the last problem, four preschool subjects and the adult subjects were given two additional training sessions. In addition, the two additional adult control groups were added. Each session was composed of 50 training trials (Phase III) followed by a selective stimulus control assessment (Phase IV). If a subject met stimulus control criteria for all elements (n=16) prior to completing all three sessions, training was discontinued.

Results

The results indicate that both the adults and preschool children established control by proportionally fewer elements as the number of elements in successive multi-element discriminative stimuli increased. Figure 1 summarizes and compares the group data for both adult and preschool subjects. The mean number of elements meeting the stimulus control
Figure 1. The mean number of elements (S₁ and S₂ combined) meeting stimulus control criteria is plotted as a function of the increased number of S+ elements with successive discrimination problems for both age groups. The preschool age group is represented by the closed circles and the adult age group (C₀) by open circles. The range of subjects' performance is represented by the horizontal lines bounding each data point.
NUMBER OF STIMULUS ELEMENTS

PROBLEM SET
criteria and the range for each problem set are plotted. The abscissa represents the total number of elements with $S_1$ and $S_2$ combined. Both groups (adult and preschool) show stimulus control by a similar number of elements in each problem set. Note, however, that the mean number of elements for adult subjects is one element greater for problem sets 2, 4, and 6 and that the four subjects demonstrate control by all elements in sets 2 and 4. Only six preschool subjects in problem set 2 and two subjects in problem set 4 show control by all stimulus elements. The two groups show similar variability in the number of elements meeting control criteria in set 6, with preschool children again having somewhat greater variability in set 8.

Figures 2 and 3 present the data for each subject in the preschool and adult groups respectively. The individual data functions for each subject are similar to the group functions in Figure 1. Six of the eight preschool subjects and three of the four adults subjects all show control by proportionally fewer of the stimulus elements as the number of elements was increased across problem sets. Only subjects $S_6$ and $S_3$ in the preschool group and subject $S_9$ in the adult group showed a continued increase in the number of elements meeting stimulus control criteria. Even these subjects, however, did not show control by all elements. However, note preschool subject $S_6$. This subject met criteria with 15 of 16 elements in problem set 8. No other subject, adult or preschool, demonstrated control by as many elements prior to overtraining.
Figure 2. The total number of elements ($S_1$ and $S_2$ combined) meeting stimulus control criteria is plotted as a function of the increased number of $S+$ elements with successive discrimination problems for each preschool subject.
NUMBER OF STIMULUS ELEMENTS

PROBLEM SET

S5

S1

S6

S2

S7

S3

S8

S4
Figure 3. The total number of elements ($S_1$ and $S_2$ combined) meeting stimulus control criteria is plotted as a function of the increased number of $S^+$ elements with successive discrimination problems for each subject (group $C_0$).
NUMBER OF STIMULUS
ELEMENTS

PROBLEM SET

S9

S10

S11

S12
Figure 4 represents the same data presented in Figures 2 and 3 but plotted individually for each discriminative stimulus ($S_1$ and $S_2$). The number of elements within each problem set meeting control criteria was approximately the same for each discriminative stimulus within a problem. Most of the stimulus control tests resulted in control by the same number of elements in $S_1$ and $S_2$. When a difference was found, it was generally one element. The largest difference in element stimulus control between $S_1$ and $S_2$ in any problem was two elements. It would appear that discrimination performance was controlled by both discriminative stimuli with all subjects attending to approximately equivalent numbers of elements from each stimulus.

Figure 5 presents the mean number of stimulus elements meeting stimulus control criteria for the two problem set presentation orders (2-4-6-8 or 2-6-4-8). Preliminary data indicated that many of the preschool subjects required a gradual increase in stimulus complexity across successive problem sets in order to maintain adequate discrimination and/or stimulus control assessment behaviors. The inversion of problem sets 4 and 6 for half of the subjects was to determine if this ordering affected the functions described in Figure 5. The data for both adult and preschool subjects are combined in this figure. The data show that neither problem set sequence differentially affected the establishment of stimulus control by elements in the various problems. The functions are similar. This would suggest that, other than for initial
Figure 4. The number of elements meeting stimulus control criteria is plotted as a function of the increased number of S+ elements with successive discrimination problems for each S+ stimulus (S₁ or S₂). S₁ is represented by the closed circle and S₂ by the open circle. Individual data is presented for both preschool and adult subjects. A difference between the two functions would suggest bias or preference for one of the S+ stimuli. No strong bias was found.
Figure 5. The mean number of elements ($S_1$ and $S_2$ combined) meeting stimulus control criteria is plotted as a function of the increased number of S+ elements with successive discrimination problems for two orders of problem set exposure. The open circles represent data from subjects receiving the 2, 4, 6, then 8 element problem set and the closed circle represents data from subjects receiving the 2, 6, 4, then 8 element problem set. Each function represents the performance of both preschool and adult subjects. The open triangle represents the initial stimulus control data from adult group $C_1$. 
discrimination training, for the preschool subjects, the order of presentation of the successive problems may not have had a substantial effect upon selective stimulus control. This result is further strengthened by examining the initial number of elements meeting the stimulus control criteria for group $C_1$ during overtraining (Figure 6 below). The adults in this group were given only one problem set (problem set 8), and despite having not been exposed to sets 2, 4, and 6, showed control by the same number of elements as those adults that did (group $C_0$).

Figure 6 presents the group data resulting from overtraining on problem set 8 (total of 16 possible elements on $S_1$ and $S_2$). The mean and range of the number of elements meeting stimulus control criteria on successive blocks of 50 training trials are plotted for all adult (including groups $C_1$ and $C_2$) and preschool subjects. The graph on the left of Figure 6 compares adult ($C_0$) and preschool performance. The two groups differed substantially when given additional discrimination training trials. The preschool children did not show an increase in the number of elements meeting control criteria when given additional training. Both the mean number and range of elements meeting control criteria did not change over three successive training sessions. The adults, however, showed an increase in the number of elements meeting criteria. By the end of the third session all four adult subjects were correctly sorting all 16 elements. Figure 7 presents the individual data. Group $C_1$
Figure 6. The left graph displays the mean number of elements \((S_1 \text{ and } S_2 \text{ combined})\) meeting stimulus control of criteria plotted as a function of the number of overtraining trials for both age groups. The closed circles represent the preschool age group and the open circles the adult age group \((C_0)\). The data from two additional adult age control groups \((C_1 \text{ and } C_2)\) are contrasted with the original adult group on the right. As in the left graph the number of elements meeting stimulus control criteria is plotted as a function of the number of overtraining trials. The open triangles represents adult group \(C_1\) and the closed triangles adult group \(C_2\). The range of subject performance in both groups is represented by the horizontal line bounding each data point.
Figure 7. The total number of elements ($S_1$ and $S_2$ combined) meeting stimulus control criteria is plotted as a function of overtraining trials for individual subjects. Only four of eight preschool subjects were given overtraining trials. Preschool subjects ($S_1$, $S_4$, $S_5$, $S_7$) are presented in the top row and adult group $C_0$ ($S_9$, $S_{10}$, $S_{11}$, $S_{12}$) are presented in the bottom row.
OVERTRAINING TRIALS
shows similar results, only one adult subject (P) in group C₀ required less than three training sessions to establish control by all elements.

