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LEARNING AND INSTRUCTIONAL SUCCESS IN PEOPLE WITH A MENTAL HANDICAP

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LEARNING AND INSTRUCTIONAL SUCCESS IN
PEOPLE WITH A MENTAL HANDICAP

Stephen Charles Strand

A thesis submitted to the Council for National Academic
Awards in partial fulfillment of the requirements for the
degree of Doctor of Philosophy

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Declaration

1. While registered for this degree, I have not been a registered candidate for another award of the CNAA or of a University.

2. None of the material contained herein has been used in any ^{OTHER} submission for an academic award.

A handwritten signature in black ink, appearing to read 'Stephen Strand', with a horizontal line drawn underneath it.

(STEPHEN. CHARLES STRAND)

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Dedication

To my parents for their support throughout the years, and especially to the memory of my grandfather, whose belief in his grandson, and in the value of education, led to the completion of this thesis.

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Learning and Instructional Success in People With a Mental Handicap

Stephen Charles Strand

Abstract

Learning - the process by which new skills and behaviours are acquired - is a central concept in the understanding of mental handicap. Discrimination learning is specifically identified as an essential pre-requisite for the acquisition of a variety of more complex behaviours and skills. Many studies have reported that severely mentally handicapped persons show a relative inability to profit from unstructured learning experiences, and frequently fail to learn discriminations trained through simple differential reinforcement (trial-and-error training). Programmed training procedures are identified as important vehicles to facilitate the discrimination learning of severely mentally handicapped children.

An initial study is reported that confirms the superiority of programmed over trial-and-error discrimination training, and demonstrates this superiority is maintained over a series of similar discrimination tasks. The results also demonstrate that stimulus fading procedures can be successfully implemented using micro-computer technology, and that 'errorless' learning can be effected through the sequencing and fading of trainer prompts.

However, programmed procedures are not invariably effective in teaching discriminations to developmentally impaired persons, and failures to learn following programmed training are not infrequently reported. In a series of studies, some of the basic procedural parameters underlying diverse programmed techniques were evaluated as determinants of the development (or lack of development) of appropriate stimulus control. Increasing the salience of S+, whether through manipulation of S+ or S-, was shown to be more effective than increasing the salience of S-. Further, congruence between prompt and training cue dimensions was shown to be a significant variable affecting the outcome of training. The effectiveness of programmed procedures was also shown to interact with task difficulty.

Finally, wide individual differences in learning within the population of severely mentally handicapped persons have frequently been reported, and were also observed in the present research. In a final study, individual differences in some basic cognitive abilities and aspects of classroom behaviour were assessed and shown to be significantly correlated with discrimination performance.

The results are related to the literature on compound conditioning (e.g., Kamin, 1968) and theories of discrimination learning (Terrace, 1966; Rescorla & Wagner, 1972; Zeaman and House, 1963, 1979), and suggest the importance of attentional processes in discrimination learning. Lastly, some educational implications of the results are discussed.

CHAPTER 1

Programmed Discrimination Training for Severely

Mentally Handicapped Children: Introduction

Chapter 1

Programmed Discrimination Training for Severely Mentally Handicapped Children: Introduction

1.1 The Subject Population

The principle component underlying all general definitions of mental handicap/retardation is of a permanently reduced global capacity to learn, using learn very broadly to include early neurological and psychological development. It is this that intelligence tests try to measure, and historically IQ tests have been the main criteria for defining mental handicap/retardation. For example, in the U.K. the Mental Health Act (1959) defined mental subnormality in general terms as a state of 'arrested or incomplete development of mind which includes subnormality of intelligence'.

Two sub-categories were identified. Those described as severely subnormal (SSN) had IQ scores of less than 55, while those described as subnormal (SN) had IQ scores between 55 and 70.

In the U.S.A., the American Association on Mental Deficiency (AAMD) has adopted a system which defines grades of retardation (Grossman, 1983). Specifically profound, severe, moderate, and mild retardation are employed. With respect to IQ measures groups are defined as follows; profound retardation, 0-21; severe retardation, 25-39; moderate retardation, 40-54; and mild retardation 55-69.

Conventionally, an IQ score below 50 characterizes severe intellectual

impairment (SII), while IQ over 50, but below 70, represents mild intellectual impairment (MII) (Fryers, 1987). However, IQ alone has not usually been considered sufficient for defining mental handicap (Clarke & Clarke, 1985). For example, the AAMD also employs social criteria such as adaptive behaviour, defined as 'the effectiveness with which the individual meets the standards of personal independence and social responsibility expected of his age and cultural group'. Similarly, the 1983 Mental Health Act defines mental impairment as 'a state of arrested or incomplete development of mind which includes significant impairment of intelligence and social functioning'. However, Fryers (1987) argues that "all people with an IQ below 50, at all ages, in all societies and in all services, will be considered retarded, and no other feature is necessary for this category.

Therefore, IQ is actually the sole criterion for definition and severe mental retardation/handicap is co-terminous with severe intellectual impairment (p368)". This is unlikely to be true for higher ability groups, such as the mildly intellectually impaired (MII). Most of those with IQ scores over 50 will need to exhibit other impairments, disabilities, behaviours, illnesses, or social problems to be included in the group mentally handicapped (Richardson, Koeller, Katz, & McLaren, 1984a).

The children participating in this research all had IQ scores below 50, and may therefore be described as severely intellectually impaired (SII) or severely mentally handicapped (SMH). In terms of educational criteria, these children are described as having severe learning difficulties (SLD). Learning difficulty is not the precise equivalent of intellectual impairment, since LD may include children with learning problems due to other reasons e.g., physical and sensory impairments, deprivation, childhood psychosis, etc. However, for the SMH child the learning difficulties are

also likely to be severe. All the children participating in this research were attending special schools for children with Severe Learning Difficulties (SLD).

In this thesis it is intended to use the term 'mental handicap' and derivatives therefrom in describing the children participating in the research. More generally, the term 'developmentally impaired' will be preferred when discussing wider populations (e.g., autistic, mentally handicapped, multiply handicapped).

Finally, for purposes of comparison with studies conducted in the United States, our subjects may be considered equivalent to the profound, severe, or moderately retarded in the USA. In American educational usage these children are termed the 'trainable' mentally retarded (TMR), in contrast to the mildly retarded, who are termed 'educable' mentally retarded (EMR).

1.2 Research Design

The research reported in this thesis involves an investigation of the role of training variables and individual differences in the discrimination learning of severely mentally handicapped children. With this objective in mind, there has been no intention of carrying out work that would involve a comparison of mentally handicapped and non-handicapped individuals. As Baumelster (1967) argues "...to understand the behavior of retardates one must study the behaviour of retardates. The study of normal behavior is quite irrelevant to this purpose" (p875).

1.3 Discrimination Learning and the Severely Mentally Handicapped

Children who are difficult to teach, such as the mentally handicapped, need special consideration. By definition severely mentally handicapped children have extreme difficulty in learning. All learning requires that a child must detect some differences in the events of his/her environment. At the simplest level, the child needs to be able to discriminate between what s/he touches, sees, or hears. Learning to discriminate (i.e., respond differently to stimuli) is an essential prerequisite for the acquisition of more complex behaviours. For example, in learning to read the child must first learn that each letter is unique and that it varies in some way from all other letters of the alphabet. Similarly, the child needs to be able to discriminate between sounds before s/he can later appreciate the significance of words. In general, learning to discriminate between objects, colours, forms, or pictures is essential for the acquisition of academic skills.

Operant discrimination training involves the establishment of differential relationships between two or more discriminative stimuli, and a stimulus which the subject will make some arbitrary response to obtain (a reinforcer). Discriminative stimuli may be presented concurrently (simultaneous discrimination) or alternately (successive discrimination). The 'correct' and 'incorrect' discriminative stimuli, or S₊ and S₋, are distinguished as responses to S₊ are reinforced while responses to S₋ are not reinforced.

The traditional method of discrimination training relies only on such differential reinforcement. The child must learn from the consequences of his/her responses (reward or non-reward) to select the rewarded stimulus, hence the method is typically named trial-and-error learning. Most theories of discrimination learning view the acquisition of a discrimination as the result of two antagonistic mechanisms: conditioning, resulting from the reinforcement of responses to S+, and extinction, resulting from the non-reinforcement of responses to S-. An account of how a discrimination is formed would run as follows: the reinforcement of a response in the presence of S+ adds a large increment of response strength at S+ and, via the process of generalization of excitation, a smaller increment of response strength is added at S-. Non-reinforcement of responding to S- results in a large increment of inhibition at S-, and a smaller increment of inhibition at S+. As this process is repeated there results a high probability of a response to S+ and a low probability of a response to S-, and a discrimination is formed. Such conditioning-excitation theories (Hull 1950; Spence, 1936) therefore attribute an active role to S- within a discrimination task, contending that errors (responses to S-) are an essential component of discrimination acquisition.

Broadly speaking, the philosophy underlying such theories is that we 'learn by our mistakes'; that errors are a necessary part of learning. However, one of the most consistent findings in this area is the failure of trial-and-error training in teaching discriminations to severely mentally handicapped individuals. For example, Barrett (1965) found no learning in seven of 25 mentally handicapped individuals after over 16 hours of differential reinforcement. Even those studies reporting some success in discrimination training also report that a sizeable proportion of subjects

fail to learn the discriminations and have to be dropped from the study (e.g., Orlando, 1961; Moore & Goldiamond, 1964; Touchette, 1968). For example, Ellis, Girardeau, and Pryer (1962) report that, from an initial sample of 93 severely mentally handicapped children, no fewer than 35 children had to be eliminated from the experimental sample. In general, the performance of severely mentally handicapped children is characterized by an abnormal amount of responding to S-, even after prolonged exposure to the training programme, and by the development of marked perseverative error strategies (e.g., position perseveration).

However, in the early 1960's a major step toward facilitating the discrimination learning of mentally handicapped persons was initiated through studies which showed that, through the use of fading operations, discriminations could be learned without the necessity of responding to S-.

1.4 Programmed Discrimination Training

Historically, the development of programmed discrimination training techniques can be traced to early studies which demonstrated that a difficult discrimination can be more easily and efficiently established if subjects are first exposed to simpler discriminations involving similar stimulus materials (Schlosberg & Solomon, 1943; Lawrence, 1949). This phenomena was systematically investigated by Lawrence (1952). Rats were trained to discriminate between two narrowly separated grays. A control group were trained throughout on a difficult dark gray - light gray discrimination. An experimental group were trained initially on a black-white discrimination, and only then gradually transferred through a

series of intermediate discriminations to the final light gray - dark gray discrimination. Results showed that the experimental group performed significantly more accurately on the final difficult discrimination than the control animals trained from the outset on the difficult discrimination. Lawrence termed this effect 'transfer along a continuum'.

Terrace's Experiments

The now classic studies conducted by Terrace (1963a; 1963b) built upon this evidence. In the first experiment (Terrace, 1963a) pigeons were trained to discriminate a red (S+) and a green (S-) light. Two variables were studied: the time and the manner of the introduction of S-. Either S- was introduced during the first training session, or after a number of weeks of training. These were referred to as the 'early' and 'late' conditions. Under both conditions, S- was introduced by one of two procedures. Either S- was initially the same brightness and duration as S+, or S- was less bright and of shorter duration, these values being progressively increased until the values of S+ were reached. These two conditions were referred to as 'constant' and 'progressive'. The combination of both sets of variables yielded four experimental groups.

Group 1: early-constant. S- was introduced during the first experimental session. Its brightness and duration (3 min) were the same as those of S+.

Group 2: early-progressive. During the first stages, S- was a dim light of 5 sec duration. Over successive presentations of S-, its duration was progressively increased to 30 sec. During the second stage, the intensity of S- was gradually increased until the green and the red keys were equally bright. During the final phase, the duration of S- was increased from 5 sec

to 3 min, i.e. the duration of S₊.

Group 3: late-constant. S₋ was introduced after 21 sessions of responding to S₊ alone. It was fully bright and of 3 min duration.

Group 4: late-progressive. S₋ was introduced after 21 sessions. The method of presentation of S₋ was the same as for Group 2.

Results showed that the early-progressive group acquired the discrimination in such a way that their performance could be described as 'errorless' (i.e., only five to nine errors). The late-constant group made the most errors during acquisition, from 1922 to 4153. The two other groups fell between these two extremes.

In a second experiment, Terrace (1963b) studied the transfer from a red (S₊) versus green (S₋) discrimination to a discrimination between a vertical (S₊) and a horizontal (S₋) bar. All pigeons were initially trained on a red-green discrimination by the errorless procedure described above. Pigeons were then shifted to the line discrimination in one of three ways.

Group 1: abrupt. An abrupt shift from the red-green to the vertical-horizontal discrimination was made after the fifteenth red-green session.

Group 2: superimposition only. At the end of the tenth session, a vertical line was superimposed on the red background and a horizontal line was superimposed upon the the green background. From the start of the sixteenth session the lines appeared without coloured backgrounds.

Group 3: superimposition and fading. As for Group 2, the lines were superimposed upon their respective backgrounds during sessions 11 to 15. However, during the course of the sixteenth session, the intensities of the

red and green lights were progressively reduced until the lights were no longer visible. at the end of this fading procedure, the lines were presented on white backgrounds.

Group 4: vertical-horizontal only. A control group received no training on the colour discrimination. Only the vertical-horizontal lines, at full intensity and duration, were presented throughout training.

Results showed that the birds who received superimposition and fading acquired the vertical-horizontal discrimination with no errors, whereas the birds in the other three groups made considerable errors (range 157 to 2609).

Both experiments present clear evidence that discriminations can be acquired with few or no responses to S-. These results had important implications, both for theories of discrimination learning, and for teaching developmentally impaired individuals. First, they challenged the assumptions of the traditional conditioning-extinction theories of discrimination learning (e.g., Spence, 1936; Hull 1950) described in section 1.3. These theories contend that extinction of responding to S- through the occurrence of errors is an essential process for the establishment of a discrimination. However, Terraces results not only demonstrated that discriminations could be acquired in the absence of any responding to S-, but also appeared to indicate the superiority of errorless learning in facilitating discrimination acquisition. Second, the possibility of devising strategies that could establish discriminations without relying on errors appeared of great significance for human subjects affected by severe mental handicaps. Terraces work therefore gave impetus to the study of stimulus control in mentally handicapped populations.

Terraces Theory of Errorless Learning

For Terrace, the explanation of the differences between learning with and without errors lies in the properties acquired by S- during the course of discrimination acquisition. In trial-and-error learning, the occurrence of non-reinforced responses to S- results in frustration, producing negative emotional responses in the presence of S- (e.g., turning away from the key, pulling back from the key, wing flapping, etc.). This frustration establishes S- as an aversive stimulus, and S- acquires inhibitory control over responding. In support of this hypothesis, Terrace (1971) demonstrated that pigeons who had the opportunity to escape from S- during discrimination training would emit escapes responses only if they had been trained under a trial-and-error and not an errorless procedure. Terrace (1966a, 1966b, 1972) also discusses several phenomena indicative of inhibitory control (e.g., inverted generalization gradients, peak shift, behavioural contrast), which he claims are observed only following trial-and-error learning.

In contrast, the absence of non-reinforced responses to S- during errorless learning results in S- functioning as a neutral rather than aversive stimulus. S- does not acquire inhibitory control over responding, and the negative emotional responses in the presence of S-, observed following trial-and-error training, are not observed following errorless learning. The absence of these competing and incompatible emotional responses, which interfere with learning, is presumed to underly the facilitation observed in errorless learning. However, as will be argued later, Terraces theory may need to be revised in the light of subsequent research (e.g., Rilling and Caplan, 1975).

Since Terraces early studies, further refinements to the procedures, as well as some new procedures, have been developed. For the purposes of the present research five major classes of programmed techniques are identified; (1) stimulus fading, (2) stimulus shaping, (3) superimposition and fading, (4) superimposition and shaping, and (5) delayed prompting. Each of these procedures will be outlined below, together with brief descriptions of illustrative research with developmentally impaired subjects.

1.4.1 Stimulus Fading.

Typically, stimulus fading involves gradual changes along some physical dimension upon which \underline{S}_+ and \underline{S}_- differ, to a point where the terminal discrimination is based on some other dimension, usually one that is more difficult for the learner. Dimensions that may be manipulated include size, colour, intensity, duration, etc. For example, in training a discrimination between a circle and an ellipse, \underline{S}_+ might initially be presented at criterion brightness level while \underline{S}_- is invisible so the child would respond only to \underline{S}_+ . Progressively, the intensity of \underline{S}_- may be increased (faded in) until eventually the intensity of both stimuli is equated. At this point the child may continue to respond only to the \underline{S}_+ . Alternately, fading may be conducted upon the relevant dimension directly. For example, in training a discrimination between a larger (\underline{S}_+) and a smaller (\underline{S}_-) circle, fading along the dimension of size could start with a very small \underline{S}_- . Progressively, the size of \underline{S}_- may be increased until it reaches criterion level (Richmond & Bell, 1983; Strand & Morris, 1988).

Sidman and Stoddard (1967) provide an example of a stimulus fading

procedure to teach mentally handicapped children a circle (S+) versus ellipse (S-) discrimination. This programme is illustrated in Figure 1.1. At the start of the programme subjects were presented with a single bright key showing a circle. Eight other S- keys were dark. Over a six step sequence the S- keys became progressively brighter until they were the same brightness as the S+ key. Over a further 10 steps ellipses gradually appeared on the S- keys until the ellipses and circles were equally distinct. Significantly more subjects who received the fading procedure acquired the discrimination than children trained by trial-and-error methods. Fading has also been successful in training visual discriminations in several other studies (e.g., Lambert, 1975; Schreibman, 1975; Zawlocki & Walls, 1983).

Mosk and Bucher (1984) have also employed fading procedures in training visual-motor skills to mentally handicapped children. The first task consisted of inserting pegs into two specific holes of a pegboard. At the start, the pegboard contained only these holes (S+) . Subsequently, four new holes (S-) were faded in (one at a time) in various parts of the board. Each of these holes was initially too small to receive a peg but achieved criterion size over two subsequent steps. A second task consisted of hanging a familiar object (e.g., a flanel) on a specific (S+) peg of a board. The location of the correct peg was constant while three other pegs (S-) were faded in, one at a time, in other positions on the board. Each peg was very short at the first step, and achieved criterion length over two following steps. For both tasks, the fading procedures, combined with trainer prompts, established discrimination responding more effectively than employing trainer prompts alone.

Circle, Ellipse Fading Program

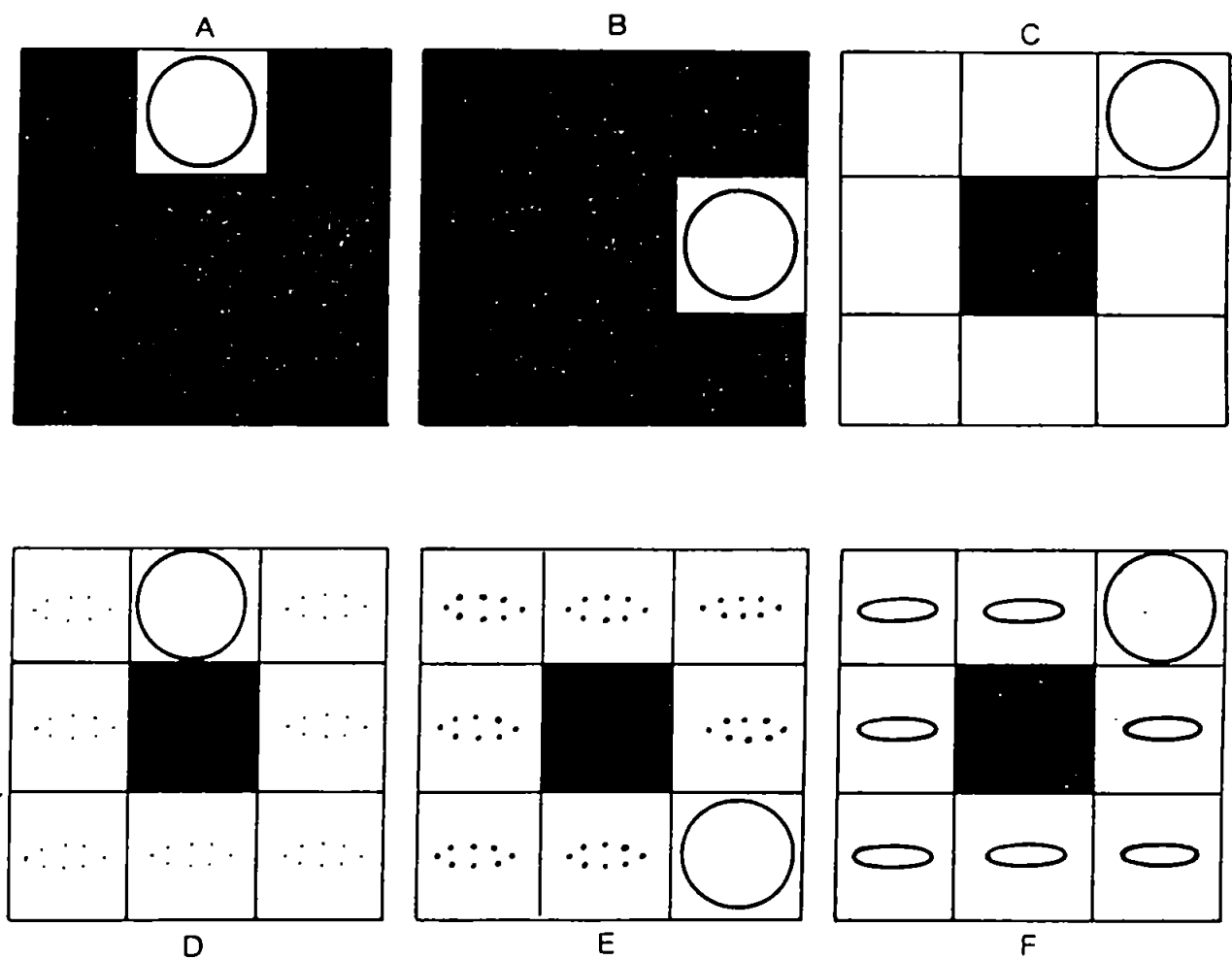


FIG. 1.1 Representative steps in the errorless training of a circle-ellipse discrimination using stimulus-fading procedures (Sidman & Stoddard, 1966).

1.4.2 Superimposition and Fading.

In these procedures, stimuli already known to control responding are used as prompts for the training of new stimuli. These procedures differ from stimulus fading in that the fading operations do not deal directly with the training stimuli per se., but with those stimuli used as prompts. For the discrimination of two alphabet letters, for example, training could start by pairing letters (or just the S+ letter) with colour/s already discriminated by the subject. Subsequently, the colours may be faded out until eventually only the two letters alone are presented. Similarly, for the discrimination of words, the starting point could consist of pairing the words with pictures of the corresponding objects already known and discriminated by subjects. Subsequently, the drawings may be faded out until responding is totally dependant on the words. As can be seen, the manipulations in these procedures deal with added or prompt stimuli (e.g., colours or pictures).

Mentally handicapped children have been trained^{on} both the above tasks using superimposition and fading procedures. First, Gurnalick (1975) taught eight mentally handicapped children to discriminate three pairs of letters. For each pair, different colour cues were used to emphasise the distinctive features of the letters during match-to-sample training. The added cues were faded out over a three step sequence. All subjects were able to learn the discriminations. Second, Dorry and Zeaman (1975) employed superimposition and fading to train moderately retarded children to acquire a simple eight-word reading vocabulary. A pretest determined that the children were unable to name the target words, while pre-training was conducted to ensure that they were able to name the corresponding pictures.

Words were presented in lists each comprising four words. Initially words were combined with pictures of the corresponding objects. In a 'no fading' condition words and pictures were paired together throughout training. In the 'fading' condition the pictures were faded out (reduced in intensity) over a six step sequence until the children were responding to the words alone. Post-tests consisting of the words alone were presented. The mean number of words correctly read by subjects in the fading group (approx. 5 words) was twice that of subjects in the no fading group (approx. 2.5 words). However, subjects performance did clearly continue to include errors.

Fading operations may also be programmed for prompts delivered by a human trainer. Such a procedure has been described by Strand and Morris (1986). The procedure employs the gradual and successive fading of three component prompts; physical, gestural, and verbal, and will be fully described in Chapter 3. The technique proved to be extremely effective in training visual discriminations with severely mentally handicapped children.

1.4.3 Stimulus Shaping.

Sldman and Stoddard (1966) are credited with the original development of shaping techniques. The procedure involves changing the topography (configuration) of the stimulus. In such cases the initial stimulus does not resemble the final or criterion stimulus on any dimension because its topography is to be gradually altered to form the criterion stimulus. Initially, as in fading, the stimuli are ones that a child can successfully discriminate. For example, in training a discrimination between a circle

and an ellipse, a child may be presented with a discrimination between a square and the ellipse. The square may then be shaped to form a circle by progressive manipulation of its topography. Figure 1.2 illustrates such a stimulus shaping programme. For comparison, a stimulus fading programme utilizing size fading is also illustrated.

Gurnalick (1975) employed a stimulus shaping procedure to train letter discriminations to eight mentally handicapped children. For example, in training a discrimination between the letters V and U, the critical dimension was identified as straight vs. curved. In a short pre-training session, a straight vertical line was contrasted with an exaggerated curved line. The degree of curvature was gradually decreased (shaped) over a three step sequence to attain criterion level. On subsequent letter discrimination tests all subjects acquired the discriminations.

Smeets, Lancioni, and Hooegeven (1984a) also used shaping procedures to teach seven mentally handicapped subjects to sight-read a set of three words. Initially, only three familiar pictures of the objects were presented. Each picture was then transformed into the letters (one at a time) of the corresponding word. The shaping was carried out on all three words simultaneously over a 28 step sequence. All subjects were successful in acquiring the discrimination.

1.4.4 Superimposition and Shaping.

This procedure is similar to superimposition and fading. However, the manipulation of the prompts leads to embedding them into the discriminative stimuli. The procedure has not been widely employed. However, Smeets,

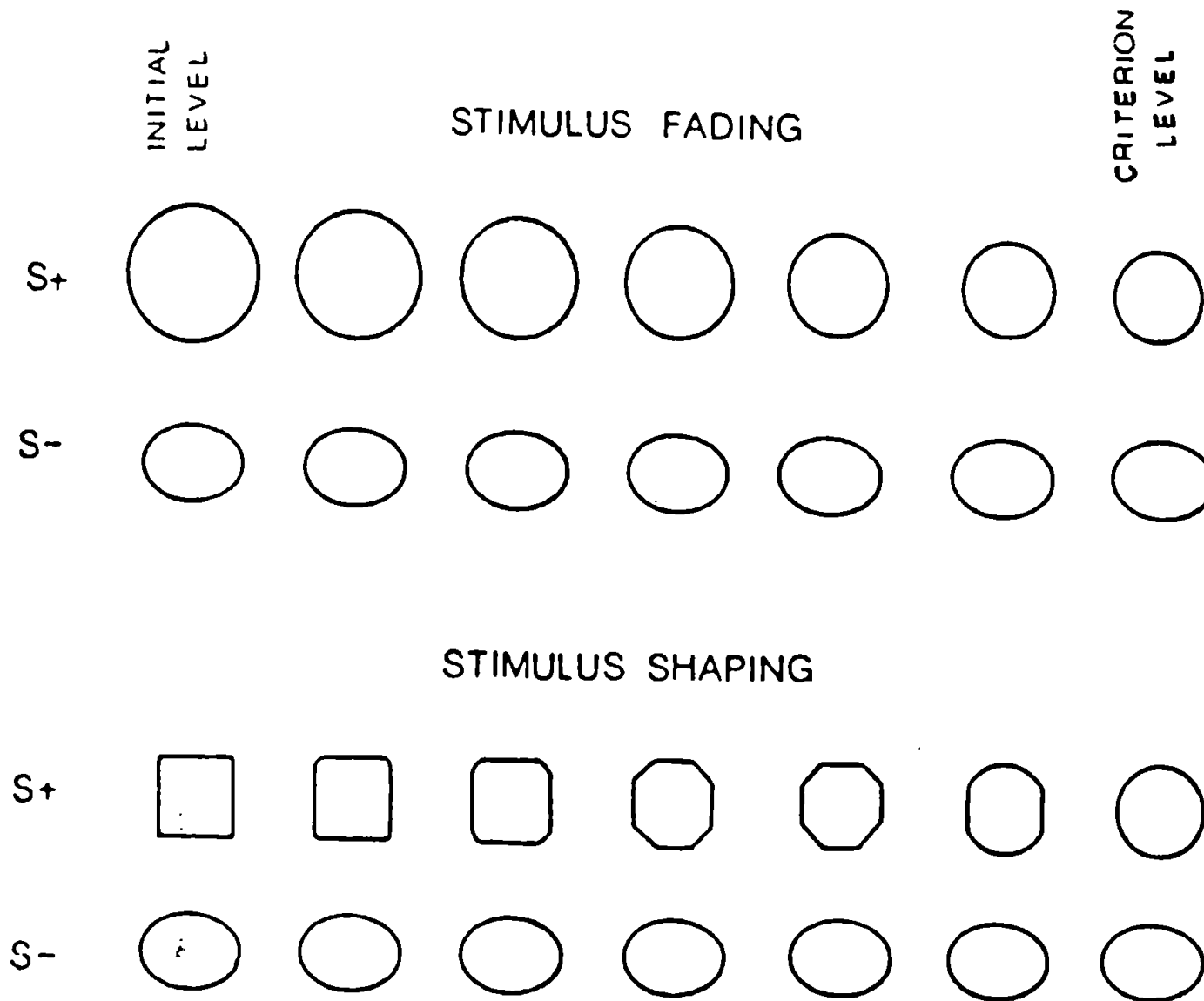


Fig. 1.2 Examples of stimulus fading and stimulus shaping, illustrating initial and criterion levels with selected intervening steps.

Lancioni, and Hoogeveen (1984b) employed superimposition and shaping to teach 15 mentally handicapped children to discriminate three-word sets. The programme started by superimposing pictures upon corresponding words. Subsequently, the pictures were shaped into a letter of the related word, until they completely overlapped with the related letter. Shaping was conducted on all three words in a set concurrently, and consisted of 32 steps. All subjects were successful in acquiring the discriminations.

1.4.5 Delayed Prompting.

This procedure was first described by Touchette (1971). Initially, mentally handicapped subjects were trained to respond to a red key. The S₊ (E with legs down) was then superimposed upon the red key, while S₋ (letter E with legs up) was superimposed upon a white key. Subsequently, the appearance of the red colour on S₊ was progressively delayed. Each correct response caused the delay in the appearance of the prompt to be increased by .5 seconds. Touchette found that all three subjects made few errors, and over time came to respond prior to the onset of the prompt so that the prompt could be discontinued. Several variations on this procedure have been developed. For example, a fixed four second delay between presentation of the training stimuli and prompt may be involved, rather than progressive increases in the delay (Johnson, 1977). Also, different reinforcement schedules may be programmed for responses occurring prior to or after the onset of the prompt (Touchette & Howard, 1984).

1.5 Procedural and Theoretical Parameters of Programmed Training

The above procedures have as a common concern the acquisition and

maintainance of appropriate stimulus control. Stimulus control refers to "the control of behaviour by its enviromental context, by events which, unlike consequences, precede or accompany the behaviour" (Sidman, 1978). 'Appropriate' controlling relations are indicated when responding is under the control of relevant task stimuli. Inappropriate control describes situations in which features of a task not relevant to its solution control responding, e.g., left-right position in a simultaneous discrimination. The aim of all programmed procedures is to facillitate the establishment of appropriate stimulus control.

The above review of studies indicates that programmed training has proved effective in training a variety of tasks with mentally handicapped individuals. However, together with findings of errorless acquisition, failures to learn and errors in acquisition have also been observed (Sidman & Stoddard, 1966a; Touchette, 1968; Gollin & Savoy, 1968; Touchette, 1971; Gold & Barclay, 1973; Dorry & Zeaman, 1975; Koegel & Rincover, 1976; Russo, 1976; Irvin & Bellamy, 1977; Lambert, 1980; Smeets and Lancioni, 1981). Further research is needed to isolate and evaluate the basic procedural parameters involved in programmed training, and has been called for repeatedly in recent reviews (Rilling, 1977; Billingsley & Romer, 1983; Lancioni & Smeets, 1986). For example, Rilling (1977) notes that the parameters of fading are generally uninvestigated, the effectiveness of particular fading techniques has not often been compared to an appropriate control group, and that procedural variables have often been ignored. He concludes that "fading remains a part of the art rather than the science of operant conditioning" (p466).

By investigating the basic parameters underlying diverse programmed

procedures, it may be possible to investigate the role of specific variables as determinants of the development (or lack of development) of appropriate stimulus control. In this context, interpretation may be aided by considering the literature on compound conditioning (e.g., Kamin, 1968; Miles & Jenkins, 1973), the role of stimulus novelty in learning (Trabbasso & Bower, 1968), and attentional theories of learning (e.g., Sutherland & Mackintosh, 1971; Zeaman & House, 1963, 1979). A better understanding of the factors underlying successful training appears of great importance for any practitioner considering the use of such procedures (Lancioni & Smeets, 1986).

The following sections will briefly review some basic procedural parameters involved in programmed training. More detailed discussion will be provided in later chapters.

1.5.1 Pre-response Versus Error Correction Prompting, and Prompt Sequences

Two general rules may be extracted from an analysis of the five 'errorless' training procedures described above. First, the discrimination is initially made easy by providing additional prompts. These prompts are provided prior to the requirement of a response from the subject in order to guide the child's performance. Second, the prompts are gradually removed so that the amount of assistance provided is progressively reduced (decreasing assistance).

However, many applications of prompting procedures in applied settings do not adhere to either one or both of these two principles. Many procedures do not provide antecedent prompts, rather they involve error

correction prompting (consequent prompts) (Gold & Barclay, 1973; Lowry & Ross, 1975; Cuvo, Leaf, & Borekove, 1978). The three term contingency consisting of (a) discriminative stimuli (b) response, (c) reinforcing stimulus is therefore modified quite differently in pre-response and error correction procedures. With pre-response prompting the prompt accompanies the discriminative stimuli and cues the correct response which is followed by a reinforcing stimulus. In error correction procedures the discriminative stimuli are presented alone. They are followed by a response that is either correct or incorrect. If correct, a reinforcing stimulus follows and then the next discriminative stimuli. If incorrect, a prompt for a correction response follows in the presence of the original discriminative stimuli.

Additionally, error correction prompting is frequently combined with an increasing rather than decreasing assistance procedure. This has been termed the least-to-most procedure, or system of least prompts (Close, Irvin, Prehm, & Taylor, 1978; Snell, 1983). If the child produces errors the trainer provides 'mild' prompts (e.g., verbal) before sequentially delivering prompts involving a greater degree of assistance (e.g., modelling, gestural, physical assistance) until the child exhibits the desired response. The procedure has proved effective in training a variety of skills to mentally handicapped children including expressive manual signs (Steege, Wacker, & McMahon, 1987), toothbrushing (Horner & Keillitz, 1975), and functional reading (Brown, Jones, Troccoli, Helser, Bellamy, & Sontag, 1972).

While error correction and increasing assistance procedures are widely employed, there have been remarkably few studies comparing these and other procedures. For example, in a recent review of prompt fading techniques,

Billingsley and Romer (1983) identified only two studies comparing decreasing with increasing assistance approaches, and these produced conflicting results (Gentry, Day, & Nakao, 1980; Csaspo, 1981). Similarly, little research has compared antecedent (pre-response) and consequent (error correction) prompting procedures. While some research suggest antecedent procedures may be more effective in reducing errors during training (Zane, Walls, & Thvedt, 1981), other research has suggested consequent prompting may produce fewer errors on test (un prompted) trials (Haught, Walls, and Crist, 1984). Billingsley and Romer (1983) conclude the body of knowledge guiding practioners in the selection and application of prompting procedures is limited. Burleigh and Marhoillin (1977) also describe this situation thus: "there is little empirical evidence to suggest when, how, how long, and in what form they (prompts) should be used" (p110).

In conclusion, it may be hypothesised that the most effective training procedures would; (a) present prompts before a response is produced, and; (b) fade prompts to provide gradually decreasing assistance. Certainly, Terraces theory would suggest procedures that do not conform to the above rules are unlikely to be truly errorless, since they fail to minimize the probability of the child emitting non-reinforced responses to S-, and may lead to the development of negative emotional by-products (see section 1.4).

However, many prompting procedures employed in applied settings, where prompts are provided by a human trainer, have not adopted such guidelines. These factors will be investigated further in Chapter 3, which will include an evaluation of the effectiveness of fading trainer prompts in teaching visual discrimination tasks.

1.5.2 Number and Size of Programmed Steps.

It is imperative that changes along the prompt dimension(s) involve gradual manipulations rather than abrupt transitions. For example, Lawrence observed that if animals were abruptly transferred from a simple black-white discrimination to a complex grey discrimination the facilitative effect of 'transfer along a continuum' (see section 1.4) was eliminated. Similarly, Terrace (1966a) has observed that errors may occur if too large a change between progressive steps in the fading of S- are programmed. The number of steps required, and the size of these steps, is an empirical issue, and usually has to be decided by the experimenter through trial-and-error experimentation (Sidman & Stoddard, 1966a).

Two general decision rules may apply. First, the steps are to be small, for the reasons described above. Second, there should not be too many steps. In such cases the programme may become unnecessarily long and/or the subject may lose motivation in responding (Sidman & Stoddard, 1966a). However, wide variations in number of programmed steps are apparent. For two-choice discrimination tasks, some studies employing stimulus fading have used as few as three programmed steps (Wolfe & Cuvo, 1978). At the other extreme, Schilmoeller and Etzel (1977) employed a shaping procedure to train a two-choice discrimination between kanji (Japanese) symbols which involved 60 programmed steps. Generally, stimulus shaping procedures have involved the greatest number of programmed steps.

The number and size of steps may be of critical importance in determining the success of any programme (Stoddard, personal communication, 1985). However, the effect of the number of steps in a programme cannot be

considered independantly of the nature of the programmed operations (e.g., fading or shaping), the nature of the task, the complexity of the task stimuli, subjects level of functioning, etc.

1.5.3 Manipulating the S+ or the S- Stimulus.

Prompting can be achieved by either the addition to S+, or subtraction from S-, of values on the prompt dimension. Both operations heighten the perceptual discriminability of the stimuli, although the stimulus manipulated during fading differs. In practice, whether S+ or S- is selected for manipulation frequently depends upon the stimulus dimension from which the prompt cue is drawn. Colour and size prompting procedures predominantly highlight and then fade colour or size cues superimposed upon S+ (e.g., ^eEgland, 1975). Conversely, intensity fading procedures predominantly manipulate S-. The intensity of S- is initially reduced relative to S+, with subsequent increments in S- intensity (e.g., Sidman & Stoddard, 1967).

However, recent research (Schreibman & Charlop, 1981; Zawlocki and Walls, 1983; Stella & Etzel, 1986) has focussed directly upon how either S+ or S- manipulation in prompting procedures may affect the process of discrimination acquisition. The results of this research are at present ambiguous. Schreibman and Charlop (1981), and Stella and Etzel (1986), report data favouring fading or shaping of the S+. These authors have suggested that the better results obtained with the manipulation of S+ are due to the fact that subjects attention is more heavily drawn on the S+ (i.e., the changing stimulus). The changing stimulus may be more salient, novel, or noticable, and therefore more likely to be selected as functional in learning (Trabbasso & Bower, 1968). In contrast, Cheney and Stein (1974),

and Zawlocki and Walls (1983), have reported that fading along the S- produced better results than fading along the S+

Comparison of S+ and S- manipulation in programmed procedures therefore appears to warrant further investigation, a need that has been recently emphasised by both Stella and Etzel (1986), and Lancioni and Smeets (1986). This issue will be addressed further in Chapter 4.

1.5.4 Type of Stimulus Manipulations

Programmed training procedures may also be contrasted in terms of the type of stimulus manipulations employed. Lancioni and Smeets (1986) have recently forwarded a classification system defining types of stimulus manipulations in terms of three key variables. While their analysis does not always concur with that proposed by other authors, and is in some instances at variance with the views of the present author, for the sake of consistency Lancioni and Smeets criteria will be employed below.

Extra-stimulus / Within-stimulus Manipulations: This parameter largely covaries with the five procedures described in section 1.4. Superimposition and fading, superimposition and shaping, and delayed cue procedures involve the manipulation of prompts, or extra stimuli, added to the criterion stimuli. In contrast, procedures involving the early and progressive introduction of S- (stimulus fading), and stimulus shaping procedures, involve manipulations that are directly concerned with the stimuli to be discriminated. Lancioni and Smeets describe such manipulations as extra-stimulus (ES) and within-stimulus (WS) respectively.

Distinctive-feature / Non Distinctive-feature Manipulations: A further differentiation can be made between manipulations that are connected, or unconnected, to relevant (differentiating) portions of the stimuli to be discriminated. Examples of the former 'distinctive-feature' (DF) manipulations would include highlighting the stem of the R in a P-R discrimination, or the base of the letters in a V-U discrimination (e.g., Wolfe & Cuvo, 1978; Rincover, 1978). The latter 'non-distinctive-feature' (NDF) manipulations might include the fading out or delaying of a background colour cue used to prompt the R in an R - P discrimination (e.g., Koegel & Rincover, 1976; Touchette, 1971).

Criterion-related / Non-criterion-related Manipulations: Schilmoeller and Etzel (1977) suggest a distinction be drawn between 'criterion-related' and 'non criterion-related' stimulus manipulations. Criterion-related (CR) manipulations involve changes along a dimension of the stimuli (e.g., size, length, intensity) that is present and relevant in the final (or criterion) discrimination. For example, fading the size of S- in a size discrimination (Richmond & Bell, 1983). In contrast, non criterion-related (NCR) manipulations involve changes along a dimension that is not present in the final discrimination. For example, fading along a dimension of intensity while the final discrimination is based on form (e.g., Sidman & Stoddard, 1966).

Recently, Lancioni and Smeets (1986) have attempted a meta-analytic investigation of the outcome of different types of stimulus manipulations. Employing the within-stimulus / extra-stimulus distinction as a superordinate variable, four classes of manipulations are identified by Lancioni and Smeets: WS-CR; WS-NCR; ES-DF; and ES-NDF. Subsequently,

studies evaluating the effectiveness of programmed discrimination training with developmentally impaired individuals are reviewed, and listed according to this classification system. The overall percentage success rates for the four types of stimulus manipulations are then compared in terms of the proportion of 'failures' to 'training instances' in each of the studies.

A summary of the results of Lancioni and Smeets analysis is presented in Table 1.1. The number of studies reviewed, the number of training instances (defined as one subject trained on a specific task), and both the number and percentage of 'successes' and 'failures' are detailed for each type of manipulation. Lancioni and Smeets conclude that procedures involving WS manipulations, or ES-DF manipulations, have appeared more effective than ES-NDF manipulations. Additionally, they conclude that of the ES-NDF manipulations, delayed cue procedures appear more successful than superimposition and fading procedures (71% versus 63% success rates respectively).

There are, however, important qualifications to this type of analysis. The authors note for example that "instances of failure", summed over diverse studies, cannot be interpreted without knowledge of both the error criteria used for determining success or failure, and the type of tasks employed. On the first point, ES-NDF manipulations have tended to be conducted using restrictive error criteria. For example, in a study conducted by Koegel and Rincover (1976) involving the fading of background colour prompts, five correct responses were necessary to advance through each of the 16 steps of the programmed sequence. However, if two errors were made on any one step training was ended in failure. Studies utilizing WS manipulations do not appear to have applied such restrictive criteria.

Table 1.1: A summary of Lancioni and Smeets (1986) meta-analysis of training outcome by type of stimulus manipulation.

Stimulus Manipulation	Number of Studies	Training Instances	Number of Instances	
			Success	Failure
WS-CR	9	85	80 (94%)	5 (6%)
WS-NCR	10	115	96 (83%)	16 (17%)
ES-DF	3	62	62 (100%)	0 (0%)
ES-NDF	16	221	144 (65%)	77 (35%)

a. Studies listed according to Lancioni and Smeets classification system, not necessarily that of the studies authors.

Note. WS-CR= within-stimulus criterion-related; WS-NCR= within-stimulus non-criterion-related; ES-DF= extra-stimulus distinctive-feature; ES-NDF= extra-stimulus non-distinctive-feature.

The differential success rates may therefore be partly ascribed to differences in error criteria.

Second, ES-NDF manipulations were also over-represented in the more difficult tasks (e.g., Dorry & Zeaman, 1973, 1975; Dorry, 1976; Walsh & Lambert, 1979), which might depress the overall percentage of successes. While ES-NDF manipulations were still relatively unsuccessful in training less complex two-choice discriminations (52% success rate), many of the failures on such tasks were reported under the restrictive error criteria mentioned above. If these studies are eliminated, the success rate rises to approximately 70%.

In summary, such meta-analysis can provide general indications concerning the overall effectiveness of different stimulus manipulations. However, the effects of specific types of stimulus manipulations may most effectively be compared within experimental situations in which the confounding effects of other types of manipulations, type of task, task difficulty, error criteria, number and size of programmed steps, and other relevant parameters can be controlled. Unfortunately, such studies are relatively rare in the empirical literature. A clear example of such a design is, however, provided by Rincover (1978), and it may be pertinent to briefly review this study.

Rincover observed that in previous studies (e.g., Schreibman, 1975; Wolfe & Cuvo, 1978) the successful prompts were both within-stimulus (located within S+), and distinctive features (features not present in S-). Similarly, the unsuccessful prompts were both extra-stimulus (not located within the discriminative stimuli) and non distinctive-features (features

present in both S⁺ and S⁻). The WS and DF variables were therefore confounded, leaving the relative contribution of each variable unclear.

Rincovers study was designed to evaluate the independent influence of each of these variables by comparing all four possible combinations of prompts: WS-DF; ES-DF; WS-NDF; and ES-NDF.¹ Eight autistic subjects were trained to discriminate pairs of three-letter words. The manipulations involved fading a pre-trained prompt that was an exaggerated feature of the first letter of the S⁺ words. The prompt could emphasise either a distinctive feature of the S⁺ letter (an element not contained in any of the S⁻ letters), or a non distinctive-feature (an element also contained in some of the S⁻ letters). Furthermore, the prompt could either be superimposed upon S⁺ (within-stimulus), or spatially separate from the corresponding feature of the S⁺ word (extra-stimulus). These combinations may more clearly be illustrated with reference to Figure 1.3. In all conditions, a six step sequence which gradually faded out the prompt was employed.

Rincover found significant main effects for both the WS/ES and DF/NDF variables. Both WS conditions produced significantly higher rates of acquisition than did either of the ES conditions. Also, more discriminations were acquired when the prompt was a DF rather than a NDF. Overall, the combination of WS-DF fading was found to be most effective, and ES-NDF least effective.

1. Rincovers definition of 'within-stimulus' and 'extra-stimulus' differs from that proposed by Lancioni and Smeets (1986). However, this interpretation accords with that originally proposed by Schreibman (1975), and is the most predominant usage (e.g., Wolfe & Cuvo, 1978; Lovaas et al, 1979; Etzel & LeBlanc, 1979; Rincover & Ducharme, 1986).

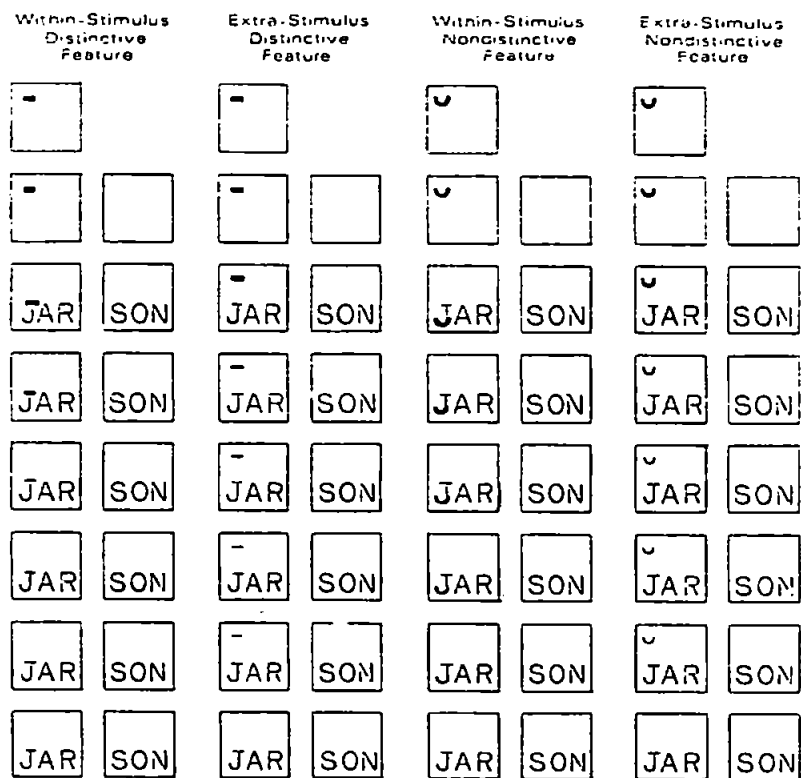


Figure 1.3: Illustrations of the four fading procedures employed by Rincover (1978) (after Rincover, 1978).

