A comparison of fading, non-fading and a combination of procedures in training word recognition with moderately retarded adults.

Leslie Ellen Weidenman

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A COMPARISON OF FADING, NON-FADING
AND A COMBINATION OF PROCEDURES IN
TRAINING WORD RECOGNITION WITH
MODERATELY RETARDED ADULTS

A Thesis Presented

By

Leslie Ellen Weidenman

Submitted to the Graduate School of the
University of Massachusetts in partial fulfillment
of the requirements for the degree of

Master of Science

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Department of Psychology
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INTRODUCTION

When planning a course, unit, or individualized lesson, a teacher is faced with the task of selecting an appropriate teaching method from among a variety of available procedures, some of which reflect different approaches to education. Often, the chosen method is selected on the basis of considerations that are not necessarily relevant to the quality of the program. For example, it is not uncommon to find materials used for reasons such as: They were used before, they required little additional preparation on the part of the teacher or they were the easiest to obtain. Teachers familiar with behavioral principles of Educational Psychology are more likely to consider factors such as the entering behavior of their students, the complexity of the behavior to be taught and the conditions under which the behavior is to be emitted, when choosing a teaching strategy. The behavioral approach to teaching advocates consideration of these factors along with the principles of learning and behavior change. This approach, which starts with the premise that teaching includes arranging effective instructional programs to meet individual student needs, focuses teacher attention on student and curriculum variables and the methods of behavior change.

It recommends that teachers be aware of and prepared
to provide the appropriate consequences for student behaviors in a learning situation. In particular, contingencies need to be arranged so the desired behaviors will occur, and be reinforced when they do occur.

Traditionally, as Skinner (1961) points out in his influential article on the importance of programming and teaching machines, student learning behaviors have been under aversive control. Instead of maintaining this type of system with its undesirable side effects (e.g. avoidance, inattention, mental fatigue) Skinner implores educators to rearrange the educational environments so positive reinforcers and not punishers will follow appropriate student behaviors. He demonstrated how careful programming and the use of teaching machines can facilitate learning, and attributed the success of these methods to the following three factors: 1) reinforcement occurs frequently and immediately, 2) students proceed at their natural rates, and 3) the program follows a coherent sequence. He also emphasized the role of the teacher and stimulus materials is to teach rather than simply to impart knowledge. This can be accomplished by active student participation in the learning process. Anderson and Faust (1975) labelled this the principle of active responding. Skinner stated it more simply, "To acquire the behavior, the student must engage in the behavior" (page 389).
What types of behavior are involved in learning in the classroom? Upon examining school experiences, one finds that students are asked to define terms, identify examples, solve problems, synthesize material, evaluate, etc. All these activities can be found in Bloom's taxonomy (1956) or William's typology (Note 8) and can be seen in school settings. With so many different behaviors and systems of describing them, the task of effective programming with active student participation appears more complex. As a basic student behavior from which many more complex ones are derived, discrimination will be examined closely. The findings from an intensive investigation of discrimination will provide an important foundation for many other skills. Skinner (1961) discussed the importance of discrimination as a fundamental skill in the following statement.

We call an effective person 'discriminating'. He can tell the difference between the colors, shapes, and sizes of objects, he can identify three dimensional forms seen from different aspects, he can find patterns concealed in other patterns, he can identify pitches, intervals and musical themes and distinguish between different tempos and rhythms --and all of this in an almost infinite variety. Subtle discriminations of this sort are as important in science and industry and in everyday life as in identifying the school of a painter or the period of a composer. (page 381)

This emphasis on discrimination is also seen in the work of psychologists interested in concept formation and the teaching of concepts. In particular, Becker, Englemann,
and Thomas (1976) in their textbook, *Teaching 2: Cognitive Learning and Instruction*, teach the reader how to test for concepts. They define a concept as a critical group of stimuli that identifies the object or the idea. Any particular example of a concept will contain all the critical features of the concept as well as many irrelevant features. The job of the learner is to discriminate those cases in which all the critical features are present, thus an example of the concept, from those instances in which some of the critical stimuli are not present. Johnson and Chase (Note 2) refer to examples in which one or two of the critical features are missing as non-examples of the concept. Thus it appears that the basic task required of a learner is to discriminate examples from non-examples of concepts. As the educational system is continually attempting to teach concepts it seems reasonable to focus on the literature on discrimination training in the search for knowledge pertaining to effective procedures and methods for teaching.

A search of the literature on discrimination training reveals a diversity of research from both the animal laboratories and applied settings. The nature of the research, which naturally reflects the theoretical orientation and interests of the investigator, may, at first glance, seem far removed from the basic concerns of the educator who seeks guidelines for effective teaching. However, the potential impact of the accumulating body of knowledge is
great. Eventually, with further research, important additional general principles of teaching will be formulated as an outcome of this area of study. To date, the impact has been limited, although, many procedures based on experimental findings of discrimination learning studies are now being used with special populations and for training a variety of specific skills.

This paper focuses on the issues in the field of discrimination training with an emphasis on the development of the field, current research directions, and the significance of the findings for the applied setting. The major topics that enter into the discussion include the theory of errorless learning, its impact on training procedures, fading techniques, and the parameters of a successful fading program.

**Early Research in Discrimination Training**

To teach a discrimination requires that the desired response be brought under the control of the positive, or discriminative, stimulus (S+ or S^D). This process can be described as reinforcing the behavior in the presence of the S+ and extinguishing the same behavior in the presence of the negative stimulus (S- or S^A). Instances of discrimination learning can be seen in hundreds of everyday situations. Consider the following examples:

-- a student learns to follow directions after...
completing the wrong assignment
-- a sales manager learns to institute an incentive program following several years of experiencing an annual post-holiday sales slump
-- an adult learns when certain comments are inappropriate after being ridiculed or ignored.

In each case, the learner experienced an unpleasant event which resulted in a change in his behavior. It is likely that under those same circumstances, those particular behaviors would not re-occur. Through continued interaction with their own environments, each learner would come to recognize those conditions under which those behaviors would not be punished. When this has occurred, one would say that the student, sales manager, or adult had learned a discrimination and their behavior was under stimulus control.

The situations described above represent examples of the traditional method of discrimination training often called trial-and-error. It is obviously effective, although there are disadvantages. Primarily, trial-and-error implies that the behavior will undergo extinction or some other unpleasant consequence, before the correct pattern of responding is learned. This feature of responding in the presence of the S- was at one time considered essential for discrimination learning. When Skinner's (1961) article
appeared, advocating the use of positive control in the learning environment, researchers began to look at discrimination learning from a new perspective. Skinner argued that errors did not promote optimal learning in that errors are often followed by aversive consequences which could produce emotional responses as well as take up learning time. This would not happen in situations where positive reinforcement was used to maximize correct responding. Errors would be kept to a minimum thus increasing the productivity of the learning time. Researchers investigating discrimination learning began to re-examine the notion that responding in the presence of the S- was essential as well as to study the role of errors in the training process.

Wells Hively, one of Skinner's graduate students, published a paper (1962) in which he demonstrated how a difficult discrimination could be taught to a group of children without the use of aversive control and without many errors. Hively developed a series of match-to-sample tasks of increasing difficulty. Children were seated in front of a response panel with several response keys upon which geometric patterns could be displayed. Children were shown a sample pattern and a row of choice patterns. The task was to select the pattern that matched the sample by pressing the appropriate response key. The complexity of the patterns and of the alternative choices
increased as the series progressed. In a sequence of experiments, Hively examined the variables that affected the children's performance on the task of greatest difficulty, called the "criterion task". He recorded the number of errors made by each subject and found that the acquisition of the criterion task was facilitated by arranging a series of progressively more difficult discriminations. He described his sequence as a series of successive approximations to the criterion task.

One interesting outcome of Hively's experiments was the finding that children who experienced the criterion task prior to receiving the progressive training sequence performed poorly in comparison with children who received the progressive sequence without the prior experience on the criterion task. This result suggested that not only were errors unnecessary for discrimination learning but they could also be detrimental.

Terrace's Research Program on Errorless Learning

Research on the effects of errors during discrimination training was also being conducted in animal laboratories. Terrace, (1963a) in his work with pigeons, developed a systematic procedure for teaching discriminations "errorlessly". The errorless procedure was quite different from the traditional trial-and-error method. Trial-and-error training consists of random presentations of the
discriminative stimuli (S+ and S-). Responding during S+ is reinforced whereas responding during S- undergoes extinction. As the name implies, trial-and-error procedures result in subjects making many errors before the discrimination is established.

In Terrace's errorless procedure, the subject was similarly presented with the S+ and the S- in a random order. However, the initial S- presented was quite different in appearance from the stimulus that was to serve as the ultimate S- at the end of discrimination training. The initial stimulus chosen was not likely to occasion a response from the subject. As the program progressed, the initial S- was altered gradually until the stimulus appeared in its final form. This type of procedure resulted in very few error responses to the S-.

Terrace's original study (1963a) demonstrated the effectiveness of the errorless procedure in teaching a red-green color discrimination to pigeons. The training sequence began with the establishment of a key peck response to the S+ (red key). When the subject was responding reliably, the S- was introduced. In this study, the initial S- was a dark key which was gradually transformed to a green key. The initial S- difference in color, intensity, and length of presentation from the terminal S-. Presenting the dark key for a brief period made it likely that the subject
would not peck the key. Gradually, the green color was faded in to the equivalent brightness of the red key. Likewise, the length of presentations was increased to match the S+.

Terrace compared the performance of birds under four training conditions that differed along the dimensions of 1) an early or late introduction of the S- following establishment of the key peck response, and 2) a progressive (faded) or constant (trial-and-error) presentation of the S-. The four experimental groups resulting from the combination of the above dimensions were:

- early progressive          - late progressive
- early constant            - late constant

The most interesting result of this study was the superior performance of the subjects in the early-progressive group when compared with others. Terrace concluded that both an early introduction and a progressive presentation of the S- were essential features of an "errorless" program.

One explanation for the success of the errorless procedure was that the gradual method transferred a known or easy discrimination to a more difficult one. In the above example, the initial discrimination required the subjects to respond to the red key (S+) and not to respond to the dark key (initial S-). This is an easy discrimination for pigeons as they are not likely to peck a dark key.
The major importance of the study was that it confirmed the belief that a discrimination could be learned and learned well without making errors. A post-acquisition test on the red-green discrimination found that the performance of the birds in the early-progressive group remained accurate.

To study this procedure further, Terrace conducted a second set of experiments in which stimulus control was transferred from a color discrimination to a more difficult line-tist discrimination. Again using pigeons as subjects, Terrace used the errorless training procedure to train subjects to discriminate the red and green keys. Then, group one was abruptly changed from the color stimuli to the horizontal vertical lines, while the second group had several trials in which the color stimuli were superimposed on the line stimuli. A third group experienced super-imposition of the colors along with a progressive reduction of the colors until only the lines remained. The fourth group received only vertical-horizontal training and did not have any previous experience with color. All groups learned the line-tilt problem, however, only the group that received superimposition and fading of stimuli acquired the discrimination errorlessly. Errors occurred in all the other groups although the superimposition-only group had fewer errors, indicating that some transfer
had occurred. These results clearly show the advantages of the progressive technique for reducing errors.

The final portion of Terrace's study consisted of administering another set of trials with the color discrimination task. Surprisingly, the performances of the different groups varied considerably. Only the birds that had been in the fading condition during the line discrimination training performed perfectly. The others, who had made errors on the line-tilt problem also made errors when they were retested on the red-green discrimination. These results were interpreted to mean that errors disrupted the performance of a previously learned problem.

Terrace's findings were similar to those that had been obtained by Hively with young children. Both studies demonstrated that discriminations could be acquired with few or no errors. The results also indicated that errors, instead of being essential for discrimination learning, might in fact have a detrimental affect on already mastered discriminations.

**Basic Research in Discrimination Training**

The following section will provide a discussion of the findings of several basic research programs investigating the variables that affect the success of "errorless" or fading programs. The term fading, which is often used interchangeably with the term errorless, refers to the
gradual change in the stimulus conditions that occur during programming. It should also be pointed out that the term "errorless" generally refers to a specific criterion of performance that is set (somewhat arbitrarily) by the experimenter. For example, in Terrace's work (1963a), he defined errorless as 25 or fewer responses to the S-. As keypecking is a high frequency, low effort response, 25 pecks does not represent a significant amount of pecking. However, some responses did occur in the presence of S-, so errorless should not be interpreted to mean a perfect performance. Such efforts from the animal laboratories make an important contribution towards increase the understanding of the mechanisms that are involved in fading for use in applied settings.

The publication of Terrace's early studies along with his chapter on Stimulus Control in Honig's book Operant Behavior: Areas of Research and Application (1966) stimulated a great deal of research in the field. Terrace essentially believed that learning "errorlessly" was somehow unique. That is, he proposed that the mechanisms involved in errorless learning were different than those underlying trial-and-error learning. To support his theory, he cited as evidence the fact that the behavioral by-products which often accompany traditional discrimination training were not present when the subjects received
errorless training. For example, his subjects did not exhibit aggressive or emotional behaviors during S-, nor did they show behavioral contrast effects. In addition, there were no shifts in the peaks of generalization gradients away from the value of the S-. Terrace attributed these effects to the errorless program. He believed that by eliminating the situation in which subjects experienced non-reinforced responses to the S-, he had produced a learning environment which would facilitate learning without the accompanying side-effects.

The impact of his work can be seen in the numerous studies that followed. In fact, a large portion of the research on discrimination learning dealt directly with Terrace's notions. However, not all investigators shared his belief in the unique products of errorless learning. Efforts were taken by several researchers to refute Terrace's claims. Specifically, the issue of the behavioral by-products of errorless learning was studied. The efforts of many investigators revealed a number of problems with the theory of errorless learning. Additionally, related research in the area detected problems with the arbitrary nature of the definition of an errorless performance and the selection of the measured response.

To illustrate the problems with the behavioral by-products issue, the research on behavioral contrast will
be examined. Terrace contended (on the basis of his own research) that errorless procedures did not occasion behavioral contrast. Rilling (1977), in his chapter on Stimulus Control, reported that he and his students conducted a series of experiments which demonstrated that the occurrence of behavioral by-products was not related to the occurrence of errors during training. In the case of behavioral contrast, Kodera and Rilling (1975) replicated the procedure in Terrace's 1963 study using a slightly different set of discriminative stimuli. Where the S+ and S- had been a red and green key in Terrace's study, Kodera and Rilling used a green key as the S+ and a dark key as the S-. This change in stimuli brought about a change in the results. Not only was errorless acquisition of the discrimination achieved in the early-progressive group but the other groups learned errorlessly as well. In addition, behavioral contrast was observed in all experimental groups. Slight differences in the degree of contrast were apparent as a function of early or late introduction of the S-. However, after analyzing the data, no direct relation was found between the number of errors and the amount of behavioral contrast observed.