The relative effects of exposure and repeated stimulus control assessment sessions are reflected in the comparison of adult group C₀ with groups C₁ and C₂. These data are contained in the right graph of Figure 7 and suggest that repeated stimulus control assessments (group C₁) appear to be a relevant factor in explaining the increased performance of adult group C₀ during overtraining. Despite an equal number of training trials, group C₂ did not exhibit control by all elements after 150 training trials. Only one of four subjects in C₂ correctly sorted all 16 elements. However, subjects in C₀ and C₁, having repeated stimulus control assessments, correctly sorted all elements. These data are summarized in Table I. Individual data are presented in Figure 8.

Exposure may have had some effect. When comparing the scores of C₁ on the first assessment (following 50 training trials) with C₂ (following 150 training trials), a mean difference of three elements between the groups is seen. C₁ demonstrated stimulus control by nine elements whereas C₂ showed control by 12 elements. Although only suggestive, the difference is further strengthened by comparison with scores obtained by adult group C₀ (X=10.0) after 50 training trials.
Table 1
Mean Number of Stimulus Elements Meeting Stimulus Control Criteria ($S_1$ and $S_2$) for Adult Subjects ($C_0$) and Adult Controls ($C_1$ and $C_2$) during Overtraining Trials

<table>
<thead>
<tr>
<th>Experimental Group</th>
<th>50</th>
<th>100</th>
<th>150</th>
</tr>
</thead>
<tbody>
<tr>
<td>$C_0$</td>
<td>10.00</td>
<td>14.00</td>
<td>16.00</td>
</tr>
<tr>
<td>$C_1$</td>
<td>9.25</td>
<td>15.00</td>
<td>16.00</td>
</tr>
<tr>
<td>$C_2$</td>
<td>-</td>
<td>-</td>
<td>12.25</td>
</tr>
</tbody>
</table>
Figure 8. The total number of elements ($S_1$ and $S_2$ combined) meeting stimulus control criteria is plotted as a function of overtraining trials for individual subjects in both adult control groups. $C_1$ (top row) received 150 overtraining trials in 3 interspersed stimulus control assessments. $C_2$ (bottom row) received 150 overtraining trials with only one stimulus control assessment following completion. Subjects 13 and 15 showed control by all elements after 100 overtraining trials and training was discontinued.
NUMBER OF STIMULUS ELEMENTS

OVERTRAINING TRIALS

S13

S14

S15

S16

S17

S18

S19

S20

50 100 150

50 100 150

50 100 150

50 100 150
III. EXPERIMENT II

Purpose

The purpose of the second procedure was to assess the effect of labeling on the development of selective stimulus control by preschool children. The previous experiment examined the effect of the total number of elements on the establishment of selective stimulus control. All of the elements used in that procedure were clearly labeled by each child (Phase I). Discrimination studies cited in the introduction argue that when discriminative stimuli are associated with distinctive labels, the discrimination problems were more rapidly acquired.

If labeling aids children in rapidly acquiring simple visual discrimination problems, perhaps, when confronted with complex visual problems, elements that are labeled are more likely to be attended to (establish stimulus control). Consequently, would subjects given problems containing elements that are easily labeled exhibit stimulus control by more of the potential elements than similar problems using elements that have no reliable label or name? Also, when labeled and non-labeled stimuli are combined, would only the labeled elements gain stimulus control (perhaps because of their distinctiveness)?

Subjects

The subjects were seven of the eight preschool children
used during the first procedure. Thus each subject had extensive experience with the discrimination learning procedure and stimulus control assessment.

**Apparatus**

The same general stimulus display, stimulus materials, table top format, and response panel were used for this procedure. Refer to Experiment I for specific details.

**General Procedure**

Following the completion of the overtraining trials in Experiment I, preschool subjects were given three additional conditional discrimination problems. Each problem contained two 6 element discriminative stimuli. As in Experiment I, the elements used in each problem set were individually chosen for each subject. No stimulus configuration, including the specific elements used within a problem set, was duplicated for any two subjects.

One problem set contained elements that met the labeling criteria outlined in Experiment I but had not been used by the specific subject during that procedure. This condition was called the labeled problem. A second problem set was developed which was composed of elements that failed to meet the general labeling criteria. These elements were not given consistent labels by each subject during Phase I of Experiment I. This condition was called the non-labeled problem. A third set was constructed by including elements of both types. One half (n=3) of the elements on each
discriminative stimulus were labeled elements, the remainder were non-labeled. The elements assigned to a particular stimulus card and position on the card were random.

A within subjects design was also used in this study. All subjects were given the three discrimination problems in one of two orders: 1) labeled problem-unlabeled problem-combination, or 2) unlabeled problem-labeled problem-combination. The labeled condition was a replication of the six element condition used in Experiment I. Training for each of the discrimination problems proceeded through the following three phases:

Phase I: Establishment of the Conditional Discrimination

The same errorless teaching procedure used in Experiment I was also used in Experiment II. In addition, no changes were made to the instructions or reinforcement contingencies.