In conclusion, these different types of manipulations have been considered extremely important in determining variations in programme effectiveness. Rincover (1978), along with other authors (e.g., Schreibman, 1975; Koegel and Rincover, 1976; Lambert, 1980), has argued that extra-stimulus non-distinctive manipulations can easily end in failure. This contention may find some support in theories addressing compound conditioning (e.g., Sutherland & Mackintosh, 1971; Rescorla & Wagner, 1972).

While these theories differ significantly in their interpretation of compound conditioning phenomena, both theories predict that when one component of a compound stimulus is 'stronger' (i.e., either more discriminable or better correlated with reinforcement) than another, the risk exists that the stronger stimulus will overshadow the weaker stimulus of the compound, blocking or reducing any attention to it. Since the prompts being manipulated in extra-stimulus procedures may often be considered stronger or more salient than the stimuli that must ultimately be discriminated, discrimination of the less salient stimuli may not result. A similar prediction can be forwarded concerning procedures involving NCR rather than CR stimulus manipulations, whereby attention to the dimension of the stimulus relevant to the final discrimination may be reduced by the presence of a salient and concurrent NCR dimension.

Unfortunately, the methodological rigour demonstrated in Rincover's (1978) study is not characteristic of many experimental evaluations of variables relating to types of stimulus manipulation. In particular, Strand and Morris (1988) have forwarded methodological criticisms of the studies evaluating the CR/NCR variable, a major deficiency being the apparent confounding of CR/NCR and WS/ES variables. As observed in Rincover's (1978) study, control of the role of the ES variable is essential, given the

inferiority of extra-stimulus compared to within-stimulus fading.

In conclusion, these variables emphasise important qualities of prompt and criterion cues that must be considered when designing effective training programmes. Further analysis of types of stimulus manipulations, and a systematic and controlled evaluation of the CR/NCR variable in particular, will be considered in Chapter 6.

1.5.5 Review

Further description of the basic procedural parameters reviewed in this section, and more detailed descriptions of relevant research, will form the introductions to subsequent chapters describing the experimental investigations of the present research. The examination of the effects of these parameters will provide the main impetus for the experimental studies.

However, other important issues will also be addressed. For example, the vast majority of studies reviewed in this chapter have investigated the effects of different discrimination training procedures on the acquisition of single discrimination tasks. Few studies have addressed the issue of extended training, or generalization across stimuli or settings (Stoddard & McIlvane, 1986). It is unclear, therefore, how fading procedures compare with trial-and-error training when such procedures are implemented over a series of discrimination tasks. It is also unclear whether repeated success under programmed training conditions may facilitate, or inhibit, subsequent learning of tasks presented without programmed assistance (Lambert, 1980). Both these issues will be addressed in the current research.

1.6 Computer Assisted Training.

The last section of this chapter considers the potential of recent advances in micro-computer technology for implementing the programmed training procedures discussed in section 1.4.

The potential of using technology to teach basic skills to mentally handicapped people was first explored in the early 1950s with the introduction of 'teaching machines'. However, high cost, low reliability, relative inflexibility, and lack of convincing evidence regarding the degree of effectiveness (Greene, 1966; Haywood, 1977) resulted in a general lack of acceptance by the educational community. More recently, advances in microelectronics have allowed the development of small, powerful, and relatively inexpensive microcomputers. The new technology potentially promises many of the benefits that teaching machines failed to provide (Hooper, 1977).

The programmed training procedures outlined in section 1.4 frequently require apparatus which can be quite complex and costly in terms of time and materials. The procedures also necessitate careful and precise control, and should ideally pace training in response to the learners performance. Such factors have in part limited the widespread application of programmed procedures. With the advent of microcomputers, now available in most special education establishments, the potential for the application of these programmed training techniques may be broadened.

Microcomputers offer several potential benefits for discrimination training; (1) rapid generation and presentation of the stimulus materials;

(2) an increased range of potential reinforcers (e.g. tunes, graphic displays, etc.). Interacting with a microcomputer can also in itself prove a motivator for clients (Splittgerber, 1979); (3) automatic recording and storage of data. This also greatly facilitates data analysis and presentation on either a trial-by-trial or summary basis; (4) individualized instruction by adjusting the rate and difficulty of material to suit individual clients. The present research therefore aims to utilize and evaluate the feasibility of conducting programmed training procedures using microcomputers. This may allow for inexpensive and flexible applications, with considerable savings in staff time and effort.

1.7 Summary

In conclusion, it has been argued that learning to discriminate (i.e., respond differentially) to stimuli is an essential pre-requisite for the acquisition of more complex behaviours. However, it was noted that traditional 'trial-and-error' training procedures have frequently proved ineffective in teaching such basic discriminations to severely mentally handicapped individuals. The development of programmed training procedures as a means of facilitating discrimination acquisition was reviewed, and several programmed (or 'errorless') training procedures were identified. It was observed that while such procedures had achieved some notable success in facilitating discrimination acquisition with mentally handicapped individuals, the occurrence of errors and failures of acquisition were also not infrequently reported. Recent reviews have suggested that further research is required to more clearly elucidate the role of specific procedural variables in determining the success (or lack of success) of programmed training. The chapter concluded by reviewing some basic

procedural and theoretical parameters of programmed procedures that may be important in determining variations in training outcome. Lastly, the potential benefits of micro-computer technology for the implementation and more widespread application of programmed procedures was discussed.

However, parameters of training procedures are not the only variables that may be presumed to influence the success of discrimination training with mentally handicapped people. In the next chapter, consideration turns to the evaluation of a second potential source of variation in training effectiveness; namely the role of individual differences.

CHAPTER 2

Discrimination Learning:

The Concept of Individual Differences

Chapter 2

Discrimination Learning: The Concept of Individual Differences

In addition to properties of the discrimination task and training techniques, characteristics of the individual are also important in determining the rate and outcome of learning. At the most peripheral level sensory defects such as visual or auditory handicaps influence training. Differences in motivation and receptiveness to different reinforcers or stimulus modalities may also be important, as may individual differences in the more fundamental parameters governing the processes involved in learning. However, the influence of individual difference factors has received scant attention.

There is a pervasive tendency in the research literature to consider subjects members of homogeneous groups, exacerbated by the plethora of comparative group research aimed at identifying the locus of the 'mental retardation deficit' (e.g., Heal & Johnson, 1970; Ellis, 1963). At the other end of the spectrum, mental handicap practitioners tend to treat each individual as an isolated and discrete case, which does not allow easy comparison of subjects. Neither approach facilitates the gathering of data concerning stable dimensions of individual difference, which may be associated with success in discrimination training.

This state of affairs may in part be due to the historical division between the study of individual differences and the study of learning, which derive from divergent psychological traditions. The individual difference, or psychometric, approach derives from the correlational tradition, and is essentially trait orientated. In contrast, learning research derives from the

experimental psychology tradition, and is predominantly process orientated. As Estes (1981) states, the areas have been "sharply compartmentalized". In psychometric approaches, since the factors studied have been viewed as traits (e.g., intelligence) the main focus has been on measurement issues of accuracy, reliability, etc. Conversely, learning research has centred on the intensive study of individual subjects (e.g., Skinner, 1938) and investigated the processes presumed to underly learning e.g., attention, retention, inhibition, generalization, etc.

Given this background, the influence of individual differences can be approached from two perspectives. First, in the psychometric tradition intelligence has frequently been equated with the ability to learn (McGeogh, 1942; Simrall, 1947; Scott, 1978). It can then be asked how individual differences in intelligence are related to learning ability. Second, we can ask how, or to what extent, individual differences are represented within any given learning theory.

2.1. Learning and Intelligence

Correlations between assessments of intelligence and learning have not produced the expected significance. For example, Rapier (1962) in her review of the area notes that the most frequent observation is that intelligence tests seem to measure learning ability, however "measures of learning in the laboratory and in the school did not support any such conclusion" (p14). Similarly, Woodrow (1946), has concluded "the ability to learn cannot be identified with the ability known as intelligence" (p148).

Some methodological criticisms have been levelled at the studies giving rise to this conclusion (Rapier, 1962). For example, one important criticism concerns the operational definition of learning adopted in most studies.

Learning is defined as the ability to improve with practice. Measurement of learning is therefore obtained from gain scores, derived by subtracting the initial score from the final or criterion score on a learning task, to give the measurement of improvement. Such a measure is criticised for poor control of individual differences in starting level. The effect is to penalize 'brighter' students by not providing enough ceiling for growth as little gain can be shown for a child who is already close to asymptote performance. Those who favour equating intelligence with learning ability (e.g., Simrall, 1946; Scott, 1978) cite significant correlations of MA with initial and criterion scores, but little relation with gain scores.

However, a fundamental problem in equating intelligence with the ability to learn arises from the implied conception of learning a single unitary 'ability'. Experimental studies have employed an extremely wide range of learning tasks, including tests of colour naming, cancellation, addition, mental multiplication, digit symbol substitution, paired associate learning, code learning, backward writing, number completion, and word building (Woodrow, 1946; Rapier, 1962). The most striking observation arising from these studies has been the absence of significant correlations across different learning tasks. Even those researchers favouring the ability to learn conception of intelligence (Stakes, 1961) conclude that no general learning ability is found, other than by definition the general aptitude measured by IQ, and that learning ability can be specific to a particular type of task. Learning does not appear to be a unitary ability, rather the term learning abilities (plural) should be employed (Husband, 1939; Woodrow, 1946).

Zeaman and House (1967) argue that with task-to-task consistency of individual differences in learning in question, it may be more instructive to consider broad classes of tasks separately. One such broad class consists of discrimination learning tasks. Comparisons of discrimination performance

across groups differing in mean intelligence have, in some cases, revealed significant differences between groups. For example, Ellis (1958), using high and low MA groups of mentally handicapped subjects, found the high MA group superior to the low MA group in learning set formation. Also, House and Zeaman (1958) found normal intelligence subjects acquired a discrimination significantly faster than mentally handicapped subjects, where groups were matched for MA.

However, there are discrepant results. Zeaman and House (1967) review 18 studies relating IQ to performance in discrimination learning tasks with MA controlled. While twelve of these studies reported positive results, with better performance from the higher IQ subjects, nine studies reported negative findings. Three studies reported both positive and negative findings for different comparisons. Zeaman and House (1967) suggest that there is a trend towards greater discrimination learning ability with increasing intelligence, although the relationship is sometimes obscured either by ceiling and floor effects arising from tasks that are either too easy or too difficult, or by attenuation in range of IQ. However Wischner (1967), in a commentary on their paper, believes the negative findings are too readily discounted: "the authors are to be congratulated on a nice job of rationalizing the findings to support their theoretical position" (p214).

Relatively few studies have reported correlations between intelligence and discrimination learning. Where correlations are reported they are generally positive but low. For example, House and Zeaman (1960) trained 71 severely mentally handicapped subjects (MA range 2 - 6 years: IQ range 17 - 67) on a two-choice visual discrimination task. They report a partial correlation (MA controlled) of only $-.28$ ($p < .05$) between IQ and log errors.

In summary, since learning and intelligence are not related in any simple

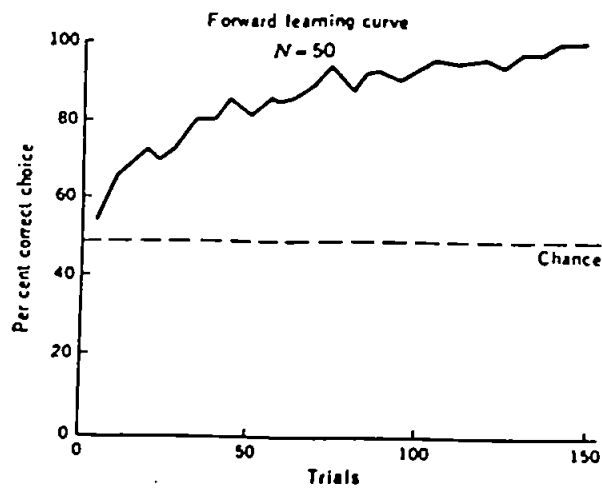
linear fashion, we are reluctant to explain a child's learning difficulties simply on the basis of demonstrably low intelligence. Furthermore, learning ability does not appear to be a single unitary construct, but serves as a global term for a variety of processes and skills. Following Zeaman and House (1967), we intend to focus on one class of learning tasks separately, i.e., visual discrimination learning. Performance on such tasks may be positively related to measures of intelligence. However, surprisingly few correlational analyses have been reported. The extent of the correlation between global ability measures (MA, IQ) and the discrimination performance of mentally handicapped children is one issue that will be assessed in the present research.

2.2. Individual differences and Learning Theory

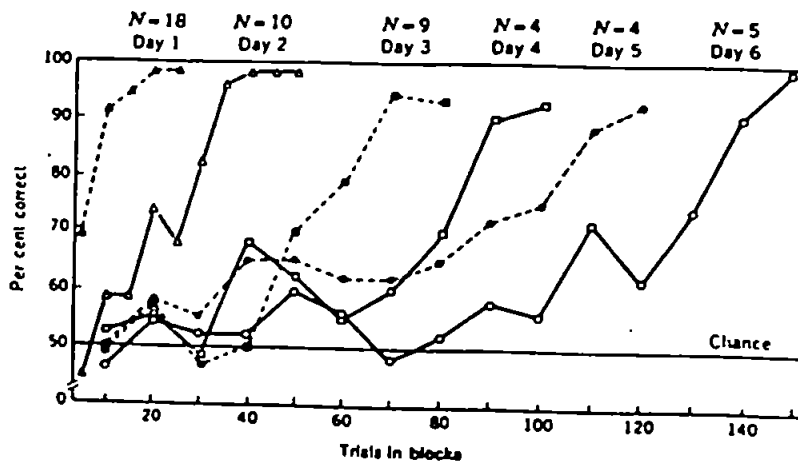
Perhaps the most frequently cited theory of discrimination learning dealing with mentally handicapped populations is Zeaman and House's 'attention theory' (1963). Due to its relevance for the present research, we will take this opportunity to describe the theory in some detail.

Zeaman and House (1963) analysed the discrimination learning performance of their subjects in the form of backward learning curves. In contrast to traditional forward learning curves - which take the initial trial of the experiment as the reference point for each subject - backward learning take the trial on which the subject met the learning criterion as the reference point. Hence the final point of all subjects' curves will coincide. Trials are plotted backwards from this point for all subjects before average curves are computed. Figure 2.1 presents both forward and backward learning curves for a sample of 50 mentally handicapped subjects (Zeaman & House, 1963).

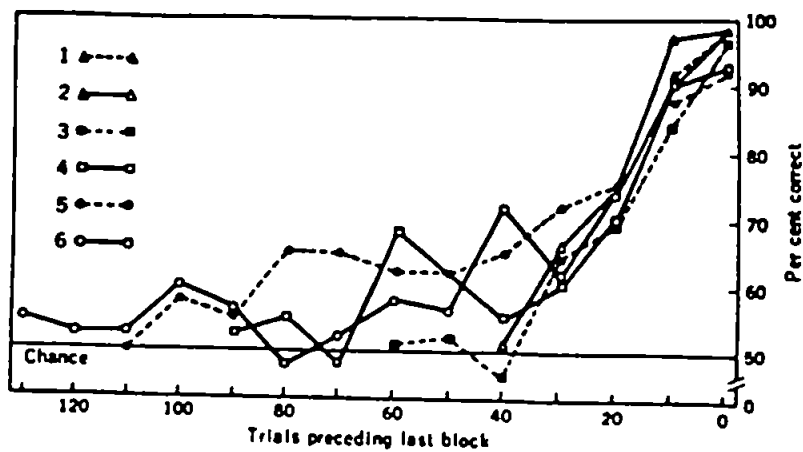
Zeaman and House analysed these backward learning curves. In essence,



Average discrimination learning curve of 50 retardates.
(After Zeaman and House, 1963.)



Learning curves of subgroups, according to the training day required to reach a success criterion. (After Zeaman and House, 1963.)



The curves shown in Figure have been regrouped as backward learning curves, that is, as curves working from the success end-point (right) to starting points (centre and left). The essential similarity of learning, once it has commenced, is obvious. (After Zeaman and House, 1963.)

they conclude that the learning curves feature two stages: (1) an initial horizontal segment hovering around chance-level performance, and (2) a sharply rising segment (see Figure 2.1). Zeaman and House refer to the first stage as the attention phase, in which the subject randomly attends to the various dimensions of the stimulus. Once the subject starts attending to the relevant dimensions of the stimulus Stage 2 begins, and an improvement in instrumental learning occurs. Comparisons of the curves revealed that the variance between subgroups was not in the rate of improvement once it began, but rather the number of trials necessary for improvement to start. Moreover, the length of the chance plateau was reported to covary with group differences in intelligence. Two groups of children of mean MA 2 years 4 months, and 4 years 6 months, were compared. The low MA group required more trials in the attention phase (Stage 1) than the high MA group.

Zeaman and House postulate a chain of two responses for discrimination learning: first, an attentional response to the relevant stimulus dimension; and second, a correct instrumental response to the positive cue on the correct dimension. The 'learning deficit' of mentally handicapped individuals was ascribed to their low initial probability of observing certain relevant dimensions, rather than poor ability to learn which of two observed cues is correct. For example, mentally handicapped individuals may attend to stimulus dimensions which are irrelevant to task mastery (e.g., position).

We now turn to the main concern of this section: How are individual differences represented within learning theories? Historically, the role of individual differences in learning has received relatively little attention from learning theorists, presumably due to their preoccupation with the formulation of universal laws of behaviour. Hence, human variations of the type studied by psychometricians have typically been treated as uncontrolled factors and viewed as sources of error variance (Scott, 1978). Indeed,

learning theorists have often been criticised for ignoring individual differences (Glaser, 1967). However, on one occasion Hull (1945) did address this issue.

Hull theorized that individuals differ, not in the presence or absence of various factors or mechanisms, but only in the values of the parameters that enter into the learning equation. Hence, while the form of the law remains the same, certain parameters may assume different values for different individuals. Hull provides an analogy in the equations of physics. The distance a body will fall (s) is a function of time (t) and gravity (g) related by the equation $s = gt^2$. g is an empirical constant that may vary as a function of altitude and position on the earth's surface, i.e., while the form of the law remains the same, the particular value of g may vary.

Hull's position received little empirical investigation, and most learning theories continue to be preoccupied with universal laws (Estes, 1970). However, Zeaman and Houses (1963) theory is rare in that it does attempt to incorporate individual variation. The treatment of individual differences accords with the view expressed by Hull (1945). Zeaman and House attempt to relate individual differences in a trait (intelligence) to parameters of the basic processes that enter into their quantitative learning equations. The process can be described as follows: (1) empirical data on the performance of groups of subjects of differing developmental level are collected; (2) mathematical equations are written for the theoretical processes presumed to underlie performance, including parameters for attention, learning, extinction, retention, etc.; (3) equations are evaluated by computer simulation and the output of the simulation (statschild) is compared with empirical data. The fitting of the equation to the empirical data is conducted by "simply judging (by eyeball) the similarity of statschild and retardate" (Zeaman, 1973, p83); (4) If variation in a parameter produce

changes in simulated learning functions that are similar to the empirical learning functions observed across groups of differing intelligence, then the parameter is considered to be a candidate for covariation with intelligence.

For example, variation of learning rate and extinction rate parameters (α and β) by computer simulation affected only the final rates of rise of backward learning curves, which were invariant with respect to group differences in MA. However, simulations involving variations of the attentional parameter (P_0) affected the length of the initial plateaus, which did covary with group differences in MA. P_0 (the initial probability of attending to the relevant dimension) was therefore posited as a parameter covarying with intelligence.

The strength of such theory in regard to the effect of individual differences on learning lies in the role the theory plays in guiding the search for relevant individual difference variables. For example, the investigation of the influence of attentional processes on performance has been highlighted since the publication of the theory. Theoretical analyses may also generate new insights. In the 1963 model it was proposed that the learner observed the numerous stimulus dimensions as one aggregate dimension (one-look model) immediately prior to the instrumental response. A potential shortcoming of this model was the omission of the possibility that several dimensions with known attention value may combine to influence attention processes, i.e., a learner may simultaneously attend to several relevant dimensions on a given trial. However, Zeaman (1973) proposed a 'multiple-look' model which offered the idea that a learner may simultaneously attend to more than one dimension on a given trial. The multiple-look model has led to the formulation of the 'breadth of attention' concept; i.e., the number of dimensions a learner can attend to simultaneously, which has also been posited as a parameter that may covary with intelligence (Fisher &

Zeaman, 1973; Zeaman & House, 1979). This concept has proved extremely influential in subsequent research, e.g., research concerning 'stimulus overselectivity' (see Section 2.3).

However, it must be emphasised that this approach to individual differences is very different from the measurement of individual differences. As Brooks and Baumeister (1977) note, the empirical data do not assess individual differences so much as "gross differences in either IQ and/or MA" (p409). Also, presumed individual variation in the theoretical parameters is not generally equated with measurable aspects of individuals behaviour. Indeed, the theoretical models are of such complexity that testing is conducted only via computer simulations (Statschild). Zeaman contrasts this procedure ("experimental process analysis") with "the traditional psychometric approach" (1978, p56-57). There is a substantial divide between comparing the performance of groups, and positing theoretical parameters of processes that may relate to intelligence, and the assessment of individual differences in the psychometric sense, involving issues of accuracy and reliability of measurement etc.

Discussion therefore turns to a review of research concerning the empirical measurement of individual differences in developmentally impaired populations. Specifically, research concerning dimensions of individual difference presumed to be significant for discrimination learning is reviewed.

2.3 Empirical Measurement of Individual Differences related to Discrimination^a Performance in Developmentally Impaired Individuals

2.3.1 Attention

The concept of 'attention' has historically attracted considerable psychological investigation. The manner in which attention is defined and explored is dependant upon the context in which the research is conducted, whether as a 'pool of effort' in cognitively orientated research on dual task performance (Kahneman, 1973), or as 'duration of visual fixation of stimuli' in studies of the hyperactive child (Maier & Hogg, 1974a, 1974b). While few studies have investigated individual differences in 'attention' in the mentally handicapped, two conceptions of attention appear relevant. First, attention has commonly been viewed as the length of time a person can attend to one thing. This has variously been described as sustained attention, distractability, or attention span (Martin & Powers, 1967). In this context, Siegel, Crawford, and Eversizer (1985) have explored the relation between teacher ratings of inattention and performance on discrimination learning tasks. Second, the concept of 'selective attention' has been drawn from theories of discrimination learning (e.g., Zeaman & House, 1963, 1979). Underlying this usage is the idea that selective attention, in addition to sensory awareness, is a cognitive process which features active information processing. Such a conceptualization incorporates concepts of breadth and narrowness of attention, and recent research has concerned the number of components of a complex stimulus children 'attend' to when acquiring a discrimination with multiple relevant cues (e.g., Wilhelm & Lovaas, 1976).

(a) Sustained Attention.

Siegel, Crawford, and Eversizer (1985) obtained teacher ratings on the

presence or absence of five anomolous classroom behaviours (hyperactivity, inattention, perceptual-motor impairment, perseveration, and stereotypy) from a sample of 82 mentally handicapped schoolchildren. Subjects also completed a two-choice matching task on stimuli differing on five dimension of form, colour, border, central figure, and number of figures. From this task measures of total number of errors, and number of dimensions attended to were obtained. The measure of inattention correlated significantly with MA and IQ ($p < .01$), but not with CA. Interestingly, the measure of attention derived from teacher ratings did not correlate significantly with the attentional measure derived from discrimination learning performance (number of dimensions), or with discrimination learning performance (number of errors).

However, presenting teachers with a simple presence/absence dichotomous measure of attention necessarily entails the loss of considerable information, since attention may be presumed to be a broad dimension upon which individuals may vary, rather than a dichotomous variable. Differing result may be obtained if a more differentiated measure of attention was employed. Further investigation of the suggestive relationships between global ability estimates, variables derived from discrimination learning performance, and teacher rated attention appears warranted.

(b) Breadth of Learning.

Much recent research with mentally handicapped children has been concerned with the concept of 'stimulus overselectivity'. Stimulus overselectivity refers to the control of responses by one or a restricted number of components of a complex stimulus. For example, Lovaas, Schreibman, Koegel, and Rehm (1971) suggested that autistic children 'overselect' when presented with a complex stimuli, attending only to one aspect of it. The general paradigm for assessing such restricted breadth of learning, or

overselective responding, utilizes simple discriminations involving relevant and redundant cues. Each stimulus is a compound of two or more cues so that the discrimination can be made even if the child attends to only one of the stimulus dimensions. Breadth of learning is then measured by the number of cues to which the child responds when they are presented alone on test trials.

Stimulus overselectivity therefore describes a narrowness of attention, although theoretical connotations are avoided since attention is operationally defined in terms of the number of cues responded to on test trials.

In the Lovaas et al., (1971) study three groups of children (autistic, retarded, and normal intelligence) were reinforced for responding to a complex stimulus involving the simultaneous presentation of auditory, visual, and tactile cues. Once this discrimination was established individual elements of the complex stimulus were presented separately; the autistic children responded primarily to only one of the cues; the normal intelligence children responded uniformly to all three cues; and the retarded children functioned at a level between these two extremes. A subsequent study (Lovaas & Schreibman, 1971) confirmed this overselectivity in a two cue situation using visual and auditory components. Autistic children have also been found to overselect with complex stimuli presented within a single modality. Reynolds, Newsom, and Lovaas (1974) found autistic children responded to only one component of a two component auditory stimulus (high tone and relay click) whereas normal intelligence children responded reliably to both of the components. Similar results have been reported for the visual modality; autistic children have been shown to overselect when the cues presented are spatially separated (Koegel & Wilhelm, 1973; Schreibman, Koegel, & Craig, 1977) or are components of a single visual stimulus (e.g., colour, form, size, etc.) (Kovattana & Kraemer, 1974; Schover & Newsom, 1976). An extensive review of the above

research can be found in Lovaas, Koegel, and Schreibman (1979).

Despite the predominance of interest in autistic children in the above studies, it is unlikely that stimulus overselectivity is a feature specific to autism. In the studies reviewed so far a few autistic children showed little or no overselectivity, whereas some children who were not autistic did overselect (e.g., the retarded subjects in the Lovaas et al., (1971) study). A relationship may exist between low MA and overselective responding. Wilhelm and Lovaas (1976) presented subjects with a discrimination that could be solved using one, two, or all three component cues. The low IQ (20) group responded on average to 1.6 cues at testing, the higher IQ (40) group to 2.1 cues, and the normal IQ children responded to all three cues. Schover and Newsom (1976) have also found a high correlation between MA and degree of overselectivity in both the autistic ($n=13$, $r = .81$) and normal intelligence ($n=13$; $r = .62$) groups they studied. Bailey (1981) reports a relationship between MA and overselectivity in learning disabled children with greater MA being associated with less overselectivity, although no correlations are reported. The relationship between overselectivity and MA amongst young educable mentally retarded subjects was weak, although in the expected direction.

Stimulus overselectivity may be implicated in difficulties developmentally impaired children have in acquiring new discriminations. Overselectivity may be particularly relevant to superimposition and fading procedures. Such procedures require the child to respond to multiple cues (the prompt and training cues presented together), situations in which stimulus overselectivity may be likely to occur. Autistic children do often fail to learn discriminations when trained with extra-stimulus prompts (Schreibman, 1975; Koegel & Rincover, 1976; Rincover, 1978), and these populations also often demonstrate restricted breadth of learning. However;

(a) not all subjects in these groups demonstrate overselectivity, blanket generalizations about these populations are therefore inappropriate; and (b) no studies have directly measured the correlation between subjects degree of overselectivity and performance on discrimination training tasks.

Given that stimulus overselectivity is a stimulus control deficit, it is perhaps suprising that little research has been conducted to investigate whether the problem is a generalized one (across learning situations) or whether stimulus variables may play a role in the overselectivity phenomenon, with stimulus overselectivity occuring only under certain stimulus conditions.

Since this variable may have important implications for training procedures, further research to evaluate the correlation between overselective responding and other individual difference and task related variables appears warranted.

2.3.2 Inhibition and Excitation

The concept of inhibition has been widely used in theoretical accounts of discrimination learning (Pavlov, 1927; Spence 1936, 1956; Hull, 1943; Harlow, 1959). It will be remembered that the experimental operation involved in discrimination learning is differential reinforcement of responses in the presence of different stimuli. The simplest case is consistent reward of one stimulus (S+) and non-reward of another (S-). The theoretical processes assumed to underly reinforcement and non-reinforcement are conditioning and extinction, or excitation of responses to S+, and inhibition of responses to S- respectively (see Chapter 1, section 1.3). Such duo-process models predominate in current learning theory.

In relating theory to mental handicap, Denny (1964) and Heal and Johnson (1970), have hypothesised an 'inhibition deficit' characterizes the performance of the mentally handicapped. The approach adopted by these

authors is to review a large number of experiments concerning tasks that may involve inhibitory processes (e.g., extinction (classical and operant); discrimination learning (classical and operant); inhibition of transfer of learning; and discrimination reversals). If the mentally handicapped group are found to differ significantly from appropriately matched normal groups (either on CA or MA) this is taken as evidence of their inhibition deficit. However, the logical status of the hypothesised inhibition deficit has been challenged (Evans, 1975; 1982). Evans argues that if the mentally handicapped themselves vary on the inhibition factor "it would seem reasonable to hypothesise that some retarded individuals may be weak in their inhibitory processes, but, on the other hand, others may not be. To describe them all, therefore, as demonstrating an inhibitory deficit would be too great a generalization" (Evans 1982, p82).

Evans (1975) assessed individual differences in inhibition/excitation using a teacher completed questionnaire, the items of which were derived from Pevesners (1963) clinical descriptions of the behaviour of the mentally handicapped. Factor analysis revealed two factors. These factors were identified as attention/distraction (AD) and inhibition/excitation (IE) dimensions. A child's position on the latter IE dimension was found to correlate significantly with experimental indices of inhibition derived from performance on a successive discrimination task (Hogg & Evans, 1975). Specifically, those children rated as excitable (e.g., active, unrestrained, talkative) showed a greater tendency to respond following stimulus offset, to respond to the S- and to adjacent stimuli during stimulus generalization testing, and to lose the discrimination in extinction by beginning to respond to the S- rather than ceasing to respond to the S+. Beveridge and Evans (1978) have also observed severely handicapped children in the classroom environment. High excitation scores correlated significantly with such

classroom behaviours as the frequency of initiation of interaction, amount of speech, and number of approaches to, and likelihood of interaction with, the teacher. Hence, individual differences along an IE dimension may reflect fairly stable behavioural characteristics, since the classroom rating scale appear to be validated both by experimental measures of inhibitory variables, and by direct observation of classroom behaviour.

However, there has been no independent replication of the factor structure of the classroom rating scale employed by Evans (1975) and Evans and Hogg (1984). The present study will attempt to determine whether the factor structure of the scale is replicated. The research will also report detailed validity analyses not previously reported. These will include the investigation of the relationship of the extracted factors with scales from the British Ability Scales (BAS), performance during simultaneous discrimination learning, and breadth of learning.

2.3.3 Standardized Psychometric Tests

Global ability measures (IQ, MA) may be useful in predicting a child's gross functioning over a range of tasks of varying difficulty. Such measures may also be important indirectly, for example degree of overselective responding may be related to MA (Wilhelm & Lovaas, 1976; Schover & Newsom, 1976; Bailey, 1981). However, given the lack of clarity concerning the relationship between global intelligence and learning abilities, reviewed in section 2.1, it may be more fruitful to employ selected scales from psychometric tests on a 'task relevant' basis. For example, successful discrimination learning requires a variety of perceptual, attentional, and retentional processes (Fisher & Zeaman, 1973). Psychometric scales which tap these abilities (e.g., perceptual matching, short-term memory, spatial

ability, etc.) may therefore provide important and relevant assessments of individual difference. Therefore, in addition to measures of MA and IQ, several scales from the British Ability Scales (BAS) will be employed for the above purpose in the present research.

2.4 Summary

In summary, the influence of individual differences in the success of discrimination training has received relatively little investigation. However, considerable individual variability in discrimination performance among severely mentally handicapped persons is frequently observed (e.g., Berkson and Landesman-Dwyer, 1977; Haywood, Meyers, & Switsky, 1982; Ellis et al., 1982). That little research on individual differences has been conducted is in part due to the limitations of single subject and small 'n' group designs, which do not facilitate the use of correlational analyses and cannot easily be combined for meta-analytic investigation. Therefore, one aim of the present research was to collect, during the course of the experimental studies, data on each of the dimensions of individual difference described above. The intention is to acquire a substantial data base to enable further analysis concerning the role of individual difference variables in discrimination learning. An attempt will be made to determine whether part of the observed variance in the discrimination performance of severely mentally handicapped children can be meaningfully ascribed to these dimensions of individual differences. The inter-relationships between the variables will also be investigated, and an attempt will be made to interpret the results of the analyses in terms of theoretical processes underlying performance (e.g., Zeaman & House 1963, 1979).

Chapter 1 reviewed different discrimination training techniques, and highlighted the importance of programmed training procedures for teaching discriminations to mentally handicapped children. The chapter also identified the need for further research concerning the effects of specific procedural and theoretical parameters of these training procedures. Chapter 2 suggested characteristics of the individual may also be significant in determining the rate and outcome of discrimination training. Several dimensions of individual difference, which research suggests may be related to the discrimination performance of developmentally impaired children, were reviewed.

Thus, two broad areas for further investigation have been identified. The next four chapters will present experimental evaluations of various procedural and theoretical parameters of discrimination training procedures. The analysis of individual difference parameters, being dependant upon data collected during the course of the experimental investigations, will be presented in Chapter 7.

CHAPTER 3

Programmed Training of Visual Discriminations:

A Comparison of Techniques

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Programmed Training of Visual Discriminations: A Comparison of Techniques

This chapter reports the first experimental investigation of the present research. The study was designed to evaluate a number of issues relating to the effectiveness of discrimination training procedures in teaching visual discriminations to severely mentally handicapped children.

Experiment 1: Programmed Training of Visual Discriminations: A Comparison of Techniques.

In Chapter 1, several studies were discussed which pointed to the facilitative effect of stimulus fading in teaching visual discriminations to mentally handicapped individuals (e.g., Sidman & Stoddard, 1966; Etzel & Leblanc, 1979; Lambert, 1980). It was also noted, however, that fading has not always proved successful in teaching such discriminations (e.g., Powers et al, 1970; Gold & Barclay, 1973). The first aim of the initial study was to replicate the reported superiority of stimulus fading over trial-and-error training in teaching discriminations to severely mentally handicapped children.

In contrast to the experimental work employing stimulus fading, prompting procedures involving physical guidance, gestural, and verbal prompts delivered by a human trainer, are the most widely used instructional aids employed in practice with mentally handicapped children. In principle, such an approach can also be used to produce "errorless" learning. However, Chapter 1 (section 1.5) described research indicating that in applied settings such prompts have

typically been used in a corrective fashion, contingent upon the occurrence of errors (e.g., Gold & Barclay, 1973; Lowry & Ross, 1975; Cuvo et al., 1978). Furthermore, where prompt sequences are employed, mild prompts (verbal, gestural) have typically been delivered before more intrusive prompts (physical contact) until a correct response is produced (Increasing assistance approach, or system of least prompts, Close et al., 1978). This situation is also the case in many experimental comparisons of trainer prompts with other training procedures (e.g., Mosk & Bucher, 1984). However, we may hypothesise that applied procedures employing trainer prompts may be structured to produce effective errorless learning. In order to emulate stimulus fading procedures, at least in the amount of help available, prompts must (1) be available before a response is produced, and (2) faded in order of their intrusiveness (i.e. physical to gestural to verbal) so as to guide the student through the instructional sequence with a minimum of errors.

Schreibman (1975) utilized fading of a gestural (pointing) prompt in training visual discriminations with autistic children. The procedure proved ineffective, though a stimulus fading programme was extremely successful. However, Glendenning, Adams, and Sternberg (1983), using combinations of prompts obtained results suggesting that, in terms of generating self-initiated responses, a prompting sequence that combined verbal prompts with lessening amounts of physical assistance was superior to physical assistance or verbal prompts presented alone. A more comprehensive approach then, involving the simultaneous presentation and fading of multiple prompts, both physical, gestural, and verbal, may prove more effective. Such an approach is described in the Education of the Developmentally Young (EDY) behavioural methods training course (Trainee Handbook, Unit 4; Foxen & McBrien, 1981). This procedure is suitable for use with mentally handicapped children while potentially fulfilling the requirements of an errorless

training procedure. Interestingly, no empirical studies investigating the efficacy of such a procedure in training visual discriminations can be found. Therefore, the present experiment was designed to determine the effectiveness of a 'graded prompt fading' procedure in facilitating discrimination learning, compared both to traditional trial-and-error training and stimulus fading.

A third question concerned the relative efficacy of programmed fading versus trial-and-error training over a series of discrimination problems. In the majority of previous research demonstrating the superiority of programmed training, the procedures have been applied only to a single discrimination problem. One study that did address the question of extended training, (Bricker, Heal, Bricker, Hayes, & Larsen, 1969), found no evidence for a facilitative effect of stimulus fading compared to trial-and-error training on the development of learning set (a progressive improvement in rate of learning over a series of similar discrimination problems). In their study only one programmed fading procedure was employed, so it is not yet clear how other fading procedures compare with trial-and-error training over a series of discrimination problems.

A fourth question concerned the relative efficacy of programmed and trial-and-error training on the learning of subsequent trial-and-error tasks. Will repeated success under programmed training conditions facilitate learning of subsequent problems presented without programmed assistance? Robinson and Storm (1978) found that normal intelligence children who originally acquired a red-green discrimination with few or no errors during programmed training made fewer errors during subsequent trial-and-error reversals than subjects who learned the original discrimination with trial-and-error training. In contrast, Marsh and Johnson (1968) were unsuccessful in obtaining reversal learning with pigeons after a successive colour discrimination was acquired errorlessly. However these studies addressed only reversal learning.

Therefore, this experiment aimed to determine whether trial-and-error training, although possibly inferior as a method of training an initial discrimination, would remain inferior to stimulus fading and graded prompting in terms of subsequent learning of a novel task by trial-and-error training.

Finally, despite reports of the effectiveness of stimulus fading procedures, the apparatus required for fading can be quite complex and costly in terms of time and materials. This has in part restricted the widespread application of fading techniques, and most applications are limited to experimental studies. However, the advent of microcomputers, now available in most special education schools, provides a potential tool for the inexpensive, efficient, and flexible application of fading procedures. A final aim of the study was to evaluate the feasibility and effectiveness of employing micro-computer technology to implement stimulus fading procedures.

In summary, the aims of the experiment were: To compare the effectiveness of; (a) an automated stimulus fading procedure, presented and controlled by a micro-computer; (b) a training programme based on the gradual fading of physical, gestural, and verbal prompts, and (c) a trial-and-error procedure, in (i) an initial discrimination task, (ii) over a series of additional tasks using the same training procedures, and (iii) in a subsequent trial-and-error task.

Method

Subjects

Twenty-one children, nine girls and twelve boys, attending school for children with severe learning difficulties participated in this study. Subjects were drawn from a pool of 31 children aged seven to fourteen years

who were all administered scales from the the short-term memory, perceptual matching, and spatial imagery process areas of the British Ability Scales (BAS) (Elliot, Murray, & Pearson, 1978). Each subject was individually matched with two others on the basis of total score on the three scales, producing seven sets of matched subjects. Within each set subjects were randomly assigned to the experimental conditions forming three matched groups of seven subjects each. Table 3.1 gives the sex, chronological age, and BAS total score of each subject. All children were diagnosed as severely mentally handicapped and had IQ scores below 50, this being one criterion for education in special schools. None of the subjects had any previous experience with discrimination problems of this kind.

Apparatus

The tasks were presented using a 48K Apple II micro-computer, double disk drives, and colour monitor. The screen measured 21 cm in height and 27.5 cm in width. Fitted beneath the screen was a two-button response box (38.5 cm long, 8 cm high, and 10.5 cm wide) connected to the computer. The response buttons were raised 1.5 cm from the surface of the box and spaced 6 cm apart, divided in the middle by a parallel bar. Stimuli presented on the screen appeared directly above the response buttons. All data were automatically recorded and saved at the end of each session. The screen and response box were set on a table at the child's seated height, and the micro-computer and other equipment positioned away from the subject.

Stimuli and Tasks

Eight coloured shapes, approximately 7.5 cm high by 8.0 cm wide, were presented on the screen in either green, violet, yellow, or blue. Four pairs of shapes, presented on white backgrounds, constituted the discrimination tasks (see Figure 3.1). The training tasks were two-choice simultaneous

Table 3.1: Descriptive Characteristics of Subjects

Graded Prompt Fading				Stimulus Fading				Trial-and-error			
S	Sex	CA	BAS	S	Sex	CA	BAS	S	Sex	CA	BAS
1	F	13:6	149	8	M	12:2	148	15	M	13:9	146.5
2	F	12:10	130	9	M	13:6	139.5	16	F	13:1	141.5
^a 3	M	11:8	116	^a 10	F	14:3	98	^a 17	M	13:9	97
4	M	11:4	97	11	F	12:11	97	18	M	14:8	97
5	M	12:1	70	12	F	12:2	68	19	F	14:0	63
6	M	11:4	61	13	M	7:1	61	20	M	11:7	61
^a 7	F	10:7	21	^a 14	M	11:4	30	^a 21	F	13:7	37
Mean		11:11	92			11:11	91.1			13:6	91.9
SD		1:0	44.3			2:4	41.8			1:0	41.4

Note. a. The subject completed Task 1 only.

S= Subject number; CA= Chronological Age; BAS= British Ability Scales composite score.

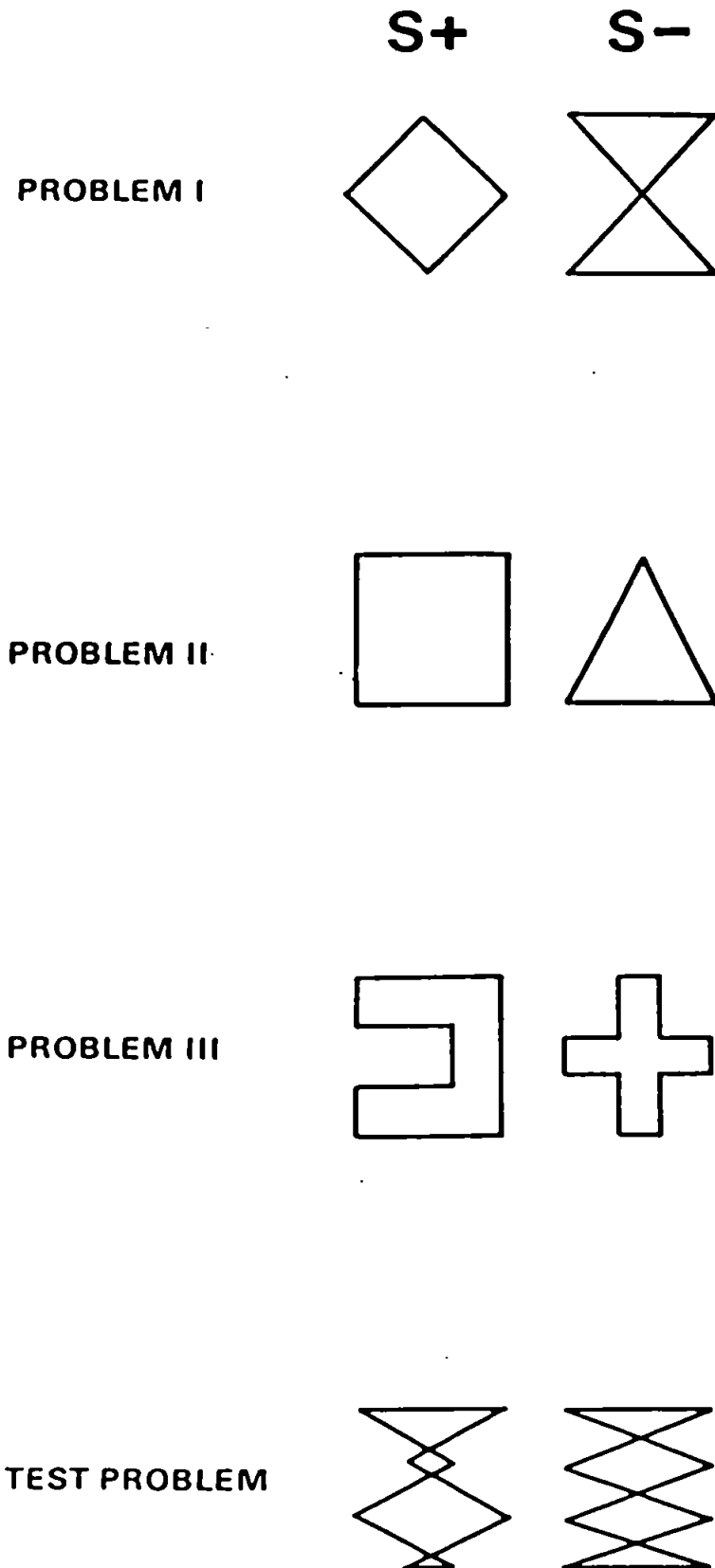


Figure 3.1: Task stimuli for the four discrimination tasks. Colour pairs employed in the tasks were; Task 1, blue/violet; Task 2, green/yellow; Task 3, blue/green; Test task, yellow/violet. The different colours appeared equally often in S+ and S.

discrimination problems. Each task used two stimulus dimensions; shape, which was relevant to solution of the task so that choice of one shape (S+) was reinforced while choice of the other (S-) was never reinforced, and colour, which was irrelevant. Each task used two colours. On every trial one shape was of one colour and the other was of the other colour of the pair. Each colour appeared equally often in S+ and S- with the constraint that no shape remained the same colour for more than three successive trials. The pair of colours employed was varied between tasks. For example, in Task 2 selection of the square regardless of its colour resulted in reinforcement, while selection of the triangle, again regardless of the colour, never resulted in reinforcement.

The position of S+ and S- on the screen (left or right) was randomly determined by the computer, with the constraint that a shape could not be presented in the same position on more than three consecutive trials.

Procedure

All sessions were conducted in a quiet experimental room away from the classrooms and occurred once daily on consecutive weekdays. The criteria for ending a session were; (a) 80 trials completed; (b) 20 minutes elapsed; or (c) the learning criterion for the task was attained, whichever occurred first. Additionally, if the child stood up, or expressed the desire to leave, the session was discontinued and restarted the next day.

Apart from the six subjects who received only Task 1 the criterion for advancement to the next task was; (a) the learning criterion for the task was attained; or (b) 160 trials were completed, again whichever occurred first.

The experiment was conducted in two stages. The first stage was aimed at assessing the effectiveness of the training procedures in facilitating the

acquisition of a visual discrimination. Twenty-one subjects, seven per condition, completed the first discrimination task and comparisons between groups were planned.

The second stage of the experiment was aimed at assessing the effects of extended programmed and trial-and-error training over a series of similar discrimination tasks. Five of the sets of matched subjects, randomly selected before the start of the experiment, were given an additional two tasks using the same training procedures they received on the first task, and a final trial-and-error test task. These discriminations used different shapes and colour combinations but were otherwise the same as the first discrimination task.

Pre-training. A pre-training procedure was employed to familiarize the children with the apparatus and the correspondance of the positions of the stimuli on the screen and the buttons beneath them. A single white square was presented randomly on either the right or left of the screen. A correct response (selection of the button beneath the stimulus) produced a tune from the computer and was rewarded with a small edible and verbal praise. An incorrect response produced no consequences. A non-correction procedure was used so that every response terminated that specific trial. Initially the experimenter modelled the correct response and provided extra physical, verbal, and imitative prompts whenever necessary. The criterion for successful completion of the problem was 20 consecutive, unprompted, correct responses.