Another issue addressed by Terrace's critics was his notion of the neutrality of the S- during errorless learning. Terrace (1966b; 1972) maintained that the S- functions
as an aversive stimulus following learning with errors whereas it functions as a neutral stimulus following errorless learning. Neutrality was assumed due to the lack of emotional and aggressive behaviors emitted by subjects in the errorless conditions. Subjects in the error (or traditional) groups were observed to emit emotional behaviors such as wing flapping and aggressive behaviors towards the key when the S- was present.

Two explanations have been offered for the occurrence of emotional and aggressive behaviors. Terrace proposed that aggression is produced by the "frustration that occurs as a by-product of non-reinforced trials". Rilling, on the other hand, suggests that the withdrawal of the opportunity for reinforcement is the cause. Research specifically concerned with the occurrence of aggressive behaviors was conducted in an attempt to clarify the situation.

Rilling and Caplan (1973) trained pigeons to discriminate between a green key (S+) and a dark key (S-) using an errorless procedure. In addition, they provided a target bird in the experimental chamber which set the occasion for aggressive and attack behaviors. The rate of attack during each stimulus condition was recorded throughout discrimination training. The results showed a rate of attack significantly higher than the operant level for all subjects regardless of the training procedure and
the resultant errorless acquisition of the discrimination by all subjects. These data cannot accommodate Terrace's assertion that aggression is the outcome of non-reinforced responses to the S- but do lend support to Rillings notion that the withdrawal of the opportunity for reinforcement is the crucial variable in determining whether or not aggressive behavior will occur.

In addition to the investigation of aggression, Rilling and his colleagues examined the question of neutrality of the S- by directly measuring the aversive quality of the S- during discrimination training. First, Rilling, Askew, Ahlskog, and Kramer (1969) established a successive discrimination or "escape procedure" as a valid indicator of the aversiveness of the S-. The successive discrimination procedure involved two response keys and a pair of discriminative stimuli. Appropriate responding to the S+ and the S- was established on the first key. Responses to the second key resulted in a "time-out" or termination of the stimulus appearing on the first key and a 5-second darkening of the chamber. During traditional discrimination training, Rilling et al, found that responses to the second key were more frequent during S- than S+. This finding, Rilling noted, was consistent with Azrin, Hutchinson and Hake's (1966) study and Rilling and Caplan's (1973) work on aggression and supported the notion that the
subjects' responding to produce "time-out" was an index of the aversiveness of the S-.

With the validation of the procedure, Rilling, Kramer and Richards, (1973) applied the technique to an errorless discrimination to test Skinner's assertion that errors are aversive and a learner will escape or avoid a situation in which errors have occurred. Varying the dimensions of 1) early or late introduction of the S-, and 2) a progressive or constant presentation of the S- (modelled after Terrace's 1963a study) four experimental groups were studied. Training which consisted of a red-green color discrimination, and the opportunity for escaping S- was available for each group. The results of the discrimination training replicated Terrace's findings in which the subjects in the progressive groups made the fewest errors. The effect of the dimensions of the training procedure on the number of time-outs showed that the time dimension (early or late introduction of the S-) had a greater effect than the method of presentation (progressive or constant). Subjects in both the late-constant and late-progressive groups emitted many more escape (time-out) responses than the early groups. Rilling concluded that the number of responses made to the S- was a poor predictor of the number of time-outs or escape responses. The significance of this finding, according to Rilling, is that it fails to support Terrace's notions concerning the aversive properties of
the S-. He summarizes his conclusion in the following statement:

To the extent that time-outs from S- are an index of the aversive properties of S-, these data do not support the view that the aversiveness of a stimulus is directly proportional to the number of unreinforced responses emitted in its presence. (page 470)

Other investigators showed that the use of a progressive technique as originally outlined by Terrace is not necessary to produce an errorless performance. Wessells (1974) for example, obtained an "errorless" performance in an autoshaping experiment with pigeons. Autoshaping refers to a procedure in which the experimenter does not directly shape the subject's response. In the Wessells study, a discrimination between a green key (S+) and a white vertical line (S-) was trained in the following manner. The S+ was illuminated for 6-seconds and immediately followed by reinforcement regardless of the bird's behavior. The white line (S-) was illuminated and never followed by reinforcement. Pecking emerged during the presentation of the S+. The pigeons learned to discriminate the S+ from the S- without pecking the S-. Throughout the study, Wessells recorded two pre-pecking responses, orientation and approach to the response key, in addition to the number of pecking responses. He found that the rate of these behaviors increased and decreased during S+ and S- respectively as the autoshaping progressed until, essentially no responses
were emitted during S-.

The results of Wessell's study raise the question of the validity of the definition of errorless learning. In restricting the definition of an errorless performance to the nonoccurrence of a particular response, one should remember the response may be the terminal point in a chain of behavior. As Wessell demonstrated, both orientation and approach to the response key are important links in pecking response chain. By recording the frequency of these pre-pecking behaviors, he has shown that 1) they do occur within the "errorless" procedure, and 2) they come under the control of the discriminative stimuli as the key-peck itself does. It does not seem realistic to assume that different mechanisms of learning could account for the development of stimulus control of two portions of the same response chain. In Wessell's study, only the key pecking response could be said to have been acquired errorlessly according to Terrace's definition. If one accepts the errorless premise then the orientation and approach responses would have to have come under stimulus control by means of the trial-and-error procedure.

Another problem encountered in a discussion of errorless learning is that it is not always clear that the distinction has been made between outcome (i.e. no responses to the S-) and procedure (progressive methods or fading
techniques). Errorless learning refers to the outcome whereas errorless training refers to the procedure. The use of "errorless" in both instances can lead to confusion as it is conceivable (and actual) that an errorless procedure might not result in errorless learning. As has been noted, the criteria for an errorless performance is selected arbitrarily, and as Wessells has demonstrated, the response measured may be arbitrary as well. Some of the research conducted on the specific behavioral by-products of discrimination training has pointed out that the training procedure (progressive or abrupt introduction of the S-) may not have any relevance to the number of errors made by the subjects in the program. The problem with the dual usage of the term "errorless" is that it may fail to convey the appropriate meaning. Therefore, it seems that its usefulness as a descriptor of a body of research is limited and perhaps should be replaced by less ambiguous terms (eg. fading) where meaning is restricted to the procedure or the outcome but not both.

From the evidence described, it seems clear that errorless learning is not the special process that Terrace believed it to be. His theory is unable to account for all the available data and needs to be re-examined, perhaps reformulated, or discarded. Rilling emphasizes this point in his chapter and suggests that researchers might profit
from approaching the problem of errorless learning and fading procedures from the point of view of stimulus control. This would enable investigators to determine the variables that affect the rate of response to the S- which in turn would provide valuable information for programmers interested in engineering systems for applied settings.

The major variables that have proven to be important can be categorized as procedural and physical. Both Terrace and Rilling have isolated two distinct procedural variables. They are: (1) the time in the subject's experimental history that the S- is introduced, and (2) the rapidity with which the S- is introduced. The importance of both variables can be seen in the development of fading procedures and in the original work on errorless learning. For example, in Terrace's 1963 studies, an early progressive introduction of the S- resulted in the least number of errors. Both procedural variables were manipulated in Terrace's work, and now, it appears that both have contributed to the control of the error responses.

Once the variables have been identified, the next task is to determine the degree of stimulus control exerted by them. For the procedural variables, one determinant that has been identified is the physical similarity of the discriminative stimuli. Whether or not the S+ and the S- differ on an inter- or an intra-dimensional basis has been found
to be a good predictor of the number of responses that occur during S- in a traditional discrimination procedure. Kodera and Rilling (1975) conducted a study with pigeons and examined the effects of using intradimensional discriminative stimuli and compared the results with interdimensional training. The sets of stimuli used were a green key (S+) and a dark key (S-) for the interdimensional set, and a green key (S+) and a red key (S-) as the intradimensional pair. In a statement summarizing the results of his work and other investigations on the effects of stimulus similarity, Rilling concluded that interdimensional training produces fewer errors than intradimensional training primarily because of the dissimilarity of the stimuli.

To reduce the likelihood of errors in the case of intradimensional training, fading procedures can be employed. By definition, the changes in the stimulus would be gradual which would improve the chances of success. Based on the actual evidence amassed so far on the effects of different procedural variables, fading procedures seem like a viable solution to some of the problems encountered in training difficult discriminations in applied settings. What the effects of fading would be in an interdimensional discrimination are less apparent. The parameters of fading need to be studied further in order to understand the limitations of the procedure. Rilling (1977) addresses this issue in the following statement:
Regrettably, fading remains a part of the art rather than the science of operant conditioning. . . . The parameters of fading which are necessary for errorless learning remain uninvestigated. How rapidly should the intensity and duration of the S- be increased to obtain optimal errorless learning? Furthermore, the effectiveness of fading is rarely compared with appropriate control conditions in which fading is not employed. (page 466)

**Transfer of Stimulus Control**

In addition to the emphasis on error reduction that results from the application of fading procedures, fading is interesting from the point of view of transfer of stimulus control. Fading techniques provide a means of shifting stimulus control from one set of discriminative stimuli to another. Generally, when the variables are arranged properly, subjects in fading programs make relatively few errors, which is usually the goal of the designer of the fading program. Although applied research programs use fading techniques to transfer stimulus control from one set of discriminative stimuli to another, the research emphasis for the most part has focused on the subjects' acquisition of the target discrimination rather than on the changes in stimulus control that accompany the various stages in the fading program.

The fact that fading can facilitate the change in stimulus control from one set of discriminative stimuli to another is particularly interesting when consideration is given to the results of another procedure used in animal
learning studies that is analogous to fading. The procedure involves training subjects to respond simultaneously to compound sets of discriminative stimuli (thus the term simultaneous compound conditioning). The stimulus control exerted by the components of the compound is effected by prior experience with the stimuli. Impaired stimulus control has been reported when a training sequence, similar in some respects to the fading procedure, has been used. This reduction in the degree of stimulus control acquired by the stimulus components has been termed "blocking". Blocking has been demonstrated both in classical conditioning paradigms (Kamin, 1969) and recently within an instrumental paradigm (Donahoe, 1977).

A blocking design can be described as a three phase experimental procedure which can be diagrammed as follows:

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<td>AC, BD</td>
<td>C, D</td>
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In phase 1, subjects are trained to respond differentially to a set of stimuli, A and B. In phase 2, additional stimuli C and D are added to the original set thus producing a pair of compound stimuli, AC and BD. The third phase consists of a generalization test for the stimulus control acquired by the components C and D. A comparison of the
results of the generalization test (phase 3) of the experimental group and the control group indicates whether or not blocking has occurred. If the acquisition of stimulus control has been blocked, the generalization gradients of the experimental subjects will be flatter and less pronounced than the gradients of the control subjects.

The subjects in Donahoe's 1977 study were pigeons and the response was a keypeck. The discriminative stimuli consisted of two line angles, in phase 1, to which two different wavelengths of light were superimposed in phase 2. The testing conditions in phase 3 consisted of a generalization test over a range of wavelengths. The results indicated that control of responding by the wavelengths of light was weaker for subjects in the experimental group than in the control group. That is, the acquisition of stimulus control was "blocked" by the phase 1 conditioning with the line angle stimuli. The relevance of these findings to fading should be clear if the blocking design is regarded as another method of transferring stimulus control from one set of stimuli (A,B) to another (C,D) through a process of simultaneous compound conditioning (AC,BD).

Essentially, the fading procedure which employs a progressive change in stimuli has seemed to successfully accomplish what the blocking design seems to inhibit. However, it should be kept in mind that the weakened stimulus control
reported in the blocking studies refers to the relation between the level of control in the experimental and control groups. Without an equivalent comparison group for the fading studies, where control groups received prior experience with components of the compound stimuli (e.g., phase 1 of blocking design), it is difficult to specify the degree to which one procedure inhibits and the other facilitates the transfer of stimulus control.

One study concerned with the degree of stimulus control exerted by the components of the stimuli used in a fading program was conducted by Fields, Bruno, and Keller (1976). They designed a procedure using compound discriminative stimuli and probe trials that permitted monitoring of stimulus control of all components during the entire fading program. Fields, Bruno, and Keller trained pigeons to differentially respond to a red (S+) and black (S−) key. A fading procedure was used to transfer stimulus control to the white lines that differed in orientation by 90°. The lines were gradually faded in until they appeared at full intensity on the response key along with the color stimuli. This was followed by the gradual removal of the color components which completed the transfer of stimulus control to the line stimuli. Throughout training, probe trials consisting of independent presentations of each component and the compound stimuli were presented. The
degree of responding to the probes provided a measure of the stimulus control achieved by each of the components.

The results showed that during the initial fading in of the lines, only the color stimuli controlled responding. When the compound probes were presented, responding occurred but to a lesser degree than to the colors alone, indicating that responding was controlled entirely by the color stimuli. During the early stages of the removal of the red stimulus, responding to red was greater than to either the compound stimulus or the lines. As fading continued, the compound stimuli gained greater control and eventually, when the red was nearly faded, the line stimuli achieved control to the approximate level of the compound S+. They also reported that reintroducing the color stimuli resulted in appropriate responding and control by the colors. This indicates that control by the color stimuli was not lost in the transfer of stimulus control from color to line stimuli.

What the authors consider the most significant outcome of this study is that it confirms a previously suggested notion that new stimuli presented in a fading program acquire stimulus control in two stages. To explain the two stage process, the authors turned to the blocking paradigm. Blocking, according to Fields, Bruno and Keller, means:
previous discrimination training with one set of stimulus elements found in compound stimuli reduces the control acquired by the other elements of the compound stimuli. (page 299)

They also point out how the blocking design relates to the acquisition of stimulus control in fading in the following statement.