Phase II: Discrimination Training

Following the completion of Phase I each subject was given an additional 50 training trials prior to assessing selective stimulus control. Each stimulus card \(S_1\) and \(S_2\) was presented an equal number of times and in random order. The only restriction on the order of presentation was that \(S_1\) or \(S_2\) could not be presented more than three consecutive times. Each trial was separated by a five to seven second inter-trial interval during which the response was recorded, reinforcement administered (token plus verbal praise), and the next stimulus card chosen.
Phase III: Assessing Selective Stimulus Control

Following the completion of Phase II for each problem, each subject was given a sorting task similar to that used in Experiment I. The sort was used to measure each element's control of correct choice behavior. As in the first study, each individual stimulus element was individually affixed to a white 3x5 inch index card. The cards were presented to each subject, one at a time and in random order. Subjects were instructed to place each card beneath the response panel to which the element was associated. A sort trial was completed when all elements were placed beneath one of the response panels. An analysis of the data from Experiment I indicated that there were no significant differences between the stimulus control functions when comparing data from the first five sorting trials to that based upon all 10 trials. These data are shown in Figures 9 and 10. Because of the reliability of the five trial sort, and the difficulty in maintaining the children's motivation to continue with the task after Experiment I, only five sort trials were used for this procedure.

Results

Figure 11 presents the data for each preschool subject comparing his/her performance with labeled elements (distinctive), unlabeled elements (non-distinctive), or a combination of both. Both group and individual subjects' data are displayed. The average group data as well as those of the
Figure 9. The total number of elements ($S_1$ and $S_2$ combined) meeting stimulus control criteria in Experiment I is plotted as a function of the increased number of elements with successive discrimination problems for two different stimulus control criteria. The closed squares represent a four of five correct sort criterion and the open circles an eight of ten correct sort. Individual data for preschool subjects are presented.
NUMBER OF STIMULUS ELEMENTS

PROBLEM SET

S1

S2

S3

S4

S5

S6

S7

S8
Figure 10. This figure presents the summary group data ($S_1$ and $S_2$ combined). Elements meeting stimulus control criteria in Experiment I are plotted as a function of the increased number of elements with successive discrimination problems for two different stimulus control criteria. The closed squares represent four of five correct sort criterion and the open circles an eight of ten correct sort. The range of subject performance is represented by the horizontal lines bounding each data point.
NUMBER OF STIMULUS ELEMENTS

PROBLEM SET

0  4  8  12  16
Figure 11. The total number of elements ($S_1$ and $S_2$ combined) meeting stimulus control criteria is displayed for three different sets of discriminative stimuli. NL represents the set of elements for which the children could not produce reliable labels. L represents the set of elements for which a reliable label was given and L & NL represents the set which was comprised of both labeled and non-labeled elements. Both individual and group (lower right) data are presented. The range of subject performance is represented by the horizontal lines bounding the group data points.
NUMBER OF STIMULUS ELEMENTS

PROBLEM SET

GROUP

S6

S7

S8

S1

S3

S4

S5
individual subjects show that more elements in the labeled condition met stimulus control criteria during testing than either the non-labeled or combination conditions. In the labeled condition an average of seven elements met stimulus control criteria whereas only five elements met criteria in either the non-labeled or combination conditions. Variability of data within each condition was not significantly different, though the greatest range of scores (7) was found in the combination.

The difference between stimulus conditions, though small, is systematic and replicable across subjects. Six of the seven subjects demonstrate control by more elements in the labeled as compared to the non-labeled condition. The differences ranged from one to three elements. Only one subject (7) showed no difference between labeled and non-labeled elements and no subjects demonstrated control by more elements from the non-labeled condition. Five of the seven subjects show control by more elements in the labeled condition than in the combination (labeled and non-labeled) condition. Only two subjects (3 and 4) showed no difference and no subjects demonstrated control by more elements in the combination condition. Thus of the 14 possible comparisons (labeled vs. non-labeled or combination) across subjects, 11 show greater control by the labeled condition and three show no difference. The data suggest that problems containing elements that are easily labeled exhibit stimulus control by more of the potential elements than problems using elements that have no reliable label or name.
Figure 12 presents the group and individual data obtained in the combination condition where labeled and non-labeled elements were presented together. The data represent the number of elements from each category that met the stimulus control criteria. The group data suggest that there is no significant difference between labeled and non-labeled elements in the number meeting stimulus control criteria. Only three of the seven subjects showed control by more of the labeled than non-labeled elements. It is interesting to note, however, that none of the remaining four subjects showed greater control by the non-labeled elements. They were controlled by an equal number of elements from both categories. The data indicate that when both labeled and non-labeled elements are combined, subjects will demonstrate stimulus control to both categories of elements. This suggests that although labeling of the elements aids in establishing control by individual elements, the effect is not strong and will not lead to the exclusion of non-labeled elements when combined.
Figure 12. The total number of stimulus elements ($S_1$ and $S_2$ combined) meeting stimulus control criteria is presented for both labeled and non-labeled elements when combined (L & NL condition). NL represents the non-labeled set of elements and L the labeled set. Both individual and group (lower right) data are presented. The range of subject performance for each stimulus category is represented by the horizontal lines bounding each data point.
NUMBER OF STIMULUS ELEMENTS

PROBLEM SET

GROUP

NL

L

0 2 4 6

S1

S3

S4

S5

S6

S7

S8
IV. DISCUSSION OF RESULTS

This dissertation has three substantial findings. The first is that both the children and adult subjects used in this study demonstrated control by proportionally fewer of the stimulus elements as the total number of elements in successive discrimination problems was increased. The second was that there were no substantial differences between the two age groups in the number of elements establishing control in each problem. Only during overtraining was a difference found. In overtraining, the adults eventually demonstrated control by all elements. The preschool children showed no increase. The third finding was that preschool subjects established stimulus control with more labeled elements than unlabeled elements.

Number of Elements

This experiment's first hypothesis was that subjects, when given successive multi-element discrimination problems (each with greater numbers of elements), would demonstrate control by proportionally fewer of the elements. This hypothesis was confirmed. The results are similar to many of the findings of cognitively oriented short term memory studies and confirm the expectations that normal human subjects, when given a multi-element discrimination problem, would establish control by more than three elements. These
data extend the selective control data collected on normal subjects by Lovaas et al (1971).

The data, however, are difficult to interpret. Why do subjects exhibit control by only a subset of the possible number of stimulus elements? One answer was offered by Norman and Bobrow (1975). They have suggested that selective stimulus control is a result of two cognitive functions: resource and data limited processes. The first refers to subject skills, stimulus characteristics and task demands that reflect the "effort" needed to complete the task. In general, the amount of effort required can be compensated for by allowing more exposure or training time. The second refers to factors which, despite all training efforts, remain constant (e.g., sensory neural processing). What is implied by this model is that when discrimination tasks are made more difficult by decreasing stimulus exposure, increasing stimulus complexity, or increasing response requirements, etc., the subject must effectively allocate greater resources (orientation towards stimulus elements, coding, etc.). Unless a greater amount of time is given during training, fewer of the stimulus elements will be recalled during stimulus control or memory tests.