Training. At the start of each session the child was given the following directions. "Now (child's name) we are going to play a game, this game is called play the tune. We will see some pictures on the television, one will be a winning picture which will play the tune and the other will be a losing

picture. Your job is to find out which is the winning picture and play the tune every time."

The child was shown the response buttons. Any button press blanked the screen and all correct responses were reinforced with computer tunes and extensive verbal praise. In addition a small edible reward was initially provided for every correct response and later for three consecutive correct responses. If the child failed to respond within six seconds, or attempted to elicit a direction from the experimenter before responding, one non-directional prompt such as "Which picture will play the tune? Where is the winning picture?" etc., was used. If the child still failed to respond an error was scored. The screen was blank during each six second inter trial interval. The learning criterion for all tasks was set at 10 consecutive, unprompted, correct responses.

Graded Prompt Fading Programme (Group 1)

Three types of prompts were employed; physical guidance, gestural, and verbal (see Table 3.2). Initially a combination of all three of prompts, at maximum level, was delivered which precluded the occurrence of errors. Subsequently each component prompt was gradually faded, beginning with the physical guidance prompts and then the gestural prompts; finally the verbal prompt was removed, giving eight steps in all. The final fading step, where no prompts were given, was identical to trial-and-error training conditions.

A criterion of two consecutive correct responses were required to advance to the next step, and a back-up procedure was employed whereby an error returned the subject to the previously mastered step. No step could be advanced through, even on a second or third attempt, until the criterion had again been fulfilled. Once two consecutive correct responses were made in the absence of prompting (Step 8), the programme was completed and any subsequent

Table 3.2: Graded Prompt Fading Procedure

Fading Step	Type of Prompt		
	Verbal	Gestural	Physical Guidance
1	It's the Left /Right hand picture, look.	Full point to the picture.	Subjects hand brought up to touch picture, and then down to button.
2	"	"	Subjects hand brought up to touch picture only.
3	"	"	Subjects hand moved up and half-way to the picture.
4	"	"	Subjects hand started upward.
5	"	Finger moved half-way between picture and centre of screen & angled to point.	No prompt.
6	"	Finger moved to centre of screen & angled slightly.	No prompt.
7	"	No prompt.	No prompt.
8	No prompt.	No prompt.	No prompt.

errors failed to reinstate the programme. The learning criterion was attainable only after the prompting programme had been successfully completed.

On each trial the computer presented a number corresponding to the fading step at the center bottom of the screen, thus precluding the potential problem of error on the part of the experimenter in level of prompt delivered.

Stimulus Fading Programme (Group 2)

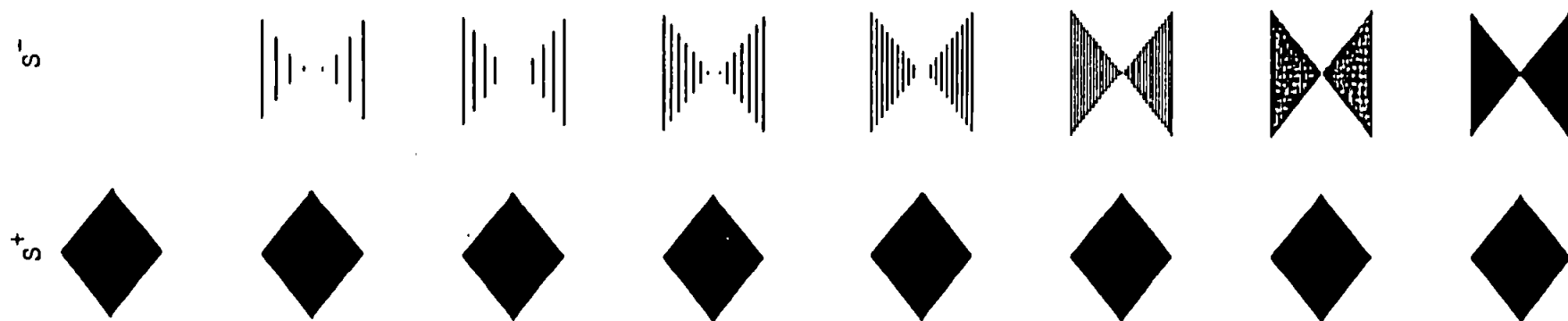
The programme consisted of eight steps that differed in the level of prompt presented along the dimension of intensity. Initially \underline{S}_+ was presented at full intensity with a blank space as \underline{S}_- to enhance the probability that subjects would respond to \underline{S}_+ . Subsequently the intensity of \underline{S}_- was gradually increased (i.e., faded in) by systematically incrementing the number of lines composing the shape, while \underline{S}_+ remained at full intensity. This sequence continued until Step 8 where both stimuli were at full intensity, and was identical to Step 8 in the graded prompting programme and to the trial-and-error training condition. An example of this sequence for the first discrimination task is presented in Figure 3.2.

The criteria for step advancement and the back-up procedure were identical to those in the graded prompting programme, and were controlled automatically by the micro-computer. Again the learning criterion was attainable only after the programme had been successfully completed.

Trial-and-Error Training (Group 3)

This procedure followed the traditional simultaneous discrimination training procedure and was identical to the preceding training programmes except that both stimuli were presented at maximum intensity and no prompts were delivered by the experimenter.

Figure 3.2: Illustration of the steps involved in the stimulus fading programme for Task 1. g^+ remains at full strength throughout, while g^- is faded in.



Results

Task 1

Figures 3.3 and 3.4 present the number of errors and trials to criterion for each child for the first discrimination task. The distribution of scores were neither normal nor homogenous, therefore non-parametric statistics were used throughout. An analysis of the number of children reaching or failing the learning criterion across the three groups proved significant, (Cochran's $Q = 8.00$, $p < .02$), all four non-learners were in the trial-and-error group. Additionally, a Freidman analysis of variance of ranks showed significant overall differences between the three matched groups in both number of errors ($S = 12.27$, $p < .001$) and trials ($S = 7.143$, $p < .027$). Planned orthogonal comparisons between groups using the Wilcoxon test (Kirk, 1968) showed significant differences in favour of the graded prompting and stimulus fading treatments when compared to trial-and-error training, both for errors ($W = 0$, $p < .01$ one-tailed, in both cases) and trials ($W = 1$, $p < .025$ one-tailed, in both cases). The stimulus fading group required slightly more trials to criterion and produced a few more errors than the graded prompting group. However there was considerable overlap, the occurrence of ties reducing N to five, and the results did not differ significantly.

Tasks 2 and 3

Table 3.3 presents the number of errors and trials to criterion for each individual child who completed the series of all four tasks. Subjects in the two programmed training conditions continued to perform at a high level on tasks 2 and 3, making few or no errors. Freidman tests for overall

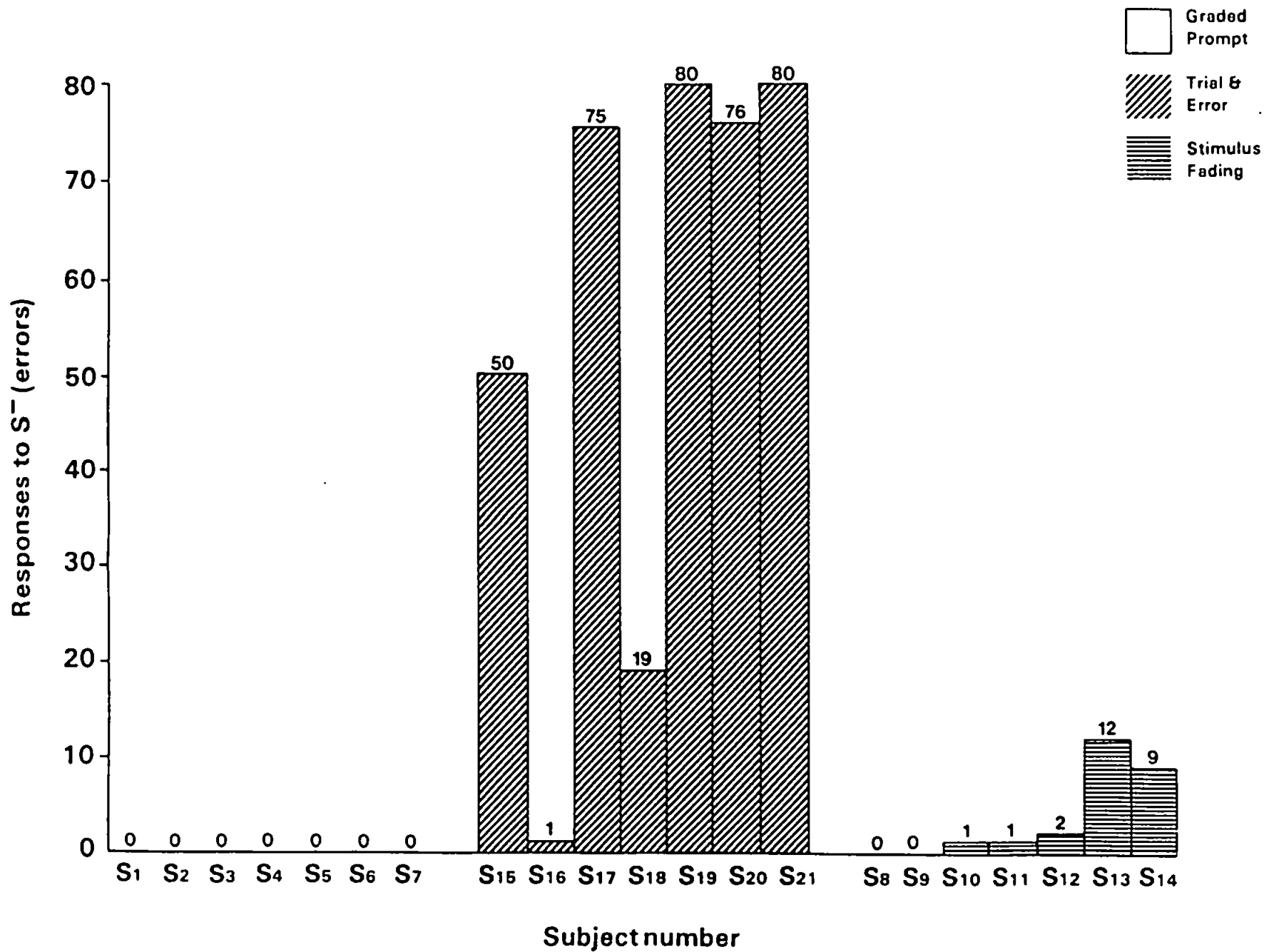


Figure 3.3: Responses to S^- (errors) emitted by each child for the first discrimination task.

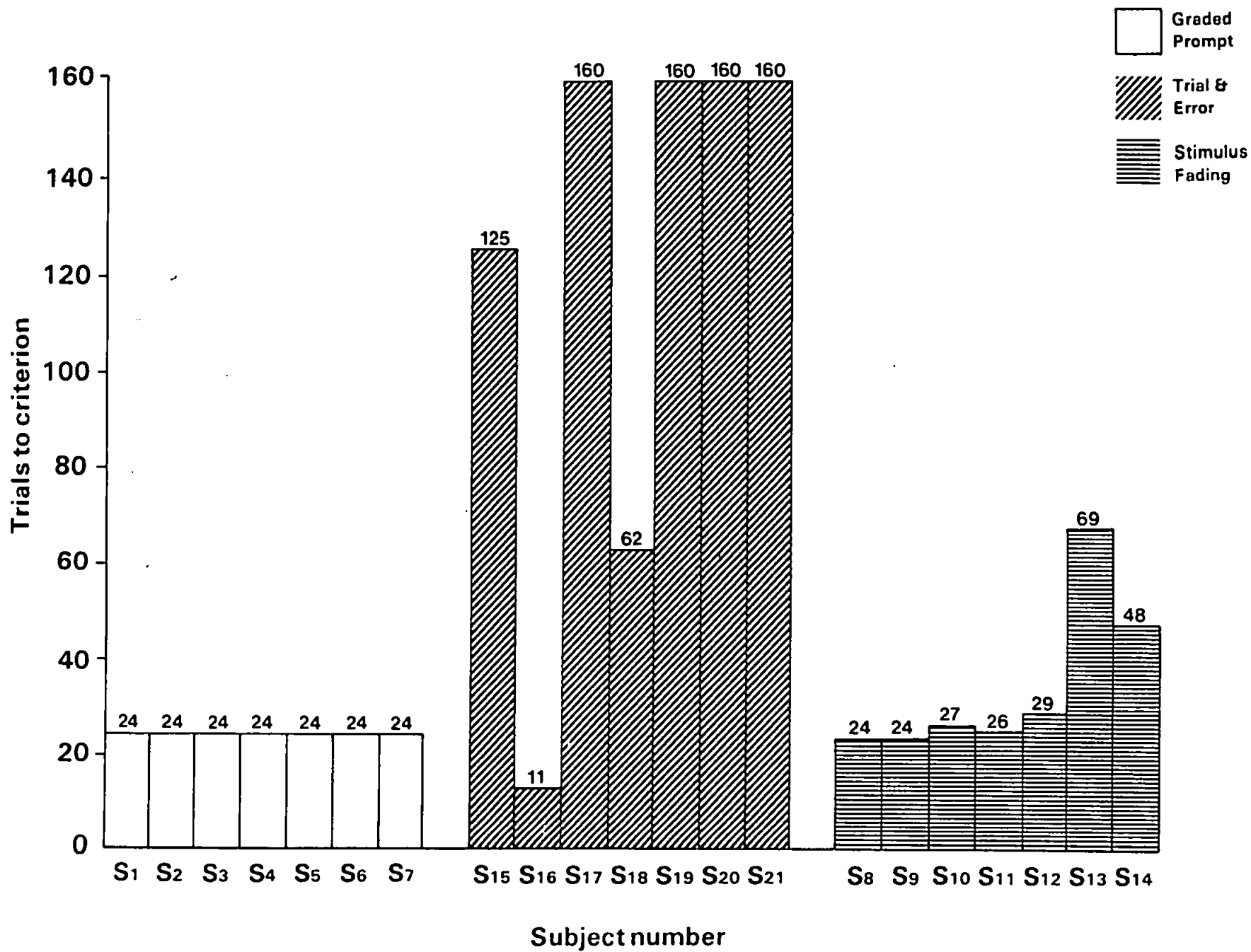


Figure 3.4: Number of trials to criterion for each child for the first discrimination task. Training was discontinued after a maximum of 160 trials.

Table 3.3: Number of Errors and Trials to Criterion for Subjects Completing all Four Discrimination Tasks

Subject Number and Group	Number of Errors For Each Task				Number of Trials For Each Task			
	1	2	3	Test	1	2	3	Test
<u>Graded Prompt</u>								
1	0	0	0	4	- ^a	-	-	18
2	0	0	0	34	-	-	-	65
4	0	0	0	40	-	-	-	80 ^c
5	0	1	0	39	-	32	-	80 ^c
6	0	0	0	42	-	-	-	80 ^c
Total	0	1	0	159	120	128	120	323
<u>Stimulus Fading</u>								
8	0	0	0	44	-	-	-	80 ^c
9	0	0	0	16	-	-	-	30
11	1	0	0	0	26	-	-	10
12	2	0	1	10	29	-	34	28
13	12	0	8	44	69	-	52	80 ^c
Total	15	0	9	114	172	120	158	228
<u>Trial & Error</u>								
15	50	62	10	57	125	160 ^b	32	80 ^c
16	1	3	2	15	11	21	17	39
18	19	9	22	41	62	25	63	80 ^c
19	80	87	84	37	160 ^b	160 ^b	160 ^b	80 ^c
20	76	38	2	12	160 ^b	109	12	53
Total	226	199	120	162	518	475	284	332

a. Dash indicates criterion was met in the minimum of 24 trials.
b. Subject failed to meet criterion in the maximum of 160 trials.
c. Subject failed to meet criterion in the maximum of 80 trials.

group differences in number of errors (see Table 3.3) proved significant for Task 2 ($\underline{S}= 7.6$, $p<.024$), and was marked but not statistically significant for Task 3 ($\underline{S}= 5.7$, $p<.09$). Group 1 (graded prompting) made fewer errors than Group 3 (trial-and-error) in both tasks ($\underline{W}= 0$, $p<.05$ in each case). Group 2 (stimulus fading) also made significantly fewer errors than Group 3 on Task 2 ($\underline{W}= 0$, $p<.05$), and fewer errors on Task 3, although the latter difference did not reach statistical significance. The two programmed training groups did not differ significantly in either task.

In terms of number of trials to criterion both programmed procedures again continued to be effective, with the majority of these subjects reaching criterion in the minimum number of trials. Increased variability was apparent within the trial-and-error group, with some subjects coming to acquire the tasks rapidly. However, while programmed training continued to be effective for all subjects, even the lowest functioning ones, some trial-and-error subjects still failed to learn. $\underline{S}15$, $\underline{S}19$, and $\underline{S}20$ required a substantially greater number of trials than their matched programmed companions on Task 2, as did $\underline{S}18$ and $\underline{S}19$ on Task 3 (see Table 3.3).

Test Task

A Friedman test was computed on performance data from the test task. No significant differences were found between the three groups in either trials to criterion or number of errors. Since the programmed training procedures masked any trends over the initial three tasks in Groups 1 and 2, a subsidiary analysis was conducted on data from Group 3 (trial-and-error) to evaluate any trend towards more efficient learning across the initial three tasks. Pages L trend test failed to show significant change over tasks in either trials to criterion or errors. There is no evidence then of a

significant improvement in learning rate over the three tasks for the trial-and-error group.

Discussion

The results of this experiment can be summarized as follows:

1. Both programmed training procedures resulted in all subjects acquiring the trained discriminations, and doing so faster and with few or no errors compared to trial-and-error training, under which some subjects failed to learn the tasks.

2. The facilitative effect of programmed training over trial-and-error training observed on the initial task continued to be observed over two subsequent tasks.

3. The two programmed training procedures did not produce significant differences in performance on any of the training tasks.

4. No significant differences appeared between the groups in performance on the final test task where all groups received trial-and-error training.

The results confirm previous findings concerning the efficacy of stimulus fading procedures in facilitating the errorless acquisition of visual discriminations (e.g., Touchette, 1968; Lambert, 1980; Etzel, LeBlanc, Schilmoeller, & Stella, 1981), and also demonstrate the effectiveness of an errorless procedure based on the gradual fading of physical, gestural and verbal prompts.

Significantly, the superiority of fading over trial-and-error training was maintained over the subsequent two tasks. The magnitude of group differences, especially in trials to criterion, did reduce over subsequent tasks. However, the fact that some subjects (S16, S20) came to learn the third task rapidly does not detract from the most important consideration about relative efficiency: no programmed subject failed to learn. In the trial-and-error group one subject (S18) still had considerable difficulty on the third task, and one subject (S19) never learned a single task. It should be noted in comparing the training procedures that the number of steps in the stimulus fading and graded prompt fading programmes were arbitrarily determined from a survey of previous research. Optimization via variations in the number and size of steps might produce even more marked and durable advantages for the programmed procedures (Stoddard, personnel communication, 1985).

It is interesting that while some subjects in the trial-and-error group made large gains in performance over successive tasks (e.g., S20), others failed to benefit at all (e.g., S19). One of the strongest arguments in favour of the programmed training procedures was the elimination of this variance in performance, such that all subjects, whatever their abilities as measured by the BAS, acquired these tasks in the minimum, or near minimum, number of trials throughout all the tasks using the programmed procedures.

Problems in transfer of stimulus control from prompts to training stimuli have been noted with both intensity fading (e.g., Schreibman & Charlop, 1981) and manual prompts (e.g., Wolfe & Cuvo, 1978). It is impossible to guarantee that a subject will attend to the relevant stimulus, and not simply respond to the additional prompt provided by the stimulus

display or the trainer, yet this did not appear to be a problem in the present study. Transfer from the prompts to the unprompted criterion level discrimination invariably occurred errorlessly in Group 1, and near errorlessly in Group 2. This may appear surprising since previous research has hypothesized that procedures involving extra-stimulus manipulations (such as graded prompt fading) may be less effective than within-stimulus manipulations (such as stimulus fading) (see section 1.5.4). However, the difficulty of the discrimination is one factor that has been implicated in problems of transfer from prompted to unaided trials; such transfer may occur more readily when the discrimination is easy (Russo, 1976; Smeets & Lancioni, 1981). The present tasks were simple 2-choice discriminations and it remains to be seen whether similar results would be obtained with more complex tasks.

With regard to the question of facilitating later trial-and-error learning, prior programmed training failed to significantly facilitate performance on the trial-and-error test task relative to subjects with a history of trial-and-error training alone. Equally, however, the performance of the programmed groups was no worse than that of the trial-and-error group. This result is in accord with the findings of Bricker et al., (1969). However, it is possible that task difficulty was a factor influencing performance. This is suggested by some data from the trial-and-error group. S16 learned all three initial problems readily; S15 and S20 came to do so by the third problem; and S18 learned all three problems with more or less modest difficulty. However, on the test problem S16 and S20 had considerably more difficulty, the first time this had happened for S16. Furthermore, S15 and S18 failed to learn the test problem, and this was the first failure for S18. These data may suggest that the test task was at least more difficult than Task 3. If it were not

for this, more programmed subjects may have done better. As it was, three stimulus fading subjects did learn the test task more rapidly (in fewer trials) than any subject in the trial-and-error group.

It is also possible that the absence of an overall facilitative effect from prior programmed training was due to too rapid a transition between the conditions of training and testing, the programmed training subjects being faced with the sudden removal of all prompts. This interpretation may be indicated by the rapid appearance of position habit and colour preference strategies among the programmed training subjects on the trial-and-error test task, where no such strategies had been exhibited during programmed training. In Group 1 (graded prompting) S2, S4, and S6 rapidly developed colour preferences and S5 a position habit (both strategies being defined as deviations from chance responding significant at $p < .001$, chi-squared). Slightly fewer subjects developed such strategies in Group 2 (stimulus fading); S13 developed a colour preference and S8 exhibited both colour preference and position habit strategies. This is in contrast to Group 3 (trial-and-error) in which such strategies were also apparent during their prior training tasks as well as the test task. The method of transition from programmed fading procedures to trial-and-error training is open to question at present, it may be that prompts should be gradually eliminated across tasks in a manner parallel to fading within a single task.

Subsequent to the publication of the present study (Strand & Morris, 1986), a further study (Richmond & Bell, 1986) has also compared trial-and-error and stimulus fading procedures in teaching a series of discrimination tasks to mentally handicapped individuals. Their results replicate the present findings concerning extended programmed training, since they report that while all subjects who received stimulus fading

readily acquired the four training tasks, there was marked variability in performance with trial-and-error training: Two of five subjects receiving trial-and-error training still exhibited difficulty in acquiring the fourth task. Richmond and Bells study did not evaluate the effect of prior fading versus prior trial-and-error training on subsequent trial-and-error learning. However, they do report that two of their five subjects who had performed near errorlessly on their final task under stimulus fading, had difficulties with a subsequent trial-and-error training task. Richmond and Bell had expected that the subjects trained with stimulus fading should have continued to perform with few errors when changed to trial-and-error training, because of the high density of reinforcement that occurs following an observing response in stimulus fading compared to trial-and-error training. However, in their study the change from programmed to trial-and-error training was confounded with changes in the relevant stimulus dimension of the task (from a size discrimination to a shape discrimination). Their results may be interpreted as demonstrating that stimulus fading (on a size dimension) may demand attention to cues which, while relevant to the (size) discriminations at hand, are irrelevant and interfere with performance on subsequent (shape) discriminations. It is perhaps somewhat more surprising then that three of their five subjects did acquire the subsequent shape discriminations with so few errors, rather than that two of their subjects exhibited some difficulty. In the present experiment, changes in training procedure were not confounded with changes in the relevant task dimension, since shape was the relevant dimension on both training and test tasks.

Finally, the results may also have significance for the classroom application of programmed procedures with mentally handicapped students. With the advent of micro-computer technology, the stimulus fading programme

could be used for individualized instruction with relevant material such as coins without the need for constant supervision from the teacher, since the programme provides response feedback and automatically adjusts the level of difficulty (i.e., level of fading) as appropriate. Conversely, the advantage of the graded prompt fading procedure may lie in the interactive nature of the training. For students with whom on-task behaviour is difficult to maintain without supervision, or who react primarily to social reinforcement, the procedure offers a readily applied errorless technique without the necessity of stimulus manipulation. Hence the procedure can readily be employed in many varied training contexts.

* * * * *

The results of the present experiment appear to confirm the superiority of programmed training over trial-and-error instruction. The results also extend previous findings by demonstrating the continued superiority of programmed training over successive tasks. Some data concerning the relationship between programmed training and subsequent learning without programmed assistance was also forwarded, and it was noted that three of five subjects receiving stimulus fading performed better than their trial-and-error training companions on a subsequent unassisted task.

Having replicated the basic facilitatory effect of programmed training, the next chapter considers some of the parameters of fading procedures that may be influential in determining this success. Various parameters describing differences between programmed training techniques were identified (although not specifically manipulated) in the experimental

procedures, for example employing within-stimulus or extra-stimulus prompts, etc. A further parameter concerned the particular stimulus (S⁺ or S⁻) that was manipulated during programmed training. The stimulus fading procedure involved graduated stimulus change along S⁻, while the graded prompt fading procedure involved manipulations related to S⁺. No significant differences between the procedures in task acquisition were noted. However, in the next chapter a series of experiments are reported that specifically compare the effects of manipulating the S⁺ or S⁻ respectively during programmed training.

CHAPTER 4

S+ versus S- Manipulation in Teaching Visual

Discriminations to Severely Mentally

Handicapped Children.

Chapter 4

S+ versus S- Manipulation in Teaching Visual Discriminations to Severely Mentally Handicapped Children.

Fading procedures involve adding a more discriminable prompt cue to a complex training cue in order to facilitate initial correct responding. The prompt cue is subsequently faded (made less discriminable) until finally the subject is responding to the training stimuli alone (e.g., Terrace, 1963a, 1963b; Touchette, 1968). Experiment 1 demonstrated the effectiveness of two such procedures in training visual discriminations to severely mentally handicapped children.

Prompt fading can be achieved by either the addition to the reinforced stimulus (S+), or subtraction from the non-reinforced stimulus (S-), of values on the prompt dimension. Both operations heighten the discriminability of the stimuli, although the stimulus manipulated during fading differs. In practice, whether S+ or S- is selected for manipulation frequently depends upon the stimulus dimension from which the prompt cue is drawn. Colour and size fading procedures predominantly highlight and then fade colour or size cues superimposed upon S+ (e.g., England, 1975; Wolfe & Cuvo, 1978). Conversely, intensity fading procedures predominantly manipulate S-. The intensity of S- is initially reduced relative to S+, with subsequent increments in S- intensity (e.g., Sidman & Stoddard, 1967). However, recent research (Schreibman & Charlop, 1981; Zawlocki and Walls, 1983; Stella & Etzel, 1986) has focussed directly upon how either S+ or S- manipulation in graduated stimulus change procedures may affect the process of discrimination acquisition.

Schreibman and Charlop (1981) taught eight autistic children two discrimination tasks. At the criterion level, the stimuli of one task resembled a manikin with both arms down and a manikin with one arm down and one arm up. The stimuli of the second task consisted of an X combined with two dots in horizontal line, and an X combined with two dots in a vertical line. Two fading procedures were compared. The first procedure started with the presentation of the relevant component of S₊ (i.e., one of the arm positions for the manikin stimuli or one of the dots arrangements for the other task), and subsequently faded in the relevant component of S₋ (i.e., the arm position or dots arrangement not used in S₊). This fading (along an intensity dimension) was carried out over five steps. The procedure continued with the reduction in size of both relevant components over steps 6 to 10, and fading in of the common S₊ and S₋ components (i.e., the stick and the head to complete the manikins or the Xs) over steps 11 to 15.

The second procedure was identical to the first with one exception. That is, it started with the presentation of the relevant component of S₋ and subsequently faded in the relevant S₊ component. Schreibman and Charlop (1981) report that seven out of eight subjects acquired discriminations faster and with fewer errors with the latter procedure, where S₊ rather than S₋ was manipulated first.

However, although fading was initially conducted on either S₊ or S₋, subsequent training phases manipulated both S₊ and S₋ simultaneously to attain the terminal discrimination. Stella and Etzel (1986) note that "no empirical data exist to indicate which of two simultaneously presented stimuli (S₊ or S₋) should be manipulated in programmes that manipulate only one stimulus" (p.138). Stella and Etzel investigated stimulus shaping procedures involving either S₊ or S₋ manipulation. While the results of

their study also suggested that fewer errors may result from S⁺ manipulation, differences in number of errors between conditions were minimal. Although four out of five normal intelligence pre-school subjects made fewer errors during S⁺ rather than S⁻ shaping, S⁺ and S⁻ conditions differed by only two or three errors for all subjects. Interestingly, all discriminations had first to be established by S⁻ fading to ensure reliable correct responding to S⁺.

These results contrast with those presented by Zawlocki and Walls (1983), and Cheney and Stein (1974). Zawlocki and Walls trained size as well as numerosity discriminations to 12 severely mentally handicapped adults (mean IQ 27.6). Ten levels of size and ten levels of numerosity were generated. S⁻ fading increased the size or numerosity of S⁻ to criterion level over a five-step sequence (level 1 to level 5), while S⁺ fading reduced the size or numerosity of S⁺ to criterion level also over a five step sequence (level 10 to level 6). Zawlocki and Walls found no significant differences between S⁺ fading, S⁻ fading, or simultaneous S⁺ and S⁻ fading procedures, although all fading procedures were more successful than trial-and-error training. However, these results were based upon a combination of 40 fading and 40 test trials in each condition. Analysis of the fading trials independently suggested that S⁻ fading was superior to S⁺ fading. Furthermore, Cheney and Stein (1974) compared superimposition and fading of colour cues on either S⁺ or S⁻ in teaching an oddity learning task to normal intelligence preschool children. While the procedures produced no significant differences in task acquisition, S⁻ manipulations led to greater transfer of observation to the relevant shape dimension.

In summary, comparison of S⁺ and S⁻ manipulation in fading programmes appears to warrant further investigation.

Experiment 2: S+ versus S- Manipulation in Superimposition and Fading Procedures for Teaching Visual Discriminations to Severely Mentally Handicapped Children.

Superimposition and fading procedures that have combined training stimuli with separate colours (e.g., superimposing S+ on a red background and S- on a green background) have not always proved successful with developmentally impaired individuals (e.g., Koegel & Rincover, 1976). More frequently, procedures employ a single colour hue, usually combined with S+ (e.g., Touchette, 1968; Egland, 1975; Irvin & Bellamy, 1977). The success of some of these procedures may also be due to their highlighting distinctive-features rather than non distinctive-features of the task stimuli (Egland, 1975; Rincover, 1978). In the present study therefore, procedures involving a single colour hue, superimposed upon a distinctive feature of either S+ or S-, were compared.

Jenkins and Sainsbury (1969, 1970) have described a 'feature positive' effect in discrimination learning in the pigeon. In discriminations where S+ and S- share common visual elements and are distinguished only by the presence or absence of a visual feature, placement of the feature in S+ (feature-positive (FP) condition) typically results in more subjects acquiring the discrimination, and more rapidly, than when the feature is contained in S- (feature negative (FN) condition). This effect has also been demonstrated with young children of normal intelligence (Sainsbury, 1971). Sainsbury employed a two-choice simultaneous discrimination task. One stimulus contained four common shapes (e.g., four squares), while the second stimulus contained three common and one distinctive shape (e.g., three squares and one triangle). In the FP condition the distinctive

feature (i.e., the triangle) was contained in S+, while in the FN condition the feature was contained in S-. All twelve children in the FP condition acquired the task, compared to only one of 12 children in the FN condition.

Jenkins and Sainsbury (1970), and Sainsbury (1971), suggest that the FN discrimination can be learned only by the formation of a conditional discrimination based on the distinctive feature, while the FP discrimination can be accomplished by simply learning to respond to the feature. Mentally handicapped children have also been shown to find conditional discriminations more difficult to acquire than simple discriminations (Golln & Savoy, 1968; Schilmoeller, Schilmoeller, Etzel, & LeBlanc, 1979).

The above results may have some implications for the relative efficiency of S+ and S- fading. Where the prompt highlights a distinctive (relevant) feature of the training stimuli, occurs in only one of the stimuli, and is a salient cue due to its high discriminability relative to the training cue, the asymmetry in learning rates observed in the FP effect may be obtained.

However, the stimuli in feature positive tasks contain only one relevant cue, the feature itself, and this cue is present throughout training. In contrast, fading tasks contain multiple cues (both the prompt and criterion cues), and the prompt cue must be removed (faded) so that responding comes under the control of the criterion cue alone. Given this requirement for the transfer of stimulus control from prompt to training stimuli, it is less clear whether the asymmetry in learning rates observed in the feature positive effect would be observed following S+ or S- fading.

In summary, the present study aims to employ S+ fading, S- fading, and trial-and-error training with a sample of severely mentally handicapped children to determine whether: (1) prompt fading is a more effective

procedure than trial-and-error training; and (2) S⁺ and S⁻ fading procedures differ in facilitating (a) performance during the early stages of fading where the prompt cue is prominent, and (b) efficiency of transfer from the prompt to criterion cue.

Method

Subjects

Twenty-seven children attending a special school for children with Severe Learning Difficulties participated in the study. Subjects were selected from a pool of 35 children who were administered four selected scales from the British Ability Scales (BAS) (Elliot, Murray, & Pearson, 1978). These scales were Matching Letter-Like Forms, Copying, Visual Recognition, and Early Number Skills. A composite score for each subject was derived by summing the total scores on each of the scales. Nine sets of three subjects each were selected, each subject being matched with two others having the same or closest composite score. Within each set subjects were randomly allocated to the training conditions, producing three groups of nine subjects each. Table 4.1 presents descriptive characteristics of the subjects. The mean chronological age of the sample was 12 years 11 months (range 7:11 - 16:2, SD 22.9 months). The mean Mental Age of the sample (Peabody Picture Vocabulary Test) was 5 years 9 months (range 3:1 - 12:10, SD 30.0 months). Nine of these subjects were experimentally naive, while 18 subjects had also participated in Experiment 1 some 9 months previously.

Apparatus

The tasks were presented using a 32K BBC(B) micro-computer, single disk

Table 4.1: Descriptive Characteristics of Subjects

Group 1 S+ Fading				Group 2 S- fading				Group 3 Trial-and-Error			
^a S	Sex	^b CA	^c BAS	S	Sex	CA	BAS	S	Sex	CA	BAS
1	M	182	295	10	F	172	293	19	F	149	297
2	F	175	287	11	F	167	282	20	M	156	291
3	F	164	260	12	M	172	263	21	M	175	259
4	F	129	250	13	F	142	258	22	M	170	241
5	F	156	222	14	M	122	221	23	M	150	233
6	F	165	216	15	M	146	214	24	F	181	209
7	M	175	190	16	M	186	185	25	M	155	194
8	F	141	116	17	M	146	129	26	M	95	115
9	F	137	96	18	M	131	86	27	M	123	92
Mean		158.2	214.7			153.8	214.6			150.4	214.6
SD		18.6	70.2			21.4	70.4			26.9	71.6

a. Subject number.

b. Chronological age in months.

c. British Ability Scales Composite Score.

drive, and colour monitor. The screen measured 21cm in height and 27.5cm in width. Fitted beneath the screen was a two button response box (38.5cm long, 8cm high, and 10.5cm wide) connected to the computer. The response buttons were raised 1.5cm from the surface of the box and spaced 6cm apart, divided in the middle by a parallel bar. Stimuli presented on the screen appeared directly above the response buttons. All data was automatically recorded and saved at the end of each session.

The screen and response box were set on a table at the child's seated height, and the micro-computer and other equipment positioned away from the subject. All sessions were conducted in a separate, quiet experimental room adjoining the classrooms and lasted approximately 20-25 minutes. Sessions were conducted once daily on consecutive weekdays.

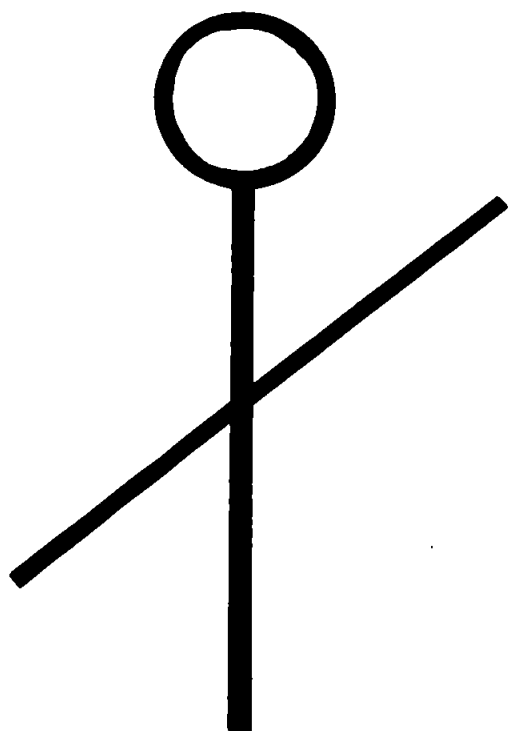
Stimuli

Two discrimination tasks were employed in the study. Both discriminations differed on only one relevant component, and were white line forms presented on black backgrounds. Task 1 consisted of two manikins (approximately 8cm by 13cm) with 'arms' angled at 45 degrees to the right of vertical (S+) or 45 degrees to the left of vertical (S-). Task 2 consisted of two "X" shapes, approximately 8 cm by 8 cm. On S+ a horizontal bar joined the upper left and right corners of the figure. On S- the line joined the lower left and right corners (see Figure 4.1).

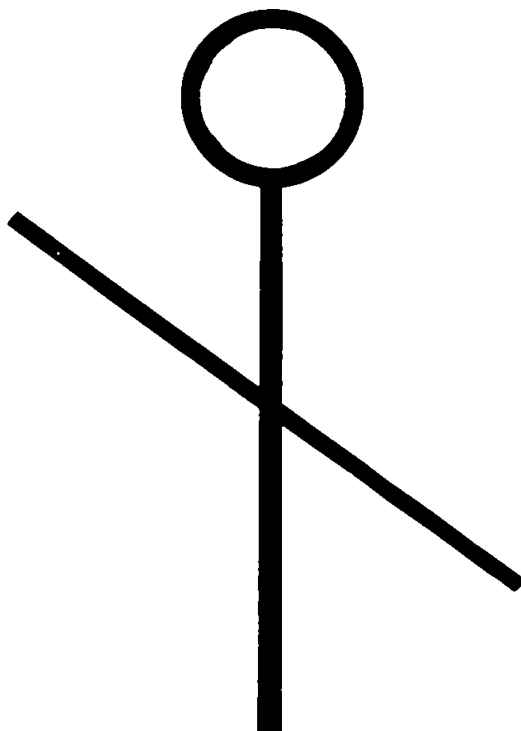
Procedure

Pre-training. A pre-training procedure was employed to familiarize the children with the apparatus and the association between the position of the stimuli on the screen and the buttons beneath them. This procedure was as described in Experiment 1.

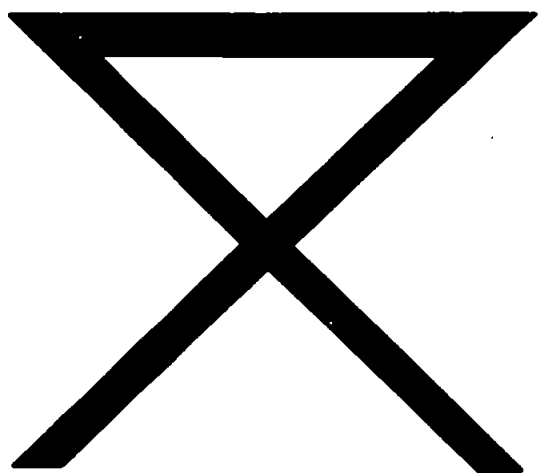
S+



S-



VS



VS

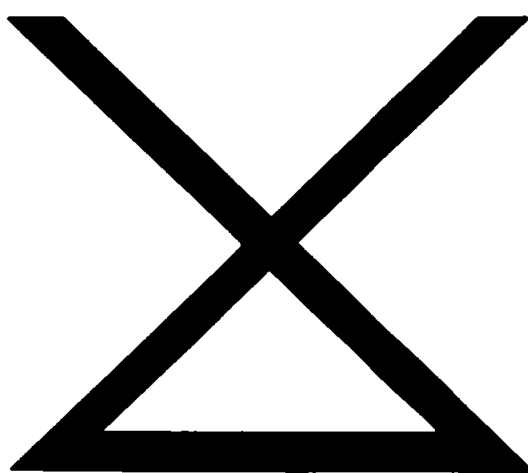


Figure 4.1: Stimuli employed in the two visual discrimination tasks.

Training programmes. The instructions given to subjects, reinforcement contingencies, and inter-trial intervals were as described for Experiment 1.

If the child failed to respond within six seconds, or attempted to elicit a direction from the experimenter before responding, one non-directional prompt such as "Which picture will play the tune? Where is the winning picture?" etc., was used. If the child still failed to respond an error was scored. Again, the learning criterion for tasks was 10 consecutive, unprompted, correct responses. All subjects initially received training on Task 1, and subsequently on Task 2.

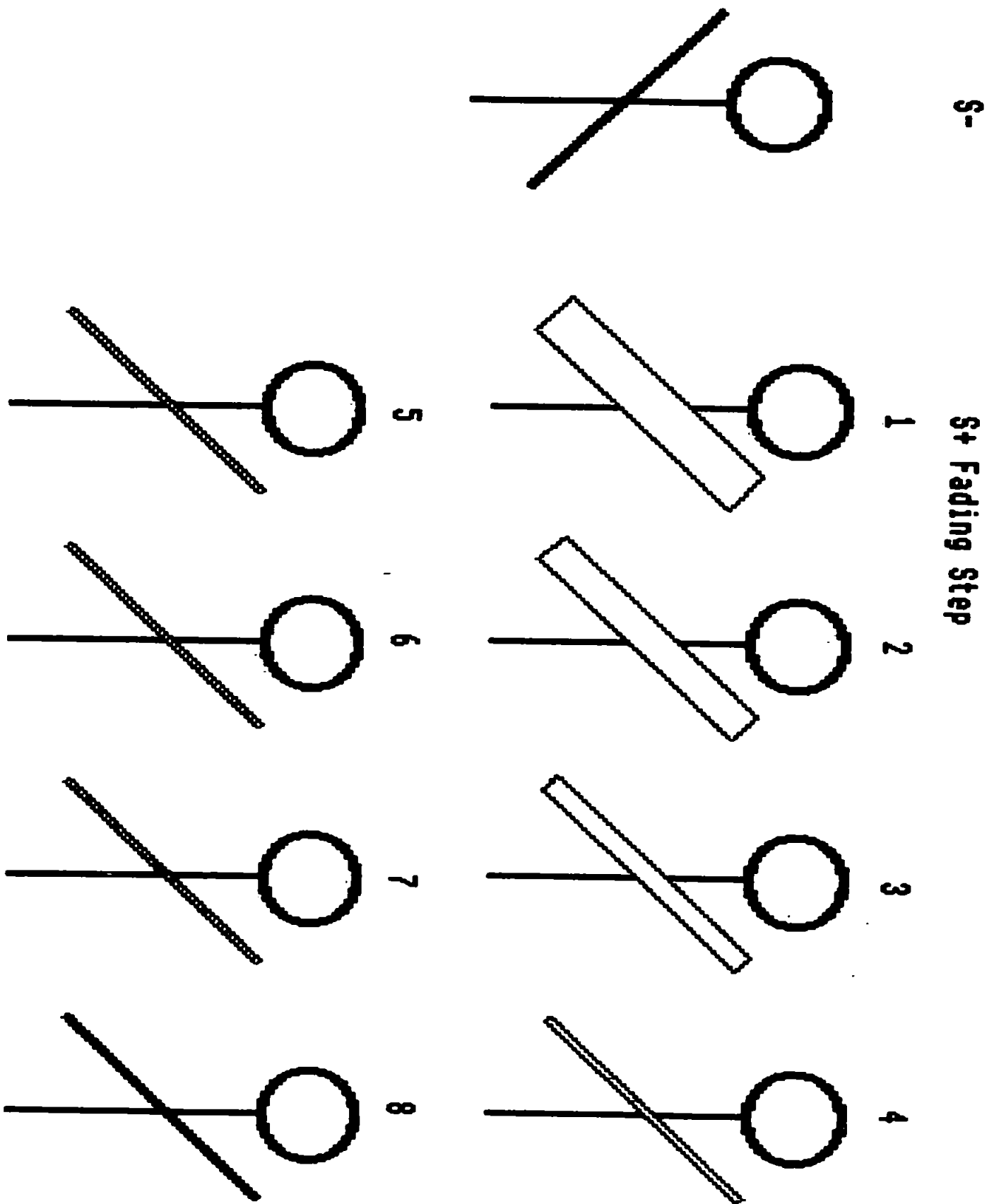
S+ and S- Fading Programmes (Groups 1 and 2).

The prompt used in these programmes was an exaggeration of the relevant components of the stimuli, i.e., the diagonal line in Task 1, and the horizontal bar in Task 2 (see Figure 4.1). Prompting involved increasing the size of the relevant component sevenfold and highlighting it in blue. S+ and S- fading programmes were identical except that fading was conducted on a prompt added to S+ or S- respectively. The S+ fading programme for Task 1 is presented in Figure 4.2. An identical procedure was followed for Task 2, except that the fading operations were conducted on the horizontal bar.

The fading programmes consisted of eight steps. Steps 1 to 4 faded the size of the prompt in 0.5cm width stages, until at Step 4 the prompt was at criterion size in both S+ and S-. Steps 5 to 8 faded colour saturation. At Step 8 all colour was completely faded and both S+ and S- were white. This final fading step was identical to trial-and-error training.

A criterion of two consecutive correct responses were required to advance each step, and a back-up procedure was employed whereby an error

Figure 4.2: Illustration of the eight steps of the S^+ fading programme for Task 1. Step 1 to Step 4 fade a size cue superimposed on S^+ , while Step 5 to Step 8 fade a superimposed colour cue. S^- remains constant throughout.



returned the subject to the previously mastered step. No step could be advanced through, even on a second or third attempt, until the criterion had again been fulfilled. Once five consecutive correct responses were made in the absence of prompting (Step 8) the programme was completed and any subsequent errors failed to reinstate the programme. The learning criterion could be attained only after the prompting programme had been successfully completed.

Trial-and-Error Training (Group 3).

This programme followed the traditional simultaneous discrimination training procedure and was identical to the preceding training programmes except that no prompts were added to the training stimuli.

Results

Task 1

A one-way related ANOVA revealed significant differences between groups in number of errors emitted during training ($F(2,16) = 8.24, p < .01$). The number of errors emitted by both the S_+ group (mean = 26.1, $SD = 9.9$) and the S_- group (mean = 29.4, $SD = 9.4$), were significantly lower than the trial-and-error group (mean = 46.9, $SD = 13.2$) ($t_s = 3.78$ and 3.17 respectively, $df = 16, p < .01$). S_+ and S_- groups did not differ significantly ($t = 0.60, df = 16, p > .05$). However, of the 27 subjects only S_4 (S_+ fading), S_{14} (S_- fading), and S_{19} (trial-and-error training) acquired the discrimination in the maximum 100 trials.