In fading experiments where the intensity of the original (blocking) stimuli systematically decreases, the blocking effects might be expected to decrease as fading progresses and the new stimuli should acquire control of responding. This, in fact, is what happened, and in an errorless fashion. Stimulus fading, then, can be conceptualized as a procedure by which a thoroughly blocked stimulus dimension acquires control of responding in an errorless fashion due to the gradual elimination of the original blocking stimuli. (page 299)

They further suggest that the parameters that affect or reduce the likelihood of blocking should in turn enhance the effectiveness of a fading procedure when applied to the original stimuli. Such a notion is appealing yet remains to be empirically demonstrated. Although some of the parameters in question still need to be identified, the blocking design provides a theoretical framework which may further the understanding of fading as well as provide a direction for future research. For example, by viewing the problem of transfer of stimulus control as a continuum with fading or facilitated transfer at one end and blocking or impaired transfer at the other, one can direct the search for controlling variables to those that would affect
movement along the continuum. This view of fading eliminates the apparent contradiction of outcomes of fading and blocking. However, the identification of the controlling variables is still incomplete. Once determined, they would allow for systematic variation to produce varying degrees of blocking or transfer of stimulus control in specific training programs. As has been discussed, it appears that when and how the S- is introduced, as well as the physical dimensions of the stimuli are important variables in determining the rate of acquisition of a discrimination. How these particular variables interact with each other would also need to be evaluated if a comprehensive account of stimulus control is to be achieved.

In spite of the lack of a complete understanding of the controlling variables involved in fading, the procedures have been widely used with a variety of responses and subject populations. The many studies that appear in the literature have reported varying degrees of success in discrimination learning with minimal errors. Perhaps when the parameters have been identified, the results of many studies can be re-examined and explained. Until that time, attempts to isolate the important features will continue as the use of fading procedures continues. It seems that a major problem confronting applied researchers which prevents a totally systematic approach to identifying parameters
is that the immediate needs of clients and available resources often direct the course of the investigations. However, commonalities can be found among the features of the reported studies from which the importance of particular variables can be inferred. Once the variables have been isolated in this manner, they can then be subjected to a complete experimental analysis.

The following sections of this paper will be devoted to a discussion of the applied research in the areas of fading and "errorless" learning. The original applied studies of fading grew from attempts to test Terrace's notions on errorless training. Later studies focused on an investigation of some of the effects of errorless training on retention and transfer of the learned discriminations using a variety of populations. Throughout the discussion, reference will be made to concurrent studies conducted in the animal labs which often provided the impetus for the applied research.

Applied Research in Discrimination Training

In 1964, Moore and Goldiamond reported an early study on errorless discrimination using Terrace's procedures with human subjects. They trained a form discrimination with pre-schoolers using a delayed match-to-sample format. In a delayed match-to-sample procedure, the subject is shown a sample for a few seconds after which it is removed from
A row of choice stimuli are then presented (one of which is identical to the sample), and the subject is asked to choose the one that is the same as the sample.

Two series of stimuli were developed, a faded series and a full presentation. The faded series transferred stimulus control from a brightness dimension to a form dimension whereas the full presentation represented a control procedure with all the stimuli at full intensity. In the fading series, the correct choice was always at full intensity. The incorrect choices were initially dark and intensity was gradually increased as the program progressed. The experimenters varied the point at which the fading series was introduced and terminated for each of the six subjects. This enabled them to examine several variables such as the effect of prior training with full intensity on performance, the dependence on the irrelevant cue of brightness, and the need for fading in order to acquire the discrimination.

For all subjects, the fading procedure was necessary to achieve performance at greater than chance levels. The subjects who received predominately faded training made fewer errors and established the discrimination in less time than those who were trained primarily with the full series. Examination of individual data revealed that most subjects were dependent on the brightness cue until very
late in the series and that performance was disrupted by introducing the criterion series before fading was completed. In some cases, after the introduction of the full series, backtracking on previously mastered fading trials was necessary before accuracy was restored. This study clearly demonstrated one of the advantages of using a fading procedure which consequently affected its popularity. It was more effective in teaching a discrimination than the traditional trial-and-error methods and it succeeded in a case where the other method failed.

The usefulness of errorless procedures was shown in several studies by Sidman and Stoddard (1967), Stoddard and Sidman (1967), and Touchette (1968) with severely and profoundly retarded boys, a population of subjects generally regarded as unable to learn. Using the rationale that errors are the products of the teaching methodology (Skinner, 1961) and procedures that eliminate errors from the learning process make learning easier for those who originally had difficulty, Sidman and Stoddard developed a fading program to teach a circle-ellipse discrimination.

In the Sidman and Stoddard study, stimuli were presented on the outer eight keys of a nine key matrix. The subject's task was to select the circle from the ellipses by pressing the correct key. The first group of subjects, the Program Group, received a fading sequence consisting of
background fading followed by ellipse fading. A back-up procedure was in effect where an error on any trial resulted in the representation of the preceding array of stimuli. The second group, the Test Group, received conventional trial and error training that consisted of two components. First, the subjects were presented with the circle-ellipse problem. If a subject did not master the discrimination, he was presented with a form-no form discrimination also in the conventional fashion and then re-tested on the circle-ellipse.

The results showed that 7 out of 10 children in the Program Group learned the discrimination although not without making mistakes. In the Test Group, only one subject mastered the discrimination with the first presentation of the circle-ellipse stimuli. Of the remaining 8 subjects who received the form-no form test, 6 were able to master it but only 3 were able to acquire the circle-ellipse discrimination on the second presentation. In the overall analysis of the data, the subjects in the fading group established the discrimination in less time and with fewer errors than the test group subjects.

This study is interesting as it demonstrates again that fading procedures can succeed where trial-and-error training cannot. In addition, it points out that other factors besides a slow, gradual introduction of the S- can
effect the outcome of training (i.e. whether or not errorless acquisition is achieved). A training program, with many alternative choices may occasion errors in the fading program. Sidman and Stoddard carefully examined the errors emitted by their subjects and found that imperfections in both the arrangement of contingencies and in the use of a back-up procedure often resulted in reinforced error patterns which interfered with the subjects' ability to learn the appropriate response.

In a follow up study, Stoddard and Sidman (1967) investigated the effects of errors on children's performance on the circle-ellipse discrimination. Using a procedure to establish thresholds of circle-ellipse differentiation, they designed one program to generate errors and one program to reduce the probability of errors. In the first phase of the experiment, all the subjects were given the original circle-ellipse discrimination program. In the second phase, the control group continued through the fading program until their detection thresholds were reached. The experimental group was advanced to the last stage of the program where the circle was virtually indistinguishable from the ellipse but with each error the program backed-up one step thus making the discrimination slightly easier. When the child could reliably select the circle that stage became the reverse order threshold. Once this threshold
was established, the forward program was administered. The subjects in the experimental group displayed discrepant threshold values when the reverse order and forward values were compared. The results of the comparison showed the reverse order levels were lower than the forward levels. These data suggest that errors have an adverse effect on performance.

The experimenters also noted the occurrence of error patterns in the experimental group. Once established, these error patterns would appear whenever the subjects were faced with discriminations they were unable to solve. The effects of error patterns were quite severe in two instances where the subjects did not recover the appropriate response.

Sidman's and Stoddard's results were further supported by Touchette's work (1968) with retarded boys. He examined the effects of trial-and-error learning on criterion and retention tests of a position discrimination. With a three-key response panel, a small black square was presented on either side of the center key and subjects were trained to press the key nearest the square. A trial-and-error procedure and a fading program were given to two groups of subjects in different orders. The instructional value of fading procedures was once again demonstrated. The results showed that more boys who were initially trained with the fading program learned the discrimination than
boys who received the traditional training first. Those subjects who did not learn with the conventional approach were able to learn with the fading procedures, however, their performances on criterion and retention tests were clearly affected by the prior trial-and-error learning. This finding was especially evident when error patterns were examined. Subjects who had exhibited error patterns during conventional training also exhibited the same patterns on the criterion and retention tests.

The studies reported so far have all demonstrated the success of fading procedures and their superiority to traditional training when comparisons are made on the basis of errors during acquisition and retention. In all cases, fading consisted of a slow gradual presentation of the S-, which was one of the important procedural variables affecting error rate. The discriminative stimuli were mainly intradimensional (e.g., circle-ellipse, left-right position). As intradimensional training is generally considered difficult, it is not surprising that a fading program was successful in reducing errors. Another feature common to these studies but not often addressed in the literature which may bear consideration is the issue of the task difficulty relative to the abilities of the specific subject population. Although Mosher and Reese (Note 4) examined the effects of increasing difficulty on acquisition,
retention and transfer of a word recognition task, the subjects were always able to master the words with or without the aid of a fading program. In each of the studies mentioned above, the subjects were unable to master the task during traditional training. Additional assistance in the form of a systematic presentation of the S- was required before the problems were learned.

It should also be noted that errors did occur during the fading programs. This again points out the limitations of errorless learning. For example, it would be possible for the experimenters to define "errorless" to fit the performances of their subjects but doing so would not further the understanding of important issues of how stimulus control is acquired with a fading program. Instead it seems that concentrating on the parameters that determine the effectiveness of fading procedures would be more beneficial from both a practical and theoretical standpoint.

Another consideration for the practical uses of fading techniques is the effect of the program on student behaviors other than the rate of errors. Results from Hively (1962) and Stoddard and Sidman (1967) already indicated one potential problem: the development of error patterns as a result of the reinforcement contingencies present in the program. In Hively's match-to-sample format and Stoddard and Sidman's multi-choice discrimination problems, it was
discovered that error patterns developed when subjects continued to respond after an error until the correct response was emitted. In such instances, the entire chain of events was reinforced increasing the likelihood of it being repeated and reinforced again. They also found that the use of a back-up or correction procedure often resulted in the reinforcement of behaviors that were incompatible with learning the task (e.g. perseveration and circling the key matrix). Sajwaj and Knight (1971) in a tutoring program with a young retarded boy reported that a correction procedure in which the missed frame was repeated after correction actually reinforced the occurrence of errors.

Sidman and Stoddard (1967) attributed the appearance of error patterns to the ineffectiveness of extinction as a teaching technique. This may be particularly true with retarded populations. When extinction is coupled with reinforcement for a pattern of errors, the error patterns are strengthened. This may be seen more clearly as an instance of intermittent reinforcement of inappropriate discriminatory behavior. That is, the subject may be responding on the basis of an irrelevant dimension (e.g. position of the stimulus) which is reinforced periodically when it corresponds to the experimenters' definition of a correct response. Sajwaj and Knight speculated that the represented item acted as a conditioned positive reinforcement.
for errors and thus superstitious chaining resulted. Both explanations have some merit and indicate that the training apparatus, the program, and the type of client, as well as the progressive presentation of stimuli can influence learning.

The results achieved with fading programs are particularly exciting for the field of special education. However, being aware of the effects of fading programs is essential if successful programs are to be developed for widespread use. Armed with the knowledge of fading procedures, training can be extended to individuals and tasks that otherwise might not have been attempted.

There may, however, be some serious disadvantages to fading, particularly following training. Considerable research has been concerned with the after effects of progressive training programs. The problems and potential negative effects of fading will be discussed below.

Reversal Training

One of the first areas to be investigated in relation to the effects of fading programs was discrimination reversal training. In a reversal study, a discrimination is established and when the subject is responding appropriately to the discriminative stimuli, the stimulus values are reversed. That is, the former S+ is paired with extinction, and the former S- is paired with reinforcement.
In two experiments with the California Sea Lion, Schusterman (1966; 1967) demonstrated that sea lions develop preferences for size and shape and that these preferences could be reversed without errors through the use of fading procedures. In comparison, he attempted to reverse the preferences with a minimal amount of training and was not successful. Not only did the animals fail to learn the reversal but the persistent errors had an adverse effect on performance when the previously mastered discrimination problem was reinstated. However, the same subjects were able to learn the reversal with progressive training. In his second study, Schusterman replicated the results of the first study and went on to demonstrate that repeated reversals could be obtained without error via the fading techniques.

In the control portion of his experiment, Schusterman reversed the stimulus values for the subjects without implementing a fading procedure. These subjects had learned the original discrimination with fading and acquired it with only a few errors if any at all. The reversals, on the other hand, were not easily learned. The first trial showed the animals responding at a high rate to the S- (the former S+). It was apparent that the behavior was still under the control of the original S+. With continued reversals, through, the number of errors emitted during
acquisition decreased considerably.

Marsh and Johnson (1968) studied the acquisition of reversals with pigeons following progressive discrimination training. The performances of subjects in the fading condition were compared to a control condition in which the birds were trained to respond only to the S+. The control group was not exposed to the S- during initial training. Once responding was established, the values of the discriminative stimuli were reversed for the experimental subjects and the control birds were presented with the S-. The results showed that the birds in the fading condition were unable to learn the reversal whereas responding to the S- by the control birds underwent extinction. For the fading group, the number of responses to the S- decreased across sessions and the resulting graph resembled the curve obtained from the control group, but responding to the S+ (the former S-) did not increase, indicating that stimulus control was not achieved.

These results point to potential disadvantages of fading procedures. They may lead to inflexibility. Although Schusterman's sea lions perseverated on the first trial, they did eventually learn the reversal. Perhaps the contrast with Marsh and Johnson's subjects who did not learn the reversal can be attributed to the fact that they are different species or that preferences were established
with Schusterman's subjects. Other factors that easily could have influenced the outcomes of the studies include the length of the original discrimination training, the number of steps in the fading programs, the length of individual experimental sessions, and others. In any event, both sets of data indicate that a discrimination learned with fading procedures may limit the organism's flexibility in approaching novel learning experiences.

Gollin and Savoy (1968) studied the problem of reversal learning with human subjects. They worked with young children on a form discrimination task using two sets of compound discriminative stimuli. During training, the forms triangle (S+) and circle (S-) were placed up on a single-striped background. In the reversal condition the stimulus values were reversed and the backgrounds were changed to multi-striped patterns. The third phase of the study, a conditional discrimination task, consisted of presenting subjects with the form-background stimulus combinations that were used in original and reversal training. Success required that the subjects respond to the S+ combinations that had been reinforced in both phases. The performances of subjects trained with fading procedures, modified fading, or trial and error method were compared during all three phases of the study.

In the fading group, a brightness dimension was used
as the irrelevant cue and the brightness of the S- was faded until it reached the full intensity of the S+. The traditional group received trial-and-error training with all stimuli at the same intensity. The modified fading group had a shortened version of the fading program.