This resource model, though inferring internal processes, suggests that increasing the number of learning strategies required by subjects during acquisition will produce a concurrent decrease in the number of stimulus elements meeting a control criterion assuming equal training
time. In Experiment I the increase in the number of elements with successive discrimination problems can be assumed to increase the probability of a number of behaviors including scanning behavior, stimulus coding and association or other mneumonic behavior. This increase in the number or complexity of behaviors during acquisition would require an increase in the amount of training time to establish control by all elements. In the present study the effect of increased training time on selective stimulus control is demonstrated by comparison of the first stimulus control assessment (following 50 trials) of adult groups $C_0$ and $C_1$ with the first assessment (following 150 trials) of group $C_2$. The greater number of exposure trials did result in more elements being correctly sorted during stimulus control trials. Perhaps if given more than 150 trials group $C_2$ might correctly sort all elements as group $C_0$ did for sets 2 and 4 after only 50 trials.

An alternative interpretation has been suggested by Carter and Werner (1978) in their discussion of the conditional discrimination performance of the pigeon. They argued that a pigeon's performance during a conditional discrimination problem suggests that the subjects acquire rules. The authors defined the rule concept as an "empirically demonstrable relationship between the presentation of a critical feature of the ground (the sign), and the selection of a particular discriminative stimulus" (p. 567). These rules specify which of the potential discriminative responses is correct. Assuming that the human subjects used in the current experiment
may also develop rules associated with stimulus features during acquisition, the observed decrease in the proportional number of elements controlling behavior as elements were increased may reflect the subject's difficulty in acquiring all of the rules associated with a particular problem's discriminative stimuli. A study by Maki and Leith (1973) demonstrated this effect using pigeons.

Their study was designed to examine what they called shared attention. The subjects were presented with a matching to sample task where the sample stimuli were either solid colors, white lines, or a combination of both. The comparison stimuli were either the solids or white lines. When the sample stimuli were colors or lines, the comparison stimuli were colors or lines respectively. When the sample was a compound, the comparisons were either color or lines but not both. The authors were interested in how control by the stimulus elements of a compound were affected when the responses to each have been reinforced. The data clearly demonstrated that when the elements were combined there was a correlated decrease in the subject's matching behavior. Both subjects made more errors when given the stimulus compound than when presented with the elements alone. The results were similar to those obtained earlier by Maki and Levin (1972).

Carter and Werner argue that if one assumes that the subjects are learning a series of if-then rules the interpretation of Maki and Leith's data is clear. Carter suggests that the element problems require only four S+ rules to
describe stimulus control behavior. For example, sample red-peck red; sample vertical line-peck vertical line, etc. When the elements are compounded, however, the rules necessary to describe the behavior increase. When the subject is given a red-vertical line compound sample, for example, two rules are appropriate, dependent upon the comparison. If the comparisons are hues then the rule is: if red element is present, peck red; if the comparisons are lines, then the rule is: if vertical line element is present, peck vertical line. Following this line of argument, the decrease in matching performance of Maki and Leith's subjects during compound trials was the result of an increased number of rules relative to trials having single elements.

Although the studies cited above used either simple one element or compound stimuli, it is reasonable to speculate that mult-element discrimination stimuli (greater than two elements) would be associated with similar rule building behavior. Carter and Werner speculated that each of the elements of the compound used by Maki and Leith would be associated with a specific rule. Accordingly it can be assumed that in the present experiment using multiple elements, rules associated with each element of a stimulus can be
developed by the subjects. Thus the number of elements shown to meet the stimulus control criteria reflect the number of rules developed by the subject to guide his/her behavior at that point in training.

In this study as the number of elements increased over successive problems, the number of S+ rules can also be assumed to increase. For example, a discriminative stimulus having two elements would have only two S+ rules; a discriminative stimulus having four elements would have four rules, and so forth. Despite the increase in elements and therefore S+ rules, all problems in this study had the same number of training trials during acquisition. Thus, fewer rules could be acquired, resulting in fewer elements meeting stimulus control criteria during the sorting task. Presumably, if a sufficient number of trials were administered, the subjects would have the opportunity to learn most if not all the S+ rules associated with the stimulus resulting in control by all elements. As noted above, adult control group C2, which received 150 training trials, did show control by more elements than groups C0 and C1 (each receiving 50 training trials) during the first stimulus control assessment.

Unfortunately, neither the data resource model proposed by Norman and Bobrow nor the rule model by Carter and Werner offer more than a restatement of the present data. The procedures used in this dissertation were not designed to specifically evaluate either model as a potential explanation for the obtained results. The rule model, however, has
been helpful in understanding and predicting the acquisition of identity and oddity match-to-sample behavior in non human subjects. It would appear reasonable that human subjects could develop similar rule behavior during the acquisition of a conditional discrimination problem, and that the model could potentially help to understand and predict the development of selective stimulus control in that paradigm. An appropriately designed experimental procedure will have to be developed, however. Future research may provide sufficient evidence to evaluate the usefulness of the rule model to explain this study's results.

Preschool and Adult Comparisons: Successive Problem Sets

This study's second hypothesis was that there would be a difference in performance between the preschool and adult subjects. This hypothesis was not confirmed. The adult and preschool subjects used in this study exhibited control by similar numbers of elements in each problem set. These data are not in agreement with studies of short term memory which have found that younger children have difficulty in recalling as many elements as older subjects when given a typical serial learning task (Flavell et al., 1966). It has been assumed that the younger subject has not acquired the learning strategies (behaviors) necessary to remember as many potential stimulus elements as have older children or adults (Keeney et al., 1967).

This study assumed that because many of an analogy between serial learning and conditional discrimination tasks
which predicts that adults would show control by more elements in most problem sets.

One study (Keeney et al., 1967) has shown, however, that when the young subjects are instructed or cued to use such behavior their performance does approximate that of older subjects. Perhaps, the procedure or apparatus used in this experiment cued the younger subjects to utilize behaviors that minimized potential group differences in selective stimulus control. For example, the typical serial learning task (word series) provides each subject with the opportunity to use one or more of many potential behaviors that would increase the probability of remembering many of the stimulus elements. The task format provides no cue or instructions as to which behavior may be most effective. The subject's learning history and behavioral repertoire would be primary determinants of what behaviors are to be used. In such conditions young children would have greater difficulty selecting and using appropriate learning behaviors.