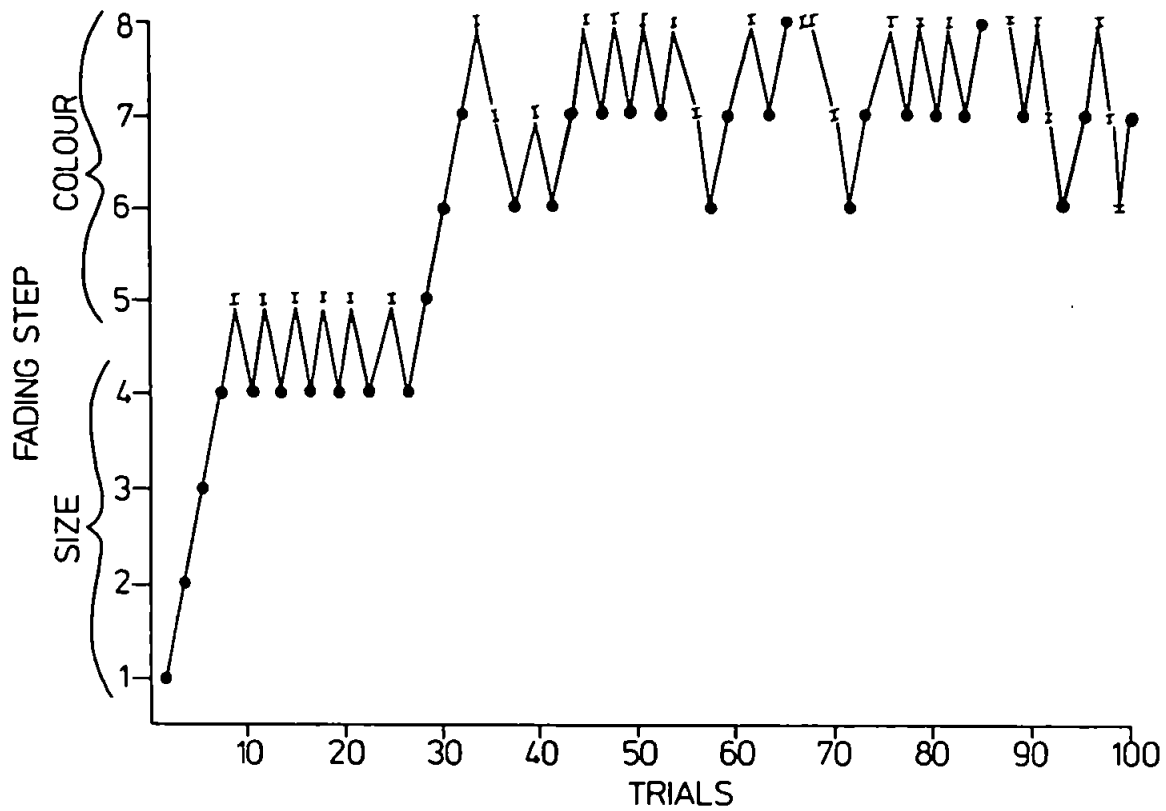
Analysis of individual performances revealed distinctive patterns of responding. The majority of both S_+ and S_- fading subjects failed to transfer correct responding from the final prompted step to unprompted

trials. Overall, the mean proportion of errors on fading trials was extremely low (.09 for S⁺ fading; .16 for S⁻ fading) while the number of errors on criterion trials approached 0.5 (chance level) for both groups. These differences were highly significant for both S⁺ and S⁻ groups ($t_s = 8.51$ and 5.62 , respectively, $df = 8$, $p < .0005$). Illustrative data for S₈ and S₁₀ are presented in Figure 4.3.

S₈ (S⁺ fading) progressed errorlessly through the size fading steps. Some errors were emitted upon initial fading of the colour component of the prompt (Step 5), although the subject then responded errorlessly through to the last fading step. Subsequently, an alternating pattern of predominantly error free responding at Step 7 and frequent errors at Step 8 was observed. A similar pattern was observed for S₁₀ (S⁻ fading), although in common with the majority of S⁻ fading subjects some errors were emitted through initially responding to the prompted stimulus. At the end of the training session, this alternating pattern of error-free responding at Step 7 with frequent errors on Step 8, had become a stable mode of responding for all but two of the 24 subjects who failed to attain the learning criterion.

In conclusion, neither S⁺ nor S⁻ fading facilitated acquisition of the discrimination, since subjects failed to transfer correct responding from the prompt to the training cue. However, questions may still be asked concerning the relative effectiveness of prompting either S⁺ or S⁻ during the fading trials. As noted above, two subjects failed to respond reliably to the prompt cue at the penultimate level of fading (step 7). S₁₃ progressed errorlessly through the size fading steps, and consistently responded correctly on Step 4 (size cue eliminated). However, she failed to maintain correct responding when attenuation of the colour cue was initiated, and repeatedly failed Step 5. The performance of S₁₆ was more variable, but again he rarely responded correctly above Step 4. Both these

Subject 8



Subject 10

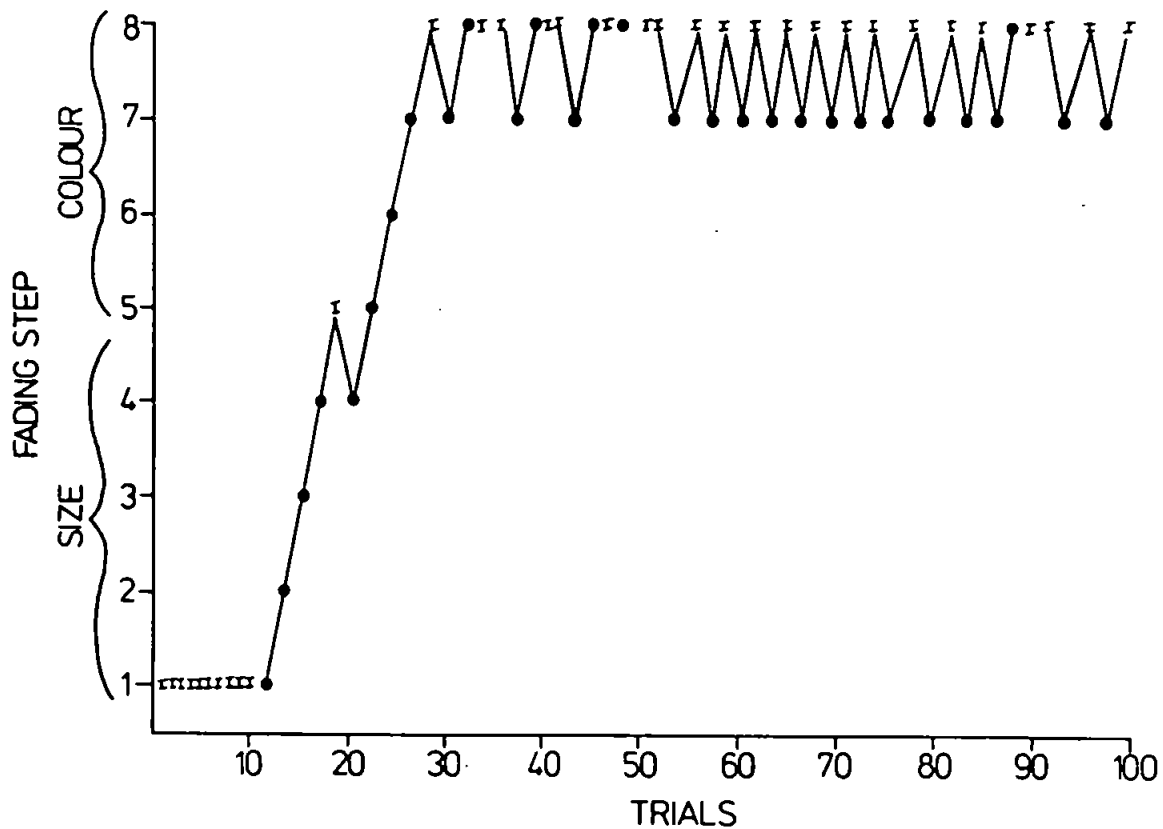


Figure 4.3: Trial-by-trial performance of S8 (top figure) and S10 (bottom figure) during the first training session of Task 1. I= incorrect response; O= two consecutive correct responses.

subjects received S- fading. S+ and S- fading groups were also compared for number of trials to first criterion level trial (an index of speed of progress through the fading programme), and number of errors on fading trials (Steps 1 to 7) (an index of the efficiency of the prompt in precluding errors). the S+ group required fewer trials to reach their first criterion level trial than the S- group (means= 22.2 and 39.6, SDs= 9.9 and 28.0, respectively, $t = 1.79$, $df=8$, $p<.06$), and made fewer responses to S- on fading trials (means= 5.6 and 12.0, SDs= 5.6 and 10.9, respectively, $t = 1.62$, $df = 8$, $p<.07$).

Task 2

All S+ fading subjects acquired the discrimination in the maximum 175 trials. Three subjects in the trial-and-error group, and one in the S- fading group, failed to attain the learning criterion. Number of errors and trials to criterion for each subject are presented in Table 4.2.

A one-way related ANOVA revealed significant differences between groups in number of errors ($F(2,16) = 5.96$, $p<.025$). Planned t-tests revealed both the S+ group ($t = 3.29$, $df = 16$, $p<.005$) and the S- group ($t = 2.55$, $df = 16$, $p<.025$) made significantly fewer errors than the trial-and-error group. The two fading groups did not differ significantly ($t = 0.75$, $df = 16$, $p>.05$). However, the S+ group again required significantly fewer trials to reach their first criterion level trial than the S- group (means= 15.7 and 20.9, SDs= 1.4 and 6.7, respectively, $t = 2.66$, $df = 8$, $p<.05$) and made significantly fewer errors on fading trials (means= 1.1 and 4.7, SDs= 2.1 and 5.7, respectively, $t = 2.04$, $df = 8$, $p<.05$).

Table 4.2: Number of Trials to Criterion and Errors for Task 2

Matched Set	Number of Trials			Number of Errors		
	S+ Fading	S- Fading	Trial & Error	S+ Fading	S- Fading	Trial & Error
1	24	124	11	0	25	1
2	24	24	17	0	0	6
3	24	27	73	0	1	32
4	29	109	175 ^a	1	26	94
5	24	25	92	0	1	41
6	27	34	175 ^a	1	1	83
7	60	51	27	11	11	7
8	147	62	69	29	10	19
9	29	175 ^a	175 ^a	2	41	78
Mean	43.1	70.1	90.4	4.9	12.9	90.4
SD	40.6	53.8	68.9	9.70	14.6	36.2

a. The subject failed to meet the learning criterion in the maximum of 175 trials.

Discussion

Differences between groups on Task 1 were obscured by a floor effect, since only three subjects (one from each training group) acquired the task. However, 17 of 18 subjects (94.4%) from the S⁺ and S⁻ superimposition and fading groups acquired Task 2, compared to only 6 of 9 subjects (66%) who received trial-and-error training. The fading groups also both made significantly fewer errors than the trial-and-error group. The results of the present study therefore confirm the superiority of programmed training over trial-and-error instruction in teaching visual discriminations to severely mentally handicapped children (e.g., Strand & Morris, 1986).

While there was a clear trend towards increasing number of errors and trials to criterion across S⁺ fading, S⁻ fading, and trial-and-error groups on Task 2 (see Table 4.2), the difference between S⁺ and S⁻ fading groups was not significant. However, on both tasks the S⁺ fading group progressed through the fading sequence faster, and made fewer errors on fading trials, than the S⁻ fading group. Furthermore, the performance of individual subjects does provide some data favouring S⁺ fading. The two subjects (S13, S16) who exhibited the greatest difficulty during fading of the prompt cue in Task 1 received S⁻ fading. In addition, the only programmed subject who failed to acquire Task 2 (S18) also received S⁻ fading. The results therefore suggest that the most extreme difficulties were manifested following S⁻ rather than S⁺ fading.

The direction of this difference concurs with the results of FP/FN studies. Sainsbury (1971) reported that only one of twelve normal intelligence pre-school children was able to acquire a task in the condition in which the feature was contained in S⁻ (FN), although all children acquired the task in the condition in which the feature was contained in S⁺

(FP). However, the results from the FN condition contrast with the results of S- fading, since the majority of the S- fading subjects were able to use the prompt contained in S- as a cue, leading to significant differential responding on the fading trials. Only S16, whose level of correct responding on Task 1 was extremely variable across steps, appeared to have extreme and persistent difficulty in inhibiting approach tendencies to the prompted (S-) stimulus.

However, the present experiment has clearly illustrated a potential problem with programmed training procedures. During the training of the line-tilt task, many subjects perseverated in responding to the prompt cue, and failed to transfer correct responding to the criterion cue once the prompt was removed (see Figure 4.3). For this reason training of Task 1 was not extended beyond 100 trials. However, Experiment 3 involved extended training of the task, and was concerned to further elucidate the conditions controlling perseverative responding to the prompt.

Experiment 3: Further Investigation of Perseverative Responding to the Prompt Cue Following S+ and S- Fading

The purpose of the experiment was to determine whether the prompt perseveration exhibited by subjects in the training of the line-tilt task could be ameliorated. Sixteen children who failed to acquire Task 1 were involved in the experiment. The efficacy of four training procedures was investigated: (1) continued trial-and-error training; (2) continued S+ and S- prompt fading; (3) reversals of the prompt between S+ and S-; and (4) S- intensity fading.

Trial-and-error training, S+ prompt fading, and S- prompt fading were

continued as controls to determine whether subjects would acquire the task without additional remedial intervention. The two novel procedures were attempts to eliminate perseverative responding to the prompt cue.

First, the prompt reversal programme was predicated upon research suggesting that, in a discrimination involving multiple relevant cues, the cue that best predicts reinforcement is most likely to control responding (Sutherland & Mackintosh, 1971). It was hypothesised that if the prompt cue was subject to a number of reversals between $\underline{S}+$ and $\underline{S}-$, subjects may be encouraged to search for other aspects of the stimulus display which were positively and consistently correlated with reward (i.e., line orientation).

Second, the effectiveness of stimulus fading along an intensity dimension was evaluated. In Experiment 2, although the majority of subjects successfully progressed through fading of the size component of the prompt, they perseverated in responding to the faded colour cue. Suchman and Trabasso (1966), and Corah (1964), have charted developmental changes in colour and form preference in children of normal intelligence. Suchman and Trabbaso (1966) report younger children predominantly preferred colour and older children form, with the median transition age at 4 years, 2 months. It may be hypothesised that for discriminations where form and colour are relevant and redundant cues, a similar preference for colour over form may be demonstrated by mentally handicapped children of similar developmental level. To evaluate whether perseveration to the prompt cue in the present task was specific to the use of a colour cue, the discrimination was also trained employing fading along an intensity dimension.

Method

Extended Trial-and-Error Training.

Two children were chosen randomly from the trial-and-error group for extended training. These subjects received an additional 100 trials with the traditional simultaneous discrimination training procedure.

Extended Prompt Fading.

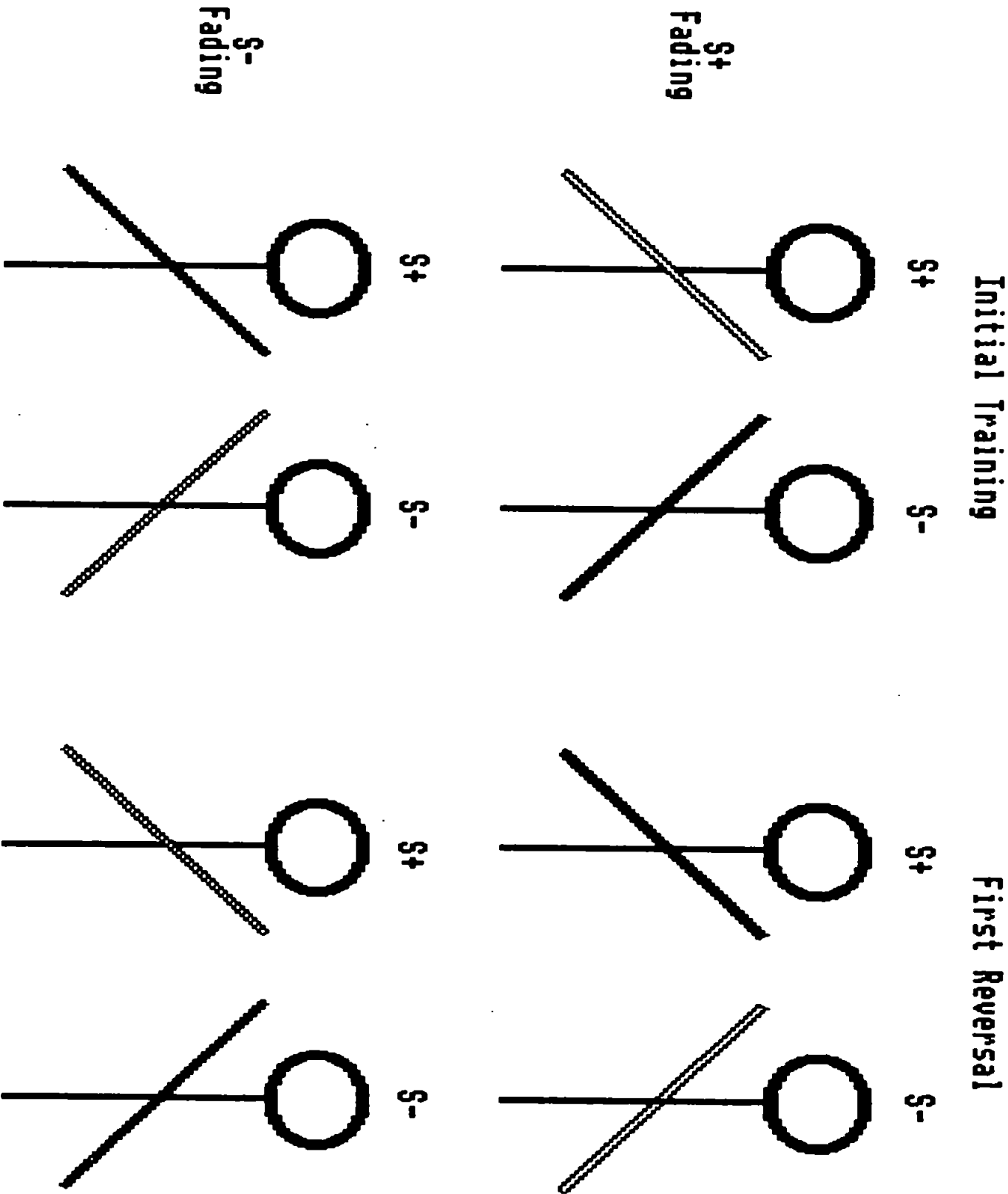
Six subjects, three S⁺ and three S⁻ fading, were selected at random and received an additional 100 trials of training with the S⁺ and S⁻ fading programmes, as described in Experiment 2.

Prompt Reversals.

Four subjects, two S⁺ fading and two S⁻ fading, were again selected randomly for the reversal programme. Four further subjects (two S⁺ and two S⁻ fading) received reversal training following unsuccessful extended prompt fading. Subjects initially received a further 30 trials of S⁺ or S⁻ fading respectively before the first prompt reversal was initiated. For those subjects who initially received S⁺ fading the prompt was subsequently placed on S⁻, while for subjects who initially received S⁻ fading the prompt was moved to S⁺. Hence, the reinforcement contingencies for the prompt cue were reversed. However, the reinforcement contingencies for the training cue remained unchanged; S⁺ was always the stimulus containing the 135° tilted line, while S⁻ was always the stimulus containing the 45° tilted line. This is illustrated in Figure 4.4.

After either 40 or 60 trials a second reversal was conducted which returned the prompt to the original stimulus for a further 30 trials. During the initial reversal the back-up procedure by which errors returned

Figure 4.4: Prompt reversal training (see text for details).



subjects to previously mastered steps was discontinued. The purpose of this procedure was to prevent the prompt from rapidly returning to full colour saturation and exaggerated size as a result of initial errors.

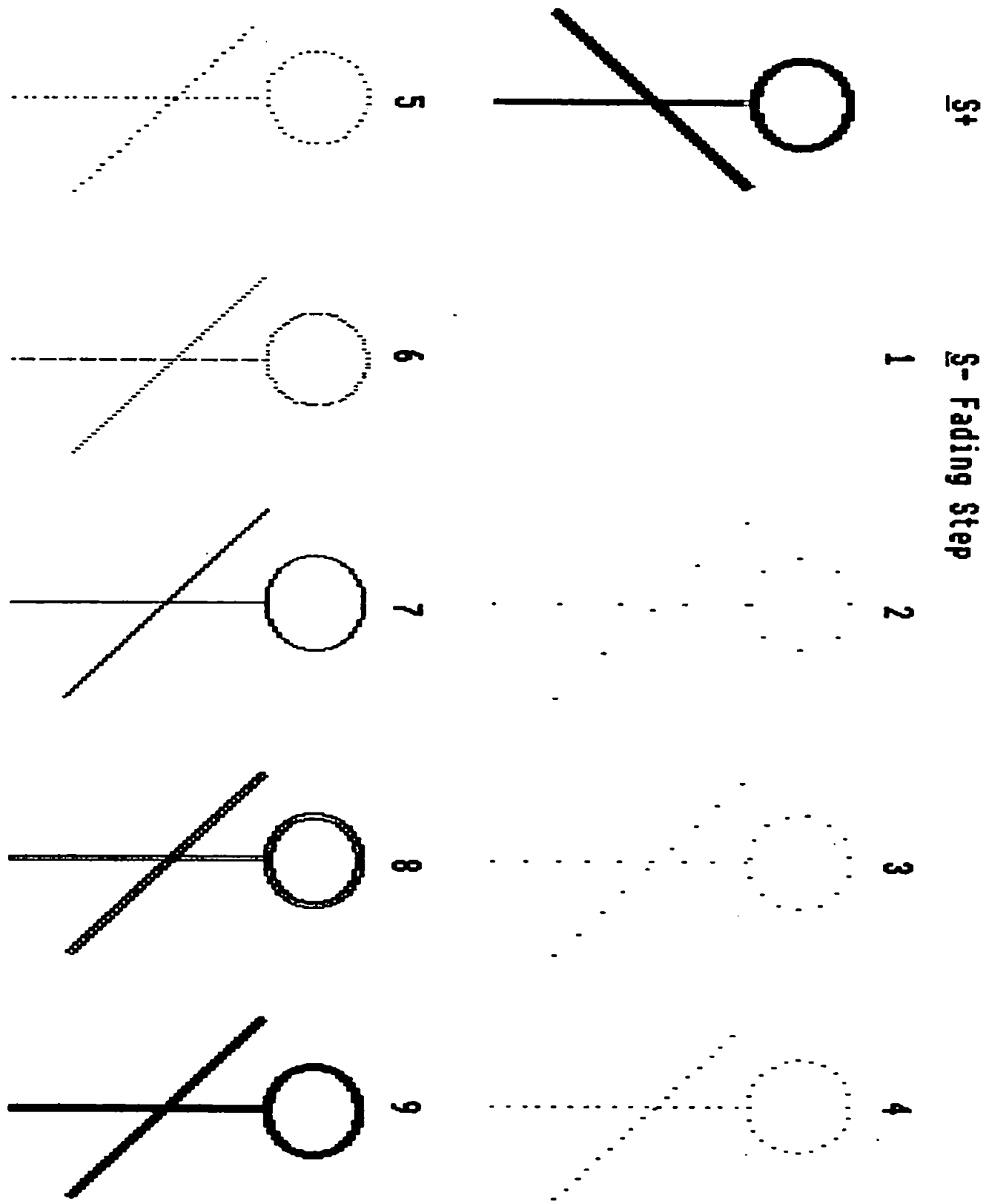
S- Intensity Fading.

Three S+ fading and three S- fading subjects were randomly selected for the stimulus fading programme. The programme consisted of nine steps which differed in the level of prompt presented along the dimension of intensity. Only S- was manipulated during training for all subjects. Initially S+ was presented at full intensity with a blank space as S- to enhance the probability that subjects would respond to S+. Subsequently, the intensity of S- was gradually increased over nine steps by systematically incrementing the number of dots composing the lines of the S- stimulus. S+ remained at full intensity throughout. At Step 9 both stimuli were at equal (criterion) intensity. Step 9 was identical to Step 8 in the prompt fading programmes and trial-and-error training. This fading sequence is illustrated in Figure 4.5. The criteria for step advancement and the back-up procedure were identical to the fading programmes described in Experiment 2, and again the learning criterion could be attained only after the programme had been successfully completed.

Results and Discussion

Neither of the two subjects receiving continued trial-and-error training acquired the discrimination after a total of 200 training trials. For both subjects correct responding remained at chance level. Similarly, of six subjects given extended prompt fading only S1 (S+ fading) acquired the discrimination after a total of 200 trials of either S+ or S- prompt fading. For the other five subjects, the perseveration in responding to the

Figure 4.5: Illustration of the nine steps of the intensity fading programme. S^+ remains at criterion intensity throughout, while S^- is faded in.



prompt cue observed in Experiment 2 continued throughout subsequent training.

The two remedial procedures were also unsuccessful in training the discrimination. No subjects receiving the prompt reversal programme acquired the criterion discrimination. Table 4.3 presents the number of errors on stimulus compound trials (per block of ten trials) immediately prior to the first reversal, during the first reversal, and during the second reversal that returned the prompt to the original stimulus. Prior to the discussion of this data, three preliminary points may be made.

First, only the reinforcement contingencies for the prompt cue were reversed, the reinforcement contingencies for the training cue were unchanged (see Figure 4.4). Second, no differences during reversal training were apparent across groups of subjects receiving either 100 (S3, S8, S11, S16) or 200 (S6, S9, S13, S18) prior training trials with S+ or S- fading. Therefore no distinction between subjects is made on this variable. Third, the data for S16 are omitted from the analysis since alone of the eight subjects he failed to respond appropriately to the prompt cue during initial training, evidenced by the high number of errors in the 30 trials immediately preceding reversal (see Table 4.3). As described in Experiment 2, this subject appeared unable to inhibit inappropriate responses to the prompted S- stimulus. Since appropriate differential responding to the prompt cue was not acquired prior to reversal, reversal learning cannot be studied. (n.b., the low level of errors emitted by S16 during the first reversal is an artefact of this failure to acquire the initial discrimination, and not an indication of rapid learning of the reversed prompt contingencies. In fact, S16 continued to respond to the prompted stimulus over both reversals).

Table 4.3: Number of Responses to S- on Stimulus Compound Trials Immediately Prior to the First Prompt Reversal, During the First Prompt Reversal, and in the Second Prompt Reversal.

----- Blocks of 10 Trials -----												
Subject and Group	Immediate Pre-reversal			First Reversal						Second Reversal		

S+ <u>Fading</u>												
S3	0	0	0	9	6	3	3	-	-	2	0	0
S6	0	0	0	5	0	0	0	-	-	3	0	1
S8	1	0	0	10	5	4	1	-	-	2	1	1
^a S9	0	0	0	10	10	10	10	10	10	0	0	0
S- <u>Fading</u>												
S11	0	0	0	10	10	10	10	-	-	0	0	0
S13	0	0	0	3	1	0	0	-	-	-	-	-
^{ab} S16	7	8	10	0	3	1	0	0	0	5	6	5
^c S18	0	1	3	9	8	4	4	-	-	4	3	^d *

- a. Subject received 60 trials in the first reversal.
- b. Subject omitted from analysis due to failure to demonstrate appropriate responding to the prompt cue prior to reversal.
- c. Subject exhibited a position perseveration bias throughout initial training and both reversals.
- d. Data lost due to equipment failure.

During the prompt reversal phase, two predominant patterns of responding were observed. First, four of the seven subjects perseverated in responding on the basis of the original prompt contingencies, and showed little, if any, correct responding to the training cue. This was most marked in both S9 and S11 (see Table 4.3). S9 (Initial S+ fading) invariably responded to the prompted stimulus despite the reversals, producing 60 consecutive errors during the first reversal, although none of these responses were reinforced. Similarly, S11 (Initial S- fading) perseverated in responding to the non-prompted stimulus on every reversal trial, even though this again resulted in a total absence of reinforcement. Clearly, prior training with either S+ or S- fading was not a relevant variable. While S3 and S18 demonstrated some learning of the reversed contingencies for the prompt (errors reduced from nine on the first block of 10 reversal trials to 3 and 4 errors respectively on the final block), perseveration to the original value of the prompt cue was still present in the final block of reversal trials.

Second, the remaining three subjects demonstrated rapid acquisition of the reversed reinforcement contingencies for the prompt cue. This pattern was most clearly exhibited by both S6 (Initial S+ fading) and S13 (Initial S- fading). Although both subjects emitted some errors immediately following each reversal, they rapidly learned to respond to S+ again (See Table 4.3). S8 also came to respond appropriately to the new contingencies.

While his initial level of perseveration to S-, and the rate of decrease in responses to S-, differed substantially from S6 and S13, he emitted only a single error in the final block of reversal trials. Again, since S6 and S8 had received S+ fading and S13 S- fading, prior training with either S+ or S- fading was not a relevant variable.

Clearly, reversal training revealed marked contrasts in performance

between subjects. Four of seven subjects perseverated in responding on the basis of the original (pre-reversal) prompt contingencies, while three subjects showed rapid learning compatible with the reversed contingencies for the prompt. However, for all subjects, including the latter three, the discriminative response was still under the exclusive control of the prompt cue, rather than the training cue. This may be illustrated through reference to Figure 4.6, which presents the performance of S9 (upper figure) and S6 (lower figure). S9 perseverated in responding to the prompted stimulus and emitted 60 consecutive errors during the first reversal, while S16 rapidly learned to cease responding to the prompted stimulus. However, for both subject continued and exclusive stimulus control by the prompt cue is demonstrated, since in neither case was correct responding maintained when the prompt cue was totally removed (step 8).

It may be argued that making the prompt an irrelevant cue varying randomly between S+ and S-, rather than instigating discrete reversal phases, might have proved more effective in facilitating transfer to the criterion cue. However, such a procedure would not have facilitated the performance of the subjects who continued to make non-rewarded responses either to the prompt (initial S+ fading), or away from the prompt (initial S- fading) on every trial during the first reversal (e.g., S9 and S11, see Table 4.3). For these subjects prompt responding was placed in extinction during reversal; making the prompt an irrelevant cue would in effect have maintained the original responding to the prompt cue on a VR2 schedule, since at least 50% of responses to the prompt cue would result in reinforcement.

Finally, the intensity fading programme was also unsuccessful in shifting control from the prompt to training cue. Of the six subjects trained, only S10 (initial S- fading) acquired the discrimination. The

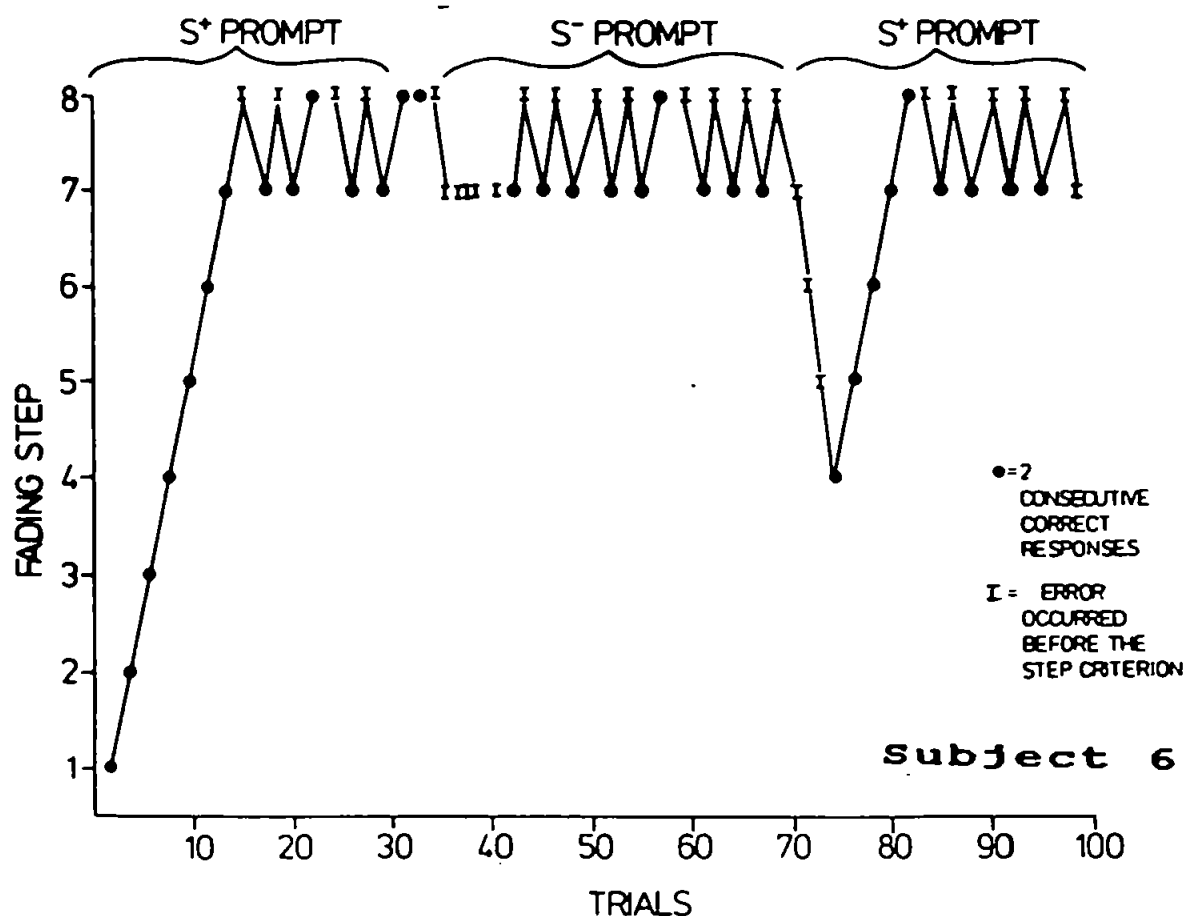
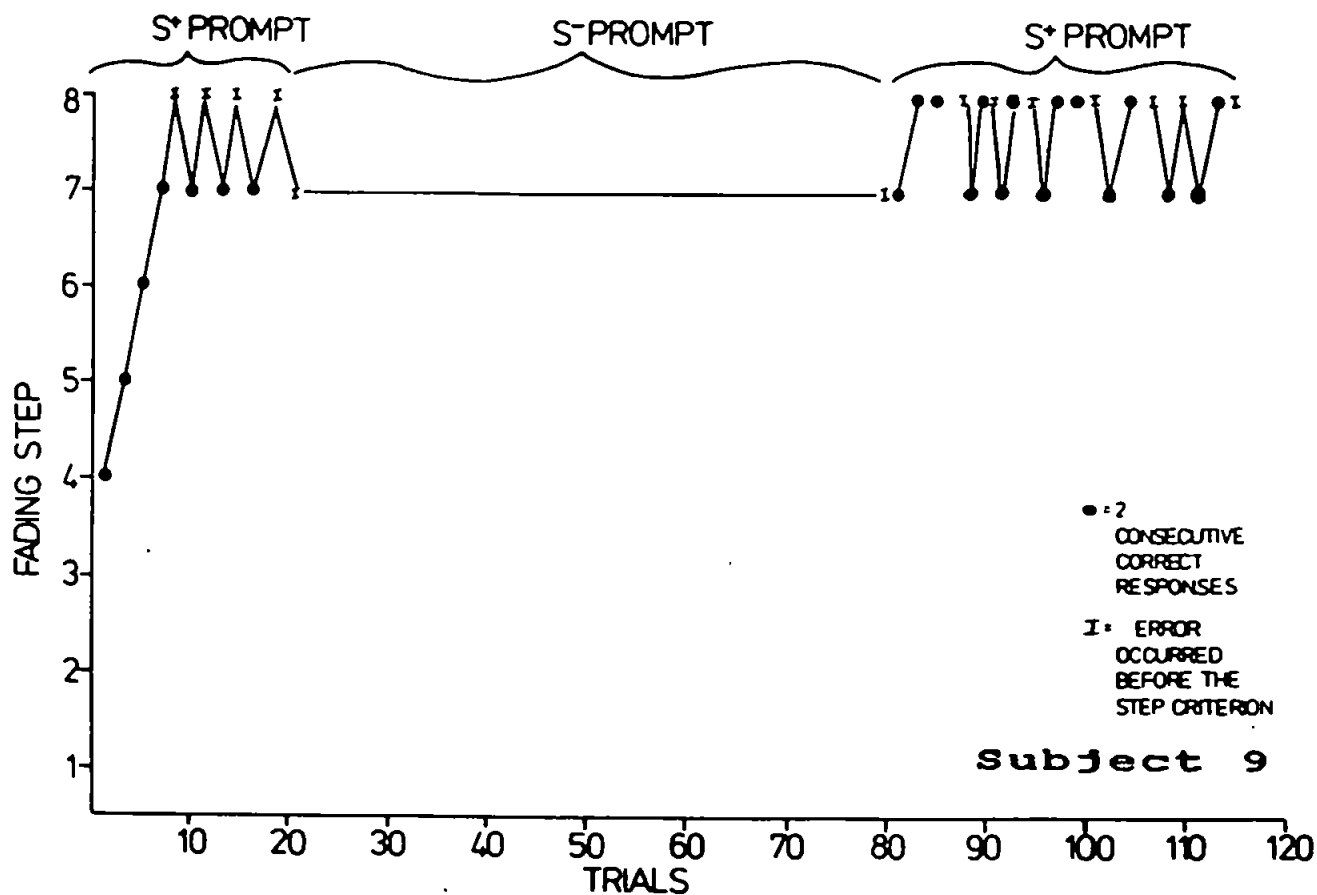


Figure 4.6: Trial-by-trial performance of g9 (top figure) and g6 (bottom figure) during prompt reversal training. I= incorrect response; ●= two consecutive correct responses.

problem again appeared to be a failure to transfer correct responding from the prompt cue (in this case intensity) to the training cue. As in the original superimposition and fading programme, few errors were made on fading trials, significantly more errors being produced on criterion trials ($t = 10.84$, $df = 5$, $p < .0005$). Perseverative responding to the prompt on this task was therefore not specific to the use of a colour cue.

General Discussion

Programmed Versus Trial-and-error training

The programmed training procedures proved more effective than trial-and-error training in facilitating task acquisition. More subjects from the superimposition and fading groups acquired the discriminations, and did so with significantly fewer errors, than subjects from the trial-and-error group. The present experiments therefore replicate the results of Experiment 1, and confirms the superiority of programmed training over trial-and-error instruction in teaching discriminations to severely mentally handicapped children.

S+ versus S- Manipulation

As noted in the discussion of Experiment 2, S+ manipulation significantly facilitated the performance of subjects in the early stages of fading where the prompt cue was prominent, although the observed reduction in total number of errors to criterion relative to S- fading (see Table 4.2) was not statistically significant. However, if errorless learning is defined as the acquisition of a discrimination with less than 10% errors (Lancioni & Smeets, 1986), seven S+ fading subjects acquired Task 2

errorlessly, compared to only four S- fading subjects. Furthermore, the two subjects (S13, S16) who exhibited the greatest difficulty during fading of the prompt cue on Task 1, and the only programmed subject to fail to acquire Task 2 (S18), all received S- fading. Experiment 3 also provided further support for this observation, since the only subject (S1) to acquire the task with extended S+ or S- fading received S+ fading.

These results may be interpreted in terms of the differing inhibitory demands of the procedures. Adding a highly discriminable prompt to a stimulus may increase the salience of that stimulus for learning, since Trabasso and Bower (1968) observe the more salient or noticable a stimulus the more likely it is to be selected as functional in learning. Therefore, in contrast to S+ fading, an initial approach-avoidance conflict may be assumed to exist in the discrimination in which the prompted stimulus is negative (S- fading). Responses to the salient stimulus are not reinforced, and subjects are required to inhibit approaches to the highly discriminable prompted stimulus. This proved extremely difficult for some subjects. Zeaman and House (1962) have reported data suggesting that, early in learning, approach tendencies are formed more rapidly than avoidance tendencies (although once the discrimination is established approach and avoidance tendencies may have approximately equal strength). We may conclude therefore that faster learning may be achieved by initially prompting approach to S+ rather than avoidance of S-. However, it must be noted that prompting avoidance of the negative stimulus, by superimposing and fading a prompt upon S-, still proved significantly more effective than trial-and-error training.

Perseverative Responding to the Prompt Cue in Programmed Training

In Experiment 3, the majority of subjects receiving extended S+ and S-

fading continued to demonstrate perseverative responding to the attenuated prompt cue (Step 7) and failed to transfer correct responding to the criterion level stimuli. This represented a continuation of the response patterns noted in Experiment 2, and demonstrated that simply extending training with the same procedures was unlikely to result in task acquisition.

The results of prompt reversal training also demonstrated that the control exerted by the prompt cue was extremely resistant to change. All subjects perseverated in responding to the prompt cue (colour) and failed to transfer to the training cue. Additionally, four of seven subjects also perseverated in approaching or avoiding the stimulus containing the prompt (initial S+ and S- fading respectively), even when such responses were placed in extinction during reversal training.

Perseveration in responding to the original S+ in reversal shifts has been noted with both normal intelligence and developmentally impaired subjects (e.g., Heal & Johnson, 1970; Robinson & Storm, 1978; Charlop & Carlson, 1983). It has been suggested that inhibitory processes may be of special significance during reversal learning, since "the learning of a reversal necessarily requires the subject to abandon the performance of old habits" (Heal & Johnson, 1970, p120). Many studies of reversal learning (see Heal & Johnson, 1970, for a comprehensive review) have compared mentally handicapped and normal intelligence subjects in an attempt to identify an 'inhibition deficit' in the mentally handicapped. However, Evans (1975, 1982) has argued that rather than demonstrating a generalized deficit, mentally handicapped people may be presumed to differ along a dimension of weak to strong inhibitory control (see Chapter 2, section 2.3.2).

Some authors (e.g., Umetani, Kitao, & Katada, 1985) have suggested that the number of errors emitted prior to the first correct response in the reversal phase may be used as a measure of response inhibition. Wide variations in this measure were observed during reversal training (range 3 - 40, median= 11). It was hypothesised that individual differences in response inhibition during reversal learning might correlate significantly with scores on a rating scale designed to assess individual differences in inhibition. This scale, specifically devised with reference to mentally handicapped children (Evans, 1975), involves the child's teacher rating the child on a series of items related to classroom behaviour, and will be more fully described in Chapter 7. However, the correlation between number of pre-reversal errors and inhibition/excitation (I/E) score was not significant ($r = -.498$, $df = 5$, $p < .10$). Correlations with CA ($r = .155$), PPVT-MA ($r = -.147$), and BAS composite ($r = .005$) were also not significant. While the two subjects who never made any correct responses during reversal (S9 & S10) also received extreme scores on the IE scale (IE= -3.82 and -3.37 respectively), one of the most rapid reversal learners (S6) received an equally extreme IE score (IE= -3.02). However, the number of subjects in the sample was extremely small ($n=7$), and this may preclude obtaining significant correlations.

While it was difficult to relate the reaction of the subjects during prompt reversal to any simple quantitative variable (e.g., CA, MA, BAS, IE, prior S+ or S- training, amount of prior training), the observation that reversal training was unsuccessful in producing transfer to the training cue for every subject may be the most relevant result.

Fading on a novel prompt dimension (intensity) was also largely ineffective, since only one of six subjects acquired the task following S- intensity fading. Had intensity fading had been employed before the child

acquired a history of errors through unsuccessful colour fading, it may have proved more effective. However, perseverative responding to the prompt cue was clearly not specific to the colour dimension. Perseveration to other types of prompts (e.g., trainer finger points) has also been reported (e.g., Schreibman, 1975; Wolfe & Cuvo, 1978).

Alteration of other parameters of the fading programmes, such as step size or number of steps, may have proved more effective. However, the cue values of the prompt employed in fading on Task 1 were identical to those employed for Task 2, in which only S18 exhibited prolonged perseveration to the prompt cue and failed to acquire the task. All other subjects successfully transferred correct responding from the prompt to the training cue, although this process could not be described as 'errorless' for six of the seventeen subjects receiving fading (see Table 4.2). An important factor influencing the success of fading was therefore the discriminability of the training cue. The difficulty of a discrimination between lines of 45° and 135° for both normal intelligence and mentally handicapped subjects has been independently verified (Jeffrey, 1966; Rudel & Teuber, 1963; Stoddard, 1968; Touchette, 1971). It would appear that when presented with a difficult training cue, perseveration in responding to the prompt cue is more likely to occur. Koegel and Rincover (1976), and Smeets and Lancioni (1981), have also reported fading to be a more effective procedure in training simple rather than difficult discriminations.

The particular difficulty of the line-tilt task may result from the stimuli being mirror-image reversals, and particularly left-to-right mirror-image reversals. In this task, the S- manikin was a mirror image reversal of the S+ manikin. In Task 2, S- was a 180° rotation of S+. When stimuli are positioned side by side, mirror-image forms are more difficult to discriminate than non mirror-image forms (Touchette, 1971; Asso & Wyke,

1971). The line-tilt task also contrasts in this respect with the four tasks successfully trained in Experiment 1. Although Touchette (1969, 1971) has reported that discriminations of opposing 45 line tilts may be acquired through fading procedures, considerable inter-subject variability in acquisition is reported. In the present study only five subjects acquired the task; four learning with programmed assistance and one without programmed assistance.

The relatively infrequent success of the fading procedures in facilitating acquisition of the line-tilt task may be interpreted as an example of 'overshadowing'. Pavlov (1927) found that a stimulus which would condition a response when presented singly, failed to become a conditioned stimulus when presented in a compound with a stronger stimulus. He referred to the stronger stimulus as overshadowing the weaker one. In the case of instrumental discrimination learning, overshadowing occurs when the control exerted over the discriminative response by one cue is reduced by the presence of a second concurrent cue.

In the present experiment, it may be suggested that the more discriminable prompt cue (colour or intensity) 'overshadowed' the less discriminable training cue (line orientation) during learning, so that little was learned about the training cue. Certainly, the responding of subjects was characterized by the exclusive control of the prompt cue. Such an analysis may suggest procedures for overcoming the perseveration to the prompt cue. Research reported by Schilmoeller and Etzel (1977), and Strand and Morris (1988), suggests fading criterion-related (CR) cues (cues drawn from the same dimension as the training cue) may be more effective in facilitating task acquisition than fading non criterion-related (NCR) cues (cues drawn from a different dimension), since CR fading does not necessitate the transfer of stimulus control from the prompt to criterion

cue. For example, manipulating a CR cue, such as progressive fading along a dimension of line orientation, might prove effective in training this task. An extended analysis of overshadowing, including an evaluation of such a CR programme for training the line-tilt task, will be presented in Chapter 5, once further empirical data has been gathered.

While the failure of the fading procedures to facilitate the acquisition of the line-tilt task was disappointing, trial-and-error training was equally ineffective. The present studies have shown that superimposition and fading is, in general, superior to trial-and-error training, although the success of the fading procedures may depend upon the relative discriminability of prompt and training cues. In summary, while the manipulation of either S+ or S- during fading appeared to exert some effect on programme outcome, factors such as the dimension that prompts are faded on (CR or NCR), procedural aspects of the fading programme (size and number of steps), and the discriminability of the training cue, may be even more significant in determining the success of programmed training.

Experiment 4: Training Between-Case Letter Matching to Severely Mentally Handicapped Children: A Comparison of S+ and S- Manipulation in Stimulus Fading Procedures

S+ versus S- Manipulation

Experiments 2 and 3 compared S+ and S- manipulation in superimposition and fading procedures, and it was concluded that S+ manipulation may on occasion prove superior to S- manipulation. This result was interpreted in terms of the differing inhibitory demands of the procedures. It was hypothesised that S- fading may generate an approach-avoidance conflict,

since S- fading required subjects to inhibit approaches to the highly discriminable prompted stimulus. Results suggesting that, early in learning, approach tendencies are formed more rapidly than avoidance tendencies (Zeaman & House, 1962), were advanced to support the conclusion that S+ manipulation may lead to faster learning through prompting approach to S+ rather than avoidance of S-.

However, such conclusions may not necessarily obtain for stimulus fading procedures. The first description of stimulus fading procedures (Terrace, 1963a) emphasised the manipulation of S- during fading, and manipulations of S- predominate in subsequent research (e.g., Gollin & Savoy, 1968; Sidman & Stoddard, 1967; Schreibman, 1975). For example, even though Stella and Etzel (1986) have reported data suggesting S+ manipulation may be more effective than S- manipulation in stimulus shaping procedures, all their subjects first received S- stimulus fading to establish discriminative control by S+, prior to stimulus shaping.

Only two studies have directly compared S+ and S- manipulation in stimulus fading procedures, and these studies have produced conflicting results. Both studies (Schreibman & Charlop, 1981; Zawlocki & Walls, 1983), were described in the introduction to this chapter. Zawlocki and Walls (1983) results support the emphasis on S- manipulation in stimulus fading procedures. They report S- fading resulted in significantly fewer errors on fading trials than S+ fading, although no differences between the two conditions were found on subsequent test trials. In contrast to these results, Schreibman and Charlop (1981) have reported that a procedure that first presented S+ at criterion level and faded in S-, was less effective than a procedure which first presented S- at criterion level and faded in S+

Schreibman and Charlop (1981) offer a theoretical interpretation of the superiority of S+ stimulus fading observed in their study in terms of stimulus novelty and learning. A novel stimulus has typically been defined as a stimulus that changes, rather than remaining static (Fantz, 1964). Several studies have shown that young children, and children of low MA, prefer a novel or changing stimulus to a familiar stimulus (e.g., Zeaman, 1976). Furthermore, in relating stimulus novelty to learning, Trabasso and Bower (1968) have pointed out the more salient, novel, or noticeable a stimulus the more likely it is to be selected as functional in learning. Hence, they hypothesise S+ manipulation may prove more effective than S- manipulation since S+ remains novel and thus more salient for learning. Conversely, during S- fading, the changing nature of the S- stimulus may serve to direct children's responses to the incorrect stimulus, thus impairing learning.