The results showed that very few errors were made by the subjects in either fading group or the original discrimination and reversal tasks. The traditional group conversely, made many errors on the same two tasks. The results of the conditional discrimination task, however, were quite different. In that phase of the study, 40% of the group presented with traditional training acquired the conditional discrimination errorlessly in comparison to only 4% of the fading groups. It appears that the traditional procedure facilitated the performance on the transfer task. This finding also indicates that an outcome of training via fading procedures could be limited adaptability of the subjects. Gollin and Savoy commented on this result in the following statement:

The success of the majority of subjects in the traditional group on the conditional discrimination test suggests that in transfer paradigms of the type used in the present experiment, access to S+ and S- compounds throughout training can be efficacious. The gradual introduction of the S- compound in the fading procedure may not provide the subject with sufficient comparative experience to permit efficient transfer. (p. 405)

Gollin and Savoy's concept of sufficient comparative
experience is intuitively appealing, although further specification would be useful. After a moment's consideration, it becomes clear that there are several possible types of "comparative experience" none of which would be sufficient. One would assume that the authors were referring to an experience which would direct the subject's attention to the components of the stimulus compounds. For example, it is questionable whether continued presentations of the S+ and the S- compounds following the end of the fading sequence could improve the acquisition of the conditional discrimination task. Such a procedure could certainly be categorized as comparative experience yet would not seem to provide the necessary conditions for developing stimulus control of the individual features of the compound. Without stimulus control by the components, success on the conditional discrimination task would be limited. It is possible, though, to envision a programmed sequence which could achieve the necessary control in a systematic fashion. The cost-benefit of such a program might warrant careful consideration especially in view of the success of the existing traditional method.

The suggestion that comparative experience after fading would improve the transfer after fading falls short of explaining why this would help and why the results occurred. One plausible explanation can be derived from a comparison
of the design of the study to the blocking paradigm discussed earlier. Similarities in the two procedures are apparent as well as in the resulting data. Most striking is the finding that the fading group (experimental group) demonstrated impaired stimulus control in relation to the traditional training group (control group). In the blocking paradigm, the initial training with half of the components of the stimulus compound "blocked" the acquisition of stimulus control by the other features of the compound. The same can be said of Gollin and Savoy's findings. Stimulus control by the background components may have been "blocked" by the explicit training with the forms (circle and triangle) during original and reversal training. Although the blocking design itself does not completely explain the specific mechanisms that are operating it does provide a framework from which the results of this study as well as others can be interpreted.

The problem of acquisition of discrimination reversals following fading or progressive training was investigated by Robinson, Storm, Fortucci, and Hubbard (Note 6) using a variation on typical fading procedures. Rather than fade along a dimension of the S- they employed a graded-choice procedure which fades in the opportunity to respond to the S-. This is accomplished by means of a retractible manipulandum which can be either withheld or presented to
the subject. In Robinson et al's study, colored lights were used as the discriminative stimuli and were located on a panel above the response manipulandums. In the early phases of training with the graded-choice procedure, subjects were taught to respond to the S+ light. At this stage, the S- light was not illuminated. Once responding stabilized, the S- light was presented but without the response key. As trials progressed, the availability of the manipulandum was gradually decreased until it was present for the full length of each trial. Previous research conducted by Storm and Robinson (1973) demonstrated the success of the graded-choice procedure in teaching discriminations with few errors.

Robinson et al. compared performance on reversal tasks following training with the graded-choice procedure or the trial-and-error method. The results were consistent with other studies that used fading along a stimulus dimension in that the graded choice group made fewer errors in acquisition of the discrimination than the traditional group. Similarly consistent was the finding that on the reversal task, the subjects in the graded choice group made many more errors than the traditional group and they perseverated on responses to the S-.

Robinson et al. conducted a second study where the effects of a graded-choice procedure and verbal instructions
on the number of errors emitted in a reversal task were compared to a trial-and-error method. They also examined individual data to determine the distribution of errors during reversal. The results supported the findings in the first study, and in addition, demonstrated that verbal instructions could be used as a procedure to teach a discrimination without errors. On the reversal task, in both conditions that promoted errorless learning, perseveration was observed on the first trial. The subjects were able to learn the discrimination but in comparison to the trial-and-error group, they made many more errors on the initial trial. However, on subsequent reversals, the number of errors on the initial trial decreased significantly.

Aside from the contributions of this study and others reported on the problem of discrimination reversal learning, the results offer some additional insights on the requirements of a successful fading program. Further, they identify a number of important issues that should be considered when designing training programs for research and/or applied uses. A summary of these primarily practical considerations include the following:

(1) Fading programs can produce superior results (as measured by the number of errors) on the acquisition of a discrimination in comparison with trial-and-error training.
(2) When fading programs are used to train a discrimination, they do not necessarily promote as efficient transfer to a new task (eg. Gollin and Savoy's conditional discrimination task) as does the trial-and-error training method.

(3) (a) It is possible to design a fading program to facilitate transfer, and such a method would have to focus the subject's attention directly upon all the relevant components of the discriminative stimulus compounds.

(b) It is possible to train a discrimination using progressive methods that do not involve fading of the stimulus itself. Other procedures, such as the graded-choice procedure indicate that fading the opportunity to respond can also be effective in teaching discriminations "errorlessly."

(4) One must question the practical value of designing an extended fading program considering the cost-benefits and the availability of a relatively equivalently successful alternative such as a traditional unsystematic training procedure.

In addition to the considerations for program design, a summary of the research in the area of reversal learning following progressive training demonstrates that reversals
can be acquired but they are apt to be accompanied by a perseveration of the response to the S- (the former S+). As subsequent reversals are presented, subjects generally exhibit a diminishing number of errors in the first few trials of the reversal task. It was also shown that a reversal can be taught without the characteristic perseveration when a fading procedure is employed.

These findings seem to have a special significance for educators and other consumers of innovative programming. They suggest the importance of considering the environmental context in which the terminal behavior is to occur when selecting a training program. If, for example, adaptability and flexibility in response to alterations in the stimuli or stimulus environments is desired, fading procedures may not be the most efficient or even desirable training method given the problems of perseveration. However, this does not imply that such procedures couldn't be useful if careful attention was given to programming maintenance and generalization of the learned behavior.

Fading Procedures

Within the literature reviewed so far, a number of different procedures have been introduced which resulted in errorless or near errorless learning. Although the notion of errorless learning as originally presented by
Terrace has been shown to be insufficient, discovering the parameters that affect the probability of errors in a given program seems to be a worthwhile undertaking. The early studies generally faded along one dimension of the S-, although variations in the specific procedures were seen. Among the most popular methods used were match-to-sample, delayed match-to-sample, and superimposition of additional stimuli. Different programs included anywhere from two to eight alternative choices in the match-to-sample formats. Later developments in the field broadened the application of progressive techniques from fading in the strict sense of gradual alteration of the discriminative stimuli to include the gradual change in the availability of a response manipulandum and the opportunity to respond. Although the latter method technically is not fading, the procedure is analogous in both the progressive format and training outcome.

Considering the variety of methods present in the different programs, there is a question concerning the critical variables necessary for fading programs to be effective. We have already seen that a gradual change of stimuli is necessary, but the specific conditions that lead to errorless acquisition have not been fully determined.

Several studies have explored this question. McDonald and Martin (Note 3), for example, compared three types of
fading and traditional training procedures for the effects on acquisition, retention, and generalization of a discrimination. In their first of two studies, young girls were trained to discriminate color words. The procedures employed included the following:

- **Fading I**: the S+ word was initially the color it described which was gradually faded to black.

- **Fading II**: the S+ word was printed in black but a patch of color appeared on the card which was later faded.

- **Traditional I**: trial-and-error training with random presentation of the discriminative stimuli.

- **Traditional II**: same as Traditional I with the addition of color cues on each of the stimulus cards.

Results of the initial training phase of the study showed that all training formats with the exception of Traditional I, resulted in errorless or near errorless acquisition of the discrimination. The outcome of the generalization and retention phases, however, showed the Traditional I group making the fewest errors of all training formats.

The second study conducted by McDonald and Martin in the series on fading procedures, resembled the first
study but used number words and cues instead of color as the discriminative stimuli. In addition, they altered the fading procedures so that fading occurred along a dimension of the S- instead of along the S+. (In the first study, color had been added to the S+ and was gradually removed as the fading program progressed.) The result of the modification in the procedure was a change in the relative positions of the four training programs on the generalization and retention tests. Whereas the Traditional I group had shown the highest degree of generalization in the first study, the second study showed the Fading I condition with the highest generalization.

A comparison of the results of the two experiments indicates that fading on the S- leads to better retention and generalization. An examination of the two procedures indicates that fading on the S- provides a more favorable condition for developing stimulus control by the S+ than does fading along the S+. On the one hand, the properties of the S+ remain constant throughout training. When fading occurs along the S+, the additional cues or irrelevant stimuli initially present in the training program, may acquire control of responding thus lowering the likelihood that the critical features of the S+ will acquire control. This difference in results can also be viewed in terms of the extent of the contact the subjects have with the S+.
when the S+ is faded, and thus continually changing, the subjects have greater contact with the S- which remains stable throughout the program. The reverse would be true during fading along the S-. The notion here is that greater contact would allow for the development of stronger stimulus control. The consequence of this difference in procedures may not be apparent on a short term basis but the results of the retention and generalization tests indicates that it is important in the long run.

Smith and Filler (1975) also conducted a study in which fading occurred along the S+. They trained a form discrimination using either a fading or non-fading format to groups of young children. In this case, an irrelevant feature was superimposed on the stimulus and subsequently faded out. The irrelevant cue used was a blinking light which surrounded the S+. The results showed that both groups acquired the discrimination easily but the performance of the non-fading group on a post test was superior. These results are consistent with the findings of McDonald and Martin's study (Note 3) and support the contention that fading on the S- is more effective than fading on the S+.

Independent of the question of the superiority of fading on the S+ versus the S- is the question of superimposition of an additional irrelevant cue compared to
fading along a highlighted stimulus dimension. Several aspects of this question have been examined by investigators. For example, Corey and Shamow (1972) tested the effects of superimposition of pictoral stimuli and superimposition plus fading of pictures on the acquisition and retention of oral reading. In addition, they examined the effects of an "observing response" which required subjects to touch the stimulus word as they read. A comparison of the mean number of correct responses to the six training words presented after training without the pictoral stimuli indicated that fading was superior to superimposition during acquisition and retention. There were no effects of significance for the observing response. These results imply that fading is a beneficial procedure in fostering acquisition and retention of sight words. The methodology employed however, does not permit a comparison of the effects of fading along a highlighted or exaggerated stimulus dimension to superimposition of supplementary cue such as a picture of the word.

Several studies demonstrated the breadth of stimulus modalities that could be superimposed as cues and then faded in discrimination training. Already mentioned was the Robinson et al. (Note 6) study with verbal instructions. Other sensory modalities were used successfully such as fading the presence of a white noise, (Powers,
et al., 1970) and the fading of echoic, tactual, and intraverbal stimuli in a reading program with kindergarten children. (McDowell, 1968; McDowell, Nunn and McCutcheon, 1969).

Reese, Howard, and Rosenberger (1975) examined different fading procedures and their effect on teaching a line-bisection discrimination with profoundly retarded boys. They compared the traditional reinforcement-extinction program to omission training (OT) and alternative response (Alt R) with fading. The results again demonstrated the benefits of fading procedures. Subjects emitted for fewer errors under Alt R and OT conditions than reinforcement-extinction. The subjects who did not succeed in learning the discrimination were then given OT. These subjects made more errors than a comparative group that did not have a history of trial-and-error learning, thus indicating the deleterious effects of errors. This study demonstrates how fading procedures can be successfully combined with other reinforcement contingencies to bring about stimulus control. Such a technique might be a particularly good way to avoid the occurrence of error patterns. Part of the appeal of this method is that the subject can be reinforced for an appropriate response during the S- instead of developing error patterns.

In summary, it is not possible to fully delineate all
the essential procedural variables relevant to effective fading programs. However, the data gathered so far suggest that fading along the S- is superior to fading along the S+, particularly in terms of the long term retention and generalization effects. The question of whether superimposition of additional cues is more efficient than fading of an exaggerated feature has not yet been answered. Speculation on the success of the two procedures would favor fading along a highlighted critical stimulus feature, primarily because this procedure directly focuses the subjects' attention to the distinctive aspects of the stimulus. Where fading of a superimposed cue (such as the blinking light) occurs, the subject can respond correctly without attending to the stimulus for a major portion of the program.

The use of complex discriminative stimuli and fading procedures further complicates the issue as in Mosher and Reese's (Note 4) word recognition program which uses size fading of selective letters in the word to draw attention to the actual configuration of the words. The only letters faded in this program are the ones in the alternative choice words which are not in common position with the training word. In a sequence of five fading steps, the initial small size of the faded letters is gradually enlarged to full size. (See Appendix A for sample of the fading format). The irregular appearance of the alternative
words is designed to focus attention to the specific letters; however, it is possible for subjects to discriminate the correct choice by simply selecting the word fully printed in block-letters. Whether or not subjects attend to the actual letters or rely on the overall shape of the printed word may depend on other factors such as the number of letters the alternative and training words have in common. (See Mosher and Reese, Note 4, for a discussion of task difficulty.)

**Emotionality**

A major issue that has emerged from the research on fading concerns the effects of discrimination programs on subject behavior during training. The concept of emotionality has frequently appeared in relation to the subject's behavior. Many of the animal and human studies discussed so far have reported instances of "emotional" behavior during trial-and-error phases of the investigations. Depending on the subject population, emotional behavior has been defined as agitated behavior, wing flapping and foot stomping in pigeons, escape responses, verbal outbursts and in some cases, crying in children. The lack of emotional responses during errorless or fading programs has been attributed by some researchers to the fact that the subjects have not had to experience unreinforced trials to the S− (Terrace, 1966). Extinction
studies frequently report emotional behavior as a side effect of the procedure therefore it was not regarded as unusual that emotional responses accompanied the extinction trials present in trial-and-error programs.

Emotional behavior was reported in Terrace's original study with pigeons (1963a) in which the birds in the traditional group flapped wings and stamped the floor in comparison with the pigeons in the progressive group who stood quietly facing the key during the S-. Schusterman's report on sea lions (1966) cited instances of emotional behavior by the members of the control group who did not receive errorless reversal training. In the human studies, Stoddard and Sidman (1967) reported that the subjects in the high error condition often asked to leave and wished to discontinue the experiment. Powers et al. (1970) noted that preschool children in the conventional training group of a program training a fine color discrimination, banged the apparatus and roamed around the experimental room whereas children in the fading group were attentive to the stimulus panel and sat relatively still. Both Reese, Howard and Rosenberger's (1975) and Mosher and Reeses (Note 4) studies with retardates reported the occurrence of collateral behaviors that could be termed "emotional" during the S- trials of the reinforcement-extinction procedure. The collateral behaviors were not observed during
other training procedures where errors occurred infrequently.

Terrace (1974) investigated the nature of responding during the S- in a study with college undergraduates. Using a joystick as a manipulandum, he instructed the students to pull the stick towards them each time a square was flashed on a screen and to hold onto it at all other times. A transducer attached to the stick measured the force applied in opposite directions. This tendency to push in the opposite direction was considered as an antagonistic response, analogous to the emotional behaviors in other studies. He found that the frequency of antagonistic responses increased with errors during discrimination training and did not increase when errors were emitted and placed on extinction.