The procedure used in this dissertation, however, may have cued the young subjects to use a specific learning behavior that increased their probability of success. The task format, for example, placed or organized all stimulus elements into one of two categories. These categories were defined by the discriminative response; either the red or blue circle. This procedure had an inherent, albeit simple organization of stimulus elements. This may have aided the recall of the young subjects during selective stimulus control testing.
The effect of subject or experimenter imposed organization of stimulus material has been well documented in the memory literature (Kintsch, 1977). In a serial learning task if the elements are organized or clustered into functional categories, subjects will recall more of the elements (Cofer, Bruce, and Reicher, 1966). Even if the material is not organized prior to stimulus presentation, subjects tend to recall (free recall) the elements in ways that suggest use of previously learned or "subjective" categorizations. This subjective categorization appears to increase the number of elements recalled (Tulving, 1962). Mandler and Pearlstone (1966), for example, demonstrated that both experimenter and subject imposed categorization enhanced recall of elements when subjects were given word lists to memorize.

The task imposed organization of the discrimination procedure used in this study may have functioned in a manner similar to the instructions given young subjects by Keeney et al (1967). The researchers told young subjects to rehearse the words that they learned, increasing the probability that the subjects would do so. The present experiment used a task which, because of format, can be assumed to increase the probability that stimulus elements would be grouped or categorized by the young subjects. The result in both studies was a decrease in performance differences between young children and adults. In Keeney's study the young children increased recall performance. Unfortunately the present study does not provide a baseline with which to assess the children's performance without the organizational cues.
Preschool and Adult Comparison: Overtraining

The data collected during overtraining trials show major differences between the performance of preschool and adult subjects. These differences are in contrast to the results discussed above. The adult subjects alone show an increase in the number of elements meeting criteria during successive stimulus control assessments. The preschool subjects show no such increase. The results are similar to those reported by Masur et al. (1973) who showed that only the adult subjects recalled more elements of a serial learning task with repeated exposure and recall testing. Like the present study, the children (seven year olds) did not show a similar increase. The authors attributed the adults' increased performance with overtraining to the subjects' effective use of feedback during the recall testing-training sequence. The children, presumably, had not acquired the skills necessary to use the repeated recall test-training sequences as a form of feedback.

The importance of the stimulus control assessments following repeated training sessions was clearly documented for the adult subjects in the present study. Despite an equivalent number of training trials without intervening stimulus control assessment trials, only one of four subjects in adult group C₂ showed control by all potential stimulus elements. All subjects in adult C₁ and C₀ (n=8) were given repeated control assessment during the same number of trials and demonstrated control by all elements by the end of 150 trials. How might the repeated stimulus control assessment procedures aid in the establishment of increased element control?
One could speculate that during stimulus control assessment trials subjects are given the opportunity to develop a new set of multi-element stimuli that would approximate the original sample stimuli. How closely the new stimuli will approximate the original is dependent upon the number of elements that have established control relations with the discriminative response. These "new" sample stimuli will be called test samples in order to avoid confusion with the original sample stimuli. Observations of the adults subjects during control assessment suggest that their sorting behavior could have resulted in such stimuli. These subjects would often sort most of the elements into the same category during each assessment trial. Many of the incorrectly sorted elements were so treated on every trial. Thus the assessment trials provided the subjects with a relatively stable ten trial simultaneous exposure of two approximations to the original sample stimuli.

Following the completion of the sort task each subject was again presented with each of the original discriminative stimuli in random order. Informal observations of the adult subjects suggest that the initial presentations may have functioned as delayed comparison stimuli for the new samples developed during stimulus control assessment. Generally, adult subjects appeared to scan the array more slowly on the first trial following the assessment and frequently commented on which elements were incorrectly sorted during testing. It is likely that the subjects would then engage in behaviors that would increase the probability of establishing control
by the incorrectly sorted elements. Subjects could do this by actively focusing on these elements during training, with only infrequent focus on the elements that were correctly sorted during testing.

The children did not appear to respond in the same manner as the adults to sample stimuli following stimulus control assessment. They did not verbally indicate, as many of the adults had, which elements were correctly or incorrectly sorted nor did they engage in any behavior which would have suggested that the original sample stimuli were functioning as delayed comparison stimuli for "new" stimuli developed during sort trials. Was it that the children were unable to make such comparison, or rather that they never produced a new sample stimulus during assessment trials? Some informal observations suggest the latter. Unlike the adult subjects, the children's sort behaviors were not as stable. A greater number of the elements which had not gained control during training were sorted between both response circles. It is unlikely that such sorting would be appropriate for the development of a functional sample stimulus within ten trials.

For adult subjects, despite the contribution of repeated stimulus control assessments, part of the overtraining effect appears to be due to the subjects' repeated exposure to the discriminative stimuli. This conclusion is the result of comparing the number of elements meeting stimulus control criteria with groups C₀ and C₁ on their first sort task (after 50 training trials) with that of group C₂ having 150
trials prior to the first sort task. Group C₂ showed control by more elements. As stated earlier, this increase in the number of elements that gain control could be the result of a greater number of rules (Carter and Werner, 1978) being acquired during the longer training period experienced by C₂. Unfortunately, overtraining was not continued long enough to ascertain whether the subjects could have acquired control by all elements by repeated exposure alone. Would the preschool subjects eventually have acquired control by all elements despite ineffective use of assessment trials if more training exposure was given?

**Element Labeling**

This experiment's third hypothesis (Experiment II) was that a greater number of stimulus elements that were reliably labeled by the preschool subjects prior to discrimination training would meet stimulus control criteria than those elements that could not be so labeled. This hypothesis was also substantiated. The data suggest, however, that the relative effect of labeling was not strong. The results appear to lend partial support to what has been called the coding hypothesis (Carter and Werner, 1978) in conditional discrimination learning.

The concept of a coding response has often been used in the learning literature. Lawrence (1963) has provided one commonly held definition of the concept.