In summary, the only two studies to compare the effectiveness of S+ and S- manipulation in stimulus fading procedures have produced conflicting results. However, Schreibman and Charlop's theoretical analysis clearly predicts that manipulating S+ should prove more effective than manipulating S-. The purpose of the present experiment was to evaluate this prediction. Two types of fading procedures were studied. In one procedure, the S+ training stimulus remained unchanged throughout fading while the S- training stimuli were manipulated. In the other procedure, the S- training stimuli remained unchanged throughout training while the S+ training stimulus was manipulated.

Finally, in contrast to the procedures described by Schreibman and Charlop, which subsequently manipulated both S+ and S- simultaneously to attain the terminal discrimination, the present procedures will manipulate only S+ or S- during fading. Also, in contrast to Zawlocki and Walls study,

a mastery criterion will be employed during fading. Zawlocki and Walls limited training to a fixed 40 fading trials for all subjects. They note, however, that this procedure might have minimized differences between fading conditions, and that the use of a mastery criterion might have produced larger differences among the fading conditions.

Stimulus Materials: Discriminating Alphanumeric Characters

The present study had a second major aim. The training tasks employed in the preceding studies have involved discriminative stimuli that are artificial in nature, or stimuli arbitrarily designated as S+ or S-. Such tasks are frequently employed in discrimination learning studies since the process of discrimination acquisition can be studied relatively free from the confounding effects of prior experience or training. However, the present study was concerned to demonstrate the effectiveness of programmed training procedures with educationally relevant training tasks. Teachers in the SLD schools participating in the research reported children exhibited difficulty in several areas of the educational curriculum requiring discrimination skills. Specifically, extreme difficulty in matching lower-case and upper-case letter forms was reported. Between-case letter matching was also identified as an important pre-reading skill. Therefore, the present study was concerned to generate programmed procedures that would facilitate acquisition of this task.

It is commonly reported that young children encounter problems in discriminating letters (e.g., Asso & Wyke, 1971), and that such difficulties are encountered within both upper-case and lower-case alphabets. Gibson, Osser, Schiff, and Smith (1963), and Popp (1964), have produced confusion matrices for upper-case and lower-case letters respectively, which pinpoint

the letters most often confused by young children. Mentally handicapped children also experience such discrimination difficulties (e.g., Wolfe & Cuvo, 1978).

Among both normal intelligence and mentally handicapped populations programmed training techniques have been employed to facilitate the discrimination of alphabet stimuli. Techniques employed have included pre-training on distinctive features (Gurnalick, 1975); highlighting and fading of colour cues (Egland, 1975); highlighting and fading of size cues (Wolfe & Cuvo, 1978); fading of pictorial prompts (Karraker & Doke, 1970; Griffiths & Griffiths, 1976); and delayed prompting (Braddely-Johnson, Sunderman, & Johnson, 1983). The effectiveness of the programmed procedures varies across studies. However, programmed training has in general proved superior to control conditions where these were included.

These studies have only trained discriminations between letters from the same case. In contrast, the present study aimed to investigate methods of facilitating the acquisition of between-case letter matching, i.e., the matching of upper-case and lower-case forms of the same letter. Between-case matching is a more complex skill for the child to acquire than within-case matching, since the task requires arbitrary visual-visual matching, recognizing the functional equivalence of physically dissimilar forms. In contrast, within-case matching may be achieved on a simpler basis, by matching physically identical stimuli. Surprisingly, given the difficulty and educational importance of the task, no studies can be found that attempt to help young or mentally handicapped children to acquire these skills.

In summary, the present study aims to employ S⁺ intensity fading, S⁻ intensity fading, and trial-and-error training with a sample of severely

mentally handicapped children to determine whether; (1) between-case letter matching can be facilitated through match-to-sample training; (2) fading is a more effective training procedure than trial-and-error training; (3) S+ and S- manipulations differ in facilitating task acquisition.

Method

Subjects

Twenty-three children attending school for children with severe learning difficulties participated in the initial phase of the study. All subjects were administered the Word Reading Scale from the British Ability Scales (BAS) (Elliot, Murray, & Pearson, 1978). A composite ability score was also derived by summing scores from four other selected BAS scales (see Experiment 2). Following screening (see procedure) twelve of these children were selected for training. The mean chronological age of the experimental subjects was 153 months (SD 22.9 months). The mean MA (PPVT-R) was 58.2 months (SD 20.2 months). Eleven of these subjects had participated in Experiments 2 and 3 (some seven months previously), and eight had also participated in Experiment 1. One subject had not participated in any previous studies. Table 4.4 presents descriptive characteristics of the subjects.

Materials

Pre-assessment of Letter Discrimination Skills.

Four assessments of letter discrimination skills were conducted. Within-case and between-case matching tests were employed to test for eligibility for between-case matching training. Letter recognition and letter identification tests were also included to examine the relationship

Table 4.4: Descriptive Characteristics of Subjects

Subject	Sex	^a		^b
		CA	Word Reading Score	
1	F	15:5	24	287
2	M	12:11	0	129
3	F	13:9	24	222
4	F	14:6	10	260
5	F	12:2	0	96
6	F	15:2	10	293
7	M	13:8	32	194
8	F	12:6	0	116
9	F	12:7	43	258
10	M	8:8	0	115
11	F	10:11	0	147
12	M	11:0	40	92
Mean		12:9	15.3	184.1
SD		1:11	16.6	77.0

a. Data given in years and months.

b. British Ability Scales composite score.

between visual matching and associated skills.

All the letters presented in the tests were enlargements of Helvetica medium 4.2, with the exception of the lower-case letter 'a' which was Futura medium 4.2. The Futura 'O' was selected as this was the form employed by teachers in classroom practice. Letters measured 4cm by 5cm, and were printed in black on white backgrounds.

Letter Identification Test. Each of the 26 upper-case and 26 lower-case letters were presented and the child was asked to give the name of the letter. Upper-case and lower-case alphabets were administered separately, and letters were arranged in random order. In some cases children gave a phonetic identification of the letter rather than the letter name, such responses were arbitrarily recorded as errors.

Within-Case Letter Matching. Two test booklets, one consisting of upper-case and the other lower-case letters, were constructed. Each booklet contained 41 items in a four-choice match-to-sample arrangement. The sample letter appeared at the top of the page, and four comparison letters appeared below the sample. Comparison letters consisted of the correct match, identical to the sample letter, and three distractors. The distractors were chosen on the basis of high confusion with the correct match, determined from the confusion matrix presented by Gibson et al., (1963) for upper-case letters, or the Popp (1964) matrix for lower-case letters. The child was requested to point to the comparison letter that was the same as the sample. The position of S+, and the order of items within the test booklets, were randomly determined.

Between-case Letter Matching. A booklet similar to the within-case tests was produced, with the exception that letter case differed between the sample and comparison stimuli. For half the items the sample letter was in

upper-case and the comparison letters lower-case, and the reverse for the other half of the items. Seven letters that retained identical form in both cases (c,o,s,v,w,x,z) were excluded from the test. Comparison stimuli were again selected on the basis of confusion matrices. If the comparison letters were lower-case the Popp (1964) matrix was employed, if comparison letters were upper-case the Gibson et al., (1963) matrix was used. Nineteen letters were tested, each letter appearing once as an upper-case sample, and once as a lower-case sample, giving 38 items in total. Table 4.5 illustrates the items that made up the test.

Letter Recognition Test. The test booklet consisted of 26 items. Each item was a set of four letters. Half the items consisted of upper-case letters and half lower-case letters. The trainer named one letter from the array and requested the child to point to the named letter. Each item was presented on a new page. The position of S was again randomly determined.

Baseline and Training Stimuli. During baseline and training phases the letters were reproduced on a BBC (B) 32K micro-computer. These letters were slightly larger than those of the test booklets, measuring 6cm by 6cm, but otherwise appeared identical to those employed in the pre-assessments.

Apparatus

The baseline measure and training tasks were presented using a 32K BBC(B) microcomputer, single disk drive, and colour monitor. Fitted beneath the screen was a three-button response box (38.5cm long, 8cm high, and 10.5cm wide) connected to the computer. The response buttons were flush to the surface of the box and spaced 7.5cm apart, separated by parallel bars. Letters presented on the screen appeared directly above the response buttons. All data was automatically recorded and saved at the end of each session. The positioning of the apparatus, the location at which sessions

Table 4.5: Sample and Comparison Stimuli for Each Item on the Between-Case Letter Matching Pre-assessment

Page Number	Sample Stimulus	Comparison Stimuli	Page Number	Sample Stimulus	Comparison Stimuli
1	v	Y V X A	22	F	r t q f
2	X	v t x y	23	E	c e u s
3	Z	q y z s	24	u	C U J V
4	M	m o n v	25	Q	d p q b
5	L	l y i j	26	q	G C Q O
6	f	H E K F	27	h	E P H M
7	A	p e g a	28	g	G C Q B
8	a	N V A H	29	P	d q b p
9	J	i k c j	30	m	M W H N
10	b	P B R E	31	k	N F X K
11	D	d h p b	32	p	P E R F
12	T	t y u f	33	R	r v y f
13	l	E L T F	34	U	u h t n
14	e	E B F H	35	j	Q U I J
15	r	R G B P	36	i	I L J T
16	B	d q p b	37	y	X V Y K
17	G	a g q p	38	n	M N W K
18	d	N D Q O	39	l	l j r i
19	t	F E I T	40	H	d u h n
20	N	h p n u	41	Y	y h k r
21	K	k y h j	-	-	-

were conducted, and the length of sessions were as reported for Experiment 2.

Procedure

Pre-assessments

Subjects were first administered the letter discrimination skills pre-assessments. A dual criterion was employed in screening children for training. Subjects should both; (1) be able to match a significant proportion of within-case items, i.e., to demonstrate the perceptual skills necessary to perform a matching task; and (2) be unable to match a significant proportion of between-case items, i.e., fail to recognize equivalent function across cases. Twelve subjects who correctly matched at least two-thirds or more of the within-case items, but less than half of the between-case items, were selected for training.

Baseline

The experimental subjects were administered a three-choice between-case letter matching baseline, involving more intensive assessment of twelve letter matches that had proved most difficult for all subjects during the pre-assessments.

All sample letters were presented as upper-case forms and all comparison letters as lower-case forms. Nine trials were presented for each sample letter yielding 108 trials in total. Responses were never reinforced, but non-contingent praise was delivered after each nine-trial block. Chance level performance would result in three correct matches from nine trials (33%). Hence, the criterion for deciding the match was in the child's repertoire was set at six out of nine (66%) correct responses.

All twelve subjects failed to attain criterion on six case matches, which were subsequently selected for training. These were (with comparison letters in brackets); B (b,d,a); N (n,u,m); E (e,c,o); Q (q,p,g); I (i,j,l); and R (r,t,f).

Training

A within-subjects experimental design was employed. Letters were paired into three sets (NQ, BH, and RE) and assigned to treatment conditions in a counterbalanced design. Each subject received three-choice match-to-sample training under all treatment conditions with different letter pairs in each condition. The two letters within each set were trained consecutively. Order of presentation of treatments was counterbalanced across subjects. Table 4.6 details the order of presentation of treatments and letter sets received by each subject.

At the start of each session the child was given the following directions. "Now (child's name) we are going to play a game with the computer. You know there are two types of letters, capital letters and ordinary letters? Well, there will be a capital letter at the top of the television here (trainer points) and some other letters at the bottom here (trainer points). I want you to find me the letter that goes with the letter at the top. The computer will play a tune if you get it right and I have some smarties too."

The child was shown the response buttons. Any button press blanked the screen and all correct responses were reinforced with computer tunes and extensive verbal praise. In addition a small edible reward was initially provided for every correct response and later for three consecutive correct responses. If the child failed to respond within six seconds, or attempted to elicit a direction from the experimenter before responding, one

Table 4.6: Order of Presentation of Training Conditions and Tasks

Subject	a			b		
	Treatment Order			Letter Set		
8	S+	S-	TE	2	3	1
4	S+	S-	TE	2	1	3
1	S+	TE	S-	1	3	2
2	S+	TE	S-	3	1	2
11	S-	S+	TE	1	2	3
12	S-	S+	TE	1	3	2
6	S-	TE	S+	3	1	2
9	S-	TE	S+	3	2	1
3	TE	S+	S-	2	3	1
5	TE	S+	S-	2	1	3
10	TE	S-	S+	1	2	3
7	TE	S-	S+	3	2	1

a. S+ indicates S+ stimulus fading; S- indicates S- stimulus fading; TE indicates Trial-and-Error training.

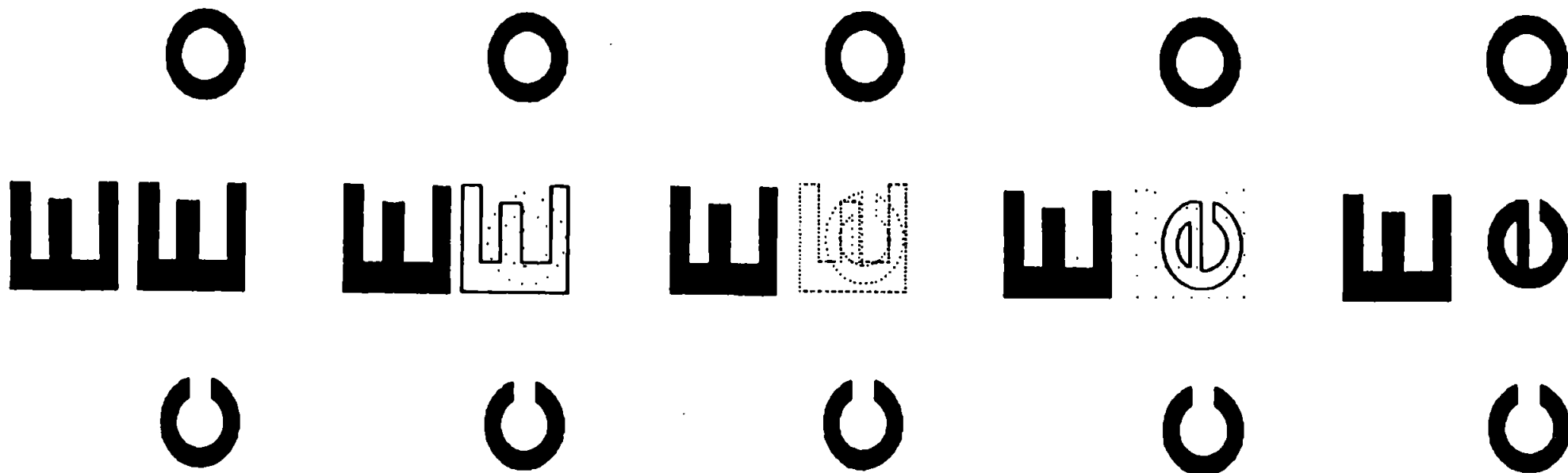
b. 1 indicates training of letters B and I; 2 indicates training of letters N and Q; 3 indicates training of letters R and E.

non-directional prompt such as "Which letter will play the tune?" etc. was used. If the child still failed to respond an error was scored. The screen was blank during the inter trial interval which averaged 10 seconds. The learning criterion for all tasks was eight consecutive, unprompted, correct responses. The child advanced to the next training task whenever; (a) the learning criterion was attained; or (b) a maximum 175 training trials were completed, whichever occurred first.

Pre-training Probe Trials. A nine-trial pre-training probe was scheduled immediately before the training of each of the six tasks. The probe assessed if a subject had acquired the letter match as a result of generalization from training on previous tasks. If criterion was attained on the probe, the task was replaced by another the subject had also failed to attain criterion on during baseline. In the six instances in which this occurred, the task H (h,y,v) was substituted.

S+ Fading Programmes. Initially, S+ was identical to the sample as it was also presented in upper-case form, while the remaining comparison stimuli were lower-case letters. This reduced the occurrence of errors since the child was initially able to respond correctly simply by matching identical forms. Over a sequence of five steps S+ was manipulated by reducing the intensity of the upper-case form while simultaneously fading in the lower-case equivalent. The S- stimuli remained at full intensity throughout training. Fading of the forms was achieved by variations in the number of points used to compose the letter. At Step 5 the upper-case form was completely faded out and the lower-case form was at maximum intensity. This final fading step, where no prompts were given, was identical to trial-and-error training. Figure 4.7 presents the S+ fading sequence for the matching of letter E.

Figure 4.7: Illustration of the five steps of the $g+$ fading programme for the letter E between-case matching task.

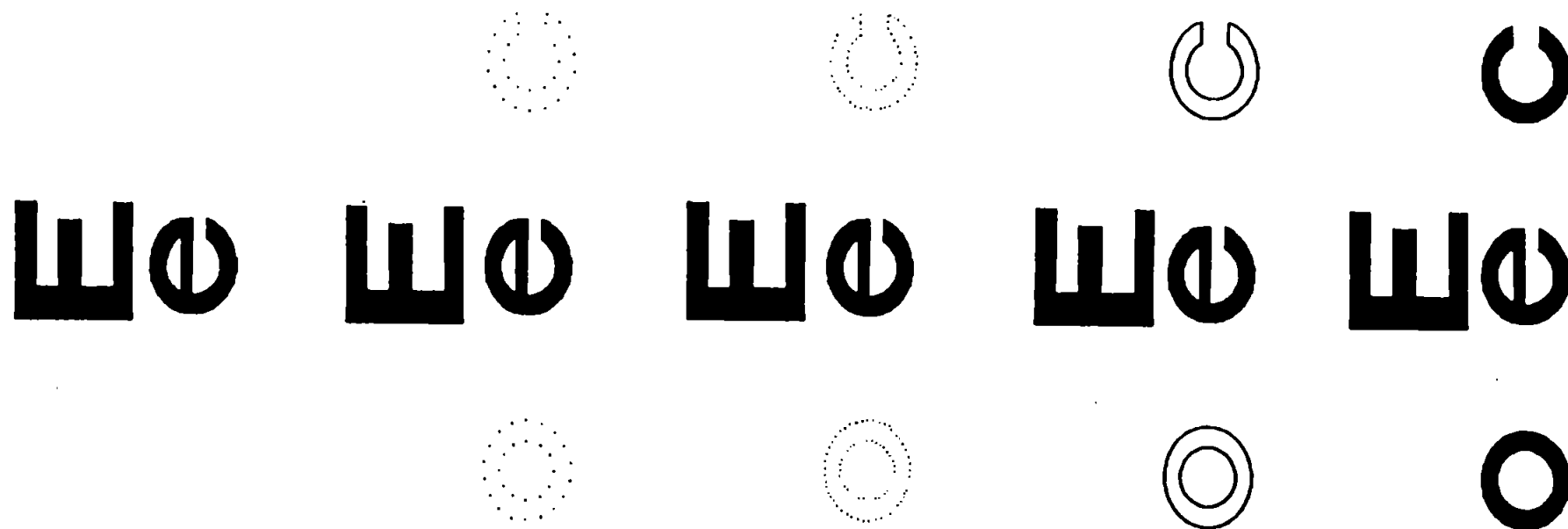


A criterion of two consecutive correct responses ~~was~~ required to advance each step, and a back-up procedure was employed whereby an error returned the subject to the previously mastered step. No step could be advanced through, even on a second or third attempt, until the criterion had again been fulfilled. If training of a task spanned more than one session, each new session commenced one fading step below the final step attained in the previous session. Once five consecutive correct responses were made in the absence of prompting (Step 5) the programme was completed and any subsequent errors failed to reinstate the programme. The learning criterion could be attained only after the prompting programme had been successfully completed.

S- Fading Programmes. These programmes consisted of five steps which varied in the level of intensity of the distractors (S-). Comparison stimuli were always lower-case letters. Initially, only S+ was presented with blank spaces as distractors to enhance the probability of correct responding to S+. Subsequently S+ remained at full intensity while the intensity of the distractors was gradually increased, until at Step 5 all comparison stimuli were at equal and maximum intensity. This final fading step was identical to Step 5 in the S+ fading programmes and to trial-and-error training. The criteria for step advancement, session starting steps, and the back-up procedure were identical to the S+ fading programmes, and again the criterion could only be achieved once the programme had been successfully completed. Figure 4.8 presents the S- fading sequence for the letter E.

Trial-and-Error Training. This procedure followed the traditional match-to-sample procedure and was identical to the preceding training programmes with the one exception that comparison stimuli were always presented in lower-case and at maximum intensity.

Figure 4.8: Illustration of the five steps of the g- fading programme for the letter E between-case matching task.



Delayed Post-test

One week after training of all six tasks was completed the between-case matching baseline was again administered to all twelve subjects.

Results

Letter Discrimination Pre-assessments

Scores for upper-case and lower-case items from the recognition, identification, and within-case matching tests were compared. Upper-case letters were more frequently identified correctly ($t = 2.91$, $df = 22$, $p < .01$), recognized correctly ($t = 3.72$, $df = 22$, $p < .01$), and matched correctly ($t = 4.37$, $df = 22$, $p < .001$) than lower-case letters.

Subjects scores on the upper-case and lower-case portions of the tests were highly correlated, ranging from $r = .92$ for within-case matching, to $r = .98$ for letter identification. Therefore, a subjects scores on the upper-case and lower-case items of each test were combined, and a single mean score for each subject on each test derived. A one-way ANOVA comparing the four assessments proved significant ($F(3,66) = 21.29$, $p < .001$).

Newman-Keuls multiple comparisons showed within-case matching differed significantly from all other tests ($p < .01$ in all cases). Between-case matching and recognition did not differ significantly from each other, but both differed significantly from identification ($p < .05$ in both cases).

Within-case matching was therefore the least complex task, and letter identification the most difficult, with between-case matching and letter recognition falling between these two extremes. These data are presented Figure 4.9.

Figure 4.9: Mean percentage correct responses on the four letter discrimination skills pre-assessments (n=23). Upper-case and lower-case scores are plotted separately where appropriate.

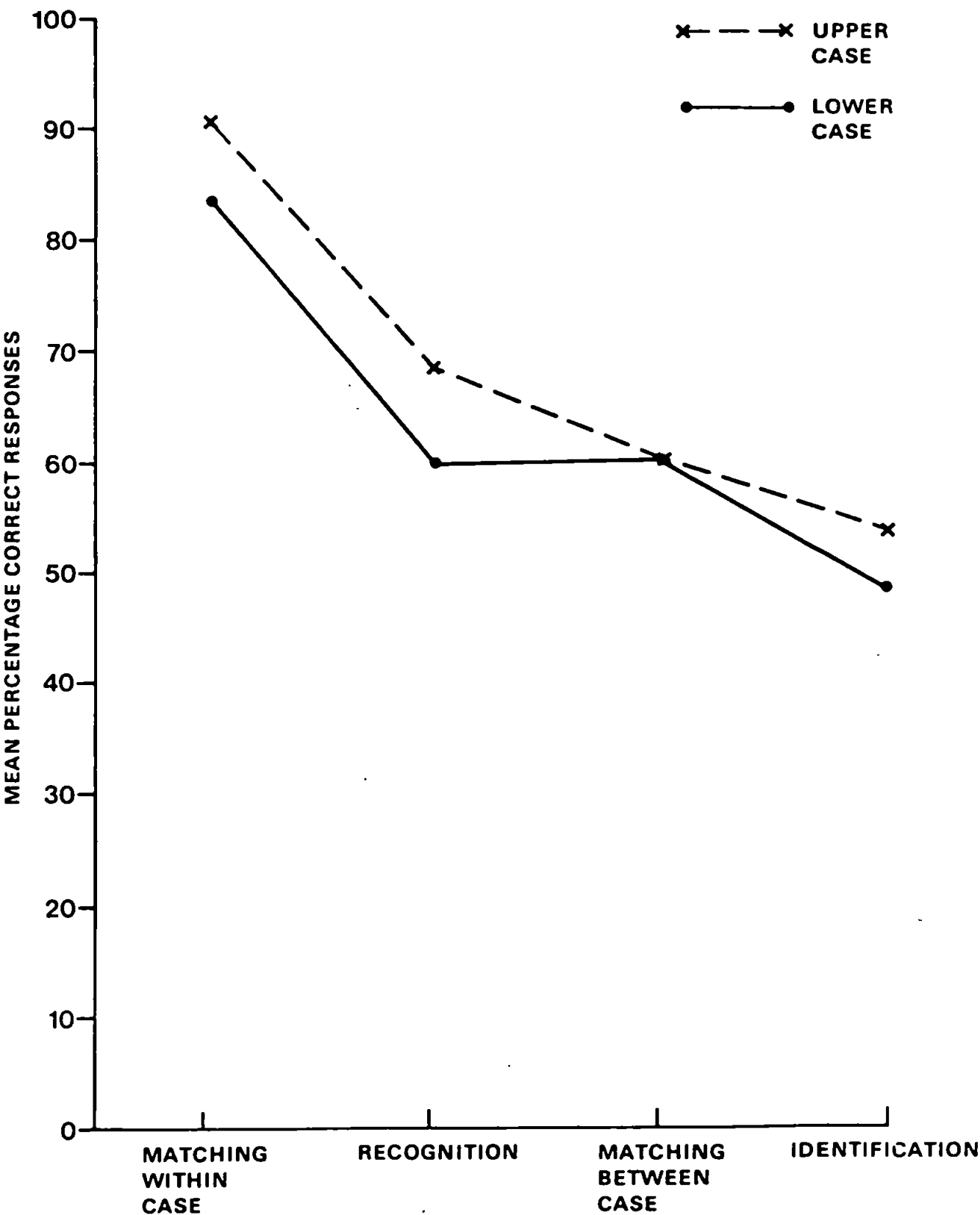


Table 4.7 presents the inter-correlations between the letter skills assessments and BAS composite and Word Reading scores. These data suggest that between-case letter matching is more closely related to letter recognition and letter identification than to within-case letter matching. The between-case matching, identification, and recognition tests all intercorrelate highly significantly. However, within-case matching has relatively low correlations with the other three letter discrimination assessments. The pattern of correlations with Word Reading and BAS composite scores further support this conclusion. The Word Reading scale correlated most highly with between-case matching, identification, and recognition, but produced a much lower correlation with within-case matching ($r = .45$, $p < .025$). In contrast, within-case matching correlated most highly with BAS composite, the general ability measure ($r = .83$, $p < .0005$).

Training

3 X 3 factorial analyses of variance with confounding and repeated measures (Winer, 1971, P646) were conducted for both number of errors and trials to criterion. Training conditions differed significantly in the number of errors emitted during training ($F(2,16) = 16.14$, $p < .001$). Newman-Keuls multiple comparisons showed $\underline{S-}$ and $\underline{S+}$ fading did not differ significantly in number of errors (means = 12.8 and 17.4 respectively), but both produced significantly fewer errors than trial-and-error training (mean = 44.3) ($p < .01$ on both cases). Training procedures did not differ significantly in trials to criterion ($F(2,16) = 1.32$, $p < .10$), although again $\underline{S-}$ fading resulted in fewer trials to criterion than either of the other two conditions. $\underline{S-}$ fading also resulted in the least number of failures to acquire the training tasks. Only three of the 24 matches trained with $\underline{S-}$ fading were not acquired. In contrast, more than twice as many failures were observed with $\underline{S+}$ fading (7 failures) and trial-and-error training (8

Table 4.7: Inter-correlations of Letter Discrimination Skills and Psychometric Assessments

	1	2	3	4	5	6
1. Identifi -cation	-	** .521	*** .842	*** .939	*** .804	* .427
2. Within -case Matching		-	** .531	** .577	* .454	*** .832
3. Between -case Matching			-	*** .845	*** .713	** .536
4. Recog- nition				-	*** .788	** .588
5. Word Reading					-	***a .569
6. BAS Composite						-

a. N=35 (All other N=23)

* $p < .025$; ** $p < .01$; *** $p < .0005$

failures). These data are presented in Table 4.8.

The effect of letter pair was significant for both errors ($F(2,16)=10.51$, $p<.01$), and trials to criterion ($F(2,16)=12.17$, $p<.001$). B and Q were identified as the most difficult to teach case matches, accounting for 15 of the 18 occasions in which tasks were not acquired. When the total 24 training instances for these two tasks are broken down by training condition, trial-and-error training was successful in only one of eight cases (12.5%), $\underline{S+}$ fading in three of eight cases (37.5%), and $\underline{S-}$ fading in five of eight cases (62.5%). Order of presentation of tasks was not related to differences in acquisition. It would appear that differences in the effectiveness of fading and trial-and-error training in facilitating task acquisition are most pronounced for difficult to teach case matches.

Delayed Post-test

When the baseline test was repeated one week after the completion of training, scores for the trained letters were significantly higher than baseline scores ($t=3.66$, $df=11$, $p<.01$). No significant differences between baseline and post-test scores were apparent for letters not directly trained in the study ($t=1.47$, $df=11$, $p>.10$). This data is presented in Table 4.9.

The improvement in performance between baseline and post-test was calculated as a gain score. Gain scores were found to correlate significantly with BAS composite score ($r=.83$, $p<.001$). This correlation remained significant when individual differences in starting level (i.e. baseline performance) were controlled through partial correlation ($r=.82$, $p<.001$).

Table 4.8. Trials to Criterion and Number of Errors for the Three Training Conditions.

S	S+ Fading			S- Fading			Trial-and-Error		
	Task	Trials	Errors	Task	Trials	Errors	Task	Trials	Errors
1	B	101	23	N	16	0	R	19	3
	I	23	1		84	19		23	10
2	R	83	19	N	32	4	B*	175	94
	E	25	3		139	33		23	10
3	E	16	0	B	161	40	N	12	3
	R	19	1		25	3		175	91
4	N	28	3	H	34	6	R	38	30
	Q*	175	44		175	44		8	0
5	I	33	5	R	27	3	Q*	175	112
	B*	175	42		16	0		175	122
6	Q	20	2	H	16	0	I	11	3
	N	16	0		16	0		33	19
7	B*	175	43	Q*	175	42	R	140	72
	I	52	9		59	13		81	45
8	Q*	175	46	R	27	3	I	52	23
	N*	175	56		31	5		175	79
9	I	24	3	E	20	2	Q*	175	114
	B	36	5		23	2		15	3
10	E	19	1	Q*	175	48	I	58	37
	R	57	13		32	3		175	69
11	N	25	4	B	73	17	R	9	1
	Q*	175	43		16	0		10	2
12	R*	175	49	I	43	10	N	25	12
	E	26	3		57	10		175	108
Mean		76.2	17.4		61.3	12.8		81.5	44.3
SD		47.5	14.5		37.1	10.3		51.0	32.1

Note. * = Task not acquired in the maximum 175 training trials.
In six cases where criterion was attained on pre-training probes, the task H(h,y,v) was substituted.

Table 4.9: Baseline and Post-Test Between-Case letter Matching Scores

Subject	Trained Letters				Untrained Letters			
	Baseline		Post-Test		Baseline		Post-Test	
	NC	%CR	NC	%CR	NC	%CR	NC	%CR
1	0	37.0	4	68.5	6	85.2	4	72.2
2	0	33.3	2	38.9	2	50.0	0	20.4
3	0	29.6	0	40.7	0	38.9	0	38.9
4	0	27.8	1	51.9	0	40.7	0	22.2
5	0	40.7	2	44.4	0	35.2	1	31.5
6	0	0.0	1	25.9	5	79.6	3	51.9
7	0	27.8	1	42.6	0	44.4	1	38.9
8	0	27.8	0	22.2	1	33.3	2	42.6
9	0	31.5	1	42.6	1	40.7	2	46.3
10	0	5.6	0	14.8	1	40.7	1	42.6
11	0	27.8	0	27.8	0	42.6	0	35.2
12	0	29.6	1	37.0	1	33.3	2	50.0
Mean		26.5		38.1		47.1		41.1
SD		11.9		14.3		17.2		13.9

Note. NC= Number of letters on which criterion was attained.
%CR= Percentage correct responses.

Retention Test

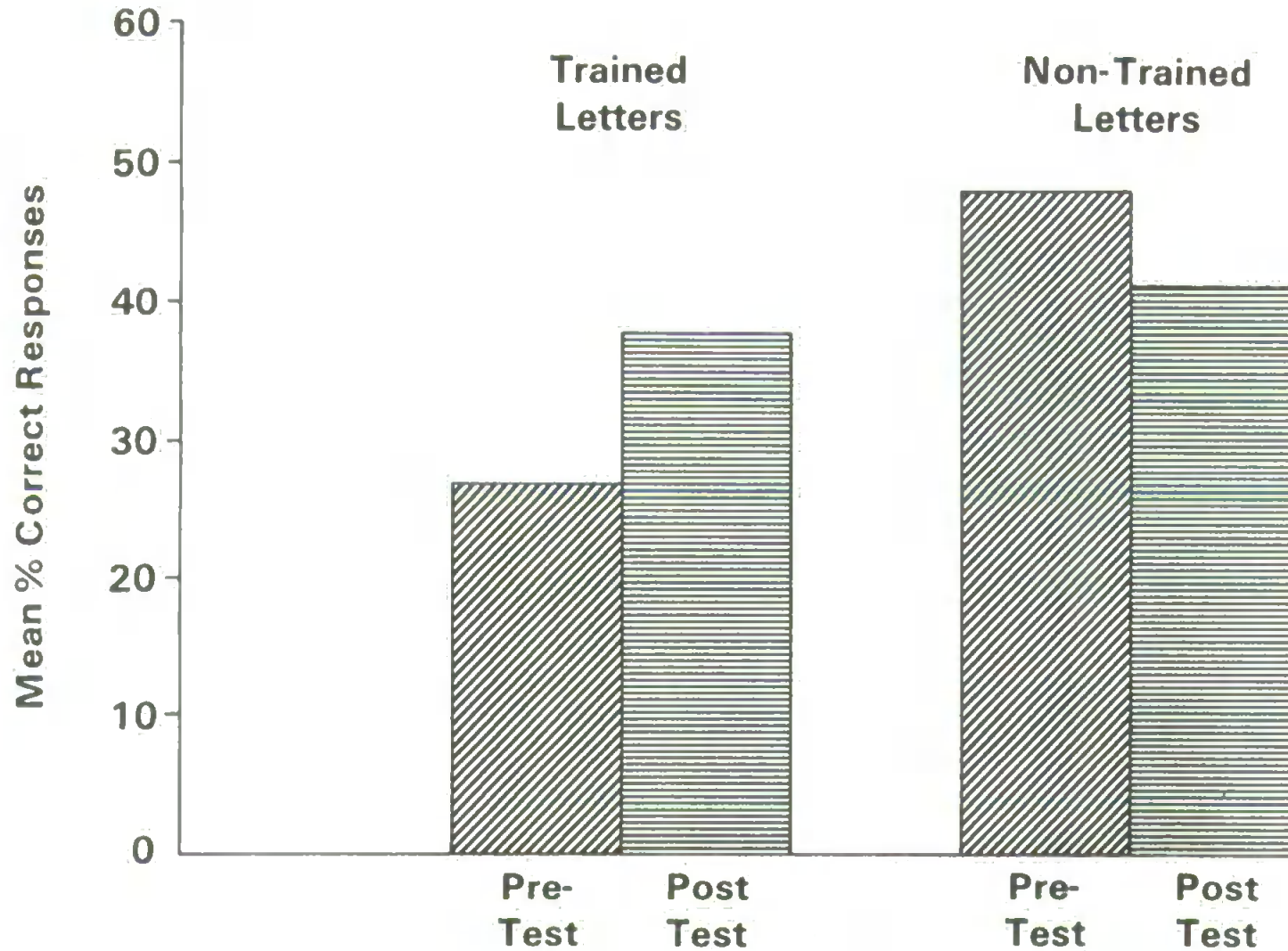


Figure 4.10: Mean percentage correct responses for trained and untrained letters on the pre-test and delayed post-test.

Discussion

The results of this study may be summarized as follows;

1. Between-case letter matching was shown to be a difficult task for mentally handicapped children. Between-case letter matching performance was more closely correlated with performance on letter identification and letter recognition tests, than tests of within-case letter matching.
2. Twelve severely mentally handicapped children who were unable to perform six lower-case to upper-case letter matching tasks acquired the majority of these tasks with training.
3. Performance on the trained tasks remained above baseline level when the baseline was readministered one week following the completion of training.
4. The programmed procedures resulted in significantly fewer errors than trial-and-error training, and facilitated the acquisition of the difficult to teach B and Q case matches.
5. S⁻ fading resulted in the least number of failures to acquire the training tasks: more than twice as many failures were observed following S⁺ fading. S⁻ and S⁺ fading did not differ significantly in number of errors or trials to criterion, although S⁻ fading was the more efficient procedure on both measures.

Previous research has shown programmed training procedures are more effective than trial-and-error instruction in facilitating within-case letter matching (e.g., Egland & Winer, 1974; Gurnalick, 1975; Wolfe & Cuvo, 1978). The results of the present study extend these findings to suggest

that fading procedures may also facilitate the more complex task of matching letter forms between cases.

However, training was not equally effective across all tasks. Matching lower-case to upper-case forms of the letters B and Q were the most difficult to teach tasks. The difficulty of these two tasks may have been due to the high confusability of the correct and distractor stimuli. While the distractors for all tasks consisted of the letters most frequently confused with the correct choice, Popp (1964) has identified the reversals 'b d' and 'p q' as the two most frequent confusions made by young children. While fading was more effective than trial-and-error training in facilitating acquisition of these two tasks, some children were unable to acquire these tasks even with fading.

The comparative lack of success in training these two tasks may highlight a procedural defect in training. Prior to between-case training, the child's ability to discriminate amongst highly confusable lower-case letters was assessed (within-case letter matching test). The overall discrimination performance of those children selected for training was high (mean percentage correct responses 87%; range 67% - 99%), where chance level responding would result in only 25% correct responses. However, subjects were not specifically pretrained to discriminate the comparison stimuli employed during training, and reanalysis of the within-case letter matching test revealed some subjects had failed to reliably match the letters b, d, p, and q during the lower-case matching pre-assessment.

However, failure to acquire the between-case matching tasks cannot be directly ascribed to initial poor within-case matching: S12 failed to discriminate b and d during lower-case matching, yet with S- fading he acquired the letter B between-case task; in contrast, S9 correctly

discriminated b and d during lower-case matching, yet trial-and-error training failed to result in acquisition of the letter B between-case task. In general, however, subjects should be pretrained to ensure they can discriminate topographically similar letters within one case, otherwise training between-case matching may not prove maximally effective.

Delayed post-test scores were significantly higher than baseline scores for the trained tasks ($p < .01$), indicating that improvements for trained matches were still evident one week following the completion of training. However, the 13/72 (18.1%) of trained matches at criterion on the post-test contrasts with the 54/72 (75%) of matches on which the learning criterion was attained during training, and also therefore demonstrates considerable loss of trained skills.

There was no indication that the effects of training generalized to untrained tasks, since untrained tasks showed no corresponding increase in scores between the two test sessions. Unfortunately, the post-test for untrained letters confounds the effects of generalization and retention. Thus, while the delayed post-test suggests the benefits of training between-case matching were task specific, this cannot be confirmed in the absence of an immediate generalization test.

S- fading proved more effective than S+ fading in facilitating task acquisition, although on measures of efficiency (e.g., total number of errors) the difference between procedures was not significant. However, Schreibman and Charlop (1981) report initial S+ fading was more effective in training discriminations to their autistic subjects than initial S- fading. A clear prediction from Schreibman and Charlop's theoretical analysis (see introduction) is that the procedure that manipulated only S+ should have proved more effective than the procedure that manipulated only S-, since the

changing S⁺ should have remained novel and therefore more salient for learning, serving to direct the child's responses to the correct rather than incorrect stimuli. This was not observed in the present study.

It may be argued that the relative effectiveness of S⁺ or S⁻ manipulation was affected by the requirements of the training task. Schreibman and Charlop (1981) employed two-choice simultaneous discrimination tasks. In the present study, matching-to-sample tasks were employed. S⁻ fading procedures initially presented S⁺ alone, and during fading the form of S⁺ remained unchanged. In contrast, S⁺ manipulation required the child to match a constantly changing comparison stimulus to an invariant sample stimulus. The task requirements may therefore have proved more confusing to the child. For the present tasks, reinforcing responses to the terminal form of S⁺, before subsequently introducing competing S⁻ stimuli, resulted in higher rates of acquisition. However, these differences in task requirements do not appear sufficient to explain the direct contradiction to Schreibman and Charlop's predictions observed in the present study. Furthermore, the only other study directly evaluating S⁺ and S⁻ stimulus fading (Zawlocki & Walls, 1983) did employ two-choice discrimination tasks and, in line with the present observations, also reported fewer errors during S⁻ fading than during S⁺ fading. The present results would appear to support the findings of this latter study.

In conclusion, the present results suggest that stimulus fading was a more effective procedure than trial-and-error training in facilitating between-case letter matching, and that S⁻ stimulus fading was more effective than S⁺ stimulus fading.

Overview: S+ versus S- Manipulation in Programmed Training

The results of Experiments 2 and 3 suggested that during superimposition and fading S+ manipulation may on occasion be superior to S- manipulation. This result was interpreted in terms of the differing inhibitory demands of the procedures. In contrast to S+ fading, an initial approach-avoidance conflict may be assumed to exist in the discrimination in which the prompted stimulus is negative (S- fading). Subjects are required to inhibit approaches to the highly discriminable prompted stimulus, and this proved difficult for some subjects. Zeaman and House (1962) have also reported data suggesting that, early in learning, approach tendencies are formed more rapidly than avoidance tendencies, although once the discrimination is established approach and avoidance tendencies have approximately equal strength. Faster learning may therefore be achieved by initially prompting approach to S+ rather than avoidance of S-. However, prompting avoidance of the negative stimulus, by superimposing and fading a prompt upon S-, still proved more effective than trial-and-error training.

An alternative interpretation in terms of stimulus novelty and its effect on stimulus selection may also be forwarded. As discussed in the introduction to Experiment 4, Schreibman and Charlop (1981) suggested that S+ intensity fading may be more effective than S- intensity fading since the changing S+ stimulus remained novel and salient for learning, so that subjects responses were directed to the appropriate S+ stimulus. However, the changing S- stimulus served only to direct responses to S-, and therefore impaired learning. Similarly, S+ manipulation in the

superimposition and fading procedures employed in Experiments 2 and 3 may have proved more effective since the changing S+ remained novel and thus more salient for learning (Trabasso & Bower, 1968).

However, the predicted superiority of S+ manipulation, which arises from this analysis of the role of stimulus novelty in graduated stimulus change procedures, was not confirmed in Experiment 4 which compared S+ and S- stimulus fading. In contrast, the procedure in which only the S+ stimulus changed during fading appeared to be less effective than the procedure in which only the S- stimuli changed. The results of Experiment 4 were interpreted as supporting the findings of Zawlocki and Walls (1983), rather than those of Schreibman and Charlop (1981).

The results of these experiments may therefore suggest that the relative effectiveness of S+ or S- manipulation may depend upon the programmed procedure employed. Zawlocki and Walls compared the effectiveness of stimulus fading procedures that involved either S- manipulation (e.g., increasing the size of S- to criterion level) or S+ manipulation (e.g., decreasing the size of S+ to criterion level). Although Schreibman and Charlop developed their 'stimulus novelty' theory with reference to stimulus fading procedures, and would clearly predict the latter procedure would be more effective than the former, the opposite result was indicated in Zawlocki and Walls study. Similarly, in Experiment 4 S- manipulation during fading proved more effective than S+ manipulation. We conclude that in stimulus fading procedures, a critical factor determining the effectiveness of S- manipulations may be the absence of competing stimuli in the early stages of programmed training. Our results suggest that reinforcing responses to the terminal form of S+, before subsequently fading in competing S- stimuli, resulted in higher rates of acquisition. The importance of such an initial 'form vs. no form' step

early in the fading sequence has also been emphasised by Stoddard (personal communication, November 1985). In this regard, we may also note that Terrace (1963a) observed that the effectiveness of his stimulus fading procedures in training successive discriminations (where S⁺ and S⁻ stimuli are presented singly and alternately), was more a function of the manipulations of the duration of S⁻, than of modifications of its degree of intensity. While S⁺ was always presented for 30 secs, the duration of S⁻ was only gradually increased from 5 through to 30 secs.

Schreibman and Charlops analysis concerning the role of stimulus change may, however, receive some support from a recent comparison of S⁺ and S⁻ manipulation in stimulus shaping procedures. Stella and Etzel (1986) have reported that manipulation of S⁺ during stimulus shaping resulted in slightly fewer errors than manipulation of S⁻. Stella and Etzel also recorded their subjects visual orientations during stimulus shaping. More frequent orientation to S⁻ was recorded when it was shaped than when it was invariant, and it may be suggested the occurrence of more errors in the procedure involving S⁻ manipulation may be associated with increased orientation to the changing S⁻ stimulus. However, we may note that, in line with our analysis concerning the role of S⁺ and S⁻ manipulation in stimulus fading, prior to the instigation of stimulus shaping Stella and Etzel had first to establish discriminative responding to S⁺ by presenting S⁺ at full intensity, and fading in S⁻ from a 'no form' baseline.

Stella and Etzels (1986) study currently represents the only comparison of S⁺ versus S⁻ stimulus shaping, and the subjects in the study were five young children of normal intelligence. The results therefore require replication with a larger sample of mentally handicapped children. Furthermore, as Stoddard and McIlvane (1986) note, orientation to the S⁻ stimulus may not necessarily be a bad thing, since if only S⁺ controls

responding the subject may fail to observe perhaps critical aspects of S⁻. The discrimination may be incomplete and be based upon only a specific feature of S⁺ rather than a general property of the stimuli. Thus, Rincover (1978) has reported that while fading a distinctive feature of S⁺ resulted in successful acquisition of the target discrimination (e.g., manipulating the horizontal bar of the J in the discrimination JAR vs. SON), performance broke down on test trials when the prompted S⁺ feature was no longer relevant (e.g., JAR vs. JON).

The present studies have evaluated the issue of S⁺ versus S⁻ manipulation in fading procedures. These studies have not investigated whether manipulation of both S⁺ and S⁻, rather than either S⁺ or S⁻ alone, may make a difference in the outcome of training. In some instances it may prove necessary to manipulate both S⁺ and S⁻ stimuli. For example, if a superimposition and fading procedure employs multiple prompts, e.g., a red background for prompting responding to S⁺, and a green background for prompting non-responding to S⁻, fading of both prompts will be necessary to eliminate the colour cue. However, as described earlier in this chapter, such procedures have proved relatively ineffective with human subjects (e.g., Koegel & Rincover, 1976), and the majority of programmed procedures do manipulate only one of the stimuli. The only research to compare S⁺ and S⁻ fading versus single stimulus fading has again produced conflicting results. While Stella and Etzel (1978) (cited in Lancioni & Smeets, 1986) report that normal intelligence children had better performance when S⁺ and S⁻ stimuli were shaped than when only one stimulus was shaped, in the former condition subjects received more training trials than in the latter condition, which may have been the source of the facilitation. Zawlocki and Walls (1983) compared conditions in which the number of fading steps and training trials across conditions were equal, and report no significant

difference between conditions in which fading was carried out along S- only, and conditions in which fading was carried out along both S+ and S- simultaneously. Therefore, on the basis of the evidence presently available, there appear to be no significant differences in outcome between conditions manipulating both S+ and S-, and conditions manipulating either S+ or S- alone.

In conclusion, the results of the present investigations provide information pertaining to an important parameter of fading: the effects of S+ or S- stimulus manipulation. The results suggest that for severely mentally handicapped children it may be advantageous to design programmed procedures so that the fading of additional prompt stimuli, at least during the initial stages of training, is conducted with the S+ stimulus. In contrast, where the discriminative stimuli themselves are to be faded, manipulations involving fading up of S- may prove more effective than manipulations that fade down the S+. However, there is a need for further systematic analyses of fading which attempt to clearly delineate the effects of component stimulus operations.

* * * * *

The experiments reported in this chapter have provided several examples of the failure of programmed training procedures to result in task acquisition. Task difficulty was identified as an important factor influencing the success of training. Problems arose more readily when the criterion discrimination was complex, rather than simple. Especially difficult tasks were those involving mirror-image reversals, e.g., opposing 45° and 135° tilted lines (Experiments 2 and 3), and the letter pairs b-d

and p-q (Experiment 4).