It is apparent from the data, that errors are often accompanied by emotional responses during traditional discrimination training. Reducing errors and the interfering emotional behavior through the application of fading procedures seems like an appropriate solution to the problem. However, in light of the disadvantages of fading procedures discussed earlier, one might wish to carefully weigh the relative advantages of implementing a fading technique just to safeguard against emotional behavior.

Several studies have investigated combining fading and traditional procedures into one treatment as a means
of obtaining the best of both methods. Reese, Muench, and Mustaine (Note 5) trained pigeons in a two-key response situation on a color discrimination. Pigeons learned to peck the right key on red and the left key on green by one of three procedures. The trial-and-error group was trained with the key lights at full intensity, whereas the fading group had color faded in on both keys. A combination group received fading on one stimulus key and trial-and-error training on the other. Once the color discrimination was established, the schedule of reinforcement was extended to a VI 45 second schedule. Collateral behaviors were observed and considered a measure of stress. During the second phase of the experiment, another discrimination was trained followed by a return to the original color problem. One response was then extinguished and finally, eight to ten weeks later, a retention test was given.

Consistent with other fading studies, the progressive group emitted fewer errors than either the traditional group or the combination group. During the extension to the VI 45 schedule, the trial-and-error birds displayed more emotional behavior than any others. In the extinction phase, the fading group performed most persistently. An interesting result was that the responses of the birds in the combination condition extinguished most rapidly and they did not exhibit any emotional behavior. This implies
that a combination of procedures might alleviate some of the disadvantages encountered in using either procedure alone.

In a study with human subjects, Mosher and Reese (Note 4) used fading, non-fading, and a combination of these procedures to train retarded adolescents and adults to recognize safety words. A retention test and a variety of transfer tasks were administered to all subjects after they reached criterion on initial word training. The results showed that the subjects in the non-fading condition consistently made more errors than either the fading or combination groups. Further, the subjects in the combination group demonstrated superior retention and transfer task performances in comparison with the other training conditions. In addition, emotional behaviors such as swearing, crying, and fist banging were observed in the high error condition but were not present in the combination condition.

The question of why the combination procedure, which in this instance consisted of alternating training of fading and non-fading words, would promote superior retention and transfer was considered by the authors. One explanation offered was that the non-fading component of the combination procedure provided the subject with the
necessary amount of comparative experience or additional contact with the relevant features of the discriminative stimulus while the fading component reduced the probability of errors and thus reduced the likelihood of accompanying emotional behaviors. This explanation implies that the occurrence of emotional behavior interferes with the acquisition of the discrimination.

A second explanation, similar to the one above, focuses more directly on the procedural aspects of the training formats used. That is, the authors suggest that the alteration of fading and non-fading training may actually train the subject to attend to the relevant stimuli (in this case the configuration of the word) sooner than would be required were fading alone employed, since fading procedures provide an irrelevant stimulus cue (eg. size of the letters) which subjects could depend on for the major portion of training. In the example of the word recognition study where stimulus control was transferred from a size dimension to the letter forms, interspersed traditional training may have taught the subject to attend to the form of the letters rather than to rely on the size cue until it was completely faded. In order to test this hypothesis, a means of measuring the point of transfer of stimulus control would be required.

One method that has been successfully used for this
purpose is the probe trial. Schusterman (1967) Fields et al. (1976), as well as Moore and Goldiamond (1964) used probe trials to determine if stimulus control had shifted to the relevant stimulus dimension. A probe trial represents a presentation of the criterion discrimination in the midst of a fading sequence. The point at which the subject can successfully execute the criterion trial is the point at which one can assume control had shifted.

Touchette (1971) devised a method for measuring the moment of transfer. He trained boys to discriminate red and green and then used color as a means of transferring control to a form discrimination. The red stimulus (S+) was superimposed over the S+ of the form discrimination. Each time the subject correctly responded the onset of the red stimulus was delayed by 0.5 seconds. Thus, when the subject was able to respond prior to the appearance of the color, the transfer of stimulus control would be complete. This procedure would provide the experimenter with a measure of the number of trials to transfer. Touchette, like Schusterman, found evidence that the point of transfer differs from subject to subject. However, a range of the differences could not be determined as the number of subjects used was too small.

The probe trial procedure provides an opportunity for an experimental analysis of the effects of the components
(fading and non-fading training formats) of the combination training package. It allows for an evaluation of the idea that the combination procedure facilitates the transfer of stimulus control by maximizing the benefits of fading and non-fading while minimizing the negative effects. This could be accomplished by inserting probe trials in the fading sequences of both the combination and fading training programs. If the non-fading component of the combination method does, in fact, facilitate earlier transfer of stimulus control one would expect differences to appear on the probe trials. It would seem reasonable for subjects in the combination group to respond correctly to probe trials placed earlier in the fading sequence than subjects trained strictly via fading.

However, probe trials alone will not prove whether or not the fading component has any effect on the occurrence of emotional behavior. Along with the probe trials, a direct measure of emotional behavior would be required. In the literature reported to date, emotional responses have primarily been inferred from a variety of collateral behaviors that occurred during the extinction phase of the traditional discrimination training procedure. The benefits of using a direct behavioral measure such as collateral behavior, physiological responses, reports of anxiety, etc. as indicators of emotional responding is that
they provide measures that are directly observable and quantifiable.

To summarize the research findings that have been reported, the following list presents the major conclusions that can be drawn from the literature on errorless learning and fading procedures.

1) Fading or progressive procedures can result in acquisition of a discrimination without errors (responses to the S-).

2) Errorless acquisition is potentially desirable as evidence exists which shows that errors in training can disrupt previously learned discriminations.

3) Variables that affect the number of errors that occur in a fading program include:
   a) dimensionality of the discriminative stimuli (inter- or intra-dimensional)
   b) rate of introduction of the S-
   c) rate of fading or gradual change of the discriminative stimuli until the final form is reached
   d) the stimulus (S+ or S-) along which fading occurs
   e) whether fading occurs along a highlighted stimulus dimension or along a superimposed cue
   f) difficulty of the task.
4) Outcomes of training with fading procedures can include:

   a) impaired acquisition of discrimination reversal problems characterized by perseveration of the response that was originally correct
   b) impaired stimulus control relative to a control group trained under traditional trial-and-error procedures as a function of the variables in the fading program, (eg. superimposition of cue or highlighted stimulus dimension).
   c) Either inferior or superior retention and transfer in comparison with other training procedures (eg. combination method, or trial-and-error), depending upon the study.

5) Training with fading procedures seems to lower the probability of emotional collateral behaviors occurring.

6) Fading procedures used in combination with other procedures may provide a situation which maximizes the benefits of the procedures while minimizing the negative effects.

Based on the research findings concerning fading and the development of stimulus control, particularly the study of the effects of using a combination of fading and non-fading methods, an experimental procedure was designed to explore the reported superiority of the combination
method. Of interest, was the question of why the alternation of fading and non-fading words resulted in significantly better retention and transfer. Using probe trials, the present study proposed to determine if the combination method promoted an earlier or faster transfer of stimulus control from the irrelevant cue to the relevant stimulus properties than did fading alone. The subject population used was comparable to that of earlier research, (eg. Mosher and Reese, Note 4) and identical stimulus materials were employed. The design included a comparison of the results of combination training to both fading and non-fading procedures used alone. This provided an opportunity to investigate the question of transfer of stimulus control as well as serving as a replication of previous work in this area.
METHOD

Subjects

Fifteen residents of the Manfield Training School, a residential facility for the retarded in Mansfield, Connecticut, served as subjects. Selection was based on performance on the Wide Range Achievement Test (WRAT) and a pre-test consisting of all the training words used in the study. The WRAT scores ranged from the Kindergarten, 2nd month level to the First grade, 3rd month level of reading ability. Scores within this range indicate that the subject is able to identify several letters of the alphabet and at the upper level can read a few three and four letter words. Prior knowledge of the training words was assessed by presenting three trials of each word and asking the subject to point to the word pictured at the top of the page. Any subject who correctly selected the word two times was excluded from the study.

The ages of the residents who participated as subjects range from 16 year 9 months to 42 years 8 months. All subjects had been previously tested on a standardized intelligence test. The measured I.Q. scores ranged from 42 to 59. Twelve of the fifteen subjects were residents in co-educational cottages that operated on a token economy. The residents were responsible for the maintenance of the
cottage and each person had a number of daily chores assigned to him. The other three subjects lived in a larger dormitory which had been re-modelled within the last five years.

Permission to conduct the study was granted by the Human Rights Committee at Mansfield Training School. In addition, all were invited to participate in a reading program and informed that they could withdraw their participation at any time.

Apparatus

A display board consisting of a wooden base (64 x 36 cm) and a sliding metal occluder (44 x 27 cm) was used to present two pictures and a row of words, one of which corresponded to the pictures. Words and pictures were printed on 8½ x 11" sheets of paper. The board is illustrated in Figure 1. The occluder was designed to permit a continuous view of the line drawings placed on the left hand side of the training sheets while the individual trials were presented.

Reinforcements in the form of "stars" were provided for each subject after each correct response. At the end of the training session earned stars could be traded in for back-up reinforcers such as small charms, trinkets, candy and other edibles.
Fig. 1: Apparatus Used for Match-to-Sample Training.
Setting

Training took place in the living areas of the residential quarters of the subjects participating in the study. In each of the different buildings, a sitting room with chairs and a table were available. However, these rooms were not secluded, and during training other residents often observed the program. Observers were permitted to remain nearby if they watched quietly and did not offer any help to the subject.

Materials

Eight, common, five and six letter words were prepared for training in both a faded and non-faded format. Materials required for the full program included a face sheet, training, review, and retention trials, and five transfer tasks for each word.* The words used in the study were: chair, child, purse, shower, smoke, stairs, square and wheel. Preparation of each word consisted of the following:

1) Illustrations: Two line drawings illustrating two uses of each word were obtained.

2) Cover or Face Sheet: The cover sheet contained the two illustrations and the written word which they represented.

3) Training Sheets: 15 training trials for each word

*We are grateful to Mosher and Reese for lending us their apparatus and stimulus materials.
were prepared in the faded and non-faded formats. A trial contained a horizontal row with four words, one of which was the training word. The three alternative choice words each had two letters in a common position with the training word. This stipulation was included as a means of control for the level of difficulty for the choices. (See Mosher and Reese, 1976, for a full discussion of difficulty level.) The first page of the two pages of training trials had a sample of the word presented at the top of the page. The illustrations were located to the left of the words and were always in view. (See Appendix A for sample training materials).

a) **Non-faded format**: 15 trials were prepared with all choices printed at full size.

b) **Faded format**: The fading condition consisted of five fading steps with three trials at each step for a total of 15 trials. In each trial, the correct choice (training word) was presented at full size regardless of the fading step. Fading occurred in the incorrect choices, and only on the letters that were not in common position with the training word. These letters were printed smaller than the other full size letters and with each
fading step were gradually increased in size. At Fading Step 5 all letters of all words were at full size.

4) **Training Sheets with Probe Trials:** In addition to the training sheets described above, fading sheets with probe trials were prepared for each word. A probe trial was a trial in which all words were printed full size inserted between the three trials of a fading step. Probe trials were placed in Fading Steps 1, 2 and 3 between the second and third trial of each.

5) **Review Sheets:** Nine trials for each word were arranged in both the faded and non-faded formats. The illustrations were included and placed on the left hand side of the review page. The non-faded trials were all at full size. The faded review sheets contained three trials each at Fading Steps 1, 3 and 5 (See Appendix B for sample review materials).

6) **Retention Sheets:** In the retention phase, three full size trials were printed on 5½ x 8½" paper with the illustrations placed at the top of the page instead of at the side. As in training and review, the alternative words had two letters in common with the training word. (See Appendix C).
7) **Transfer Tasks:** Five transfer tasks (TT) which will be described below were used. In all tasks, the words and the alternative choices were presented at full size. (See Appendix D for a sample of each transfer task).

**TT1:** This task presented the subject with three drawings, one of which contained the training word. A short narrative was read, and the subject had to select the most appropriate picture. The narrative did not specifically mention the training word, nor was the picture similar to those used in training. One of the incorrect words began with the same letter as the correct word. This task was designed to test the subject's knowledge of the concept.

**TT2:** This task, called the square format, consisted of four choice words placed around the centrally located illustrations, forming a square. The subject had to select the training word.

**TT3:** This was a flash card task. Each word was presented to the subject individually and did not contain the picture cue. The subject was asked to verbally respond to the word on the card.

**TT4:** For this task, cards with the illustrations, training words, and choice words printed on them individually were prepared. Two cards with the
Illustrations were placed on the table. Four cards, each containing a word learned during training, were placed below the drawings and the subject was asked to point to the training word. TT5: This task was the same as task #4 with the exception that the choice words were other than those words that had been learned during the course of the experiment. The comparison words all contained two letters in a common position with the training word.

Preliminary Training Materials

In order to familiarize subjects with a match-to-sample task, preliminary tasks were devised. The materials used included the following:

1) **Color Matching**: Subjects were asked to place colored squares on the corresponding color on a display sheet containing five patches of color.

2) **Picture Matching**: A row containing four line drawings of familiar objects (e.g. drinking glass, fence) were presented in a trial. A sample picture was placed to the left of the choices. The subject's task was to select the picture that matched the sample.

3) **Preliminary Word Training**: Two, 3-letter words (cat, dog) were prepared in the non-fading format
described above. Two trials were given for each word, and the alternative choices had no letters in common with the training words.

Procedure

Preliminary Training.

Preliminary training on the match-to-sample tasks outlined above was conducted prior to the start of the experimental procedure.

To stimulate the conditions during actual word training, the trials were presented one at a time by means of the display board and sliding occluder. The subjects were required to circle the correct choice. The three preliminary training tasks provided a progressively more difficult task. The word training is a delayed match-to-sample task. Once the subject circled the sample, it was covered by the occluder as each trial was presented. The illustrations, however, were always in view and served as a reminder of the word sought.

The three phases of preliminary training took place during the first session and required approximately 15 minutes per individual. In all phases, after each correct response, the subjects received verbal praise and were awarded "stars" on individual tally sheets. At the close of the session, subjects had the opportunity to trade in their stars for a variety of trinkets and edibles.
General Procedure.

After preliminary training, the subjects were randomly assigned to three experimental groups, fading (F), non-fading (NF) and combination (C) which represented a combination of fading and non-fading procedures. To teach the eight words, training sessions were conducted four or five days a week for two weeks. (See Table 2) Each session lasted between 20 and 30 minutes, during which time a maximum of two words were trained. The order of word presentation was counterbalanced for each group of subjects to distribute order effects. The following table lists the word order used for each group of five subjects.