By coding the following is meant; if there is a set of objects or events and to each of them a different
label is assigned, the labels code these objects or events. It is assumed that the subject makes an implicit, covert response. It is to be thought of as a form of behavior. It is called a coding response because in interaction with the sensory input it produces a new event or code item which then represents the stimulus (Lawrence, 1963, pp. 187-189; cited in Carter and Werner).

When investigators have provided subjects (pigeons and humans) with stimulus specific behaviors to code or label the discriminative stimuli, the subject's performance demonstrated that the behavior aided in the development of both successive discriminations and matching to sample behavior (refer to introduction). The data from Experiment II expand upon these findings. Not only may the acquisition of a discrimination problem be aided by the use of stimulus specific coding behaviors, but so also may the development of selective stimulus control by discrete elements of the stimuli.

However, by what process does such behavior effect the development of selective stimulus control? Perhaps it does so in a manner similar to what is assumed to occur when more simple discriminative stimuli are used. An evaluation of the matching-to-sample literature, for example, appears to suggest that coding responses (e.g., stimulus labeling) provides the subject with a cue for a response or chain of responses that "mediate the choice of comparison stimuli" (Carter and Werner, 1978, p. 576). Carter and Werner cite the study by Maki, Gillond, Hange, and Siders (1977) as a demonstration of the effects of the cueing properties of different coding behaviors. These investigators showed that when a previously conditional observing response was
extinguished to only one of two sample stimuli, matching accuracy for this sample alone was reduced. The performance of subjects to the sample stimulus still associated with an observing response was not disrupted.

It would appear reasonable that in the present study when elements of a multi-element problem could be individually coded (labeled) a cueing process similar to that assumed to occur with more simple discriminative stimuli occurs. During stimulus control assessments these differential cues generated by each element increase the probability of maintaining response accuracy when the element is presented in isolation. These elements which had not developed functional coding behaviors (presumably because reliable labels were not associated with each element) would not have these cues available during stimulus control assessment and accuracy would be reduced.

The general results of the study support this supposition. Certainly more of the elements in the labeled problem set met stimulus control criteria than those from the non-labeled problem. In addition, informal observations of both adults and children showed that they would often label the elements during acquisition maintenance training (e.g., car goes to red, ball bat, and dish goes to blue) and use many of the same verbal behaviors during stimulus control assessment. The results for one subject (#7), however, indicated that an equal number of stimulus elements from both conditions met control criteria. Further, the mean number of stimulus elements meeting control criteria in the labeling
condition, though reliably greater than the non-labeled condition, was not great. Also when both labeled and non-labeled elements were combined to form discriminative stimuli, both types of stimulus elements met control criteria. The labeled elements did not gain control to the exclusion of the non-labeled elements as expected.

Investigations using animals as subjects have suggested that even if coding behaviors could not be detected using the experimenter's criterion or definition, this would not signify that coding behaviors did not occur. For example, Berryman, Cumming, and Nevin (1963) in a study of delayed matching behavior of the pigeon were unable to readily identify sample specific behaviors associated to each of the sample stimuli. The investigators, however, reasoned that perhaps a finer analysis of the response topography might reveal reliable sample specific behaviors. The analysis found that two of the three subjects did develop sample specific behaviors. Carter and Werner suggested that other subject defined sample specific behaviors would have been found by the investigators if they had examined other possible response characteristics or dimensions. They reasoned that the experimenter established contingencies associated with most matching (or discrimination procedures in general) procedures do not insure that subjects will use specific coding responses. The assumption is that a subject's learning history and the characteristics of the discriminative stimulus will determine the type of coding response that will develop during the matching procedure.
The current procedure did not specify through response-reinforcer contingencies that element labeling was to be actively used by subjects during any phase of the study. It had been assumed, however, that if subjects were capable of reliably labeling elements, that it was probable that they would use labeling behavior to their advantage during training and assessment. The labels would provide the subjects with coding behaviors as defined by Carter and Werner. As suggested by the Berryman et al. study, however, element labeling need not be the only possible coding response that could develop. The animal subjects developed sample specific behaviors that required a closer examination of various response characteristics. Perhaps, the subjects used in the current study also developed element specific behaviors (other than or in addition to labeling) that would have required a closer examination of their responding. Unfortunately, the data collection procedures used in this study do not lend themselves to an analysis of other response characteristics.

Summary

The data collected in this study further document the development of selective stimulus control in normal subjects and extend the results obtained by Lovaas et al. In addition, the study has examined some of the functional characteristics of three factors that could effect the process. The primary finding is that stimulus as well as reinforcer parameters (Ray, 1969; Huguenin and Touchette, 1980) help to shape selective stimulus control. In this study all subjects showed
control by proportionately fewer of the total number of stimulus elements as the number of elements was increased in successive problems. Both the preschool children and the adult subjects exhibited a limited capacity in establishing control by all elements during training. Preschool subjects also demonstrated that if elements could be effectively labeled prior to training more of the elements would show control during testing. The effect, however, was not strong and did not preclude the development of control by non-labeled stimuli.

Subject characteristics were also shown to effect the development of selective stimulus control. There were significant age differences found when examining selective control during overtraining. Preschool subjects did not exhibit an increase in the number of elements meeting control criteria despite successive overtraining trials. Adult subjects did so. No significant differences in selective stimulus control were found between the two age groups prior to overtraining, however. The latter finding was not expected. The memory literature strongly suggests that a difference should be found. Observations of subject behavior during training suggest that characteristics of the conditional discrimination procedure may have been, in part, responsible for the results.

The results of these experiments provide evidence that selective stimulus control is not only the result of response consequences but also of stimulus and subject characteristics. The procedure used in this study proved to
be a very effective tool to analyze some of the other characteristics. Numerous questions remain, however. For example, would the proportional number of elements establishing control of behavior continue to decline as complexity is increased? Would it stabilize? Are subjects utilizing "rules?" What is responsible for the similarity between adult and child behavior during initial conditional discrimination training? What is responsible for the preschool subjects' failure to acquire control by more of the stimulus elements during overtraining? Answers to these questions will help to describe more completely the three-term contingency associated with the process of selective stimulus control.
REFERENCES


Miller, G. A. The magical number seven, plus or minus two. Psychological Review, 1956, 63, 81-97.