When failures in acquisition following programmed training occurred, the distribution of errors across fading steps was analysed. In all cases the mean proportion of errors on trials where a prompt was available was significantly lower than the proportion of errors on criterion level trials.

Trial-by-trial analyses of subjects performance revealed perseveration in responding to the prompt cue, and failure to transfer correct responding to the criterion level stimuli. This was clearly illustrated in Figures 4.3 and 4.6. Experiment 3 further demonstrated that, once perseveration in responding to the prompt cue had developed, subjects may also come to perseverate in responding to the particular value of the prompt cue that was originally reinforced, even when such responses were placed in extinction during reversal training.

The crucial mechanism that needs to be explored in programmed training is the process by which stimulus control is transferred during the fading sequence from the prompt stimulus (or dimension) to the training stimulus (or dimension). One promising approach may lie in exploring the conditions where transfer fails to occur: such investigations may help to elucidate the factors controlling transfer.

In the discussion of Experiment 3, the concepts of overshadowing and blocking were suggested as pertinent phenomena in explaining the failure of programmed training in these cases. These phenomena were only briefly introduced pending the collection of further data. The next chapter will proceed to analyse these phenomena in greater detail. First, drawing on the study of animal learning, experiments indicating the occurrence of overshadowing and blocking will be described. Second, the relevance of these findings for programmed training procedures will be outlined. Third,

variables that have been found to influence the degree of blocking and overshadowing (again drawn from the infra-human literature) will be described; specifically the discriminability of the component cues will be identified as a significant variable. Finally, a revised fading procedure, based upon the results of this analysis, will be proposed and evaluated.

CHAPTER 5

Overshadowing and Blocking During Programmed

Discrimination Training

Chapter 5

Overshadowing and Blocking During Programmed Discrimination Training

Successful prompt fading requires learning about multiple cues. Fading procedures involve the addition of a prompt cue to the training cue, forming a compound stimulus with two relevant cues. For some time it has been known that animals trained with two or more relevant cues may acquire discriminations faster than animals trained with only one relevant cue (Warren, 1953). It has also been shown that mentally handicapped children may acquire a two-choice discrimination with both form and colour cues relevant faster than when either of these cues is relevant on its own (Zeaman & House, 1963; Ullman & Routh, 1971). The tendency for subjects to learn faster with several relevant cues than with only one has come to be known as 'additivity of cues'.

However, there is an exception to this rule that acquisition is faster with two relevant cues than with one. If one of the two cues is considerably weaker than the other, then acquisition of the compound may occur at the same rate as when subjects are trained on the stronger cue alone. Furthermore, subjects may in fact learn less about the weaker stimulus in the compound, than if the weaker stimulus is presented alone. Such effects have been described as 'overshadowing' and 'blocking'.

Overshadowing and Blocking

Pavlov (1927) reported that if an animal was conditioned to a compound

CS consisting of one relatively strong and a second relatively weak component, test trials with the two components in isolation revealed conditioning to the stronger element but none to the weaker. Although the weak element served as an adequate CS when an animal was trained with it in isolation, in a compound with a stronger element it failed to acquire control. Pavlov called this effect overshadowing.

A similar effect has been demonstrated in studies of instrumental discrimination learning. Overshadowing occurs when the control exerted over the discriminative response by one cue is reduced by the presence of a concurrent second cue, and has been demonstrated in both successive (Eckerman, 1967) and simultaneous (Lovejoy & Russell, 1967) discrimination training procedures.

For example, Seraganian (1979) trained groups of pigeons to discriminate sets of black lines tilted at 30 degrees (S+) and 60 degrees (S-) to the vertical. During initial training (phase A) one group received the lines alone, while a second group also received an additional colour cue; S+ was presented on an orange background and S- on an amber background. The lines plus colour group acquired the discrimination rapidly in Phase A. However, in an immediate transfer test where groups received the lines alone, performance of the additional colour group was significantly below the lines only group. Even though during compound training the cues from the line discrimination were present and predictive of reinforcement availability, the presence of the colour cue detracted from their acquiring control, as demonstrated in the transfer test. Furthermore, during subsequent training of the lines alone (Phase B) those subjects previously trained with the colour-line compounds not only continued to perform less accurately than those trained with the lines alone, they also learned more slowly than a third group of subjects trained with the colours alone in Phase A. Hence,

acquisition of control by the lines was significantly retarded if they had been overshadowed by the presence of the more salient colour stimuli.

One specific instance of unequal cue strength occurs when pre-training has been conducted on one of the cues of a compound stimulus. Kamin (1968) describes a series of classical conditioning experiments showing that prior training on one element of a compound stimulus might completely prevent conditioning to the second element. The pre-trained cue appears to 'block' learning about the second cue, and Kamin called this effect blocking.

Again, the effect has also been demonstrated in studies of instrumental discrimination learning (Vom Saal & Jenkins, 1970; Miles, 1970). Vom Saal and Jenkins trained pigeons on a successive discrimination in two phases. During Phase 1, an experimental group received training on a red-green discrimination, while a control group received no training. In Phase 2, all subjects received compound training in which the red light was paired with a tone, and the green light with noise. All subjects then received stimulus control test trials. The experimental group showed significantly less control by the added (auditory) cue than the control group.

It can be seen that blocking and overshadowing describe the same outcome, i.e., asymmetrical control by the cues of a compound stimulus. In general, blocking may be subsumed under the more global phenomena of overshadowing, and occurs in the specific case where cues are of unequal strength due to antecedent training of one cue.

Overshadowing and Blocking in Programmed Training

Programmed training procedures involve the addition of a relatively simple prompt cue to a complex training cue, forming a compound stimulus

with two relevant cues. These cues are of unequal strength, and it has been shown that combining cues of unequal strength can suppress learning about the weaker (less discriminable) cue.

Superimposition and fading and delayed prompting procedures may involve pre-training subjects to discriminate stimuli (e.g., colours) which are subsequently employed to prompt the acquisition of new training stimuli (e.g., Terrace, 1963; Touchette, 1971; Koegel & Rincover, 1976; Rincover, 1978). In such procedures the original controlling stimuli (prompts) may act as blocking agents by dint of their previous conditioning history, and block the transfer of stimulus control to the training cue.

Stimulus fading procedures combine prompt and training cues from the outset of training. Such procedures present novel combinations of cues for which no prior training has occurred. However, since the prompt cue is stronger (more discriminable) than the training cue, such procedures may be susceptible to overshadowing.

Overshadowing of the training cue is not an inevitable outcome of procedures that combine prompt and training cues, to the extent that fading operations may prove successful in facilitating the transfer of correct responding from the prompt to training cue (e.g., Terrace, 1963a,b; Sldman & Stoddard, 1967; Gurnalick, 1975; Touchette, 1971; see also Experiments 1, 2, and 4). However, unsuccessful outcomes following fading for some subjects have also been demonstrated. In the present series of experiments, the performance of subjects who failed to acquire discriminations following fading was characterized by perseveration in responding to the prompt cue. Although subjects responded correctly throughout attenuation of the prompt cue, performance was disrupted upon the complete removal of the prompt. Subjects then cycled between predominantly correct responding to the

attenuated prompt cue and chance level correct responding to the criterion level stimuli. Similar findings have been reported in several other studies (e.g., Terrace, 1966a; Sidman & Stoddard, 1966; Schwartz, Firestone, & Terry, 1971; Sherman & Webster, 1974; Koegel & Rincover, 1976; Irvin & Bellamy, 1977; Dorry & Zeaman, 1973, 1975; Lambert, 1980).

It may be concluded that fading is a necessary but not sufficient condition for the successful transfer of stimulus control. It may further be suggested that non-acquisition following fading indicates a failure to attenuate the overshadowing effect of the prompt cue. Such an analysis suggests that the determinants of overshadowing should influence the acquisition of control by the training cue in fading. That is, parameters that influence the magnitude of the overshadowing effect, when applied to the original controlling cue in fading, may enhance rate of acquisition of control by the overshadowed training cue during fading. A review of the infra-human learning literature identified two primary variables related to overshadowing; (1) the probability of reinforcement signalled by the component cues, and; (2) the discriminability (difficulty) of the component cues.

Variables Influencing the Magnitude of the Overshadowing Effect

Schedule of Reinforcement for Component Cues

Wagner, Logan, Haberlandt, and Price (1968), report that of two equally salient stimuli, the cue that best predicts reinforcement is more likely to overshadow the other component cue. Rats were given discrete trial bar-press training for food. All animals received both a light and a tone (T1 or T2) on all acquisition trials. A partial reinforcement schedule was employed such that on 50% of presentations the light-tone compound signalled

the delivery of a reinforcer; on the remaining trials no reinforcer was presented. In one condition, the light was paired with T1 on reinforced trials and with T2 on non-reinforced trials. In a second condition, T1 and T2 occurred randomly, hence each was paired with reinforcement 50% of the time. When the different tones predicted reinforcement with complete reliability (first condition), almost no conditioning occurred to the light. When, however, reinforcement was no better predicted by the tones than by the light alone (second condition), the light came to exert strong control over behaviour. Similar findings have been reported by Wagner (1979), and St. Claire-Smith (1979).

How this variable might be manipulated to enhance the effectiveness of fading in instrumental discrimination training is unclear. Since prompt and training cues are combined to form a single compound stimulus during fading, instigating different reinforcement schedules for the separate components is problematic. In the Wagner et al., study the correlation of the tone cue with reinforcement was reduced by making T1 and T2 occur equally often on reinforced and non-reinforced trials. Applying such a procedure to a prompt cue during fading is unlikely to be effective. If the prompt cue is not reliably paired with either S₊ or S₋ it will fail to perform the function of prompting correct responding to the S₊ training stimulus. The prompt would become an irrelevant cue, and the presence of irrelevant cues has been shown to retard learning (e.g., Evans, 1968).

Discriminability of the Overshadowing Cue

The disparity in discriminability between prompt and training cues in fading procedures has already been noted, and it has been shown that combining cues of unequal strength is likely to result in overshadowing. In addition to these observations, Miles and Jenkins (1973) have further

demonstrated that the magnitude of the overshadowing effect may be systematically related to variation in the discriminability of the overshadowing cue.

Pigeons were rewarded for responding when a very bright light was on (L1), but not rewarded for responding in darkness (L6), or when different lights (L2 to L5) all less intense than L1 were presented. All birds were trained with L1 as S₊. Different groups received training with L2, L3, L4, L5, or L6 as S₋ respectively. S₊ was always coupled with a tone, while S₋ was always coupled with a background-masking noise. Following a fixed number of training trials, birds were tested with lights (L2 to L6 respectively) presented both with and without the tone. The tone exerted very little control over the behaviour of birds trained with the large light differences (L1 vs. L6), but exerted increasing control over birds trained with smaller differences in the intensity of the two training lights. A graded effect was therefore obtained depending upon the discriminability of the light cue. The easier the light discrimination, the greater the overshadowing of the tone. Similar effects of pretrained cue discriminability have been reported in blocking experiments (Mackintosh, 1965; Johnson, 1970).

Interpretation

The results of these studies may have the following implications for the outcome of fading procedures: The original controlling (prompt) cue in fading is an overshadowing agent by dint of its greater discriminability. The magnitude of overshadowing has been shown to be directly related to the discriminability of the overshadowing cue. Therefore, if the original prompt cue is highly discriminable at the onset of fading, the training cue

may fail to acquire control, or control may be acquired only late in fading.

However, if fading is started with a less discriminable prompt, the training cue may acquire control more readily.

Two studies investigating the transfer of stimulus control during superimposition and fading procedures lend support to the above analysis. Fields (1978) trained pigeons to make a successive discrimination between red and green stimuli. Subsequently, white lines differing in angular orientation by 90 degrees were gradually superimposed upon the colours, forming a red-horizontal S_+ and green-vertical S_- . Finally, the coloured backgrounds were gradually faded over a series of steps. Probe trials, consisting of non-reinforced presentations of lines on black backgrounds, were administered throughout fading to determine the point at which lines came to control responding. The results suggested that lines acquired control only late in fading, after considerable attenuation of the colour cue.

In a subsequent experiment, (Fields, 1979), a similar procedure was followed. Again, a red-green discrimination was first established. However, prior to the superimposition of the line stimuli, the red and green colours were reduced in intensity to a point where they just controlled responding. Only then were lines gradually introduced onto the colours to form the compound stimuli. The final stage again consisted of fading the colour cue. In contrast to the earlier study where no control by lines was observed till late in fading, probe results suggested that for six of eight birds some differential probe responding began to occur during superimposition of the lines. Control by the line stimuli was further strengthened during fading of the colour cue.

In comparing the two studies, Fields (1979) concludes that the point in

fading at which new stimuli acquire control of responding is directly related to the starting intensity of the original blocking stimuli.

The findings of these two studies are highly suggestive. However the results clearly require further investigation. First, the studies employed pigeons as subjects; no such studies have been conducted with mentally handicapped individuals. Second, comparisons were made across separate experiments. No concurrent comparisons of procedures for errors or trials to criterion are presented. Finally, the study deals with blocking; will similar results be obtained when compound stimuli are presented without any prior training of the component cues?

Experiment 5: Manipulating the Initial Discriminability of the Prompt Cue During Stimulus Fading When Training Discriminations to Severely Mentally Handicapped Children

It has been hypothesised that starting with less discriminable values of the prompt cue may reduce the probability of overshadowing of the training cue during stimulus fading. A problem arises, however, since less discriminable initial prompts may also fail to preclude the occurrence of errors. In the present experiment, a revised fading procedure is evaluated.

The revised procedure determines, for each subject, the lowest level of discriminability of the prompt cue that will result in reliable correct responding to S+. Subjects are initially allowed to respond to the criterion level training stimuli. Upon the occurrence of errors, prompts of the lowest discriminability are presented. Further errors cause the prompt cue to increase in discriminability until reliable correct responding to S+ is achieved. Having determined a functional baseline of prompt

discriminability, the fading out of prompts is subsequently initiated.

The effectiveness of the revised fading procedure was compared with both standard fading and trial-and-error training control groups. The following hypotheses were forwarded: More errors early in training with the revised fading procedure were expected, since training stimuli were initially presented without additional prompts. However, the revised procedure may reduce overall number of errors and trials to criterion in two ways. First, 'redundant' early fading steps may be avoided. Second, less discriminable starting prompts may reduce the overshadowing effect exerted by the prompt cue (Miles & Jenkins, 1973). Subjects may transfer to the training cue earlier, reducing errors generated through perseverative responding to the prompt cue.

Method

Subjects

Twelve children attending school for children with severe learning difficulties (SLD) participated in the experiment. Each subject was matched with two others for number of trials to criterion on a simple two-choice visual discrimination involving multiple relevant cues. Four sets of three matched subjects each were formed, and subjects randomly allocated to conditions within each set. The mean trials to criterion for each of the three groups equalled 20.5, 21.3, and 21.5.

The mean chronological age of the sample was 11 years, 3 months (range 94 to 158 months, SD 19.2). Mean MA and IQ (PPVT-R) equalled 3 years 8 months (range 25 to 68 months, SD 13.0), and 24.7 (range <20 to 43, SD 8.2) respectively. Subjects had not participated in any of the previous

experiments.

Apparatus

The apparatus employed and the arrangement of the apparatus was as described in Experiment 2. Training sessions were conducted in a separate, quiet experimental room adjoining the childrens classrooms and lasted approximately 20-25 minutes. Sessions were conducted once daily on consecutive weekdays.

Stimuli

The discrimination task consisted of two stick figures (approximately 8cm by 13cm) with 'arms' angled at 45 degrees to the right of vertical (S+), or 45 degrees to the left of vertical (S-). Stimuli were white line forms presented on black backgrounds.

This task had previously been employed in Experiments 2 and 3, and is illustrated in Figure 4.1. The task was known to be extremely difficult, since previous attempts to train the task proved unsuccessful for the majority of subjects, presumably due to a failure to attenuate the overshadowing effect. The task was selected since success in training such a difficult discrimination would constitute strong evidence of the efficacy of the revised fading procedure.

Procedure

Pre-training

Since subjects were experimentally naive, a pre-training procedure was employed to familiarize the children with the apparatus, and the association between the position of the stimuli on the screen and the buttons beneath the stimuli. This procedure was as described in Experiment 1.

Training

During training the instructions delivered to children, reinforcement contingencies, inter-trial intervals, etc. were also all as described in Experiment 1. The learning criterion for the task was again 10 consecutive, unprompted, correct responses.

Fading Steps. Nine fading steps which differed in the level of prompt presented along a dimension of intensity were programmed. Prompt discriminability was varied by presenting S_+ at full intensity on all steps, while manipulating the intensity of S_- . The prompt cue was most discriminable at Step 1, where S_- consisted of a blank space. The discriminability of the prompt cue was gradually attenuated by systematically increasing the intensity of S_- , thus reducing the intensity difference between S_- and S_+ . At Step 9 both stimuli were at full intensity. These fading steps have previously been illustrated in Chapter 4 (See Figure 4.5). Fading Step 9 was identical to the trial-and-error training condition.

Standard Fading Procedure (Group 1)

Subjects entered the fading programme at Step 1, the step involving the greatest programmed assistance. A criterion of two consecutive correct responses were required to advance to the next step, and a back-up procedure was employed whereby an error returned the subject to the previously mastered step. No step could be advanced through, even on a second or third attempt, until the criterion had again been fulfilled. Once five consecutive correct responses were made in the absence of prompting the programme was completed and any subsequent errors failed to reinstate the programme. The learning criterion was attainable only after the prompting programme had been

successfully completed.

Revised Fading Procedure (Group 2).

The lowest level of discriminability of the prompt cue that will control responding to S₊ cannot be arbitrarily determined, and may be expected to vary across subjects, since subjects may differ in the degree of assistance required to learn a discrimination. Therefore the following procedure was followed.

Subjects initially entered the programme at the terminal step in the fading sequence, where no prompts were presented (Step 9). Due to the operation of the back-up procedure, an error would cause prompts of the lowest strength to be presented (Step 8). Further errors would cause children to be backed-up still further through the sequence, and prompts would increase in strength (Step 7, Step 6, etc.,) until the child ceased to emit errors. Once the child attained criterion on a fading step, correct responding would cause the child to move forward through the programmed sequence and prompts would be faded. As a result, the child would encounter prompts of no greater discriminability than the minimum required to ensure reliable correct responding to S₊.

In summary, the only difference between the standard and revised fading procedures lay in the step at which the programme was initiated. While the standard fading subjects entered the programme at the step of greatest assistance (Step 1), subjects in the revised fading group always entered the programme at the terminal step in the fading sequence, where no prompts were presented (Step 9). All procedural aspects of the fading programmes, including the fading steps, the back-up procedure, and the criteria for step advancement and programme completion, were identical for both the standard and revised fading procedures.

Trial-and-Error Training (Group 3).

This procedure followed the standard simultaneous discrimination procedure and was identical to the preceding training programmes except that no stimulus manipulations were conducted during either of the two training phases.

Training was conducted in two phases. In each phase training was continued until either the learning criterion was attained or 100 training trials were completed. During Phase 1, the stimuli presented were as illustrated in Figure 4.5. However, if subjects had not attained the learning criterion by the end of Phase 1, the second training phase was initiated. In this phase, the relevant components of the stimuli (i.e. the tilted lines) were presented alone. On all nine fading steps the redundant components of the stimuli, i.e., those elements contained in both S₊ and S₋, were removed from the stimuli. In all other respects the fading steps were identical to Phase 1. If the learning criterion was attained on the tilted lines alone, an additional eight steps (B1 to B8) faded the redundant components back in on both S₊ and S₋ simultaneously. Figure 5.1 illustrates selected steps from these sequences.

Results and Discussion

Table 5.1 presents the number of training trials and errors emitted during training for each subject. Only two subjects acquired the task; S₇ (revised fading) attained criterion during Phase 1, and S₁₁ (trial-and-error training) attained criterion during Phase 2. None of the remaining ten subjects acquired the discrimination in either phase. While both fading groups emitted fewer errors during training than the trial-and-error group (see Table 5.1), neither of the fading procedures appeared effective in

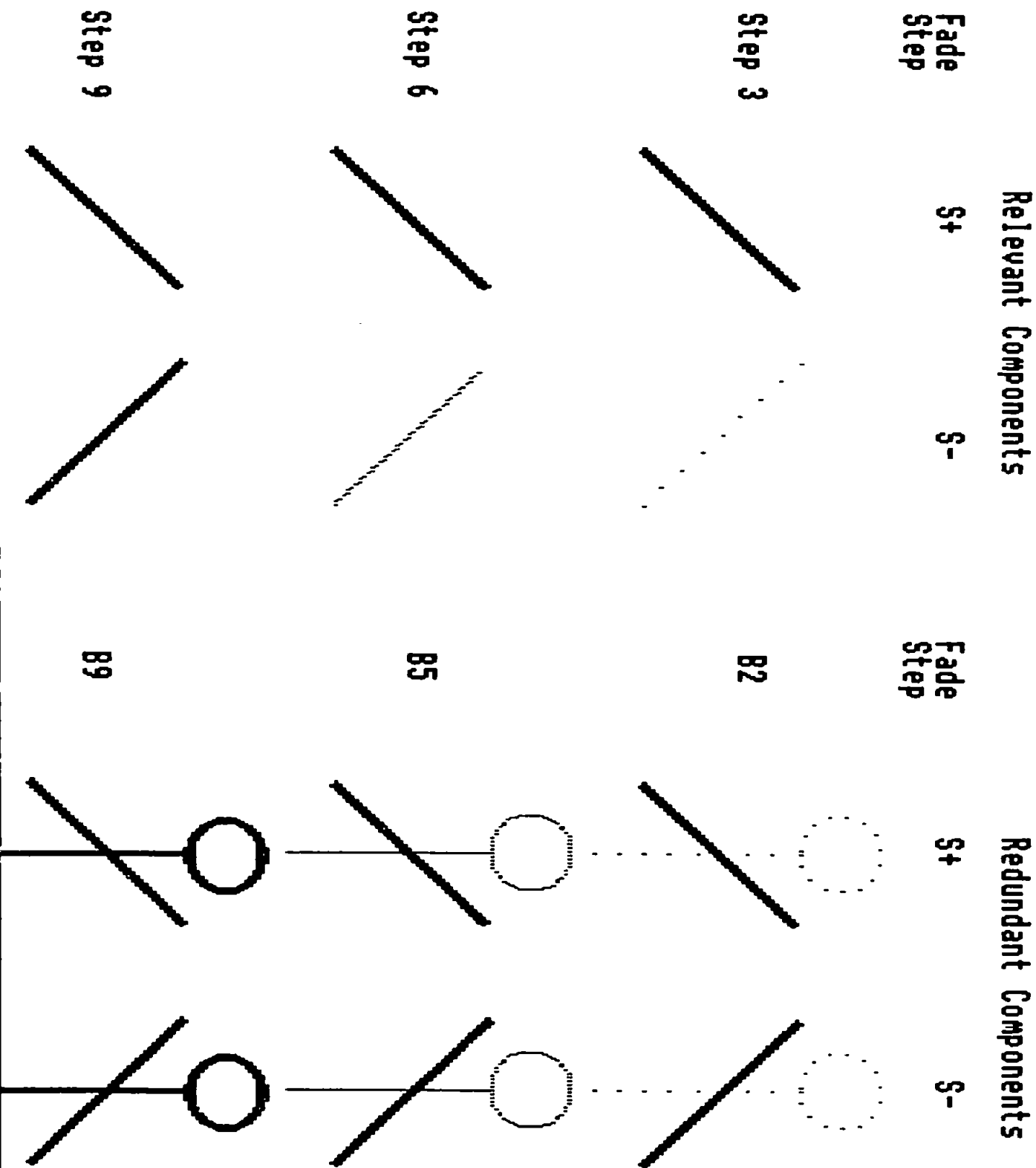


Figure 5.1: Selected fading steps during Phase 2 training. Step 1 to Step 9 present only the relevant components of S^+ and S^- . S^+ is presented at full strength throughout, while S^- increases in intensity. Steps B1 to B8 fade in redundant components on S^+ and S^- simultaneously.

Table 5.1: Number of Trials and Errors For each Subject During Phase 1 and Phase 2 Training

Subject and Condition	Phase 1		Phase 2		Combined Total	
	Trials	Errors	Trials	Errors	Trials	Errors

Group 1 (SF)						

S1	100	31	100	28	200	59
S2	100	31	100	29	200	60
S3	100	35	100	30	200	65
S4	100	33	100	35	200	68
Total		---		---		---
		130		122		252

Group 2 (RF)						

S6	100	34	100	34 ^a	200	68
S7	16	3	-	-	16	3
S8	100	36	100	36	200	72
S9	100	37	100	33	200	70
Total		---		---		---
		110		103		213

Group 3 (TE)						

S11	100	53	19	3	119	56
S12	100	47	100	56	200	103
S13	100	59	100	53	200	112
S14	100	46	100	50	200	96
Total		---		---		---
		205		162		379

Note. a= Subject attained criterion during Phase 1.

SF= Standard Fading; RF= Revised Fading; TE= Trial-and-Error training.

facilitating task acquisition.

For the revised fading group, eight fading steps of increasing assistance were potentially available to subjects when they entered the programmed sequence. However, reliable correct responding to S₊ was rapidly attained with low levels of programmed assistance. S₈ and S₉ backed up to only Step 7 of the programmed sequence, while S₆ and S₇ never failed Step 8, the minimal prompting level. While S₇ subsequently acquired the discrimination, the three remaining subjects repeatedly failed to respond appropriately to the unprompted stimuli.

This may suggest that Steps 1 to 6 were largely redundant for prompting correct responding to S₊. However, early steps in fading programmes are designed to provide readily discriminable stimuli, and are by definition difficult to fail. This is predicated upon the thesis that gradual, error-free, fading of the prompt cue will lead to successful acquisition (Terrace, 1963a). However, the results from the standard fading group did not support this position. Despite receiving graduated stimulus change the subjects failed to acquire the task. Subjects progressed errorlessly, or near errorlessly, through Steps 1 to 8, but still failed to respond correctly when the prompt cue was completely removed (Step 9).

The discriminability of the prompt cue during compound training differed between fading groups; no subjects from the revised fading group received the most discriminable prompts (Step 1 to Step 6). However, for both groups an identical pattern of responding developed over the 200 training trials. In both conditions, the stronger prompt cue appeared to completely overshadow the weaker training cue. All subjects responded correctly on line-intensity compound trials, but in only one case did line tilt alone come to acquire control over responding. For five of the seven

fading subjects who failed to acquire the task, the dimension that came to control responding following prompt fading was position. S1, S2, S6, S8, and S9 all exhibited position perseveration bias on criterion level trials (position perseveration was defined as deviation from chance responding significant at $p < .001$, chi-squared). Intensity differences between stimuli controlled responding on compound trials, while position controlled responding when the intensity cue was removed. Line tilt did not come to reliably control responding.

Position also appeared to be the controlling dimension for the three trial-and-error training subjects who failed to acquire the task. S12 and S14 exhibited position perseveration habits, while S13 exhibited a simple left-right position alternation bias (alternation bias was defined as a non-chance ($p < .05$) distribution of runs on the one sample runs test; Yeomans (1968), p310-314).

These results may indicate the graduated steps in the intensity fading sequence were inappropriately programmed in view of the difficulty of the training task. It may be that programmed stimulus change was both too gradual early in the sequence, and too abrupt at the terminal level. Greater differentiation between Steps 8 and 9, coupled with either the elimination or increase in size of early steps, may have proved more effective.

As demonstrated in Experiment 2, the discrimination of stimuli containing opposing 45 degree line tilts is a complex task. In contrast to Experiment 2, the failure to acquire the task in the present experiment cannot be ascribed to the presence of additional redundant components in S+ and S-, since the elimination of these redundant components (the head and body of the manikin) during Phase 2 training did not result in task

acquisition. Previous research has also shown that such discriminations are extremely difficult for both normal intelligence and mentally handicapped children (Jeffrey, 1966; Rudel & Teuber, 1963; Stoddard, 1968; Touchette, 1969). As argued in the discussion of Experiments 2 and 3, this difficulty may be ascribed to the stimuli being left-to-right mirror images.

The possibility that the discrimination task was of such complexity that fading programmes would prove ineffective in producing acquisition was considered. Touchette (1971) has reported that a delayed prompting procedure was successful in teaching the simultaneous discrimination of opposing 45 degree line tilts to two of three severely mentally handicapped boys. However, as Brown and Rilling (1975) have observed, Touchettes subjects had extensive and successful training histories, both within the reported study and in earlier (unspecified) research studies. To determine whether the present training task was atypical, or could be acquired through programmed training, further training of the task was conducted in Experiment 6.

Experiment 6: Training the Simultaneous Discrimination of Opposing 45 degree Line Tilts Through Fading a Criterion-Related Prompt Cue

In the discussion of Experiment 3, a distinction was proposed between criterion-related (CR) and non criterion-related (NCR) prompt cues. A CR prompt is one drawn from the same dimension that the final (or criterion) discrimination will be based upon. In contrast, a non criterion-related (NCR) prompt is drawn from a different dimension to that involved in the criterion discrimination. Schilmoeller and Etzel (1977), and Richmond and Bell (1983), have suggested that NCR prompts may be less effective than CR

prompts, since the dimension the subject is prompted to attend to due to its increased salience is unrelated to the dimension upon which the discrimination must ultimately be made. The fading programmes employed to train the line tilt task in Experiments 3 and 5 employed prompts drawn from colour and intensity stimulus dimensions respectively. Hue and intensity dimensions are clearly NCR, since following fading S₊ and S₋ differed not in hue or intensity, but in line orientation. The intention of Experiment 6 was to determine whether the task could be acquired through fading along an orientation dimension, since line orientation was the relevant dimension upon which the criterion stimuli differed.

Method

All seven subjects from the fading groups of Experiment 5 (Groups 1 and 2) who had not acquired the task participated in the experiment. The task consisted of opposing 45 degree line tilts, identical to the stimuli employed during Phase 2 of Experiment 5.

For six subjects, prompts of the greatest strength were presented first, and gradually faded to provide lessening assistance. S₆ was randomly selected to receive the revised fading procedure described in Experiment 5. For this subject training commenced with the criterion level stimuli.

Fading was conducted on a dimension of angular discrepancy between initial and criterion orientation of S₋. On Step 1, S₋ was presented as a horizontal line, making it readily discriminable from S₊ (45 degrees to the right of vertical). During eight fading steps the angle of S₋ was increased through 0, 10, 15, 20, 25, 30, 35 and 45 degrees. Figure 5.2 presents the steps involved in the orientation fading programme. The back-up procedure, step criterion, etc., were as described for Experiment 5. Training was

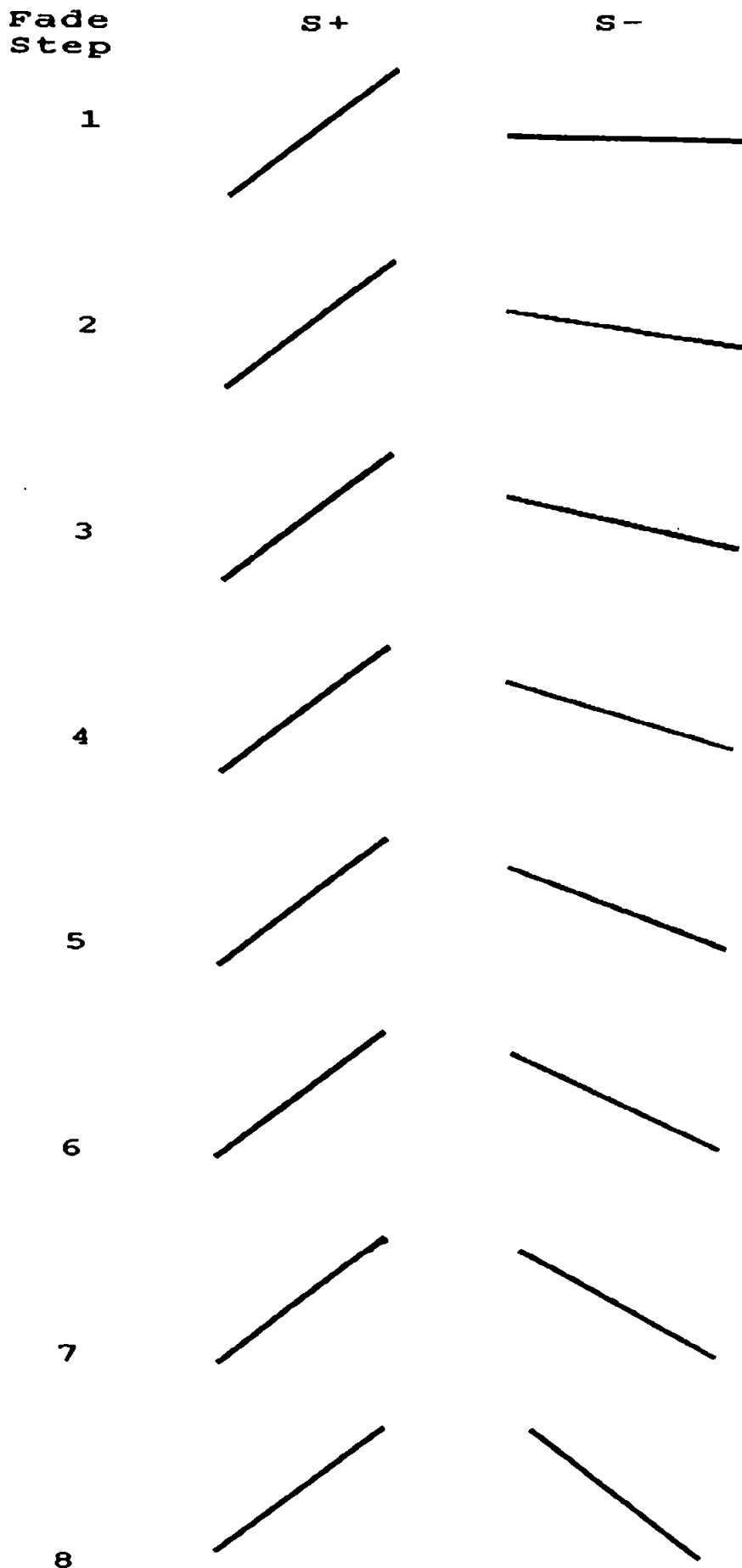


Figure 5.2: Illustration of the eight steps of the orientation fading programme. S+ is presented at criterion orientation (135°) throughout, while the orientation of S- increases from 0° through to 45°.

continued until the learning criterion was attained (10 consecutive, correct, unprompted responses), or a maximum of 100 training trials were completed.

Results and Discussion

No subject acquired the task following orientation fading. Trial-by-trial analyses of performance of the six subjects receiving graduated stimulus change are presented in Figure 5.3.

First, the performance of S2 differed from that of all other subjects. Significantly more trials were required to proceed beyond Step 1, the higher programmed steps were never mastered, and there was little consistency in correct responding across steps. Further analysis revealed a strong bias towards selecting the right-hand stimulus (chi-square, $p < .001$). S2 was also the only subject to show position perseveration on fading trials.

The other five subjects proceeded rapidly and errorlessly through the entire programmed sequence up to the criterion step, before emitting any further errors. An interesting aspect of the performance of S1, S4, and S8 was a subsequent failure to maintain errorless performance where they had previously been successful. These subjects emitted errors on previously mastered steps, producing a 'trough' in the performance profiles as subjects were backed down through the programmed sequence (See Figure 5.3). It would appear that errors may create further errors. A similar observation has been reported by Sidman and Stoddard (1966).

Over the last block of 20 training trials, five of six subjects could successfully maintain a discrimination between the S+ line and an S- line tilted at 30 degrees (Step 6). Furthermore, S4, S8, and S9 were all

ORIENTATION FADING

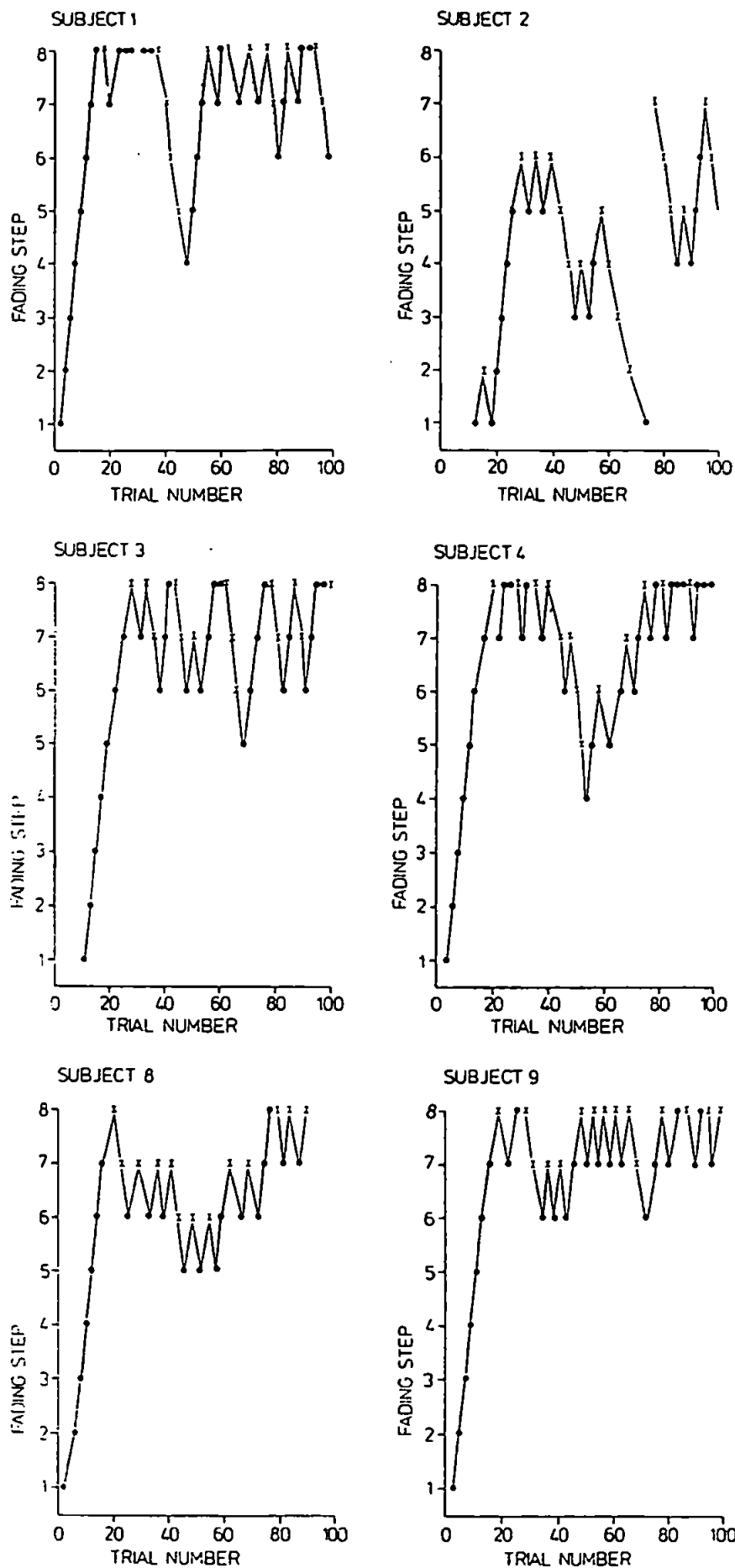


Figure 5.3: Trial-by-trial performance of subjects receiving standard orientation fading.

responding correctly to a fine-grained discrimination between lines of 35 degrees and 135 degrees (Step 7). However, with a small additional increment in S- to 45 degrees, correct responding was disrupted and many errors were emitted by all subjects.

This observation suggests some cue was exerting reliable and consistent control over responding during the fading trials, although the failure to discriminate the criterion lines suggests this was unlikely to be line tilt per se. Subtle and unexpected aspects of the stimuli may have come to control responding. For example, close inspection of Figure 5.2 revealed that the upper end of the S+ line was higher than the upper end of the S- line on all but the criterion step (see Figure 5.2). Subjects may have responded to such an incidental cue, irrelevant for solution of the criterion task, rather than to line tilt. Stoddard (1968) and Touchette (1969) have also commented on the complex nature of tilted line stimuli, which may provide more than one basis for discrimination. This observation indicates that, even when conditions are carefully arranged for establishing control by the relevant cue, seemingly trivial and easily overlooked features may acquire inappropriate control over subjects responding.

For four of the five subjects who came to successfully master the fading steps an inappropriate controlling dimension was identified on criterion trials. S1 and S9 showed a significant preference for the stimulus presented on the right of the stimulus display, while S3 and S8 showed a significant preference for the stimulus on the left side of the display, on trials presenting the criterion stimuli (Chi-squared, $p < .001$). None of these subjects demonstrated any position preference on fading trials. That position is a salient dimension for these subjects was demonstrated in Experiment 5, where position habits were also shown to control responding following fading. Programmed training may prove

effective in suppressing such habits, since only S2 exhibited position perseveration during fading trials. However, while the discriminative stimuli exercised control on fading trials, when the prompt was completely attenuated the discriminative stimuli lost control and subjects reverted to inappropriate position habits.

It may be argued that subjects would have acquired the task had training been extended further. However, prolonged experience of position perseveration is unlikely to result in task acquisition. In two-choice tasks where the correct stimulus is varied from left to right in a random sequence, a position habit will result in reinforcement on 50% of trials. Such behaviour is in fact shaped on a intermittent schedule of reinforcement, and consequently presents a high degree of resistance to extinction. Increasing the number of training trials may have only one consequence, the strengthening of the perseverative behaviours (Lambert, 1980). The one exception may be S4, who was close to attaining criterion at the end of training, and was the only subject who did not exhibit a position habit.

While subjects were capable of making fine-grained discriminations between lines tilted at 35° and 135° (see Step 7, Figure 5.2), a quantitatively small increase in S- to 45° (Step 8, Figure 5.2) disrupted performance. In this context it is interesting that S6 (revised fading), who was initially presented with the criterion stimuli, was immediately able to successfully discriminate the stimuli at Step 7 on their first presentation. The subject also maintained the discrimination on all but one of the subsequent representations of Step 7, although he exhibited a position habit on criterion trials. The lack of success of the CR programme in training the present task may therefore indicate that special qualities of mirror-image discriminations make them particularly unamenable to

training. It is concluded that the lack of differences between groups in Experiment 5 may at least in part have been due to a floor effect, engendered by the extreme difficulty of the mirror-image training stimuli.

Experiment 7: Further Assessment of the Effect of Initial Discriminability of the Prompt Cue During Stimulus Fading

Following from the above conclusion, Experiment 7 compared standard fading, revised fading, and trial-and-error instruction in training a second (non mirror-image) discrimination task. The hypotheses and rationale guiding the experiment were the same as described for Experiment 5.

Method

Subjects

All subjects from Experiment 5 were involved in the experiment. Three additional subjects, matched for trials to criterion on a simple discrimination involving multiple relevant cues, also became available at this stage, and were randomly allocated to training groups. The three new subjects were designated S5, S10, and S15. The total sample therefore consisted of 15 subjects, in three matched groups of five subjects each.

Stimuli

The discrimination task (Task 2) consisted of two "X" shapes, approximately 8cm by 8cm. The relevant components of the stimuli consisted of inverted triangles appearing in the apexs of the cross. On S+, the triangles appeared in the horizontal apexs, while on S- the triangles

appeared in the vertical apexes. Stimuli were white line forms on black backgrounds. The criterion task is presented as Step 7 in Figure 5.4.

Fading Steps

The prompt employed in training the task was an exaggeration of the size of the relevant components of \underline{S}_+ . On Step 1, the size of the triangles in \underline{S}_+ was increased fourfold to make \underline{S}_+ and \underline{S}_- highly discriminable. Six further steps were programmed in which the size of the \underline{S}_+ triangles gradually decreased, until Step 7 where the triangles were of equal (criterion) size in both \underline{S}_+ and \underline{S}_- . These steps are illustrated in Figure 5.4.

Training Groups

As in Experiment 5, the standard fading group commenced training from the step of greatest assistance (Step 1), while the revised fading group were initially presented with the criterion stimuli (Step 7). All procedural aspects of the fading programmes were as described in Experiment 5. The trial-and-error group received the criterion stimuli throughout training. Training was discontinued if a subject did not attain the learning criterion (10 consecutive, correct, unprompted responses) after a maximum 175 trials.

Results and Discussion

Significant differences between groups in the number of children acquiring the task were found (Cochrans $Q = 6.5$, $df = 2$, $p < .05$). All subjects from the revised fading group acquired the task, while one subject from the standard fading group, and four of five subjects from the trial-and-error group, failed to attain the learning criterion.

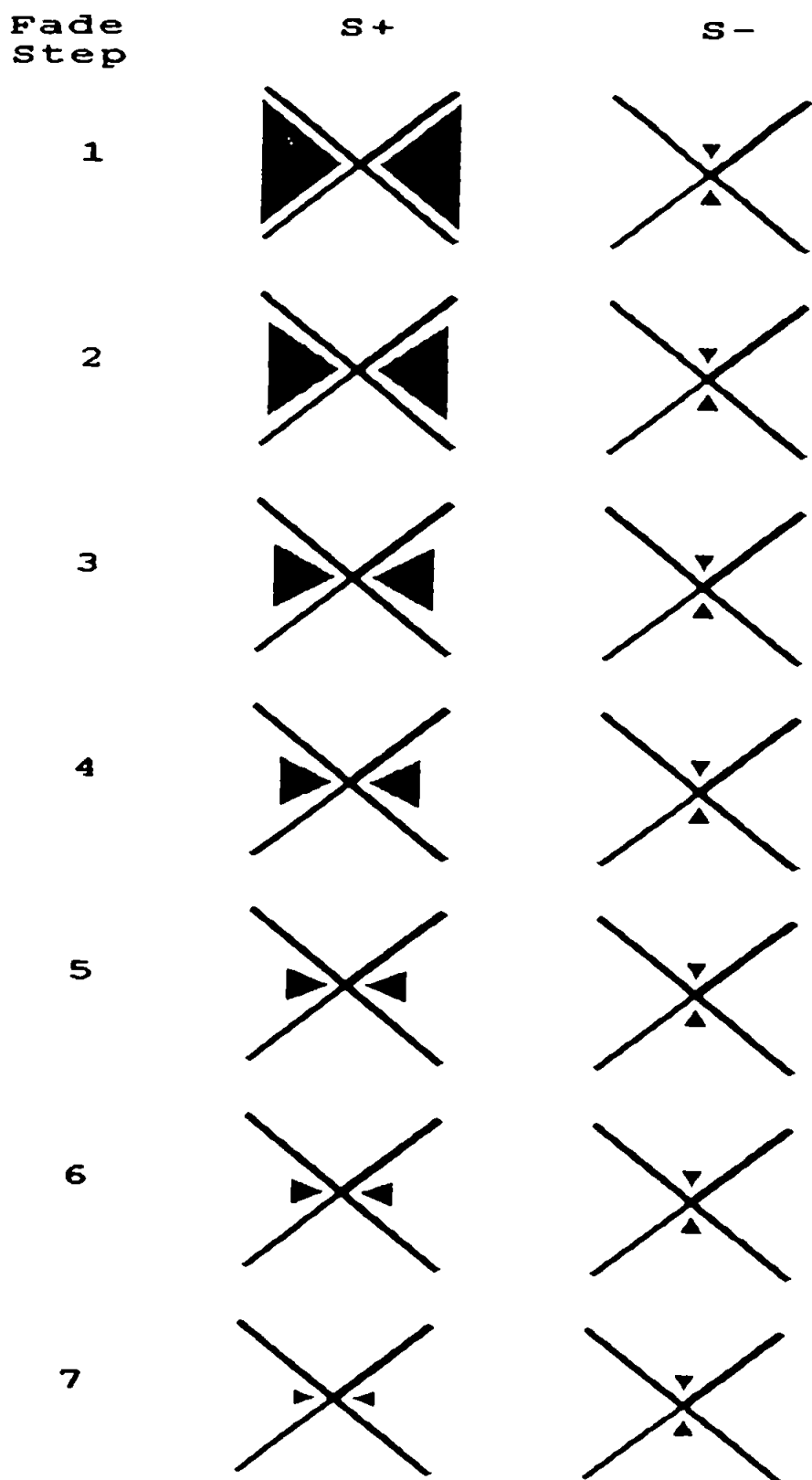


Figure 5.4: Illustration of the seven fading steps for Task 2. Step 1 increases the size of the relevant component of S+. Subsequent steps fade the size of the relevant S+ component, while S- remains constant throughout.