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Order of words trained. Three subjects (one from each training condition) received each word sequence (A, B, C, D or E).

Training.

In all three conditions, F, NF, and C, the essential training procedures were identical. The criteria for training described below, differed depending on the training
word format. Initial introduction of the training word was accomplished by presenting the cover sheet and discussing the concepts illustrated by the drawings. The subject was then instructed to find the word that represented the pictures on that page and to circle it. Next, the first training sheet was inserted into the occluder so only the illustrations and the correct word were visible. The subject circled the word and was instructed to say the word as he circled it. The experimenter proceeded to move the occluder down the page revealing individual trials for the subject's response. Each time a word was circled, the subject repeated the word.

Reinforcement.

During training and review sessions (described below), each correct response was followed by verbal praise and the subject was given a "star" on a tally sheet. Praise generally consisted of statements such as "That's right", "Very good", or "Good, you picked the right one". Stars were drawn on the tally sheets by the experimenter. At the close of the session, stars were traded in for a choice of edibles, small charms, or other trinkets. The supply of edibles varied from session to session.

Whenever an error was made, praise was withheld. Instead, the experimenter simply said "Let's try the next row".
Criteria.
Training continued until the criterion for the particular condition was reached. They consisted of the following:

Non-fading. The minimum acceptable criteria was 10 out of 15 trials correct, with the added stipulation that 3 out of the last 5 trials also be correct. If the criterion was not reached within the initial 15 trials, additional trials were presented until the criterion was met.

Fading. Due to the differences in the nature of the two training formats, the criteria were slightly different. In the fading condition, the criterion was 2 out of 3 trials correct on the final fading step (all choices full size). In addition, if 2 out of 3 errors were made at any fading step, a back-up procedure was implemented. This involved a return to an easier fading step and working back through the program until the criterion was reached. If an error occurred on Fading Step 3, 4 or 5, a subject was moved back two fading steps to insure that a correct answer would be obtained on the next trial.

Combination. The criterion for each word was determined by the particular training format used, fading or non-fading. In both instances, the criteria remained the same as described above.
During each training session, two words were trained and subjects were awarded stars and received verbal praise for each correct response. Before terminating the session, subjects exchanged their stars for small charms or pieces of candy.

**Review.**

Each training session was devoted to a review of the words learned during the preceding session. Review consisted of nine additional trials presented in the same format as original training. As described above, review of a fading word consisted of three trials at fading steps 1, 3 and 5. As in training, the criteria depended on the format. For fading words, 2 out of 3 correct responses to fading step 5 were necessary, and in the non-fading format, 3 out of the last 5 trials had to be correct for review to be complete.

**Retention and Transfer.**

After the completion of training and review, retention and transfer tasks were administered for each word trained. Measures were taken approximately 1 day, 8 days, 16 days and 56 days after training. In each session, the retention test was given first followed by the five transfer tasks. During the retention phase, the occluder was used to present trials singly. This prevented the subject from using responses on the previous trials as prompts. The retention
and transfer phases of the study differed from training and review in that feedback on the accuracy of the subject's response was not delivered. However, all praise was not withheld. Subjects were frequently complimented on their effort. At the end of the session, when all tasks were completed, subjects could select two small pieces of candy or other reinforcers.

Training Schedule.

Table 2 outlines the training schedule for the three groups of subjects. Briefly, each group received training on four words a week for two weeks. Retention and transfer tasks were administered at the end of each week followed by the 8, 16 and 56 day intervals for each set of four words.

The fading group received all words in the fading format. In addition, the 5th and 7th words trained contained probe trials. The specific words probed differed for each subject according to the word training order in Table 1. Non-fading subjects received all words in the non-fading format. The format for the combination group was alternated, starting with a faded word followed by a non faded word. Probe trials were included in the 5th and 7th words as in the fading condition. The eight-word sequence for the combination subjects was thus: F, NF, F, NF, F + probe, NF, F + probe, NF.
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<td>5,6</td>
<td>7,8</td>
<td>3,4</td>
<td>1,2</td>
<td>3,4</td>
</tr>
<tr>
<td>Trans</td>
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<td>7,8</td>
<td>7,8</td>
<td>7,8</td>
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<td>7,8</td>
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</tr>
<tr>
<td>Combination Group</td>
<td></td>
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<td></td>
<td></td>
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<tr>
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<td>1,2</td>
<td>3,F</td>
<td>3,4</td>
<td>1,2</td>
<td>5,Fp</td>
<td>5,6</td>
<td>7,Fp</td>
<td>7,8</td>
<td>1,2</td>
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<td>Rev</td>
<td>3,4</td>
<td>3,4</td>
<td>3,4</td>
<td>3,4</td>
<td>6,NF</td>
<td>6,NF</td>
<td>8,NF</td>
<td>8,NF</td>
<td>7,8</td>
<td>3,4</td>
</tr>
<tr>
<td>Trans</td>
<td>5,6</td>
<td>7,8</td>
<td>7,8</td>
<td>7,8</td>
<td>5,6</td>
<td>3,4</td>
<td>5,6</td>
<td>7,8</td>
<td>1,2</td>
<td>3,4</td>
</tr>
<tr>
<td></td>
<td>2,NF</td>
<td>4,NF</td>
<td>3,4</td>
<td>3,4</td>
<td>6,NF</td>
<td>8,NF</td>
<td>8,NF</td>
<td>8,NF</td>
<td>7,8</td>
<td>3,4</td>
</tr>
</tbody>
</table>

F = Fading word  
Fp = Fading word with probe trials  
NF = Non-fading word  
*Numbers represent the eight training words presented to each subject.
RESULTS

The results of the word recognition training program are presented in Figure 2. The percentage of correct responses made by all subjects in each of the three training conditions (fading, non-fading, and a combination of procedures) is shown for training and review. Each subject received training and review on 8 words for a total of 40 words in each condition. The data show that the highest percentage of correct responding was attained by subjects in the fading condition during training, although, the combination group were nearly as high. The lowest percentage rate of correct responding was achieved by the non-fading subjects, however, the rate attained was quite high. The differences between groups seen in training and review data were tested for statistical significance by means of a one-way analysis of variance. Neither was found to be significant, possibly because there were so few errors in any training condition.

An examination of the errors during training revealed differences between training methods in the position of errors during the 15 trial program. Fig. 3 shows the percentage of errors made by subjects in the three conditions during blocks of three trials (the equivalent of one fading step). In the fading condition, the bulk of the
Fig. 2: The percent of correct responses during training and review for three conditions: fading, non-fading and combination training.
Fig. 3: The percent of error during 15 training trials for subjects in the fading, non-fading and combination training conditions.

Fig. 4: The percent of error on fading and non-fading words by subjects in the combination training condition.
errors occurred in the final 2 fading steps (the last six trials) of the program. On the other hand, the non-fading subjects made most errors in the first six trials of the program. The curve showing the location of the errors of the combination subjects shows that errors were made both in the beginning and at the end of the program, although the combination group made fewer errors than the non-fading group. In all conditions, a low frequency of errors is apparent. The data presented in Fig. 3 are based on a possible 24 errors in each block of three trials.

Fig. 4 presents the percent of errors made by the subjects in the combination group on the fading and non-fading words. The differences in the curves of the fading and non-fading components of the combination training group with the curves of the fading group and the non-fading group shown in Fig. 3 should be noted. On the fading words, the combination subjects showed a lower rate of errors than the fading group, increasing only slightly in the last two fading steps. Their performance on non-fading words more closely approximated that of the non-fading group.

For each of the three training conditions, the number and percent of correct trials on each word during training was compared. The data are presented in Figures 5 and 6 and show the sequence effects of training. The difference
Fig. 5: The total number of correct trials on each word trained under fading, non-fading, and combination conditions.

Fig. 6: The percent of correct trials per training word in fading, non-fading and combination conditions.
in performance as a function of training procedure is most apparent during the training of the first few words. Non-fading subjects made relatively many errors while training the first two words. The combination subjects, though, only made a few errors on the first word which was in the fading format and several more on the second word which was not faded. As training progressed, however, the differences diminished, and by words 7 and 8, were non-existant. This is clearly seen in Fig. 5 in which the total number of correct trials per word is presented. The fading group required many more trials than the other groups on the first 4 words, at which point the number of necessary trials decreased until virtually no differences between groups were seen. In Fig. 6 the effects of the alternating sequence of fading and non-fading words in the combination training procedure are apparent in the major fluctuations in the group's graph. Here again, the differences diminished as training progressed. It is also interesting to note the improvement in the percent of correct trials in the non-fading subjects after the first two training words.

The performances of the subjects during retention testing and transfer tasks are presented in Figures 7 and 8 and show measures taken at four different time intervals. In both retention and transfer, the fading group had a lower percentage of correct trials than either the non-
Fig. 7: The percent of correct trials on retention tasks for 3 training conditions at 4 time intervals.
Fig. 8: The percent of correct trials on transfer tasks for 3 training conditions at 4 time intervals.
fading or combination groups. For the most part, the combination group responded correctly a greater percentage of the time than the non-fading group. The validity of these data is somewhat limited due to a loss of data at the later intervals in both the combination and non-fading groups during the retention phase of the study. The number of subjects represented by each data point is indicated in the figure. The trends in the data, however, are consistent with previous findings in word recognition training, particularly Mosher and Reese, Note 4.

The primary data of interest in this study, the performance on probe trials, was expected to reveal the point at which subjects shifted their attention from the size cue provided in the fading program to the actual letter configurations. With all subjects in the fading condition and the combination condition receiving two words with 3 probe trials each, it was anticipated that error patterns would emerge indicating the point of transfer and would show differences depending on the training conditions. Probe trial data are presented in Table 3. In the fading group, the 3 errors were made by two subjects on two words. In total, 3 out of the 10 subjects made errors on the probe trials. Due to the infrequent occurrence of errors, these data failed to show the point of transfer of stimulus control. For the same reason, even though the data are
suggestive, it cannot be said that experience with non-fading trials helped combination subjects attend to the pattern of the letters earlier than they "had" to on fading trials.

**TABLE 3**

Number of errors on probe trials by all subjects in the fading and combination groups. Maximum number of errors possible in each condition was 30. Data for the non-fading condition represent errors on the trials and training words that are analagous to the probed words in the other conditions.

<table>
<thead>
<tr>
<th></th>
<th>1st Probe</th>
<th>2nd Probe</th>
<th>3rd Probe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fading</td>
<td>1</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Combination</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Non-fading</td>
<td>3</td>
<td>3</td>
<td>0</td>
</tr>
</tbody>
</table>

In an attempt to increase the sensitivity of the probe trial measure was made, a second set of training words was designed in which the probe trials were placed earlier in the fading program. That is, instead of the first probe trial occuring after the 2nd trial at fading step 1, it was placed before the 1st trial of fading step 1. The second and third probes were inserted after trial 2 and trial 5 of the regular fading sequence. Three subjects in both the fading and combination groups received training on the additional words. The results, presented in Table 4, were similar to the findings shown in Table 3, although more errors were seen.
TABLE 4

Number of errors on second set of words with probe trials by 3 subjects in the fading and combination groups.

<table>
<thead>
<tr>
<th></th>
<th>1st Probe</th>
<th>2nd Probe</th>
<th>3rd Probe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fading</td>
<td>1</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Combination</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

The greatest number of errors occurred on the third probe trial which was an unexpected result. One would predict the first probe trial as the most likely place for errors to occur in the fading condition. In both sets of probe trial data, the fading subjects made a few more errors than the combination subjects.

On examination of the performance of the subjects in the non-fading condition, one finds many instances in which the subjects correctly responded to the first few trials of the training program. Of the 10 subjects who received training in the non-fading format, 9 were able to master a total of 26 words out of a possible 60 without error. The percent of words acquired without error for each subject is presented in Table 5.

Considering the fact that both fading and non-fading words were learned without errors, the data were re-examined along this dimension. Figures 9, and 10 show the percent of error on retention and transfer tasks for all
Fig. 9: The percent of correct trials during retention when training words were originally acquired with and without errors. Numbers in parentheses indicate the number of subjects at each interval.

Fig. 10: The percent of correct trials on transfer tasks when training words were originally acquired with and without errors.
TABLE 5

The percent of non-fading words mastered without errors during training by 5 subjects in the non-fading and combination conditions.

<table>
<thead>
<tr>
<th></th>
<th>Non-fading</th>
<th>Combination</th>
</tr>
</thead>
<tbody>
<tr>
<td>S₁</td>
<td>75</td>
<td>50</td>
</tr>
<tr>
<td>S₂</td>
<td>12.5</td>
<td>75</td>
</tr>
<tr>
<td>S₃</td>
<td>37.5</td>
<td>25</td>
</tr>
<tr>
<td>S₄</td>
<td>37.5</td>
<td>75</td>
</tr>
<tr>
<td>S₅</td>
<td>37.5</td>
<td>0</td>
</tr>
</tbody>
</table>

subjects. Separate curves were plotted for words in which errors occurred on original training and those words which were acquired without any training errors. Figures 9 and 10 represent the percent of correct responses during retention (9) and transfer (10) for all groups of subjects on all words trained regardless of training format. The number of subjects represented by each data point is indicated on the figures. In addition, Appendix E lists the data available from each subject. At 15 and 56 days following training, performance is somewhat better on words learned without errors. Figures 11-14 provide a breakdown of the results according to the original training format and present the results of retention testing (11 and 13) and transfer training (12 and 14). For the words in the fading format, it seems that errors in training resulted in poorer retention and transfer whereas an errorless acquisition facilitated retention and transfer. For the words presented in the non-fading format the trend
Fig. 11: The percent of correct trials on retention tasks for all fading words when originally acquired with and without errors. Numbers in parentheses indicate the number of subjects at each interval.

Fig. 12: The percent of correct trials on transfer tasks for all fading words when originally acquired with and without errors.
Fig. 13: The percent of correct trials on retention tasks for all non-fading words when originally acquired with and without errors. Numbers in parentheses indicate the number of subjects at each interval.

Fig. 14: The percent of correct trials on transfer tasks for all non-fading words when originally acquired with and without errors.
is reversed. It appeared that words learned without errors were not retained as well as words learned with errors with the exception of the 56 day time interval. However, the problem of subject attrition in the retention phase reduces reliability of this observation.

Throughout the course of the study, indicators of emotional behavior were monitored. Previous research reported instances of crying, fist banging, and swearing upon presentation of a training word in the non-fading formats (Mosher and Reese, Note 4). Reports also included specific requests by the subjects for the "other kind" of training word, indicating a preference for the fading format. No such incidents occurred in the present study. In fact, no subject ever verbally acknowledged a preference or even that a difference existed between the training format.