APPENDICES
Figure 13. A schematic representation of the experimental environment during a) discrimination training and maintenance/overtraining, and b) stimulus control assessment sessions.
Figure 13
Schematic Representation of the Experimental Environment
Figure 14. Compilation of all the stimuli used in Experiments I and II. These figures and symbols were chosen at random from the text entitled Symbol Sourcebook (Dreyfus, 1972).
Figure 14
Compilation of All Stimuli Used
in Experiments I and II
Figure 14 continuation
Figure 14 continuation
Figure 14 continuation
Figure 14 continuation
Figure 15. This figure represents samples of the discriminative stimuli ($S_1$ and $S_2$) used during training. A two, four, six, and eight element problem set is reproduced. Each subject's problem set was individually produced based upon the subject's responses during pretraining labeling sessions. No subject experienced the same element combination.
Figure 15

Sample of Discriminative Stimuli

$(S_1$ and $S_2$) Used During Training
Figure 15 continuation
Figure 15 continuation
Figure 15 continuation
Figure 15 continuation
Figure 15 continuation
Figure 15 continuation
Figure 15 continuation
Figure 16. Schematic representation of the stimulus fading procedure used to teach the discriminative problems. Each display ($S_1$ or $S_2$) was first positioned directly over its respective correct response circle, then over trials slowly moved closer to the centered position shown at the bottom of the figure.
Figure 16
Schematic Representation of the
Stimulus Fading Procedure

$S_1$ and $S_2$ Alternate Randomly During
Acquisition of the Discrimination

Stimulus Display on
Completion of Phase I
Table II
Specific Verbal Instructions Used in Experiments I and II

The following are the specific verbal instructions given both the preschool and adult subjects in Experiments I and II.

1) Phase I instructions:

I am going to show you many pictures. Your task (job) is to tell me what you think each picture is. Some of the pictures may be hard. Guess if you are not sure. (When you have named all the pictures in this pile you may take the toy that you have chosen.)

() used with the children only

2) Phase II instructions:

You are going to be shown two pictures. I will place each picture on this stand (E pointing). One picture goes with the red circle (E pointing) and one with the blue circle. To play this game you must learn which picture goes with the red circle and which picture goes with the blue circle. When I show you one of the pictures you are to tell me which circle it belongs to by touching either the red or the blue circle like this (E demonstrating). If you choose the correct color I will say "Good" and you may take one penny from my pile. If you are wrong, I will say "Wrong" and I will take a penny from your pile. When you have won all of my pennies you may take your prize. Remember you must win all of these pennies to get the prize that you have chosen.

In order to enhance the face validity of the task for the adults the following modified instructions were given.

Your task is to learn which of the two pictures that I am going to show you are associated with the red and blue circles. I will show you each picture one at a time. When I do so you are to point to the color circle that you believe goes with the picture. Do you understand? (Pause) If you are correct I will say "Good" and if you are wrong I will say "Wrong."
3) Phase IV instructions:

Now the task (game) is going to change. All of the pictures that you saw on the large (big) cards are individually placed (alone) on each of these small cards. I am going to give you one card at a time and you are to put each under the color that it goes to. Do you understand? (When you have collected all of these pennies then you may have the prize that you have chosen.)

( ) used with the children only
Table III
Sample Labels of the Stimulus Elements
During Phase I

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Each Subject: Experiment I

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- = incorrect response
+ = correct response
R = element sorted under red
B = element sorted under blue
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Table VI
Order of Problem Set Presentation for Each Subject: Experiment II

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L = labeled elements
N-L = non-labeled elements
NL+L = non-labeled + labeled elements
APPENDIX B

PRELIMINARY INVESTIGATION

Purpose

The purpose of the preliminary study was to determine if selective stimulus control can be adequately assessed by using single element probes following conditional discrimination training. In addition, preliminary data were collected concerning changes in selective stimulus control as the number of elements composing each discrimination problem is increased.

Subjects

The subjects for this investigation were three children, aged 4.5 to 5.5 years of age, who were enrolled in a local day care center. Teacher reports, as well as informal observations of the children suggest that all children exhibited age appropriate motor, perceptual, and intellectual skills. None of the children was described as having behavioral or emotional problems. The socioeconomic status of the children's families was reported to be middle to upper middle class.

Apparatus

All discriminative stimuli used during training and probe trials were presented using a table top format. Data were recorded by the experimenter. Stimulus cards were presented to each subject by placing them upon a wooden card stand which was positioned six inches from the subject's edge of the table.
The stand displayed each card approximately $30^\circ$ from vertical and perpendicular to the child's midline. The response panel was positioned directly in front of the display stand. Affixed to this panel were two circles, one blue and the other red. Each circle was four inches in diameter and positioned eight inches apart (center to center). Each child could comfortably reach both the stimulus cards and the response panel.

**Stimulus Materials**

Each stimulus card was composed of a number of distinctive elements. There were either four, six, or eight elements on each pair of discriminative stimuli. These elements were reproductions of the black line drawings of symbols illustrated in the text, *Symbol Sourcebook*, by Henry Dreyfus (1972). Selected symbols were photo-reproduced onto a 7x11 inch white field. Stimulus elements were positioned such that the resulting array of elements was centered within the field with each element equidistant from the surrounding elements. The stimulus cards were encased in a clear plastic sheet protector.

**General Procedure**

All test sessions were conducted in a small well lighted room at the children's day care center. Prior to the beginning of the discrimination training, the experimenter met individually with each subject. This was to establish rapport with each child and to informally assess motor, perceptual, intellectual, and social skills.
Phase I: Establishment of the Conditional Discrimination

The conditional discrimination was established using a teaching program similar to that described by Hively (1962). During the initial training trials each stimulus was presented directly above its respective correct response circle. By employing a position cue during these early trials, initial errors are reduced and the discrimination problem is established in an errorless fashion. Prior to beginning the program, each child was given the following instructions:

You are going to be shown two pictures. I will place each picture on this stand (E pointing). One picture goes with the red circle and one with the blue circle. To play this game you have to learn which picture goes with the red circle and which picture goes with the blue circle. When I show you one of the pictures you are to tell me which circle it belongs to by touching either the red or the blue circle on this board. (Pause) If you choose the correct color, I will say "Good" and you may move this little animal one space on the game board, like this. (E demonstrates) When you reach the end of the game board you are finished and you may take your prize.

One trial, using each of the stimulus cards, was then given and the child asked to respond. If the child responded correctly the teaching program was begun. If the child did not, he/she was told, "No, that is not correct." The same stimulus was presented again and the child asked to choose again.