Groups also differed significantly in the number of errors emitted during training ($F(2,8) = 7.11, p < .025$). Fading groups did not differ significantly ($t = 0.16, df = 8, p > .10$), but both revised and standard fading groups emitted significantly fewer errors than the trial-and-error group ($t_s = 3.34$ and 3.18 respectively, $df = 8, p < .01$ in both cases). For trials to criterion, planned apriori t-tests again revealed no significant difference between the fading groups ($t = 0.35, df = 8, p > .10$) although both revised and standard fading groups required fewer trials than the trial-and-error group ($t_s = 2.22$ and 1.86 respectively, $df = 8, p < .05$ in both cases). These data are presented in Table 5.2; the error data is also presented graphically in Figure 5.5.

Clearly, the availability of prompts facilitated task acquisition, since four of five subjects failed to acquire the task when no prompts were available. Prompting appeared effective in preventing the appearance of specific response biases. The four trial-and-error subjects who failed to acquire the task all demonstrated perseverative error patterns. S12, S14, and S15 demonstrated position habits, while S13 demonstrated a position habit on early trials and an alternation bias in later sessions. Of the fading subjects, only S9 (revised procedure) demonstrated any systematic response bias. This subject initially showed a preference for the right-hand stimulus on both fading and criterion level trials. S9 first broke his position habit on fading trials, thus control by the discriminative stimuli was first acquired by the stimulus compound. Subsequently, the criterion stimuli alone were able to acquire control over responding, resulting in task acquisition.

In the revised fading group, S6, S7, and S8 all acquired the task using only the least discriminable level of the prompt (Step 6). Trials to

Table 5.2: Number of Trials and Errors for Each Subject During Training of Task 2

Set of Matched Subjects	Number of Trials			Number of Errors		
	SF	RF	TE	SF	RF	TE
1	28 ^a	11	24 ^a	3	1	9
2	175	28	175 ^a	62	7	99
3	100	21	175 ^a	25	5	83
4	35	139	175 ^a	5	38	72
5	23	93	175 ^a	1	32	93
Mean	72.2	58.4	144.8	19.2	16.6	71.2
SD	65.4	55.4	67.6	25.8	17.1	36.3

Note. a= The subject failed to meet the learning criterion in the maximum 175 trials.

SF= Standard Fading; RF= Revised Fading; TE= Trial-and-error training.

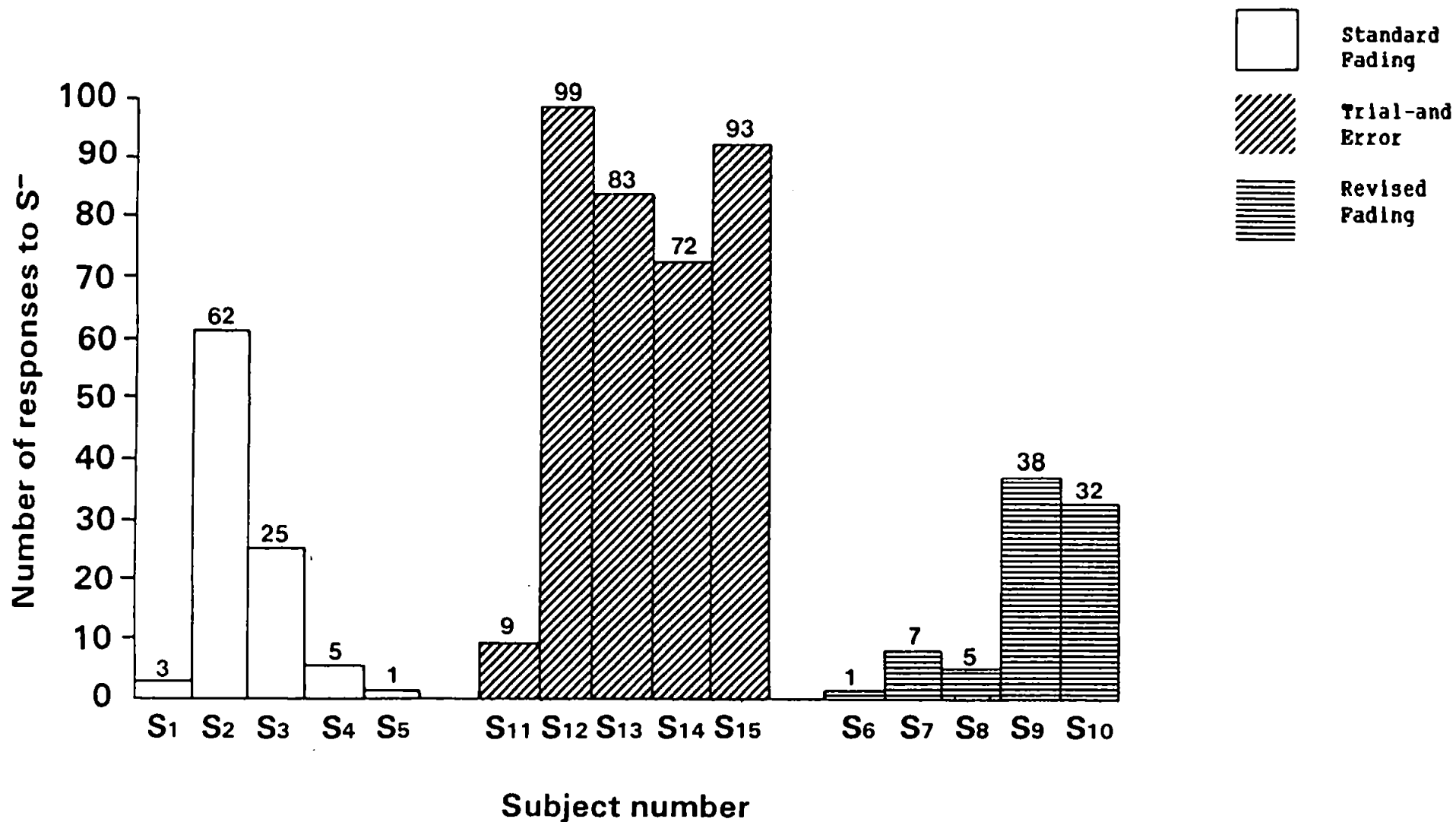


Figure 5.5: Responses to S⁻ (errors) emitted by each child during training of Task 2.

criterion and number of errors emitted by these subjects was in all instances lower than that of their matched companions who received the standard fading procedure (See Table 5.2). The two remaining subjects from the revised fading group required more discriminable prompts before acquiring the task. S9 backed up to Step 5, while S10 backed up to Step 3. These two subjects emitted more errors than their matched companions in the standard fading group.

Overall therefore, the revised and standard fading procedures did not differ significantly. The four subjects who exhibited some degree of perseveration in responding to the prompt were equally divided between the two fading groups (S2, S3, S9 and S10; see Figure 5.5).

It had been hypothesised that starting fading with less discriminable values of the prompt cue might reduce overshadowing of the training cue, leading to more rapid task acquisition than under standard fading conditions. Miles and Jenkins (1973) have demonstrated that the magnitude of the overshadowing effect increases with increasing discriminability of the overshadowing cue. Further, Fields (1978, 1979) has reported that low rather than high starting prompt intensities led to early acquisition of control by training stimuli during fading. Pigeons received superimposition and fading in an attempt to shift control from a colour (red-green) discrimination to line orientation (e.g., vertical-horizontal). Lines came to acquire control earlier in fading when lower starting colour intensities were employed. However, in the present experiment reducing starting prompt discriminability (the size of relevant components of S+) did not significantly facilitate task acquisition compared to a standard fading procedure.

Some criticisms of the revised fading procedure may be forwarded.

Rather than starting with prompts of maximum discriminability, the revised procedure established for each subject the minimum level of prompt discriminability that would result in correct responding to S+, by allowing subjects to back up through the fading sequence until reliable correct responding was obtained. However, the procedure inevitably involved the occurrence of errors early in training. Such a procedure may not provide optimal training conditions. It was observed in Experiment 6 that 'errors may create errors'. The occurrence of errors early in training may serve to disrupt subsequent performance. An alternative design would start separate groups of subjects at different points in the programmed sequence. Such a design would eliminate the potentially adverse effects of the initial errors generated by the revised procedure. It is important to note, however, that such a design could not ensure that fading began with the lowest functional level of prompt discriminability for each subject.

In conclusion, the revised fading procedure was no less effective than standard fading, and was clearly more effective than trial-and-error training. However, in the absence of a significant facilitatory effect for the new procedure, standard fading remains the procedure of choice. However, the revised procedure is useful in facilitating the identification of redundant steps in a programmed sequence. The procedure may therefore be a useful tool in the empirical development and evaluation of instructional programmes.

Overview: Overshadowing In Programmed Discrimination Training

The role of overshadowing in programmed discrimination training has been interpreted as following:

(1) Fading procedures involve the addition of a prompt cue to a training cue, forming compound stimuli with two relevant cues. In such compounds, the prompt cue is an overshadowing agent by dint of its greater discriminability (Lovejoy & Russell, 1967; Eckerman, 1967; Miles, 1965; Vom Saal & Jenkins, 1970; Sereganin, 1979).

(2) The degree of control exerted by an overshadowed cue has been shown to be inversely related to the discriminability of the overshadowing cue (Miles & Jenkins, 1973). Thus, while the basic overshadowing effect reveals a more salient cue will reduce learning about a less salient cue, Miles and Jenkins further demonstrate that the magnitude of the overshadowing effect may be determined by the discriminability of the overshadowing cue.

(3) This systematic relation between the magnitude of overshadowing and cue discriminability allows the forwarding of an explanation of the effectiveness of fading in terms of changes in cue discriminability. Where the overshadowing cue remains easily discriminable during training, the overshadowing effect is observed. Thus, Terrace (1963b) showed that when a colour cue was abruptly removed following compound training with colour-line stimuli, pigeons emitted many errors in responding to the training cue (line orientation). However, when the colour cue was gradually faded, Terrace

observed errorless acquisition of the orientation discrimination. It may be hypothesised that fading is successful to the extent that a gradual decrease in the discriminability of the salient cue attenuates the overshadowing effect, allowing the less salient cue to acquire increasing control. The few studies that have directly assessed changes in stimulus control during fading (Fields, Bruno, & Vincent, 1976; Fields, 1978, 1979; Doran & Holland, 1979) support this analysis. For example, in the Fields (1978) study described earlier, an attempt was made to shift control from a colour (red-green) discrimination to line orientation (vertical-horizontal). Probes for control by lines during fading of the colour cue confirmed that during the early stages of fading the lines exerted no control over responding; lines were overshadowed by the colour cue. However, as fading continued responding came first under the control of the compound stimulus, and finally the lines alone came to control responding. A similar progression was apparent in the performance of S9 in Experiment 7. Stimulus control was first acquired by the compound stimuli (indicated by the elimination of a position perseveration habit) before the training cue alone acquired control.

(4) Non-acquisition of discriminations following fading may therefore reflect a failure to attenuate the overshadowing effect of the prompt cue. In Experiment 5, the compound stimuli consistently elicited correct responding, through to the last level of fading. However, despite attenuation of the prompt cue, the criterion cue appeared to be completely overshadowed during fading, since subjects repeatedly failed to respond correctly to the criterion level stimuli. Similar results have been reported, although often anecdotally, in earlier studies of fading procedures (e.g., Terrace, 1966; Sidman & Stoddard, 1966).

Two theories have been forwarded to account for the overshadowing

effect. According to theories of selective attention (Zeaman & House, 1963; Sutherland & Mackintosh, 1971) stimuli compete for the subjects limited attention; the greater the extent to which the subject attends to one cue the less likely he is to attend to the other. Overshadowing is a simple consequence of the presence of a second cue reducing the extent to which a subject can attend to and hence learn about the first. Mile and Jenkins' (1973) results may be accounted for since variables which may be assumed to increase the extent to which the subject attends to the overshadowing cue (such as its discriminability, or the subjects prior experience with it) will increase the extent to which it overshadows another cue.

A second general explanation of overshadowing has been suggested by Kamin (1968), and has been more formally advanced in modified noncontinuity theory (Rescorla and Wagner, 1972). Stimuli are assumed to compete with each other not for a limited attentional capacity, but for a limited amount of associative strength conditionable by a given reinforcer. The theory yields the basic overshadowing phenomena since the control one cue can acquire will be reduced to the extent that a concurrent second cue brings the strength of the entire compound closer to the asymptotic value for the reinforcer, thus limiting the conditioning of one cue. The theory can also incorporate the finding that the extent of overshadowing depends upon the discriminability of the overshadowing cue (Miles & Jenkins, 1973). The more discriminable the overshadowing cue, the more rapidly is the associative strength of the entire compound driven to its asymptote, thus preventing any further response-strength accruing to the less salient cue.

These theories have not been applied to situations in which fading procedures are employed. However, to the extent that the discriminability of the overshadowing cue plays a role in both theories, with greater cue discriminability resulting in greater overshadowing, a decrease in

overshadowing with decreasing discriminability of the prompt cue during fading is not incongruent with either theory.

Both modified noncontinuity theory and selective attention theories explain overshadowing primarily in terms of the discriminability of the overshadowing cue. Both assume that any control that might be acquired by the less salient cue should be determined by the amount of control exerted by the overshadowing cue. In line with these predictions, Fields (1979) has reported that low rather than high starting intensities of a colour cue resulted in earlier acquisition of control by training stimuli (lines) during fading. It was therefore hypothesised that less discriminable prompts may reduce the overshadowing effect. While the present experiments have shown that children may acquire discriminations rapidly with low discriminability prompts, neither Experiment 5 nor Experiment 7 found reduced starting prompt discriminability significantly facilitated task acquisition, compared to a standard fading control group.

The present studies have shown that a second variable, the discriminability of the overshadowed cue, also influences the degree of perseverative responding to the prompt cue. In Experiment 2, it was observed that identical fading sequences resulted in acquisition of tasks of high rather than low discriminability. Experiment 2 involved the training of two discrimination tasks. Greater discriminability of Task 2 was indicated since six of nine trial-and-error training subjects acquired the task, while only a single subject from the trial-and-error group acquired Task 1. An identical size and colour fading sequence was successful in facilitating the acquisition of Task 2, but largely unsuccessful in training Task 1, where subjects perseverated in responding to the prompt cue. There is some support for this observation concerning training cue discriminability in research reported by Doran and Holland (1979). Doran

and Holland report that when identical intensity fading sequences ~~were~~ used with size discriminations of varying discriminability, errorless learning was accomplished if the training cue was very discriminable (large size differences between S₊ and S₋), but not if the training cue was of low discriminability (small size differences between S₊ and S₋).

Therefore, the results of the present experiments may suggest that not only the absolute discriminability of the prompt cue, but also the discriminability of the criterion cue, may determine the magnitude of the overshadowing effect. We suggest that as the fading cue becomes less discriminable, the criterion cue, if highly discriminable, is more likely to become effective in controlling responding. However, if the fading and criterion cues are both low in discriminability, which may obtain at the final stages of a fading sequence, the fading cue continues to control responding until it is removed. Subsequently repeated errors may occur since the criterion cue fails to acquire control.

An 'overshadowing' analysis of fading may have important implications for the selection of prompt cues in fading programmes. For example, the analysis would predict the most effective fading procedures would employ CR prompt cues. In CR fading procedures, prompt and criterion cues are drawn from the same stimulus dimension. Since such prompts are in fact an exaggeration of the relevant criterion dimension, there is no competition between cues, upon which overshadowing is predicated.

For example, Experiment 5 employed an intensity fading programme in training a line tilt discrimination. The procedure proved ineffective, and it was concluded that the presence of salient (NCR) intensity differences between S₊ and S₋ may have interfered with subjects observing the relevant orientation dimension. In Experiment 6, a CR fading programme which

manipulated S- along the relevant orientation dimension was evaluated. In contrast to the predictions of the overshadowing analysis, the CR procedure also failed to result in acquisition of this task.

However, the subjects receiving the CR programme had received 200 training trials immediately prior to the CR programme, in which all subjects emitted a considerable number of errors. An important consequence of a history of errors is not only that appropriate behaviour is not learned, but also that inappropriate behaviour may become established. During prior unsuccessful training of the task, subjects had developed specific perseverative error patterns when presented with the criterion stimuli; specifically position perseveration and position alternation biases developed. In Experiment 6, while such habits were suppressed during the fading steps and the discriminative stimuli were observed to control responding for five of six subjects, when the discrimination became difficult at the criterion step subjects reverted to the inappropriate behaviours they had demonstrated following prior NCR fading.

In summary, Experiment 6 was not designed to systematically evaluate the effect of CR and NCR prompt fading programmes. Rather, the CR fading programme was an ad hoc attempt to ascertain the difficulty of the line tilt discrimination task. Therefore, a systematic evaluation of the effectiveness of fading CR and NCR cues is required. Chapter 6 will proceed to provide a comparative evaluation of the effectiveness of CR and NCR fading programmes, while controlling for the effects of other confounding variables.

CHAPTER 6

Types of Stimulus Manipulations in Programmed Training:

Evaluating Criterion-Related Versus Non Criterion-Related

Stimulus Manipulations

Chapter 6

Types of Stimulus Manipulations in Programmed Training: Evaluating Criterion-Related Versus Non Criterion-Related Stimulus Manipulations

It has been argued in Chapter 5 that when analysing the failure of programmed training procedures to facilitate discrimination acquisition (e.g., Terrace, 1966a; Gollin & Savoy, 1968; Schwartz, Firestone, & Terry, 1971) it may be important to focus on the nature of the prompt cue employed in fading, and the relation of the prompt cue to the training discrimination. In Chapter 1 (section 1.5.4), a taxonomy of three variables related to types of stimulus manipulations was presented and some relevant studies reviewed. One variable that we have suggested may have particular significance in accounting for failures of acquisition following fading concerns the distinction between 'criterion- related' and 'non criterion-related' prompts, originally proposed by Schilmoeller and Etzel (1977). The present chapter reports the results of a study designed to systematically evaluate the effects of criterion-related and non criterion-related stimulus manipulations.

Experiment 8: Criterion-Related Versus Non Criterion-Related Fading Procedures for Teaching Discriminations to Severely Mentally Handicapped Children

Schilmoeller and Etzel (1977) have defined a criterion- related (CR) prompt as a cue drawn from the same dimension that the final (or criterion) discrimination will be based upon, whereas a non criterion-related (NCR)

prompt cue is drawn from a different dimension. Thus, for example, in Experiment 5 fading was carried out along the dimension of intensity, while the final discrimination was based on line orientation (NCR fading), while in Experiment 6 fading was conducted along the relevant (orientation) dimension (CR fading).

Schilmoeller and Etzel (1977) trained eight subjects of normal intelligence on two complex discriminations using either CR prompts, or both CR and additional NCR prompts. Correct responding on post-tests for the tasks trained with CR prompts was higher than for those tasks trained with additional NCR prompts. The authors conclude that CR fading is more effective than NCR fading. Richmond and Bell (1983) also trained three groups of five institutionalized profoundly mentally handicapped adults (mean MA 2.4 years) a size discrimination using either fading of a CR cue (increasing size of S-), fading of a NCR cue (a trainers finger point to S+), or trial-and-error training. They report the group receiving CR fading acquired the discrimination with a significantly smaller percentage of errors than either the trial-and-error or NCR fading group.

The CR/NCR distinction is an appealing one due to the availability of a theoretical mechanism to explain the effectiveness of training with CR cues.

We have hypothesised that CR fading may be more effective than NCR fading since, as both cues are drawn from the same stimulus dimension, CR fading does not necessitate the transfer of stimulus control from the prompt cue to the training cue. Such a procedure may therefore avoid the problems of overshadowing clearly illustrated in the last chapter. However, the present study contends that additional controls are required to conclusively isolate the effect of the CR/NCR variable from other confounding factors.

A Systematic Evaluation of the CR/NCR variable.

In the present study, size and intensity fading programmes will each be applied to discriminations based upon either size or intensity cues. The relation of the fading cue to the criterion discrimination may thus be systematically varied. Specifically, four combinations of fading and criterion cues will be examined; size fading/size discrimination (CR), size fading/intensity discrimination (NCR), intensity fading/intensity discrimination (CR), and intensity fading/size discrimination (NCR). Both discriminations will also be trained using a trial-and-error procedure, to provide a baseline for comparison with the fading conditions. Several factors prompted the adoption of the above design.

First, in Schilmoeller and Etzel's (1977) study the tasks were extremely complex, making manipulation of the CR variable in some respects arbitrary. Although NCR cues were indeed clearly unrelated to the criterion discriminations, it is less clear for example whether fading on a dimension of colour is unambiguously CR to a complex four colour configuration and colour sequence criterion. Employing physical dimensions of difference between stimuli (specifically size and intensity) as both fading and criterion cues, means that whether a manipulation is CR or NCR is relatively unambiguous.

Second, with a factorial investigation the main effect of dimension of fading can be separated from the CR/NCR variable. For example, Richmond and Bell's (1983) study demonstrated that size cues were more effective than finger point cues in training a size discrimination. However, to conclusively isolate the effect of the CR variable it is necessary to control for the main effect of prompt dimension. Strong confirming evidence would also demonstrate that size cues are less effective than finger point

cues on a second task in which finger point cues are CR and the size cue is NCR. While developing a task in which finger points are CR is problematic, with size and intensity dimensions such a counterbalanced design can be readily constructed, and the main effect of prompt dimension can be controlled.

Finally, a major consideration in the design of this study was the apparent problem in previous evaluations of confounding between the CR/NCR variable and other variables relating to types of stimulus manipulations, particularly the within-stimulus / extra-stimulus variable. As described in Chapter 1 (section 1.5.4), within-stimulus (WS) procedures directly manipulate the discriminative stimuli along some dimension (e.g., stimulus fading, and stimulus shaping procedures), while extra-stimulus (ES) procedures are concerned with manipulating additional prompt stimuli added to the training stimuli (e.g., superimposition and fading, and delayed cue procedures). Several studies have reported that WS manipulations may prove more effective than ES manipulations. For example, Lambert (1980) trained twelve severely mentally handicapped children to discriminate two triangles differing in angle of rotation. Training consisted of a superimposition and fading procedure. First, subjects were trained to discriminate a yellow (S+) and blue (S-) key. Subsequently the S+ triangle (apex down) and S- triangle (apex up) were superimposed upon the yellow and blue backgrounds respectively. Finally the background colours were progressively faded to white. Nine of twelve subjects failed to acquire the discrimination. Increasing the number of steps involved in fading the background colours from 20 to 30 steps still failed to result in task acquisition for five subjects. However, in a subsequent WS (stimulus fading) procedure, in which S- was progressively changed from black light to barely discernable dots and finally to lines on a white background, all subjects were successful in

acquiring the task. Similar results indicating the superiority of WS over ES manipulation have been reported by Sidman and Stoddard (1966) and Schreibman (1975).

In both the experiments reported by Schillmoeller and Etzel (1977), and Richmond and Bell (1983), the CR/NCR variable appears to be confounded with the WS/ES variable. For example, in Richmond and Bell's (1983) study the NCR cue was also extra-stimulus (a trainers finger point to S+) while the CR cue was within-stimulus (increasing size of S-). Similarly, the NCR cues in the Schillmoeller and Etzel (1977) study were also extra-stimulus (e.g., adding a red rectangle encircling the correct stimulus) while the CR cues were within-stimulus (e.g., the use of a stimulus shaping procedure for a form discrimination).

Furthermore, in this latter study the NCR prompts were not only ES, but were also spatially separate from S+. Both Smeets, Lancioni, and Hoogeveen (1984a), and Rincover (1978), have reported that ES prompts not connected to the discriminative stimuli are even less effective than ES prompts that are integrated with the training stimuli. For example, Smeets et al., (1984a) trained seven mentally handicapped children to sight read sets of three words. In a stimulus connected prompt fading (SCPF) condition the picture was spatially connected with the corresponding word. In a stimulus disconnected prompt fading (SDPF) condition the picture and word were separated spatially; the picture appeared above the word on the stimulus cards. In both conditions the pictures were gradually faded out over 29 and 27 steps respectively. All seven subjects acquired the word discriminations with SCPF, while only three subjects acquired the discriminations with SDPF.

Rincover (1978) (summarized in section 1.5.4) reports similar results favouring the manipulation of ES prompts spatially connected rather than unconnected to the discriminative stimuli.

Control of these variables in evaluating CR versus NCR manipulations is essential given the inferiority of extra-stimulus compared to within-stimulus fading, and the particular inferiority of spatially unconnected extra-stimulus manipulations. Therefore, in the present experiment within-stimulus fading was employed in all cases i.e., the discriminative stimuli themselves were directly manipulated along either a size or intensity dimension.

In sum, further systematic and controlled analysis of the CR/NCR variable appears warranted. It was hypothesised that fading would be more effective than trial-and-error training, and that significant linear trends of increasing errors over CR, NCR, and trial-and-error training conditions would be revealed on each task, with size fading more effective than intensity fading in training the size discrimination, and the reverse for training the intensity discrimination.

Method

Subjects

Thirty-three children attending special schools for children with severe learning difficulties (SLD) participated in this study. Subjects were selected from a pool of 80 children who were all administered four selected scales from the BAS (see Experiment 2). Eleven sets of three subjects each were selected, each subject being matched with two others having the same or closest composite BAS score. Within each set subjects were randomly assigned to each of the three experimental groups. Descriptive characteristics of the subjects are presented in Table 6.1. As an approximate indication of the degree of handicap the mean chronological

Table 6.1: Descriptive Characteristics of Subjects

Matched Set	Group 1 Size Prompt				Group 2 Intensity Prompt				Group 3 Trial-and Error			
	a S	Sex	b CA	c BAS	S	Sex	CA	BAS	S	Sex	CA	BAS
1	1	M	13:9	278	12	M	13:10	288	23	M	17:5	289
2	2	F	10:1	213	13	M	11:9	227	24	F	13:3	213
3	3	M	16:5	203	14	F	15:8	200	25	F	14:10	189
4	4	M	12:5	191	15	M	12:5	184	26	M	10:10	196
5	5	M	14:7	194	16	M	17:2	185	27	M	16:3	190
6	6	M	11:1	162	17	F	14:7	163	28	M	13:1	175
7	7	F	13:5	116	18	M	12:6	121	29	M	13:9	129
8	8	F	13:1	96	19	M	11:10	92	30	M	12:7	86
9	9	F	12:1	85	20	F	11:7	81	31	F	8:9	86
10	10	M	16:9	59	21	M	17:0	68	32	F	16:5	64
11	11	F	9:3	69	22	M	8:0	63	33	M	15:7	49
Mean			13:1	151.5			13:4	152.0			13:11	151.5
SD			2:4	70.7			2:8	73.0			2:7	74.4

a. Subject Number.

b. Chronological Age given in years and months.

c. British Ability Scales composite score.

age of the sample was 13 years 5 months (SD 30.0 months), while mean Mental Age (Peabody Picture Vocabulary Test), equalled 4 years 1 month (SD 12.3 months). Thirteen subjects had participated some four months previously in the experiments reported in Chapter 5, while eight subjects had last participated in experiments conducted over one year prior to the present study. Twelve subjects were experimentally naive.

Apparatus

The tasks were presented using a 32K BBC(B) micro-computer, single disk drive, and colour monitor, as described in previous experiments. All sessions were conducted in a separate, quiet experimental room adjoining the classrooms and lasted approximately 20-25 minutes. Sessions were conducted once daily on consecutive weekdays.

Design

A mixed factorial design was employed in the study. Prompt type (size, intensity, no prompt) was a between-subjects variable with separate groups each receiving one of the above types of fading. The within-subjects variable was discrimination task (size, intensity). Each subject received both discriminations, the order of presentation being counterbalanced across subjects.

Stimuli and the CR/NCR manipulation

Progressive manipulations along the size and intensity dimensions generated values for seven levels of size and seven levels of intensity respectively. This involved the gradual increase of diameter for the size dimension, and of pixel density for the intensity dimension.¹ The values selected are presented in Table 6.2.

Table 6.2: Stimulus Values Employed in the Fading Programmes

Level ^a	Size (Diameter cm)	Intensity (% pixels on)
1	- ^b	-
2	1.6	0.0
3	2.4	12.5
4	3.2	25.0
5	4.0	50.0
6	4.8	75.0
7	5.3 ^c	87.5 ^c
	5.4	100.0
	5.6	

- a. Values at levels 1 to 6 were used in fading S-. Level 7 values were used only for S+
- b. Dash indicates S- was a blank space on the initial step.
- c. Difficulty of the discrimination was manipulated by varying the S+ values.

Values at levels 1 to 6 were employed in the manipulation of S- during fading on either the size or intensity dimension. Level 7 values were employed only for S+ in order to produce the criterion discriminations. The criterion tasks employed only one relevant cue, the values of the second cue being identical in both S+ and S-. The criterion size discrimination was between levels 6 and 7 on the size dimension, with intensity held constant at level 6, and the criterion intensity discrimination was between levels 6 and 7 on the intensity dimension, with size held constant at level 6. Figure 6.1 presents the criterion size and intensity discriminations.

Size fading on both the size and intensity tasks involved increasing S- through size levels 1 to 6. Similarly, intensity fading on both the size and intensity tasks involved increasing S- through intensity levels 1 to 6. This process is most clearly illustrated by reference to Figure 6.2 which presents the size and intensity fading programmes for each of the discrimination tasks.

For the purpose of comparison between CR and NCR fading it is important to stress that the stimulus values involved in the fading of the size cue were identical whether the size cue was CR or NCR. Similarly, intensity fading involved fading through an identical set of values in both CR and NCR intensity fading programmes (see Figure 6.2).

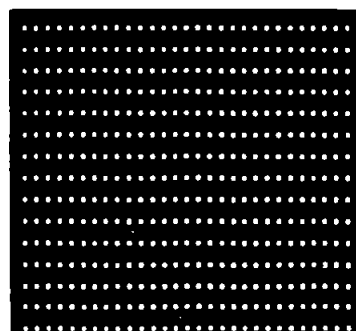
CR and NCR fading thus differ only in the relation of the prompt cue to the final discrimination. CR fading involved initially ⁹exagerating and then

1. A pixel is the smallest definable unit of the micro-computer graphics screen. The pixel can be defined as 'on' or 'off' i.e., lit or unlit, against a black background. Gradations in intensity were produced by defining tones on a 4x4 pixel grid. With all 16 pixels switched on intensity was maximum (100%). By reducing the number of pixels switched on in the grid to 14, 12, 8, 4, 2, and 0, gradations in intensity of 87.5%, 75%, 50%, 25%, 12.5%, and 0% respectively were formed. The tone generating program was published by Mr Peter Sandford in the January 1985 issue of Acorn User.

S+



S-



Size
Discrimination

Intensity
Discrimination

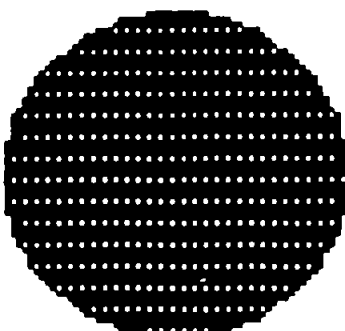
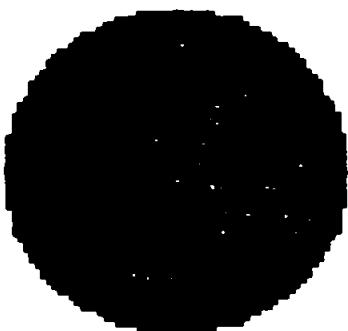
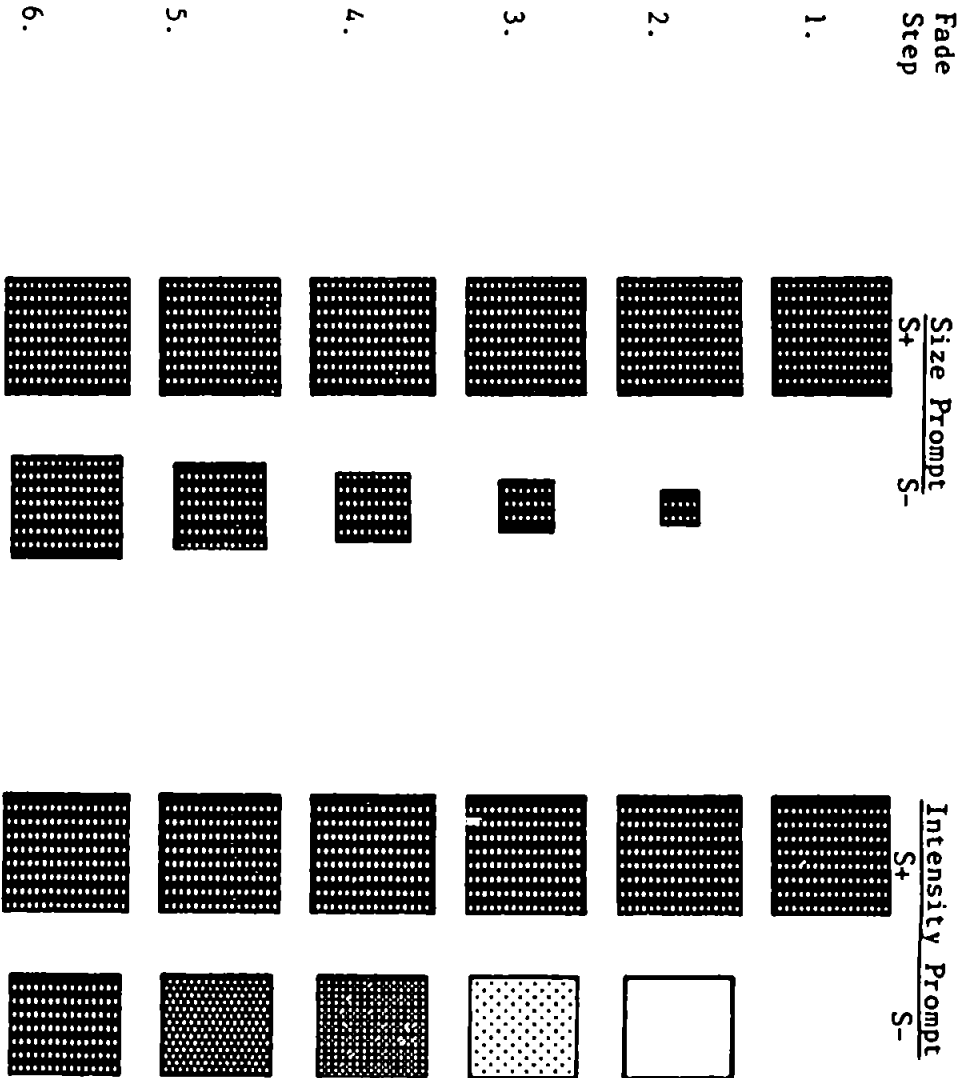


Figure 6.1: Size and intensity criterion discrimination tasks.

SIZE DISCRIMINATION



INTENSITY DISCRIMINATION

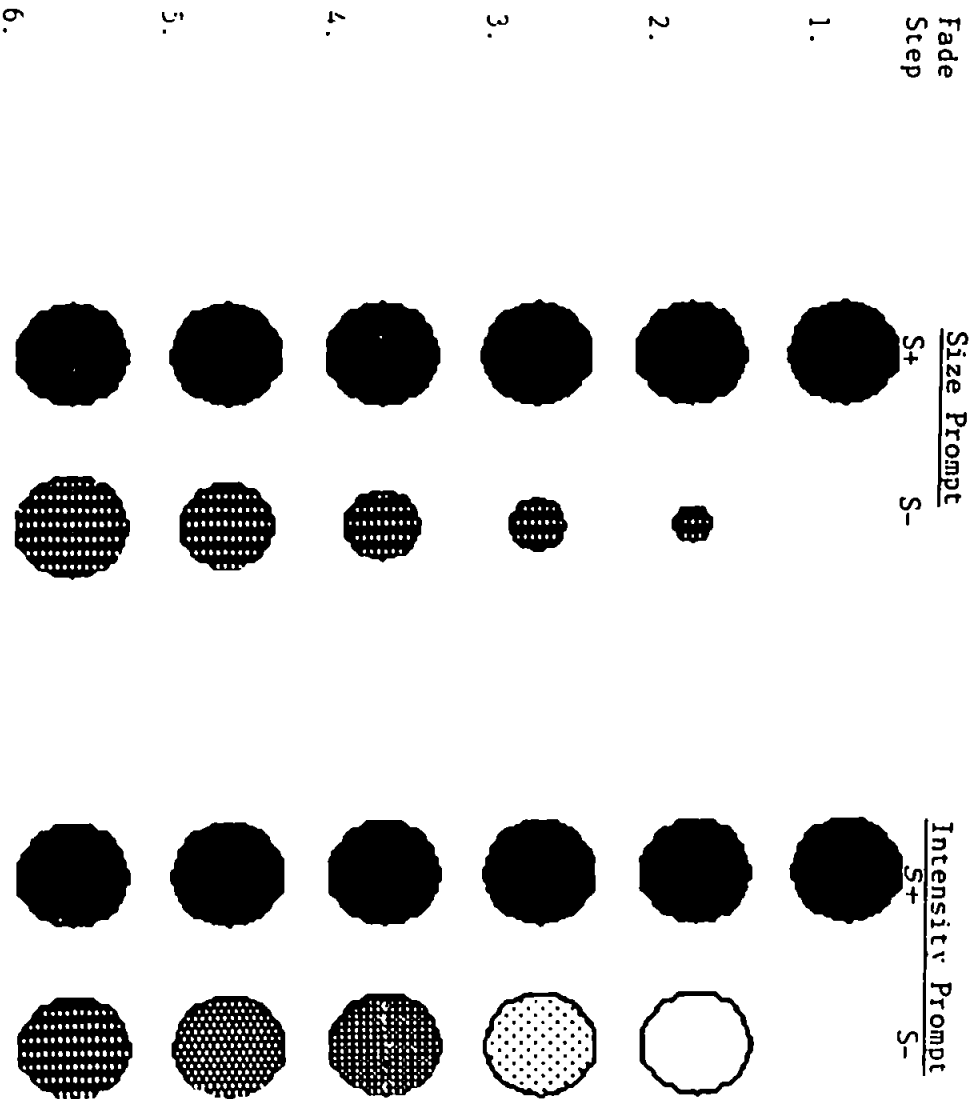


Figure 6.2: Illustration of the steps involved in the size and intensity fading programmes for both the size discrimination (upper figure) and intensity discrimination (lower figure).

fading the cue which ultimately would form the basis of the discrimination. For the size discrimination this was an ex^gaggeration of size, and for the intensity discrimination an exaggeration of intensity. NCR fading involved adding a cue that was unrelated to the dimension on which the discrimination would ultimately have to be made, i.e., a size cue for the intensity discrimination and an intensity cue for the size discrimination.

In both CR and NCR fading the addition of the prompt cue should make the discriminations easy to solve in the early stages. However, the programmes differed as successful acquisition after NCR fading would require the transfer of correct responding from the prompt to criterion cue, while this was not required by CR fading since prompt and criterion cues were drawn from the same stimulus dimension.

Procedure

All subjects were first given pre-training, as described in Experiment 1, to ensure familiarity with the apparatus. During subsequent training, the instructions given to subjects, reinforcers and reinforcement contingencies, and inter-trial intervals were as described for Experiment 1. A non-correction procedure was again employed throughout training, where any button press blanked the screen before the presentation of the next trial. Again, if the child failed to respond within six seconds, or attempted to elicit a direction from the experimenter before responding, one non-directional prompt such as "Which picture will play the tune?" was used. If the child still failed to respond an error was scored. The learning criterion for all tasks was 10 consecutive, unprompted, correct responses. Training was discontinued if the criterion was not achieved after a maximum 175 trials.

Size Fading (Group 1)

The procedure involved six steps that differed in the level of prompt presented along the dimension of size. Initially, $\underline{S_-}$ was a blank space to enhance the probability that subjects would respond to $\underline{S_+}$. Subsequent steps progressively increased the size of $\underline{S_-}$ while $\underline{S_+}$ remained constant throughout. This six step sequence was identical for both size and intensity discriminations (see Figure 6.2).

A criterion of two consecutive correct responses were required to advance through each fading step, and a back-up procedure was employed whereby any two errors on a step returned the subject to the previously mastered step. No step could be advanced through, even on a second or third attempt, until the criterion had again been fulfilled. Once five consecutive correct responses were made in the absence of fading (Step 6) the programme was completed and any subsequent errors failed to reinstate the programme. The learning criterion was attainable only after the fading programme had been successfully completed. The final fading step, where no prompts were given, was identical to trial-and-error training.

Intensity Fading (Group 2)

The programme consisted of six steps which progressively increased the intensity of $\underline{S_-}$, while $\underline{S_+}$ remained at constant intensity throughout training. Initially, $\underline{S_-}$ was a blank space to enhance the probability that subjects would respond to $\underline{S_+}$. Subsequently, the intensity of $\underline{S_-}$ was gradually increased by systematically incrementing pixel density in $\underline{S_-}$. The fading sequence was identical for both size and intensity discriminations (see Figure 6.2).

The criteria for step advancement and the back-up procedure were the

same as those adopted in the size fading programme, and the learning criterion attainable only after the programme had been successfully completed. The final fading step (Step 6) was identical to both Step 6 in the size fading programme, and to the trial-and-error training condition.

Trial-and-Error Training (Group 3)

This procedure followed the traditional simultaneous discrimination procedure and was identical to the preceding training programmes except that no prompts were added to the training stimuli.

Task Difficulty

There was considerable variation in mean BAS composite ability scores between the matched sets of subjects, ranging from 285.0 (Set 1) to 60.3 (Set 11). Training tasks of a single level of discriminability were considered inappropriate due to potential problems of both ceiling and floor effects. Therefore, the difficulty of the discriminations was varied between two sub-groups comprising Sets 1 to 5 (mean BAS 216.0) and Sets 6 to 11 (mean BAS 98.0).

Difficulty of the size discrimination was manipulated by variation in the diameter of \underline{S}_+ . For the more able subjects (Sets 1 to 5) the diameter of \underline{S}_+ equalled 5.3cm. A less complex discrimination was presented to Sets 6 to 11 by increasing \underline{S}_+ diameter to 5.4cm or 5.6cm. For the Intensity discrimination the value of \underline{S}_+ was manipulated so that Sets 1 to 5 again received a more complex criterion discrimination (87.5% vs. 75%) than Sets 6 to 11 (100% vs. 75%).

Results

A 3 (treatment) X 2 (task) X 2 (complex vs. simple discrimination) mixed analysis of variance for number of errors, revealed significantly more errors were emitted on the complex discriminations ($F(1,27) = 7.67, p < .025$), and produced a significant main effect of treatment ($F(2,27) = 6.53, p < .01$). No interaction terms reached significance. Newman-Keuls multiple comparisons for the treatment effect showed size fading and intensity fading groups did not differ significantly, but both produced significantly fewer errors than trial-and-error training ($p < .05$ in both cases). Table 6.3 presents the number of errors for each subject on each discrimination.

The treatment main effect demonstrates the superiority of prompt fading over trial-and-error training, but confounds CR and NCR training. However, planned parametric trend tests showed the predicted linear trends for increasing errors with CR, NCR, and trial-and-error training were significant for both the size discrimination ($F(1,27) = 9.12, p < .01$), and intensity discrimination ($F(1,27) = 4.28, p < .05$). Figure 6.3 presents this data graphically.

The learning criterion was not attained in six cases where discriminations were trained with a trial-and-error procedure, four cases of training with NCR fading, and for one case of CR prompt training. Hence, CR fading was the most effective procedure in facilitating acquisition of the tasks. Instances of unsuccessful training were evenly distributed across the first ($n=5$) and second ($n=6$) training tasks the subjects received.

If the learning criterion was not attained following NCR fading or trial-and-error training, the discrimination was subsequently trained with a CR fading programme. All four subjects who initially failed to acquire

Table 6.3: Number of Errors for Each Subject on Each Discrimination

Set	Size Discrimination			Intensity Discrimination		
	Size Prompt	Intensity Prompt	Trial & Error	Size Prompt	Intensity Prompt	Trial & Error
1	1	0	1 ^a	56 ^a	38 ^a	3
2	3	0	94 ^a	4	5	2 ^a
3	1	18	68	6	7	82 ^a
4	1	5 ^a	2 ^a	52 ^a	29	86 ^a
5	1	52 ^a	88 ^a	59 ^a	20	101 ^a
6	3	9	0	3	2	11
7	1	13	6 ^a	0	2	4
8	3	39	84 ^a	3	0	8
9	6	17	30	7	25	6
10	17	1	5	8	0	13
11	11	3	19	1	0	37
Mean	4.4	14.2	36.1	18.1	11.6	32.1
SD	5.2	16.8	39.1	24.3	13.8	38.5

a. The subject failed to meet the learning criterion in the maximum of 175 trials.

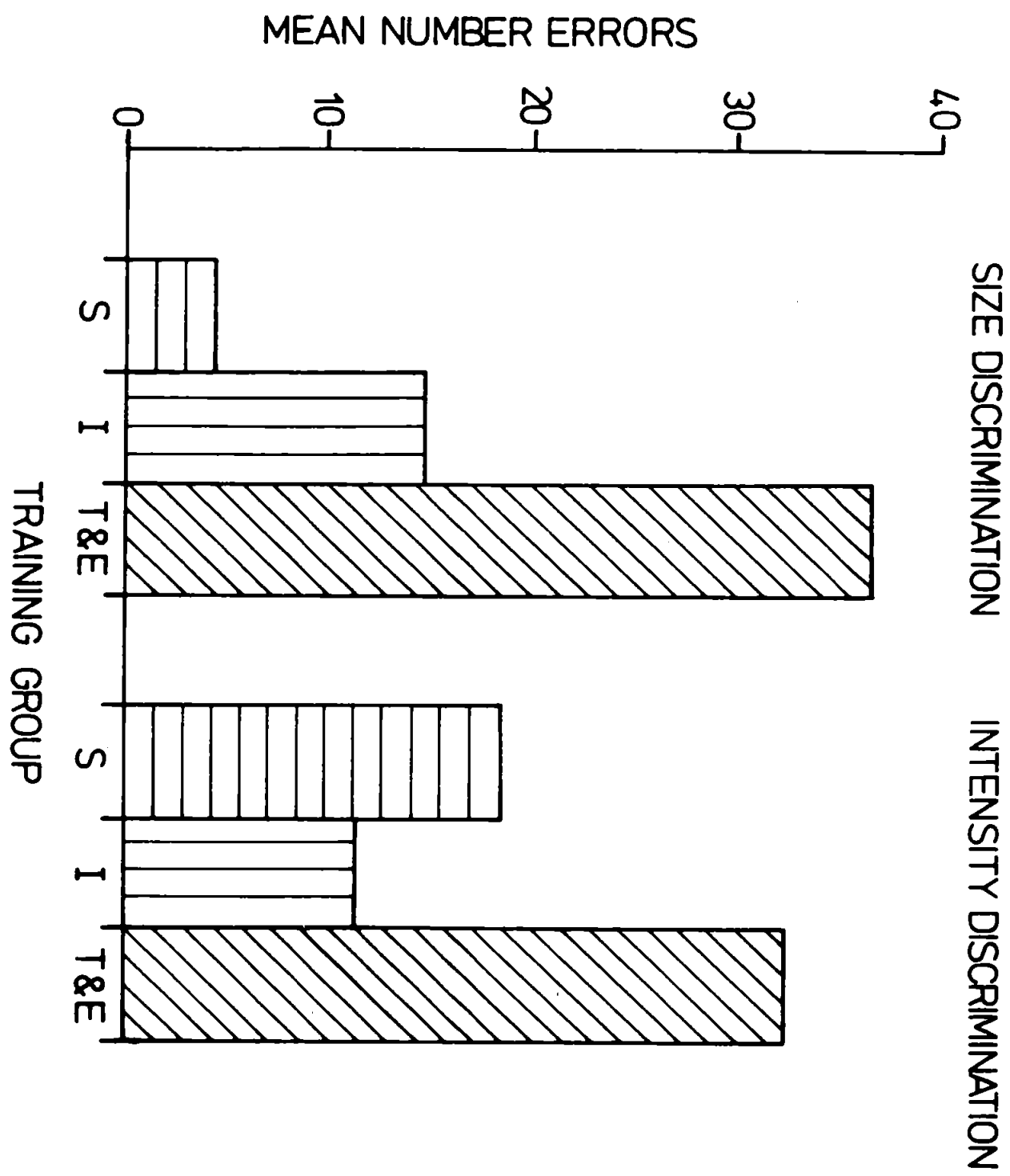


Figure 6.3: Mean number of responses to S- (errors) emitted by each group on the two discrimination tasks. (S= Size fading; I= Intensity fading; T&E= Trial-and-error training).

discriminations with NCR fading acquired the discriminations when subsequently trained with CR fading. Five subjects failed to acquire discriminations with trial-and-error training (S27 failed to acquire both discriminations). Subsequent CR fading resulted in successful acquisition in four of these six cases. Table 6.4 presents the results for all subjects receiving additional CR fading.