Several samples of time data were obtained for subjects during training on both fading and non-fading words. The samples were taken during the administration of the second set of probe trials and represent a smaller population than that assessed by Mosher and Reese (Note 4). The median time required to complete the training program for subjects in the fading condition was 270 seconds whereas the non-fading group's median time was 262 seconds. Large differences in the median times required to complete a training program reported in earlier word recognition studies were not found in the present study.
DISCUSSION

The performance of subjects in each of the three training conditions (fading, non-fading, and combination) during original training, retention, and transfer constitute the major results of this study. The primary data of interest were intended to be the comparison of performances among subjects in the fading and combination groups on the probe trials. It was hoped that the probe trial data would shed light on the problem of transfer of stimulus control in a fading program, and on the role of the two components of the combined training procedure.

The hypothesis around which the study was designed predicted that the alternating training sequence of fading and non-fading formats used in the combination method would foster attention to the criterion stimulus dimension sooner, or at an earlier trial than the strict fading sequence. In the word recognition program, stimulus control should be transferred from a size cue to the criterion dimension of word configuration. By comparing errors on the probe trials (which are identical to criterion trials) of the fading and combination subjects, it was expected that a delayed shift in stimulus control would be characterized by more errors on the later probe trials in the fading group. Evidence to support this hypothesis was not found
in the data obtained from the probe trials. Even though, as expected, combination subjects made fewer errors than fading subjects on probe trials, too few errors were made by any of the subjects to warrant drawing any conclusions.

The limited amount of information acquired from the probe trials led to a reconsideration of the methodology. Perhaps the probes could have been programmed more effectively. To test this possibility, additional words were designed with probes occurring immediately after the sample word, after the second trial at fading step 1, and after the second trial of fading step 2. However, this additional procedure did not prove to be any more revealing than the original one. Subjects were simply not making many errors; therefore, the effect of the training formats on the transfer of stimulus control could not be assessed.

In re-examining the experimental design, another methodological issue concerning the probes was noted. Probes, it will be recalled, were not instituted until subjects had received training on four words. This procedure was originally employed to provide the subjects with experience with the different training formats and to minimize potential disruption of a probe trial procedure. The limited use of probes in this study conformed to the recommendations by Stella and Etzel (Note 7) on how to probe unobtrusively. Although the design met the
requirements for probing without disruption, it could be criticized in retrospect for having provided too much training experience with the result that subjects learned to attend to the relevant stimulus before any measures were taken. It is possible that the early experience was a contributing factor, but examination of the performances on the non-fading words indicates that probing the first four words would not have revealed any additional information on the transfer of stimulus control. In 16 instances, errors were not made on the first few trials of a non-fading word and in all cases, no detectable differences were seen between the first and last four words trained. If the subjects were able to respond correctly to non-fading trials which were identical to the probe trials, then it unlikely that having probed the earlier words would have significantly altered the findings.

Subject Variables

Tied to the above concern over a possible excess of early practice prior to any probe measures, is the issue of the subject's entering behavior. The majority of subjects in the present study demonstrated a very high success level during original training. As the subject screening and selection procedures were identical to earlier research with similar populations, this finding was surprising. In both Mosher and Reese's (Note 4) and Beebe's (Note 1) work,
lower success rates and greater variability among subject performances were reported. This discrepancy indicates either that significant differences existed between the groups of subjects or that the subject selection procedures did not adequately anticipate those factors that would affect the outcome of training. The screening procedures, which included the reading portion of the Wide Range Achievement Test and a pre-test with all the training words, indicated that subjects reading skills were between the Kindergarten, 3rd month level, to the First grade, 5th month level.

It is apparent that other subject variables other than reading ability contributed to performance on the discrimination task. What those differences were can only be guessed. However, differences which may or may not have affected the outcome of the program were noted. For example, the subject populations differed in the type of institutional living arrangements available, the working conditions, and general daily experiences. The subjects from the early word-recognition studies were children in a public school system and clients in a sheltered workshop. The subjects in the present study, residents of a state facility, were living in an experimental, cooperative, co-educational cottage. These clients were responsible for maintenance of the cottage which operated on a token
Several clients attended school or held part-time jobs on the campus (e.g. at the laundry or the recreation center). Notable differences were also seen along what could be described as a social dimension. That is, clients in the cottage setting appeared more expressive verbally and gesturally, and were concerned with social functions, clothing styles, television programs, etc., whereas the workshop clients did not seem to interact much with each other or express interest in events outside of the workshop. (This may also be partly a function of the environments in which training was conducted, the workshop versus the cottage setting.) It is possible that these apparent differences in life styles contributed to the variability in performance of the two groups or it may indicate that the achievement test for reading is a poor screening device for this particular program.

Differences in subject behavior were most obvious on the measure of "emotional" behavior. Using the definitions of emotional responses from Reese's earlier work, there were no instances of emotional behavior in any portion of the training, review, retention, or transfer tasks. Perhaps if the difficulty of the program in relation to the ability of the subjects been greater, emotional responses would have been observed.
Interpretation of Obtained Data

The failure of the probe trials to provide any information regarding the transfer of stimulus control results in a need for a change in the emphasis of the present discussion. It is no longer possible to answer the experimental question for which the study was originally intended. However, the results that were obtained need to be accounted for. To do so requires that the salient features of the data be identified, and interpreted. Specifically, the data open to interpretation included the training data and their relation to retention and transfer results.

The first, and most notable, finding in the training data is the consistency with previous research of the effect of training formats on performance. As would be expected, the fading condition resulted in the highest success rate, thus the lowest error rate, whereas the non-fading condition showed the lowest success rate and the greatest amount of errors. (See Figure 2) This is a particularly interesting finding when viewed in the context of the extremely high success rate observed. In all three training conditions, subjects performed at approximately the 90% correct level on the average. This high performance level (low error rate) seems to indicate that the subjects in this study were capable of acquiring the discrimination without the use of the additional cue
provided in the fading program. This is evident from the success of the subjects in the non-fading training condition where 17 words out of 40 words trained were acquired without any errors at all. At the same time, however, evidence from the distribution of errors (Figure 3) suggests that the size cue provided in the fading format was utilized during training. The size dimension in the fading program was completely faded by trial 13 (fading step 5). If subjects were dependent upon the cue when making the discrimination, it seems reasonable to expect errors to occur once the cue is eliminated. In this instance, the majority of the errors in the fading condition occurred during the last two fading steps which supports the notion of dependency. The opposite was true in the non-fading condition. The majority of errors occurred primarily in the early trials (the equivalent of fading steps 1 and 2). This strengthens the conclusion that the distribution of errors was a result of the different training programs.

Taking the two facts together—that is, the extremely low error rate along with the difference in error patterns for fading and non-fading training conditions—seems to indicate the following notions:

- Subjects did not require a fading program in order to acquire the discrimination with few or no errors.
- Subjects depended on or made use of the size cue
present in the fading format during discrimination training.

Keeping these notions in mind, the next issue to be addressed is how the training formats affect performance on the retention and transfer tasks. Of concern are questions of how the results can be accounted for and how these findings relate to the literature on fading, stimulus control, and discrimination training.

The retention and transfer data presented in Figures 7 and 8 show trends that are consistent with the findings of Mosher and Reese (Note 4). In both studies, the performance of the combination group was superior to either the fading or non-fading group in terms of fewer errors across retention intervals. The greatest number of errors occurred in the fading condition. Despite the differences in subject populations and error frequencies between the present study and the previous work, the trends in the data indicate that the original training method does have a differential effect on retention and transfer. Although the data could not be tested for statistical significance due to incomplete data on all subjects, significance was reported in previous research (Mosher and Reese, Note 4).

To explain the occurrence of a differential effect, consideration of the known mechanism involved in fading and discrimination training is needed. The search of the
literature revealed surprisingly little in terms of the effects of fading on retention and transfer. Other than the work of Reese and her colleagues on fading with human and animal subjects, only a few studies were located that were directly interested in retention and transfer. Touchette (1968), for example, measured retention of a simple discrimination with retarded boys at a 35-day interval. He found that subjects who received discrimination training via fading performed at a higher percentage level of correct responses on the retention test than subjects who received trial-and-error training. Dorry and Zeaman (1975), in studying the effects of picture fading on the acquisition of a simple 8-word reading vocabulary, measured immediate and delayed retention. They reported that fading was more efficient than either presentations of picture stimuli and words or alternate presentations of picture-word pairs and word alone. Unfortunately, they did not indicate the length of the delayed retention interval; but interpreting what they did report, it appears that retention measures were taken immediately upon completion of the entire 8-word training program. No indication was given that suggested that training required more than one session.

Other investigators have been concerned with the problem of what happens to a subject's behavior when a fading program is discontinued but their efforts have been
directed towards questions such as the effect of fading on discrimination reversal learning or the effect of extinction following training with a fading program.

Without any specific data on retention following fading other than Reese's work, efforts towards explaining the obtained results are best directed to proposed hypotheses that will account for the data in a parsimonious manner.

The original hypothesis considered was derived from the notion that the success of the combination training procedure was due to a more rapid transfer of stimulus control than either the non-fading or fading procedures used individually. Experimental validation of this theory was attempted via the probe trials and proved to be unsuccessful. The data accumulated indicated that the hypothesis, the methodology employed, or both were inadequate to account for the findings. As mentioned, the results were consistent with previous research yet were unable to demonstrate that an earlier transfer of stimulus control from the supplementary size cue to the word configuration occurred in the combination training procedure. This lack of support led to a re-evaluation of the original experimental question. In hindsight, the question may have been premature, particularly since relatively little is known about the parameters of fading. It therefore seems unlikely that a complete
explanation could be derived for the combination procedure without a prior understanding of the mechanisms involved in the component parts.

Following this line of reasoning, it would be beneficial to shift the emphasis from an explanation of the success of the combination method to an explanation of the outcome of the fading procedure. During retention and transfer tasks, the fading group showed the poorest performance in terms of the greatest number of errors. Whether or not this is characteristic of retention tests following fading or the result of an interaction of this specific subject population with this particular training program remains to be determined.

Several explanations for the poor retention and transfer performance of the fading group are available. The first, and most theoretically oriented explanation stems from the blocking paradigm discussed earlier. The essence of the blocking design is that it demonstrates how experience with a prior stimulus can result in impaired stimulus control by a second stimulus which was presented in compound with the first stimulus. It should be pointed out that "impaired control" of the experimental group is relative to the degree of stimulus control established in the control group.

Mackintosh (1977), in his chapter on stimulus control,
discusses a probable mechanism for the occurrence of a blocking phenomenon. According to Mackintosh, blocking is entirely consistent with the notion of "overshadowing" first reported by Pavlov. Overshadowing, in the Pavlovian sense, refers to an interference with the acquisition of stimulus control by the presence of a more salient or valid stimulus. Salient and valid refer to those stimuli that are either more closely associated with the sensory processes of the subject (salient) or are more closely associated with reinforcement (valid). This indicates that an incidental or less salient stimulus will not develop stimulus control if a more salient stimulus is present. Mackintosh emphasizes this notion by stating that the important of the acceptance of the general principle that "it is not the absolute validity of the stimulus that determines its control but whether it is accompanied by more valid predictors or reinforcement." (1977, p. 496).

A discussion of blocking and the mechanism of overshadowing would seem incomplete without mention of the relational view of reinforcement which is able to accommodate both notions. This concept, derived from Premack's work on the contingent use of high frequency behaviors to increase low frequency behaviors, was further refined by Wagner and Rescorla in a classical conditioning framework. Donahoe (1977) developed a formula to express the
the relational view of reinforcement which permits predictions of the strength of an instrumental or operant response. Essentially, the relational view states that the final or asymptotic level of an operant response (termed noncontingent response) is a function of the baseline probability level of that response plus the difference between the probabilities of the contingent response (reinforcer consumption response) and the noncontingent response (operant response). In the blocking experiment, the relational view of reinforcement would predict the lower response rate in the experimental group. Looking back at the equation, one can see that the asymptotic level is a function of a difference between probabilities of responses. In the blocking design the baseline probability of the response in the experimental group is high as a result of the initial training. If this high value is subtracted from the probability of the reinforcement response, the resulting negative value would indicate a decrement in the response level. As was seen in the results reported by Donahoe (1977), the experimental group exhibited a lower response rate. The degree of stimulus control was much weaker than the control group.

This concept of the strength of a response resulting from the relative difference between the probability of the contingent and non-contingent responses is extremely
appealing due to its apparent applicability to a wide variety of responses and situations. However, Donahoe cautions that such a principle requires experimental validation before wide usage can be accepted.

In returning to the subject of fading, one can find parallels to the blocking design and thus the relational view of reinforcement. Procedurally, a fading program is similar to the experimental training phases of the blocking design. That is, subjects receive training with an initial stimulus (eg. an additional cue such as size), proceed through trials where both the additional cue and the relevant stimulus property are equally available (intermediate steps in the fading program), and are finally given criterion trials where only the relevant stimulus is available for the subject. The steps are outlined in the diagram below.

<table>
<thead>
<tr>
<th>Phase 1</th>
<th>Phase 2</th>
<th>Phase 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experimental or fading group</td>
<td>Initial Combination Test Phase</td>
<td>Stimulation (Letter Configuration)</td>
</tr>
<tr>
<td></td>
<td>Stimulus of Stimuli (size plus letter configuration)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Training (Size)</td>
<td></td>
</tr>
</tbody>
</table>

Essentially, the criterion trials are like the test phase of the blocking design. The experimenter is measuring the degree to which the actual shape of the letters controls the subjects behavior.

To describe a fading program in terms of stimulus control, one could say that the addition of the irrelevant
cui allows subjects to come under the control of this stimulus before they are controlled by the criterion stimulus. Through the gradual change in the stimulus conditions that defines fading, a subjects' response can come under control of the relevant stimulus. To return to the view of transfer of stimulus control as a continuum with "blocking" at one end and facilitated transfer via fading at the other, emphasizes the importance of the gradual versus abrupt shift in stimulus conditions as a major determinant of the outcome of a training procedure.

A second explanation for the relatively poor performance of the fading subjects during retention and transfer can be derived from a comparison of the number of criterion trials present in each training format. Within the non-fading format, the 15 trials of original training consist of full-size criterion trials, whereas only 3 criterion trials were contained in the fading program. As subjects in the non-fading condition were able to respond correctly to the first few trials, they essentially received 15 trials in which the training word could be "practiced". Although the fading subjects also received 15 trials, 12 of them were compounded by the addition of the size cue. As the data suggest that subjects utilized the size cue when it was available, it is likely that the fading group did not get the same degree of "practice" that was afforded
by the non-fading program. This discrepancy in the number of criterion trials which occurred in both training and review may well account for the inferior performance of the fading subjects.