During the next few training trials the position of each stimulus was moved in small steps to a position equidistant between the response panels. During these fading trials an incorrect response would initiate a correction procedure: the same stimulus was presented on the next trial with its display position moved closer toward the center display position on
subsequent trials. Criteria for completion of the initial teaching procedure was when both stimulus cards were presented in the center display position and the child correctly responded to five random presentations of each stimulus.

Phase II: Maintenance of the Discrimination

Following the completion of Phase I each child was given an additional 50 training trials prior to assessing selective stimulus control. Each discriminative stimulus was presented 25 times in a prearranged random order. As in Phase I, each trial was separated by a five to seven second intertrial interval during which the response was recorded, the game piece moved, and the next stimulus card chosen.

Phase III: Assessing Selective Stimulus Control

Following Phase II each child was given a series of stimulus control probes that were designed to assess selective stimulus control by individual elements in the array. The purpose was to determine which of the elements were controlling correct choice behavior during training trials. The probes consisted of each individual element presented alone in a random series. The number of individual elements within each series depended upon the number of elements that comprised the original training stimuli. All elements of both training stimuli were presented in a random order during each series. Each element was centered upon a 7x11 inch white field. No feedback was given during the probe trials.

A total of ten probe series were given to each child.
Each of the probe series was separated by a 10 trial baseline series during which the original training stimuli were again presented. This was done in order to assess any disruption of the child's discrimination performance following a probe series. The principal dependent measure was each child's choice behavior during single element presentations. Selective stimulus control by an individual element was assumed if that element resulted in correct choice behavior on 80% or more of the probe trials.

**Results**

Studies that have used errorless training procedures have shown that discrimination problems are generally acquired rapidly with few errors. This has been found to be true using both human and animal subjects. Table VII lists the number of trials required to complete Phase I of training and the number of errors made during acquisition for the three children.

For all three subjects the first discrimination problem was acquired within 40 training trials. Problems two and three were acquired within 30 and 20 trials respectively. Few errors were made by any of the subjects.

The principal dependent measure was the number of stimulus elements that demonstrated control of choice behavior during the stimulus control assessment procedure. An element was assumed to control choice behavior if $\geq 80\%$ of the stimulus control probes for that element resulted in correct choice behavior. Figure 17 documents the total number of elements
Table VII

Number of Trials to Acquisition Criterion and Number of Errors for Each Subject with Each Problem Set

<table>
<thead>
<tr>
<th>Problem Set</th>
<th>4</th>
<th>8</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subject</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>35/0</td>
<td>29/3</td>
<td>16/0</td>
</tr>
<tr>
<td>A</td>
<td>35/0</td>
<td>15/0</td>
<td></td>
</tr>
<tr>
<td>S</td>
<td>22/1</td>
<td>15/0</td>
<td></td>
</tr>
</tbody>
</table>

Number of trials to criterion/Number of errors
Figure 17. The total number of elements ($S_1$ and $S_2$ combined) meeting stimulus control criteria is plotted as a function of the increased number of elements in successive discrimination problems. Both individual and group data (bottom graph) are presented. The range of subject performance is represented by the horizontal lines bounding each group data point.
(S₁ and S₂ combined) that met criteria for the three discrimination problems for three of the subjects. The diagonal line represents the linear function that would be obtained if all elements met stimulus control criteria. Two subjects who were given only the initial eight element proble, acquired the conditional discrimination but did not show systematic control by any of the elements in isolation. Their response patterns suggested a position bias during element probe trials.

The ordinate and abscissa represent the number of elements meeting stimulus control criteria and the total number of elements in both discriminative stimuli. The individual and group data are presented. The data suggest that when preschool subjects were given discrimination problems that contained greater numbers of elements, their correct choice behavior was controlled by proportionally fewer of the elements. The subjects attented to fewer of the elements contained in each stimulus.

Figure 18 presents the same data when examining the number of elements gaining control from each discriminative stimulus (S₁ or S₂). The ordinate and abscissa remain as in Figure 17. Although each subject's stimulus control performance shows small differences between S₁ and S₂, subjects appear to attend to a number of elements from each stimulus not to the elements of one discriminative stimulus. The differences between S₁ and S₂ for two subjects may suggest a stimulus preference. More elements of S₁ for child S and S₂ for child A met stimulus control criteria. Both these stimuli were associated with the red response circle.
Figure 18. The total number of elements meeting stimulus control criteria is plotted as a function of the increased number of elements in successive discrimination problems for $S_1$ (closed circles) and $S_2$ (open circles). Both individual and group data are presented.
Discussion

The results of this preliminary investigation indicate:
a) the errorless conditional discrimination paradigm is a useful training procedure to study visual selective attention with preschool children and, b) the subjects' behavior in this study was not controlled by all of the elements comprising the discriminative stimulus. The proportional number of elements meeting control criteria appears to be inversely related to the total number of stimulus elements.

One factor which may be responsible for the children's performance was that perhaps they were unable to recognize or label many of the elements used in the procedure. All elements used during the preliminary investigation were randomly chosen from the Symbol Sourcebook (Dreyfus, 1972). No pre-test was given in order to determine if the stimuli were meaningful or discriminable to each subject. Would the number of elements that make up a discriminative stimulus effect selective stimulus control if all elements were meaningful to the children? The formal procedure should pre-test each child and use only those elements for which the child has a label or name.

Two of the five subjects used in this procedure were unable to complete the selective stimulus control assessment. Their performance suggested a position preference during probe trials. These two subjects differed from the remaining three in that they were presented the eight element problem without prior experience. The other subjects were given the four element problem before attempting the eight element problem.
These data suggest that the preschool age subject would profit from shaping the complexity of the stimulus discrimination problem and the resulting stimulus control assessment. The formal procedure should present the discrimination problems in an order of increasing numbers of elements. The question of an order effect may be answered in part by inverting the four and six element problem for some subjects.

Informal observations of the children during probe trials suggest that the probe trials given during extinction may have affected the child's performance during probes. All subjects questioned the examiner about not receiving reinforcement. The arguments given by other researchers for using such probes is that they are indistinguishable from training trials and may provide a more valid measure. These subjects distinguished the difference immediately. With normal children, probe trials apparently will be distinguished from training trials and may affect performance (e.g., random responding, position or color preferences, etc., may increase). Perhaps a more game-like selective stimulus control assessment task using non-differential reinforcement would minimize shifts in response patterns.