Despite the fact that the total number of training trials was approximately the same for all training conditions, it seems that the quality of the training experiences of the different formats had an effect on the development of stimulus control by the training words. It would follow that the fewer the number of trials requiring attention to the configuration of the word, the lower the likelihood that the words would be remembered. Whether or not this would occur in other programs where the entering skills of the subjects were not as high as the present study remains to be determined.

The two explanations for the inferior performance of the fading group are similar in some respects. A major difference lies in the theoretical nature of the two. The first explanation names the blocking process as the mechanism responsible for the poor retention observed in the fading condition. The second merely states that the fewer number of criterion trials resulting in less exposure to the critical stimuli, would thus cause weaker stimulus control and poorer retention. Implied in the second explanation is the notion that the fading program by its
design, is likely to produce weaker stimulus control when compared to a trial-and-error program of equal length. One method of reducing the imbalance is to increase the proportion of trials at criterion-level in the fading program. The inclusion of review trials, for example, in Mosher and Reese's (1976) study, as well as the present study, was intended to redress the imbalance.

The analysis of fading in terms of the blocking design may seem somewhat contradictory considering the implications and connotations that surround both procedures. On the one hand, the blocking design represents a model for the reduction or inhibition of stimulus control. Fading, on the other hand, has been presented in the literature as a facilitator of the establishment of stimulus control. The question arises, then, of how so successful a procedure as fading can be an inhibitor in the development of stimulus control as the blocking analogy implies.

To help clarify this situation, two factors need to be considered. First, the issue of comparison of the experimental or fading group to a control condition should be examined. It is important to remember that in the operant analysis by blocking, impaired control was evident only in comparison to the performance of a control condition. Rarely, in the literature on fading, have appropriate control procedures been conducted which would have allowed for this type of comparison.
This type of control would require the addition of an experimental condition in which subjects received (1) prior experience with the stimulus cue employed in the fading portion of the program, (2) training with the compound of cue plus target component, and (3) a test of stimulus control developed by the target component when the cue is abruptly removed. A comparison of subject performances after fading to performances without fading, as well as to performances of subjects who did not have any experience with the irrelevant cue would allow for a more complete picture of the specific effects of fading.

The fact that appropriate control conditions are not always included may be a direct result of the use of special populations in much of the applied research. The discovery that special populations could be taught discriminations using fading procedures where previous traditional methods had failed generated a good deal of research. In some instances, it would have been difficult, if not impossible, to establish appropriate control conditions as the subjects were unable to acquire the discriminations using the trial-and-error methods.

An example of the difficulty involved in establishing proper controls, is seen in Sidman and Stoddard's (1967) early work with severely and profoundly retarded boys. They were able to train a circle-ellipse discrimination but
only when fading procedures were implemented. The traditional trial-and-error training attempts had been completely unsuccessful. Obviously, if the subjects were unable to acquire the task using one of the procedures, establishing appropriate control conditions would be exceedingly difficult.

The above discussion on the availability of control groups in studies using special populations raises a more basic issue concerning fading which might be a direction for future research. In developing a full understanding of the mechanisms operating in this procedure it would be important to ask why certain populations require a fading program or the use of progressive procedures in order to learn. One possibility that could be investigated concerns the learning histories of special populations. It may be that the severely impaired clients, living in an institution, have had very little experience with discrimination and differential responding. For many severely and profoundly handicapped people, institutional care has been custodial and clients rarely performed any tasks for themselves. Fortunately, this situation is changing; but training new skills with these clients is a slow, gradual process. The result of limited experience with discrimination training is that subjects may need to learn how to learn. Perhaps the fading program's success is partly
due to a fulfillment of that function. Such a notion would require experimental validation, but it may bear some relation to the parameters of fading and their success with severely and profoundly retarded populations. Establishing a discrimination or a history of stimulus control may be a necessary condition for teaching a more complex discrimination.

Another related area in which investigation has begun is task difficulty. Mosher and Reese (Note 4) found that fading and combination training procedures were more effective than non-fading when used with more difficult tasks. (Difficulty, in the word recognition program, was defined as the number of letters in the choice words that were in a common position with the training word.) In addition, the authors demonstrated that programming word difficulty (i.e. presenting words of increasing difficulty) resulted in better performance than a mixed presentation of words of varying levels of difficulty.

The other issue to be considered when comparing the degree of stimulus control achieved under fading and non-fading training methods is the point in time at which the measurements are taken (the retention interval). Many of the early studies concluding that fading was a facilitative procedure measured only acquisition of the discrimination. Inhibitory effects would not be apparent if acquisition was the sole measure taken. Both procedures enable
a subject to reach a set criterion of performance on the task being trained, therefore, examining only acquisition would not reveal differences in the degree of stimulus control established by the two procedures. An additional measure or assessment of stimulus control would be required such as a generalization test or retention and transfer tasks. Despite the limited data, examination of the performance during retention and transfer across several time intervals in the present study showed substantial variation between the fading and the non-fading groups.

Combination Training Results

The proposed hypotheses for the results of the fading program seem to account for the data obtained for the fading subjects but whether or not these notions can also account for the results of combination training need to be examined.

Before determining if blocking and unequal numbers of criterion trials can be applied to the data from the combination training procedure, the framework within which the data are considered should be described. The idea is that the alternation of fading and non-fading words used in the combination method favors focusing attention to the critical features or letter shapes of the training word. For example, when a subject is presented with a non-fading word he must attend to the letters if he is to respond
correctly with any consistency. After attending to the full size trials in the non-fading word has been reinforced, he may be more likely to continue to attend to the letters in the following fading word. This does not rule out the possibility that the subject also uses the size cue available in the fading words. In fact, as a result of the training history with non-fading words, the size cue may have a different function when it appears in the fading words in the combination method. Perhaps it functions as an orienting stimulus and enables the subject to locate the correct choice easily, at which point he can more closely inspect the other stimulus properties of the word.

Support for the notion of the differential effect of fading words through a change in the function of the size cue can be found in the distribution of error data presented in Figures 3 and 4. Figure 4 depicts a breakdown in the total number of errors into the two components of the combination training procedure. What is interesting is that the fading words in the combination method did not show the sharp increase in errors during the last two fading steps as was seen in the fading condition (Figure 3). Further, the retention and transfer data indicate that the effect of fading when used in an alternate fashion with non-fading words is somewhat different than when fading is used alone. (See Figures 7 and 8) The graph shows superior
retention and transfer by subjects in the combination training group.

As with the fading data, the blocking explanation can be used to explain the findings of the combination training procedure. A consideration of the design of the combination method would lead to a prediction of superior performance by the combination subjects. If blocking accompanies fading procedures, then the combination method would only provide the occasion for blocking on half the words being trained. When examining the data accumulated for all training words, it would appear that the combination method would favor stronger stimulus control. In addition, the alternating sequence may further lessen or perhaps eliminate any blocking effects of fading through a carry-over effect of reinforced attention to the critical features which occurred in the non-fading words.

It is further possible to predict a performance that is superior to both the fading and non-fading training procedures if one assumes that the size cue present in the fading words functions differently depending on the training context. For example, if the size cue acts as an orienting stimulus and permits a close examination of the training word, subjects may be attending longer or more efficiently than in the non-fading condition. If that is the case then a superior performance based on the accumulated data is not surprising.
The actual functions of the additional stimulus cue present in the fading condition and the alternating sequence still need to be determined through rigorous experimentation; but it does seem that there is some evidence to warrant investigation along the theoretical lines outlined above.

Throughout the study of errorless learning and fading, a clear distinction between the procedural and behavioral aspects of what constitutes "errorless" learning has not always been made. The retention and transfer data from the present study were re-examined according to the outcome of training rather than by the procedure with which the words were originally trained. Retention and transfer curves were plotted for words which had been acquired with and without errors.

The data suggest that learning words errorlessly results in a greater percentage of correct trials on later tasks. (Figures 9 and 10 show the outcome of training on retention and transfer for all words regardless of the training format employed). This finding seemed most pronounced at the 56 day retention interval. At the earlier intervals, the pattern was not clear. When the data were broken down according to the original training format, (Figures 11, 12, 13 and 14) the data suggest the possibility of differential effects due to an interaction between the
training format and the presence of errors during original training. In the fading words, greater accuracy on the later tasks was seen for words acquired errorlessly. On the other hand, a trend towards improved retention for words acquired with errors was seen although the results were much less clear. Differences in transfer, favoring acquisition with errors, were also apparent for the early intervals but not for later intervals. Whether or not these differences are reliable is questionable considering the limited number of subjects and words in each condition. The results may simply represent chance variation, but this would need to be determined empirically with a much larger sample of words. The possibility of differential effects due to a combination of training procedure and outcome, however, is intriguing and should be investigated. It may be that in the fading format, an errorless acquisition facilitates improved retention and transfer when compared to fading programs in which errors have occurred. It might also be possible for trial-and-error programs which have resulted in frequent errors (i.e. programs in which a high difficulty task is trained) to promote better retention than ones which do not. Insufficient numbers of subjects and data prevent any conclusions concerning an interaction between training format and the occurrence of errors.
Throughout the discussion of the results of the present study, an emphasis has been placed on the effects of training using a fading procedure. An analogy to the blocking paradigm has been drawn which led to the conclusion that fading may be a technique which could result in impaired stimulus control. It is important, though, to view fading in a larger perspective. Even though it does not occasion retention and transfer as effectively as a non-fading procedure, it may be useful for other qualities and effects. For example, as mentioned, it has been shown to be the only successful procedure in certain training situations with profoundly retarded populations. Perhaps fading methods provide a necessary first step in which subjects with deficient learning histories can learn to discriminate.

Obviously, the decision to use or not to use a fading program should be made only after the cost-benefits of the use of programs have been analyzed for the client, as well as for the programmer. The prospective programmer should consider the following points and questions in the analysis.

1) **The subject's needs**: how important is the skill to be taught to the subject; how rapidly is the desired acquisition; is it a skill that is amenable to fading procedures.

2) **The subject's entering behavior**: what skills does
the subject already possess; what type of learning history does the subject have (impoverished or enriched?).

3) **Training materials:** are programs readily available; will a special fading program need to be designed; are funds available for such a project.

4) **Program design:** how should fading occur and along what stimulus dimensions; should the discriminative stimuli be intra- or inter-dimensional?

5) **Reinforcement:** will the subject's interest be maintained given the contingencies of the program; is the program tedious; are there enough trials?

6) **Generalization and maintenance of the behavior:** is it essential for the client to maintain the skill in the absence of the specific training materials; is flexibility in responding desired; is generalization to similar stimulus situations a goal of the program?

The above issues and considerations were derived from the research findings already in the literature on errorless learning and fading. As more data is gathered and the parameters are discovered, the job of selecting training procedures for specific clients may become a simple job of matching client needs and abilities to program specifications.
REFERENCE NOTES


8. Williams, R.G. A behavioral typology of educational objectives for the cognitive domain. Unpublished manuscript, Southern Illinois University, School of Medicine, 1977.
REFERENCES


Wessells, M.G. The effects of reinforcement upon the pre-pecking behaviors of pigeons in the autoshaping experiment. Journal of the Experimental Analysis of Behavior, 1974, 21, 124-144.
APPENDIX A

Sample Training Materials

1. Cover Sheet

2. Training Sheet
   a) Faded format
   b) Non-faded format

3. Training Sheet with Probe Trials
   a) Faded format
   b) Non-faded format
Training Sheet: Fading Format for Training Word "Office".
<table>
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<tr>
<th></th>
<th>OFFICE</th>
<th></th>
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</thead>
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<td>OLFAC</td>
<td>OBTUSE</td>
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Training Sheet: Non Fading Format for Training Word "Office"
PURSE

PαRbα kαRαE PαlοE PURSE
PURSE PεRCi lεRoE PeKιE
PυDιΕ PURSE PιRKυ VιRAE
mιReE PιJεE PURSE PιRdο
PοHaE PURSE PοReu nοRIε
PυRfι rυRIε PυGIε PURSE
TERoE PIECE PURSE PERJO
PURSE PαRGu sαReE PοfoE
TERoE PIECE PURSE PerJO
PυDιΕ PURSE PιRKυ VιRAE
PURSE PεRCi lεRoE PeKιE
PοRly wυRuΕ PeceE PURSE
PURSE PυRmα ZoRyε PaBaE

Training Sheet: Fading Format with Probe Trials for Training Word "Purse"
Page 2. Probe Trials

KARAE PALOE PURSE PARBA
PEKIE PURSE PERCI LEROE
PARBA KARAE PALOE PURSE
PURSE PERCI LEROE PEKIE
MIREE PIJEE PURSE PIRDO
POHA E PURSE POReu NOrie
PYRFI RYRIE PYGIE PURSE
PURSE PARGu SAReE POfoE
TERoE PIECE PURSE PERJo
PYDIE PURSE PIRKY vIRAe
PORLY wyRUE PECeE PURSE
PURSE PYRMA ZORYE PABAE
APPENDIX B

Review Materials

1. Review Sheet, faded format
2. Review Sheet, non-faded format
Review Sheet: Fading Format for Training Word "Clock"
Review Sheet: Non-fading Format for Training Word "Clock"
APPENDIX C

Sample       Retention Materials
SENIT SHIRT SEINP DRIET IDIAT SOILS SIACT SHIRT SHIRT SORAT AFIUT SUITS
APPENDIX D

Sample Transfer Tasks
1. Picture Task
2. Square Format
3. Flash Card
4. Card Format
5. Card Format
TTI: Picture Format for Training Word "Shirt."
Narrative: "If you're getting dressed, and need something to wear with blue pants, which drawer would you find it in?"
TT2: Square Format for Training Word "Shirt"

TT3: Flash Card Format for Training Word "Shirt"
TT4: Card Format for Training Word "Shirt".
The alternative choice cards are not training words.
TT5: Card Format for Training Word "Stairs". All the alternative choice cards are training words.
APPENDIX E

Number of Training Words for Which Retention and Transfer Data was Available for Each Subject at Each Retention Interval

<table>
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<tr>
<th>Interval</th>
<th># words Acquired Errorlessly</th>
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<td>8</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
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<td>8</td>
<td>8</td>
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<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
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<td>8</td>
<td>8</td>
<td>8</td>
<td>4</td>
</tr>
<tr>
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<td>4</td>
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<td>8</td>
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</tr>
<tr>
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