After 175 trials of training without successful acquisition the discriminations were often acquired extremely rapidly upon introduction of the CR programme. This is clearly illustrated in the trial-by-trial analyses of performance for S5 (NCR size fading / CR intensity fading), and S16 (NCR intensity fading / CR size fading) presented in Figure 6.4.

However, subjects who had first received trial-and-error training had greater difficulties acquiring the task with subsequent CR fading (mean number of trials: 100.7; mean number of errors: 30.7), than those subjects who had first received NCR fading (mean number of trials: 45.3; mean number of errors: 9.0).

Discussion

The results of this study can be summarized as follows;

1. Size fading and intensity fading groups did not differ significantly in overall number of errors, but both produced significantly fewer errors than the trial-and-error training group.
2. There were significant linear trends for increasing number of errors across CR, NCR, and trial-and-error training on both the size discrimination ($p < .01$), and intensity discrimination ($p < .05$).

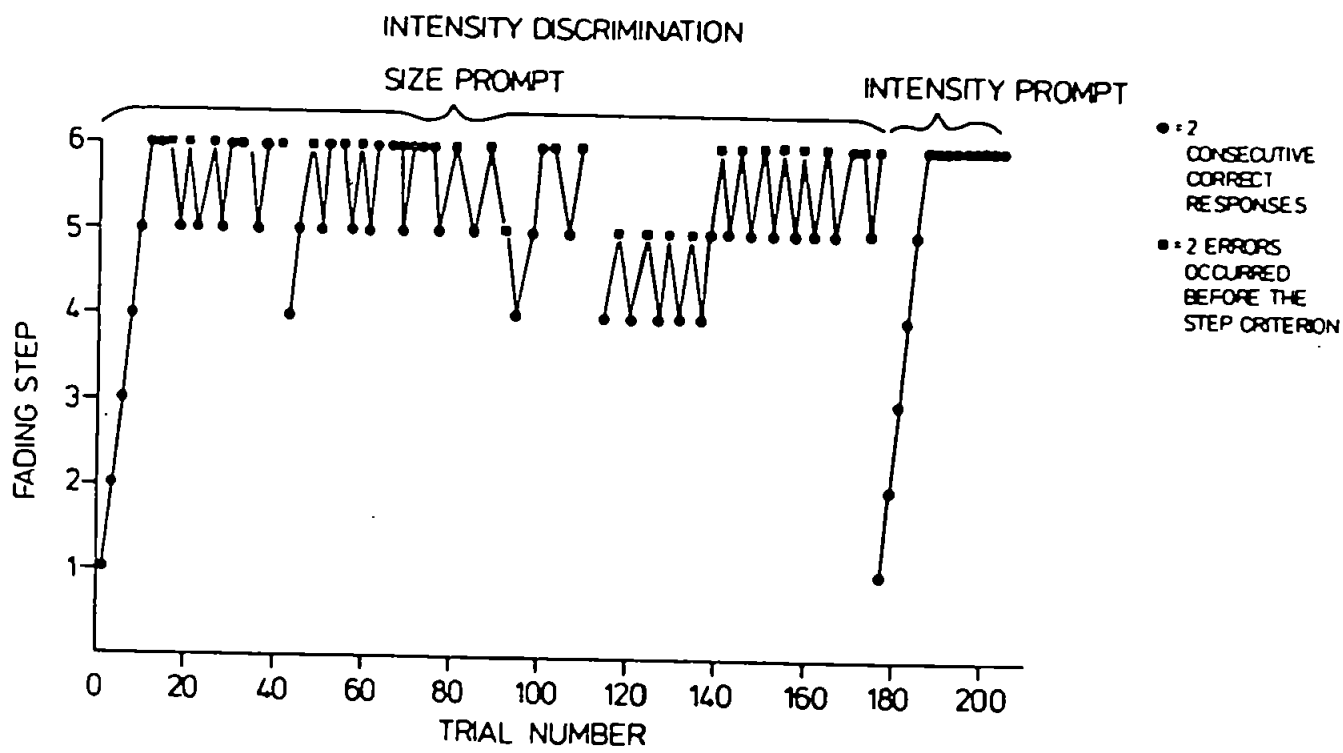
Table 6.4: Results of Retraining with Criterion-Related (CR) Fading Following Failure to Acquire Discriminations With Non-Criterion-Related (NCR) Fading or Trial-and-Error Training (T&E) During Initial 175 Trials

Subject Number	Initial Training	^a Task	Second Training	^b Criterion Acquired	Trials	Errors
16	NCR	S	CR	1	49	13
1	NCR	I	CR	1	20	0
4	NCR	I	CR	1	83	22
5	NCR	I	CR	1	29	1
24	T&E	S	CR	1	23	2
27	T&E	S	CR	1	39	6
30	T&E	S	CR	0	175	58
25	T&E	I	CR	1	62	19
26	T&E	I	CR	1	130	39
27	T&E	I	CR	0	175	60

a. S= Size; I= Intensity.

b. 1 indicates the learning criterion was acquired; 0 indicates the learning criterion was not acquired.

SUBJECT 5



SUBJECT 16

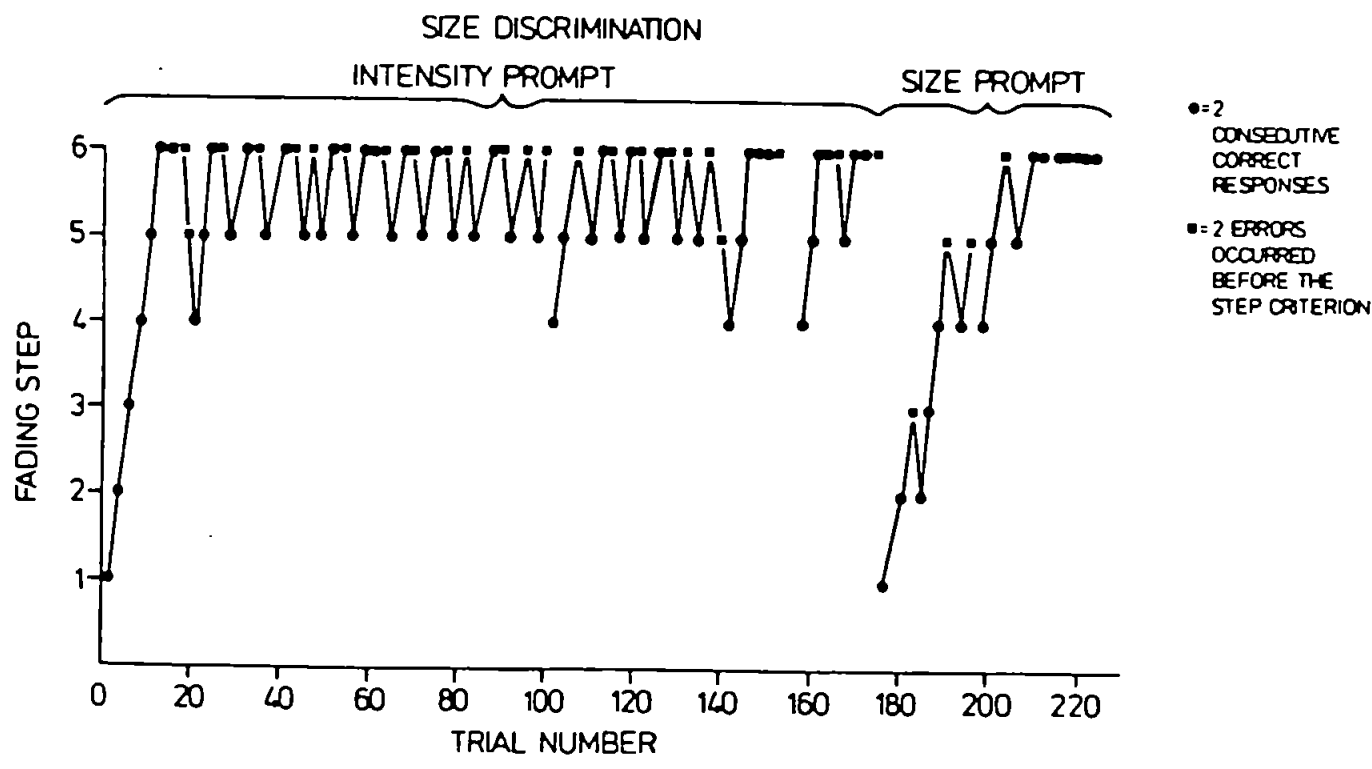


Figure 6.4: Trial-by-trial performance of S5 (upper figure) and S16 (lower figure) during first (NCR) and second (CR) training phases.

3. Fewer failures to acquire the discriminations were observed following CR fading than either NCR fading or trial-and-error training. Furthermore, in all cases where discriminations were not acquired with NCR fading, subsequent CR fading resulted in successful and often rapid acquisition.

The results of this study demonstrate that fading procedures were superior to trial-and-error training, on both measures of effectiveness (the number of children acquiring the trained discriminations), and efficiency (the number of errors emitted during discrimination learning). These results therefore provide further confirmation of the findings of previous experiments concerning the efficacy of programmed training techniques (e.g., Experiments 1, 2, 4, and 7).

The present results also indicate the superiority of CR over NCR fading in teaching visual discriminations to severely mentally handicapped children. Identical intensity fading sequences, and identical size fading sequences (see Figure 6.2), were each significantly more effective when the faded cue was CR than when the cue was NCR. Furthermore, this superiority was consistent across all combinations of prompt and training dimensions; the most effective procedure for each discrimination involved CR fading, irrespective of whether fading was conducted along a size or intensity dimension. For example, an intensity fading sequence was shown to be both; (i) more effective than a size fading sequence on the intensity discrimination; and (ii) less effective than the size fading sequence on the size discrimination. Most importantly, however, since within-stimulus manipulations were employed in all fading programmes, the results cannot be ascribed to confounding with the extra-stimulus variable (Schilmoeller & Etzel, 1977; Richmond & Bell, 1983). The results therefore increase the

confidence with which the observed effects can be directly ascribed to CR versus NCR stimulus manipulations.

It is interesting that subjects who received prior trial-and-error training were less successful during subsequent CR retraining than subjects who first received NCR fading (see Table 6.4). In particular, S27 and S30 both failed to acquire tasks with CR retraining following unsuccessful trial-and-error training. These results serve to reiterate one of the conclusions drawn from Experiment 6: programmed training procedures, including CR fading procedures, may fail to result in task acquisition where the subject has acquired a history of considerable errors during prior unsuccessful training of the task.

It was hypothesised that the failure of S27 and S30 to acquire tasks with CR retraining might be attributed to perseverative error strategies developed as a result of prior trial-and-error training. However, although both subjects did exhibit position perseveration habits during CR retraining, they had not previously exhibited such strategies. Furthermore, those subjects who did exhibit perseverative error strategies during initial trial-and-error training (S25 and S26 showed position habits, and S24 showed an alternation bias), subsequently acquired the tasks during CR retraining. While no simple perseverative error strategy could be identified in the performance of S27 and S30 during prior trial-and-error training, the adverse effect on subsequent learning of a history of errors was also observed in Chapter 5. Sidman and Stoddard (1967), and Touchette (1968), have also reported failures to acquire a task with programmed training following earlier unsuccessful trial-and-error training on the task. Although the mechanism underlying the facilitative effect of prior NCR

fading compared to prior trial-and-error training is unclear, the result is congruent with the superiority of NCR fading over trial-and-error training reported in the main analyses.

Failures of acquisition after NCR fading were characterized by perseveration in responding to the prompt cue. This is seen clearly in Figure 6.4. For both S5 and S16 correct responding is high throughout attenuation of the NCR prompt (Steps 1 to 5) but with complete removal of the prompt (Step 6) performance is disrupted and many errors are emitted. A similar pattern of responding was observed in the trial-by-trial analyses reported in Experiment 2 (see Figures 4.3 and 4.6). The difficulty appears to be located in transferring correct responding from the prompt to the criterion cue. However, the efficiency of CR fading in this regard can be seen in the CR phases of Figure 6.4, where the introduction of CR fading resulted in rapid acquisition of the previously unacquired discriminations. Similar results were observed for S1 and S4 (see Table 6.4).

Since the success of training with CR cues is directly predicted from an analysis of fading in terms of overshadowing, the present results lend clear support to the analysis of fading forwarded in Chapter 5. It will be remembered that overshadowing occurs when the control exerted over the discriminative response by one cue is reduced by the presence of a concurrent second cue. The stimuli in the discriminations trained with NCR fading did contain multiple relevant cues, i.e., the cue distinguishing the criterion stimuli and the additional prompt cue. In contrast, discriminations trained with CR fading contained only a single relevant cue, as prompt and criterion cues were drawn from the same dimension.

Overshadowing may therefore be a problem where subjects are required to transfer to a new cue at the cessation of fading; and this is required only after NCR fading. The subjects who failed to acquire discriminations trained with NCR fading may therefore have learnt to discriminate the prompt cue to the detriment of the criterion cue, observing increasingly subtle differences between $\underline{S}+$ and $\underline{S}-$ along the prompt dimension during fading to the exclusion of the criterion dimension. This interpretation is supported by Doran and Holland (1979), who observed that unsuccessful NCR training was characterized by exclusive control by the fading cue, while successful NCR training resulted in both prompt and criterion cues acquiring control over responding during fading. This analysis will be reviewed further in the concluding chapter.

However, the NCR method was not invariably ineffective. NCR fading was found to be superior to trial-and-error training; a result also reported by Richmond and Bell (1983). One factor influencing successful transfer from NCR prompts was the discriminability of the criterion task, since all but one of the subjects who failed to acquire the tasks received the complex size and intensity discriminations (see Table 6.3). Koegel and Rincover (1976), and Smeets and Lancioni (1981), have also reported that fading procedures were more effective in training simple rather than complex form discriminations. The present study extends this finding in a more controlled situation, by employing standard size or intensity discriminations in which discriminability was manipulated only through small variations in the size or intensity of $\underline{S}+$. During identical fading sequences, transfer from the prompt to the criterion cue occurred more readily when the criterion cue was more discriminable (larger size or intensity differences between $\underline{S}+$ and $\underline{S}-$) than when the training cue was less

discriminable (smaller size or intensity differences between S₊ and S₋). In contrast, the success of CR fading appeared less dependant upon the discriminability of the criterion cue, and CR fading proved extremely effective in facilitating the acquisition of low discriminability tasks, not acquired with NCR fading.

However, further research is necessary to determine why some subjects in the present study were successful in transferring responding from the NCR prompt to the criterion cue on the complex discriminations, while others were not. Successful transfer did not appear to be related to order of task presentation, participation in previous experiments, or to individual differences in BAS composite score. Even within the class of subjects who were successful in transferring responding to the criterion cue, and indeed even within the CR fading conditions, wide variations in rate of discrimination acquisition and number of errors were observed (see Table 6.3).

Despite the frequent observation of such individual variability in discrimination performance among severely mentally handicapped children (e.g., Berkson, 1966; Berkson and Landesman-Dwyer, 1977; Ellis et al., 1982), the influence of individual difference factors has received relatively little attention. Individual variability has frequently been treated as a source of error variance in the search for either treatment main effects, or for universal laws of learning (Gagne, 1967; Scott, 1978). However, increasing confidence in the significance of the overall effect of treatment variables (e.g., CR versus NCR stimulus manipulations), may encourage further research concerning the influence of individual difference variables in determining the success of discrimination training. In the

next chapter, research will be reported which attempts to determine whether part of the variance in the discrimination performance of severely mentally handicapped children can be meaningfully related to stable dimensions of individual difference.

CHAPTER 7

Individual Differences and Discrimination Learning

In Severely Mentally Handicapped Children

Chapter 7

Individual Differences and Discrimination Learning in Severely Mentally Handicapped Children

Overview

In organizing this chapter a decision was taken to index the material by sections. This appeared necessary since the chapter contained a large and varied amount of data, which did not fit easily into a standard report format. The aim of this organisation was to prevent needless repetition of material, and cross-references between sections will be made where appropriate, to reduce the presentation of redundant information.

Briefly, the organization of sections is as follows: section 7.1 introduces the study of individual differences in the discrimination learning of developmentally impaired individuals. This material was more fully described in Chapter 2, which presented the theoretical introduction to the present chapter. Therefore, Chapter 2 is only briefly reviewed, before specific hypotheses to be assessed in the present research are described. Next, Section 7.2 introduces and summarizes the assessments of individual differences, and the discrimination learning measures, employed in the present study. Brief descriptions of the variables, the rationale for their selection, and procedural details of data collection are presented. Subsequently, the results obtained in the present research are presented, in two separate sections. Section 7.3 describes the subject sample in terms of each of the collected variables, and presents means, distributions of scores, etc. This section also considers internal analyses of the variables, such as factor analyses of a teacher-completed

questionnaire assessing aspects of the child's classroom behaviour, reliability assessments, etc. Section 7.4 describes the results of the intercorrelation of variables. The primary aim of this analysis was to determine which (if any) variables accounted for significant amounts of variance in the discrimination learning measures. In addition to simple correlation, the results of partial correlation, multiple regression, and ANOVA are reported in an attempt to evaluate the independent contributions of each of the individual difference variables. Section 7.5 discusses the results reported in sections 7.3 and 7.4, and further refinement and interpretation of the results is conducted. Lastly, in this section, the implications of the results for theoretical conceptions of the processes underlying individual performance are discussed, and the implications for discrimination training with severely mentally handicapped children are elucidated. Finally, Section 7.6 presents a summary of the main results and conclusions arising from the study.

7.1 Introduction

In Chapter 2 it was argued that in addition to properties of the discrimination task and training techniques, characteristics of the individual are also important in determining the rate and outcome of learning. However, the influence of individual difference factors in the discrimination learning of severely mentally handicapped children has received scant attention (Gagne, 1967; Scott, 1978). This might in part result from the historical division between the study of individual differences and the study of learning, which derive from divergent psychological traditions (Cronbach, 1957). Learning theorists have predominantly been concerned to identify universal laws of learning, in which trait-orientated concepts are not at home (Estes, 1981). Additionally,

many studies in applied settings treat each individual as an isolated and discrete case, which does not allow easy comparison of subjects, or employ small 'n' designs, which do not facilitate the use of correlational analyses and cannot easily be combined for meta-analytic investigation. Larger n's frequently appear only in the context of comparative group research. Such research, concerned as it is with attempts to identify a cognitive deficit specific to the mentally handicapped population, tends to minimize the role of individual differences in performance through an emphasis on mean differences between groups (e.g., Ellis, 1970; Zeaman & House, 1963; Heal & Johnson, 1970). In sum, individual variability has frequently been treated as a source of error variance in the search for either a generalized cognitive deficit, for treatment main effects, or for universal laws of learning. None of these approaches facilitate the gathering of data concerning stable dimensions of individual difference, which may be associated with success in discrimination training. Research reported in the present chapter will attempt to determine whether part of the variance in discrimination performance can be meaningfully ascribed to stable dimensions of individual difference.

In the present research data has been collected on several dimensions of individual difference, and a substantial data-base for the detailed investigation of individual difference variables has been acquired. The measures obtained include; global ability estimates (e.g., PPVT MA/IQ); rating scale assessments of attention/distraction and inhibition/excitation (Evans, 1975); and selected assessments of cognitive abilities from the British Ability Scales (BAS) (Elliot et al., 1978). Measures of performance during discrimination learning were also obtained. Trials to criterion and number of errors were recorded during acquisition of a 2-choice simultaneous discrimination with multiple relevant and redundant dimensions (form,

colour, and size). A measure of 'breadth of learning' was also derived by assessing the number of dimensions responded to following acquisition of the above discrimination. The selection of these measures was informed by a review of research concerning the empirical measurement of individual differences in developmentally impaired individuals (see Section 2.3). Reference is made to Chapter 2 for a full and detailed review of relevant studies.

Hypotheses

In general, the intercorrelations between all variables collected are of interest, since no previous study has simultaneously collected data on each of these dimensions. However, several specific issues were also addressed.

(1) Zeaman and House (1967) have suggested that general intelligence (IQ) may be significantly correlated with discrimination performance. However, this finding is by no means universally supported (see section 2.1). Additionally, many of the studies reviewed by Zeaman and House have involved comparisons between groups of mentally handicapped and normal intelligence children. The present study will seek to further clarify the relationship between global ability estimates (IQ, MA) and discrimination performance, while focussing specifically on the performance of severely mentally handicapped children.

(2) In view of the conflicting results concerning the relationship between global ability measures and success in discrimination training, the research will also seek to determine whether specific psychometric scales, assessing 'task-relevant' abilities (e.g., short-term memory, perceptual

matching, spatial ability, etc.), may be more highly correlated with discrimination performance than summary measures such as MA and IQ. Six scales of the BAS were employed for this purpose.

(3) There has been no independent replication of the factor structure of the classroom rating scale reported by Evans (1975) and Evans and Hogg (1984). The present study will attempt to replicate the factor structure of the scale, and assess the reliability of the factors, necessary in the absence of any independent replication and the claim that the scale may be a useful instrument for measuring individual differences in mentally handicapped children (Evans & Hogg, 1984). The research will also attempt to replicate the correlations between the scale and the EPVT, reported by Evans and Hogg (1984). Finally, the research will also report detailed validity correlations not previously reported. These will include investigation of the relationship of the extracted factors with the BAS scales, performance during simultaneous discrimination learning, and breadth of learning, all previously unreported.

(4) Two-stage theories of discrimination learning (e.g., Sutherland & Mackintosh, 1971; Zeaman & House, 1963; 1979) emphasise the importance of attentional processes in discrimination learning. Specifically, the latter theory presumes that mentally handicapped individuals have difficulty in learning to attend to relevant stimulus dimensions. Although 'attention' in these terms is a cognitive concept referring to information processing, attention also has a behavioural component (Woods, 1988). The present study asks whether teacher ratings of 'attentional' aspects of behaviour may be correlated with performance during discrimination training. Siegel et al., (1985) failed to find a significant correlation between teacher ratings of mentally handicapped children's inattention and their discrimination

performance, although significant correlations between the inattention measure and MA and IQ were reported (see Section 2.3). However, the measure of attention consisted of teacher rating on a single dichotomously scored item. The present research will seek to determine whether a more differentiated molar measure of attention (the AD scale, Evans, 1975) will correlate with variables derived from discrimination performance.

(5) A second 'attentional' measure, more directly in accord with the manner in which the attention concept has been used by Zeaman and House (1963, 1979), was also obtained. This measure concerned breadth of learning (BOL), and was a measure of the number of stimulus dimensions a subject responded to following acquisition of a discrimination with multiple relevant stimulus dimensions. BOL has been considered a measure of 'selective attention', while the AD scale has been described as a measure of 'sustained attention' (see Section 2.3). Prior research has reported no significant correlation between such measures of 'sustained' and 'selective' attention (Siegel, et al., 1985). However, as noted above the measure of inattention employed by Siegel et al. was relatively undifferentiated. In the present study, an attempt will be made to establish the construct validity of rating scale measures of pupils attention by determining the correlation between the AD scale and BOL.

(6) As with teacher ratings of attention, some research has reported that BOL may be positively correlated with MA (e.g., Schover & Newsom, 1976; Wilhelm & Lovaas, 1976, Bailey, 1981). However, Frankel, Simmons, Fichter, and Freeman (1984) do not report significant correlations between MA or IQ and overselectivity, and maintain that "stimulus overselectivity seems to be differentially associated with the diagnosis of autism rather than a manifestation in the learning data of organisms of low mental age or IQ"

(p153). The present research will seek to provide further data pertaining to this issue.

Method

7.2.1 Subjects

The subject sample comprised 80 severely mentally handicapped children drawn from the two special (SLD) schools located in the Plymouth city area. The sample from School 1 (n=42) consisted of all children attending the middle and senior schools, while the sample from School 2 (n=38) included all children from the junior, intermediate, and senior classes.

The Measures of Individual Difference

7.2.2 Peabody Picture Vocabulary Test-Revised (PPVT-R)

The Peabody Picture Vocabulary Test (PPVT) (Dunn & Dunn, 1981) was employed to obtain estimates of MA. Picture vocabulary tests are frequently employed for assessing mentally handicapped students, since no reading, or written or oral response, is required of the child. The instructions are also simple and easily understood by mentally handicapped children (Wheldall & Jeffree, 1974). Such methods are therefore particularly appropriate for non-verbal children. Form L was administered to all subjects. Age equivalents (MA) and standard score equivalents (SS) were derived.

7.2.3 British Ability Scales (BAS)

The British Ability Scales (BAS) (Elliot et al., 1978) appeared an

especially suitable psychometric instrument for this study for several reasons: (1) The scales are based on the Rasch latent trait model which has several advantages over traditional psychometric instruments. It provides sample-free ability estimates, thus there is no need to interpret the scores in terms of age norms. The ability score which a child obtains on any scale is related only to the number of correct items scored, and not to any consideration of the child's age or group membership (Elliot, 1983); (2) The scales are related to specific process areas, (e.g., short-term memory, perceptual matching, spatial ability, etc.). This facilitated the selection of scales on a 'task-relevant' basis; (3) The scales were designed to be applicable at chronological ages as low as two and a half years with children of normal intelligence; (4) All scales emphasise the provision of teaching sequences and demonstration items, particularly if the child fails early items. This was considered an especially important factor when assessing mentally handicapped students.

The scales selected for use in the project are presented in Table 7.1. The Visual Recognition, Copying, and Matching Letter-Like Forms scales were selected since short-term memory and perceptual matching processes are necessary prerequisites for successful discrimination learning, and were therefore considered 'task-relevant' assessments. Block Design Level was included since visual-spatial abilities may also be relevant during discrimination learning. Finally, two scales were included that have been described as scholastic attainment scales (Elliot, 1983). In common with the Matching Letter-Like Forms scale, Early Number Skills also assesses visual matching skills, although using qualitative attributes (e.g., size) rather than identity relations. (e.g., matching short, intermediate, and long ladders with small, intermediate, and large houses). Visual classification skills are also assessed (e.g., selecting all small,

Table 7.1: BAS Scales employed in the Project

<u>Scale</u>	<u>Test Form</u>	<u>Process Area</u>
Visual Recognition (VR)	Test B	Short-Term Memory
Copying (COP)	Test A	Perceptual Matching
Matching Letter Like Forms (MLLF)	Test A	Perceptual Matching
Early Number Skills (ENS)	Test A	Retrieval and Application of knowledge
Word Reading (WRD)	Test A	Retrieval and application of Knowledge
Block Design Level (BDL)	Test B	Spatial Imagery

intermediate, and large buckets to match small, intermediate, and large spades). This scale may also therefore reflect relevant visual matching abilities. Lastly, the Word Reading scale was employed as more general measure of verbal learning.

7.2.4 Teacher Ratings of Classroom Behaviour: The IE2 Questionnaire

The IE2 questionnaire (Evans, 1975) consists of 23 items pertaining to the child's classroom behaviour (see Appendix A, part 1). A brief description of each of the items is presented in Table 7.2. The child's teacher is required to rate each of their pupils on a seven-point scale for each of the 23 items. Evans (1975) identified two main dimensions from a factor analysis of completed questionnaires for 138 mentally handicapped children, one factor relating to inhibition/excitation (IE) and the other attention/distraction (AD). Full details of the construction of the scale can be obtained in Evans (1975). Research reported by Evans (1975; 1982) (see section 2.3) suggests these dimensions may provide relevant information concerning aspects of the child's classroom behaviour and performance in discrimination learning tasks. Hence, in the present study all children's teachers were given the IE2 questionnaire, with instructions to complete all the items for each child in their class.

7.2.5 Discrimination Learning Measures

Subjects had first to successfully complete a simple screening task, for which assistance was provided if necessary. If subjects acquired this task, three measures of discrimination performance were subsequently obtained. Measures of trials to criterion and number of errors in acquiring a two-choice visual discrimination were recorded. Since the discriminative

Table 7.2: Brief Description of IE2 Items.

Item No.

- 1 Requires additional stimulation to continue a task:
always - never
- 2 Concentration is: poor - good
- 3 Capacity for work is: low - high
- 4 Movements are generally co-ordinated: well - poorly
- 5 Performance on a task tends to be disrupted by failure:
not at all - great extent
- 6 Reaction to a problem is: slow - fast
- 7 Perseveres for a long time: not at all - great extent
- 8 Speaks: indecisively - decisively
- 9 Speaks at length: not at all - great extent
- 10 In action is: extremely restrained - extremely impulsive
- 11 Speaks: slowly - quickly
- 12 Co-ordination of movements tends to vary when doing the
same task on diff. occasions: not at all - great extent
- 13 Performance on a task improves with success:
great extent - not at all
- 14 Listens to instructions well: not at all - all the time
- 15 Works well towards a set objective:
not at all - great extent
- 16 Speaks: softly - loudly
- 17 Responsive to praise: not at all - great extent
- 18 Is calm / excitable
- 19 Is easy / difficult to distract
- 20 Is inhibited / uninhibited
- 21 To get attention for a new task is: difficult - easy
- 22 Is upset by being told off: great extent - not at all
- 23 Actively seeks approval: always - never

stimuli differed on multiple relevant stimulus dimensions, a third measure concerned the number of stimulus dimensions responded to following acquisition of the task. These were the first tasks subjects performed, prior to participation in any of the experimental studies reported in Chapters 3 to 6.

Screening Task

All subjects first received a simple position discrimination, as described under pre-training in the preceding experimental reports. A single white square was presented randomly on either the right or left of the screen. A correct response (selection of the button beneath the stimulus) produced a tone from the computer and was rewarded with a small edible and verbal praise. An incorrect response produced no consequences. Initially, the experimenter modelled the correct response and provided extra physical, verbal, and imitative prompts whenever necessary. The criterion for successful completion of the task was 20 consecutive, unprompted, correct responses.

Two-Choice Discrimination Task

If subjects acquired the above screening discrimination, a second discrimination was subsequently presented. The discrimination task consisted of two simultaneously presented visual stimuli which differed on multiple relevant stimulus dimensions. The stimuli for the discrimination consisted of a large, pale blue, diamond (8cm high) and a small, yellow, circle (4cm high). Thus the stimuli differed from each other on three dimensions; size, colour, and form. For half the subjects the large, blue, diamond was designated S+, while for the other half the small, yellow,

circle was designated S+. The left/right position of S+ was varied randomly, with the constraint that it could not appear in the same position on more than three consecutive trials.

At the start of each session the child was given the directions described in Experiment 1. The procedure for dealing with non-responding, reinforcers and reinforcement schedules, were also as described in previous experiments. A non-correction procedure was again employed throughout training. All subjects received trial-and-error training. The learning criterion was 10 consecutive correct responses, and training was continued until the subject attained the learning criterion or to a maximum of 200 trials, whichever occurred first. The dependant variables collected were trials to criterion and number of discrimination errors.

Dimensional Testing

As soon as the subject attained the learning criterion for the above discrimination a dimensional testing phase was initiated. Test trials were alternated with stimulus complex trials which served to maintain the subjects responding and discrimination of the correct training stimuli. There were three types of test trials: a form test, 6cm green diamond vs. 6cm green circle; a colour test, 6cm pale blue 'H' vs. 6cm yellow 'H'; and a size test, 4cm green 'H' vs. 8cm green 'H'. The position of S+ was counterbalanced across probe trials so that position perseveration would result in chance level performance. The order of presentation of test trials was counterbalanced across subjects.

The whole series was repeated six times giving a total of 18 test trials. Including the additional stimulus complex trials the entire testing

session consisted of 36 trials. No responses during probe (test) trials were rewarded to prevent training of positive components. Subjects were given the following instructions; "Some of the pictures may look a little different, but I still want you to choose the winning picture. I have also got some work to do now, and I will tell you when you've finished what the winning pictures were". After reinforcing the first stimulus complex trial, the trainer moved to the far end of the room to complete his "work". This procedure was intended to minimize the likelihood that subject would interpret the absence of reinforcement from the trainer as an incorrect response.

If a cue was correctly selected on at least 5 of 6 probe trials for that cue, the cue was assumed to have been functional in learning. Since the discriminative stimuli differed on three dimensions (size, form, and colour), breadth of Learning was assessed by the number of cues the child responded to in the test phase.

Results

7.3 Analysis of the Assessments

7.3.1 CA, PPVT MA, and PPVT IQ

The mean CA of the sample was 13:10, (SD= 2:5, range= 7:11 - 18:0). PPVT MA was normally distributed with a mean of 4:3 (SD= 2:1, range= 1:9 - 12:10). Mean PPVT standard score (SS) was 26.8 (SD= 14.3, range= <20 - 83).

Due to the high chronological age and low level of performance of most subjects, it was necessary to employ supplementary norms tables in deriving SS (AGS, 1981). These tables provided standard scores for the range 39 through to <20. However, the distribution of standard scores was still

extremely positively skewed, with over 50% of the sample (42 children) receiving the same basal standard score (SS= <20). Consequently, MA/CA ratio IQs were calculated. In contrast to deviation IQ (SS), ratio IQ was normally distributed with a mean of 31.1 and SD of 13.2 (range 0 - 76). In the following analyses, 'PPVT IQ' will refer to ratio IQ.

7.3.2 BAS Scales

Table 7.3 presents the mean, range, and standard deviation for each of the BAS scales. Scores were fairly evenly distributed within each scale, with the exception of Block Design Level (BDL) and Word Reading (WRD). The distribution of scores on BDL during assessment in School 1 was found to be highly positively skewed; 75% of subjects passed only the first and least difficult item, or passed no items at all. As a result, BDL was excluded from the test battery during later assessments. The Word Reading scale also showed positive skew, with approximately 40% of subjects unable to read any of the test words. The Word Reading scale was therefore also excluded in the calculation of the BAS composite score, although retained in the test battery. The composite score (CPS) was derived by summing each subjects scores on the remaining four scales.

Table 7.4 presents the Pearson product-moment correlation matrix for the BAS scales. All correlations were extremely significant. The six scales were subject to principal components analysis, which extracted a single factor accounting for 68.1% of the total variance. All scales loaded heavily on this factor, which was identified as a general ability factor. The loadings were: COP .94197; ENS .91356; VR .86455; MLLF .82820; WRD .69320; and BDL .67135.

Table 7.3: Mean, Range, and Standard Deviation of the BAS Scales (N=80)

	VR	MLLF	COP	ENS	BDL ^a	WRD	CPS
Mean	47.53	26.85	36.89	38.03	14.63	20.35	149.29
Range	0-99	0-70	0-85	0-77	0-74	0-97	0-297
SD	27.72	18.18	28.07	26.60	19.78	24.96	94.70

Note. a. n=35.

Table 7.4: Pearson Product Moment Inter-correlations of the BAS Scales (N=80)

	VR	MLLF	COP	ENS	BDL ^a	WRD	CPS
VR	/	** .669	** .779	** .812	* .462	** .475	** .910
MLLF		/	** .745	** .675	** .498	** .471	** .825
COP			/	** .871	** .613	** .592	** .943
ENS				/	* .483	** .622	** .937
BDL					/	.350	** .573
WRD						/	** .592

Note. a. n=35; *. P<.01; **. P<.001

VR= Visual Recognition; MLLF= Matching Letter-Like Forms;
COP= Copying; ENS= Early Number Skills; BDL= Block Design
Level; WRD= Word Reading; CPS= BAS composite score.

The average of the coefficients of correlation among the four components of the composite (following Fisher Z transformations) was high ($r_{ii}' = .758$), further indicating that the composite is reasonably homogeneous. The composite may be presumed to provide a more precise and representative overall ability measure than any of the individual scales. Hence, with the exception of situations in which the correlation of a particular scale is of special interest, only composite score will be considered in subsequent analyses. The reliability of the composite was assessed through calculation of Cronbachs alpha and Spearman-Brown split-half reliability coefficients. Both measures indicated the composite was a reliable assessment ($r = .992$ and $r = .923$ respectively).

7.3.3 The Classroom Rating Scale

Factor Analysis of the IE2 Questionnaire

This section will examine the factor structure of the IE2 questionnaire to determine whether the factor structure reported by Evans (1975) is replicated. Evans (1975) extracted two major factors from the IE2, which were interpreted as attention/distraction (AD) and inhibition/excitation (IE) dimensions. Evans and Hogg (1984) factor analysed the subset of 16 items Evans (1975) had reported loaded highly on the AD and IE factors, and again extracted two factors. The aim of the present section is to verify this factor structure before examining the correlations between factor scores and other variables, which will be reported in Section 7.4.5.

Questionnaires were returned from nine teachers for a total of seventy-seven severely mentally handicapped children. All teachers had known the child in their role as class teacher for at least three months.

These ratings were subjected to principal components analysis, followed by varimax rotation (Evans, 1975; Evans & Hogg, 1984). Four factors extracted, using the conventional criterion of an eigenvalue greater than one. These factors accounted for a cumulative proportion of the total variance of 62.7%; Factor 1 accounting for 32.1%, Factor 2 for 13.3%, Factor 3 for 11.0%, and Factor 4 for 6.4% of the total variance. The factor loadings for items appear in Appendix A, part 2. The items that loaded most heavily on these four factors (i.e., $\pm .50$) were as follows (n.b., the poles of items with negative factor loadings have been reversed so that for all items the positive pole is presented on the left).

Factor 1

<u>Item No.</u>	<u>Item Description</u>
7.	Perseveres for a long time: great extent - not at all
1.	Requires additional stimulation to continue a task: never - always
3.	Capacity for work is: high - low
2.	Concentration is: good - poor
21.	To get attention for a new task is: easy - difficult
19.	Is difficult / easy to distract
6.	Reaction to problems is: fast - slow
14.	Listens to instructions well: all the time - not at all
15.	Works well towards a set objective: to a very great extent - not at all

Factor 1 was composed of nine items. Analysis of the content of the items suggested an attention/distraction factor.

Factor 2

<u>Item No.</u>	<u>Item Description</u>
10.	In action is: restrained - impulsive
18.	Is calm / excitable
20.	Is inhibited / uninhibited

Factor 2 contained three items, and was identified as an inhibition/excitation factor.

Factor 3

<u>Item no.</u>	<u>Item Description</u>
13.	Performance on a task improves with success: to a very great extent - not at all
17.	Responsive to praise: to a very great extent - not at all
23.	Actively seeks approval: always - never
22.	Upset by being told off: to a very great extent - not at all
5.	Performance on a task tends to be disrupted by failure: to a very great extent - not at all

Factor 3 was made up of five items. The content of these items led to identification of a factor reflecting sensitivity to reinforcing or punishing events in the classroom.

Factor 4

<u>Item No.</u>	<u>Item Description</u>
9.	Speaks at length: not at all - to a very great extent
8.	Speaks: indecisively - decisively
11.	Speaks: slowly - quickly

Finally, Factor 4 contained three items, and was identified as reflecting verbal expressiveness.

Interpretation

The ordering of factors in the terminal (rotated) solution differed slightly from that of the principle components analysis. Although little significance should be attached to such an observation (Nie et al., 1970) the factors will be discussed in this latter order.

Factor 1 was identified as an AD factor, and explained the largest amount of the total variance (31.6%). The item loadings for this factor generally replicate results reported by Evans (1975). All the items Evans identified as loading on his first factor (AD) also grouped together and loaded on the first factor extracted in the present analysis. One difference between the present results and those of Evans concerns the factor loadings for Item 6. Evans reported that Item 6 loaded most heavily on a second inhibition/excitation (IE) factor. However, Evans and Hogg (1984) reported Item 6 loaded most heavily on the AD factor. The present analysis supports the latter finding; Item 6 loads most heavily on the AD factor.

Factor 3, accounting for 11.0% of the total variance, consisted of five items that related to improvements in performance following success, responsiveness to praise, active approval seeking, reaction to being told off, and disruption of performance following failure. Low ratings on these items indicated a child whose performance on task was not affected by success or failure experiences, who was not responsive to praise, or upset by being told off, and who did not actively seek approval. The content of

these items led to identification of a factor relating to susceptibility to reinforcing and punishing events in the classroom (REW).

Two further factors were extracted. Factor 2 consisted of items 10, 18, and 20, and accounted for 13.3% of the total variance. These items concerned the dimensions restrained to impulsive, calm to excitable, and inhibited to uninhibited. Factor 2 therefore appeared to constitute an inhibition/excitation (IE) factor. Factor 4 consisted of items 8, 9, and 11, and accounted for 6.4% of the total variance. These items all assessed aspects of the child's speech. High ratings on these items identify a child who speaks at length, speaks decisively, and speaks quickly. Therefore, Factor 4 was interpreted as identifying verbal expressiveness (VRB). The fourth IE2 item assessing speech (Item 16: speaks softly-loudly) also loaded most highly on the VRB factor, although the loading of .40 was below the .50 criterion employed.

Both Evans (1975), and Evans and Hogg (1984), have reported that the above seven items loaded on a single factor (IE), and together constituted an IE scale. The present results suggest Evans's IE factor splits into two sub-factors; the main IE factor (Factor 2) and a separate factor containing the speech items (Factor 4).

The items loading on the VRB factor had low loadings on the IE factor following rotation, but had exhibited moderate loadings on the IE factor in the principle components analysis. Orthogonal factor rotations, such as varimax rotation, result in factors that are uncorrelated. It is possible that if correlations between factors were permissible, Factor 2 and Factor 4 may be positively correlated. If this was the case, it might indicate that the IE and VRB factors could be accounted for in terms of a common

higher-order factor. Consequently, an oblique rotation was also conducted to evaluate the factor structure resulting when correlation between factors was allowed.

The factor structure derived from the oblique rotation did not differ from the factor structure derived from the varimax rotation. Four factors with eigenvalues greater than one were again extracted, and the same items loaded on each of the four factors as in the varimax rotation reported above. Factor 2 and Factor 4 were not highly correlated ($r = .146$). (The factor loading resulting from the oblique rotation are presented in Appendix A, part 3). It is concluded that the IE and VRB factors represent independent and orthogonal dimensions.

Finally, a direct comparison was made with the analysis reported by Evans and Hogg (1984). Evans and Hogg analysed only the subset of 16 items identified by Evans (1975) as loading on the AD and IE factors. They identified two factors, an AD factor accounting for 37.5% of the variance, and an IE factor accounting for 21.5% of the variance. The present analysis also extracted an AD factor accounting for 39.6% of the variance, and an IE factor accounting for 17.8% of the total variance. However, as in the complete 23 item analysis reported above, a third factor was also extracted, accounting for a further 8.3% of the total variance. As in the Evans and Hogg study, a varimax ^arotation method was employed, and items were selected that had a loading greater than $\pm .40$. While identical items loaded on the AD factor in the present analysis and in Evans and Hogg's analysis, Evans's IE items were again separated into two sets, with significant loadings on either Factor 2 (IE) (items 10, 16, 18, and 20), or Factor 3 (VRB) (items 8, 9, and 11). Thus, with the restricted item subset, Item 16 did load most highly on the IE factor (.42), although it still also loaded moderately on

the VRB factor (.33). However, a separate verbal expressiveness factor, consisting of the same three speech items previously identified, was again extracted.

Distribution of Scores and Reliability

Reliabilities for each of the factors were calculated by summing the raw scores of those items that loaded on each factor. Estimates of reliability based on Cronbachs alpha (r_1), and Spearman-Brown split-half reliabilities (r_2), were calculated. The results were: Factor 1, $r_1 = .925$, $r_2 = .943$; Factor 2, $r_1 = .793$, $r_2 = .801$; Factor 3, $r_1 = .783$, $r_2 = .780$; Factor 4, $r_1 = .707$, $r_2 = .736$. The reliabilities for Factor 4 are low, but acceptable.

Factor scores were calculated for each subject, and indicated the child's position on each of the four dimensions (Evans, 1975). Where scores for individual items were omitted, then the mean score for that item was substituted (Evans & Hogg, 1984). Four sets of factor scores were derived by the regression method, one for each factor. All scores had a mean of zero and SD of 1.0. The range of scores on each dimension was as follows: AD (-1.94 to 2.73) where low scores indicated the distraction pole and high scores the attention pole; IE (-1.97 to 2.08) where low scores indicated the inhibition pole and high scores the excitation pole; REW (-2.00 to 2.79) where low and high scores indicated low and high susceptibility to reinforcing events; and VRB (-2.74 to 2.67) where low and high scores indicated low and high verbal expressiveness respectively.

Summary

Four factors were extracted from a factor analysis of the IE2 questionnaire. These factors were identified as: attention/distraction (AD); inhibition/excitation (IE); susceptibility to reinforcing and punishing events in the classroom (REW); and verbal expressiveness (VRB). Cronbachs alpha and Spearman-Brown coefficients indicated acceptable levels of reliability for all factors. Section 7.4.5 will examine the validity of the factors through evaluating the correlations between subjects factor scores on these dimensions and criterion variables.

7.3.4 Discrimination Learning Measures

Trials to Criterion and Number of Errors

Ten subjects failed to acquire the simple position discrimination following several sessions of training, and therefore did not progress to the training task. These subjects received by default the maximum score for trials to criterion and error variables. Five further subjects failed to acquire the training task, and were still responding at chance after 200 training trials. Trials to criterion and errors for the remaining 65 children who acquired the training task were positively skewed. Median trials to criterion equalled 16.5 (range 10-150), while the median number of errors was 3 (range 0-60). Since statistical analyses to be reported in section 7.4 require linearity of regression as one of their assumptions, log transformations were applied to trials to criterion and errors (House & Zeaman, 1960) to help linearize the relation of the learning measures to the other variables. .

Dimensions

Fifteen subjects did not undergo dimensional testing since they failed to acquire either the pre-training or training tasks. Data for a further four subjects was eliminated since the subjects failed to maintain at least 70% correct responding to the stimulus compound trials included during dimensional testing. The remaining 61 subjects maintained responding to the 18 stimulus compound trials at a significant level (minimum $p < .05$) during the test phase (mode= 18; mean= 16.4; range 13 - 18).

The dependant variable (number of dimensions) was computed as follows. If the child responded correctly to at least five of six (83.3%) test trials for a cue, that cue was assumed to have been functional in controlling behaviour during discrimination learning. A subjects dimensional score was the total number of cues at criterion. Dimensional testing revealed the vast majority of subjects responded to only a restricted number of cues. Only eight subjects responded to all three cues, 17 subjects responded to two of three cues, while the remaining 36 subjects responded to at most a single cue. Overall, subjects responded to a mean 1.5 cues.

A one-way analysis of variance was computed to test for cue preferences. Results showed no significant differences in overall level of correct responding to the size (mean= 4.61), form (mean= 3.90), or colour (mean= 4.26) cues. Thus there is no evidence that any one cue was significantly preferred over another. The total number of correct responses on test trials for each child was also calculated to evaluate the normality of the distribution. A child's total score could range from 0-18, with a score of nine expected from chance performance. The scores fell in an approximately normal distribution, with a mean of 12.1 (SD= 2.94, range

6-18).

7.4 Analysis of the Correlations Between Variables

The raw correlation matrix for all variables is presented in Appendix B. The following sections will consider the correlations between specific subsets of variables drawn from this matrix.

7.4.1. Predicting Rate of Acquisition and Errors in Discrimination Learning

Table 7.5 extracts the correlations between individual difference (ID) variables and discrimination learning variables, which were viewed as dependant variables. It can be seen that MA, IQ, the BAS scales, AD and REW are all significantly correlated with discrimination learning.

Table 7.6 presents the inter-correlations between those ID variables that were significantly correlated with learning. Only BAS composite score is included since the inter-correlations between the BAS scales have already been described (see Table 7.4). Table 7.6 reveals that, as well as being highly correlated with learning scores, these variables were all also highly inter-correlated. The aim of the following analyses was to determine whether all the ID variables were independantly correlated with learning, or whether the significant correlations of some of the ID variables was a result of shared variance with other ID variables. Initially, only BAS composite score will be considered in this analysis, since the correlation between composite score and learning variables was greater than the correlation of any of the individual scales that went to make up the composite (see Table 7.5).

Table 7.5: Correlations Between Individual difference Measures and Discrimination Learning Variables

Variable	Trials	Errors	Dimensions
CA	.078	.092	.192
MA	*** -.553	*** -.529	* .225
IQ	*** -.609	*** -.588	.114
SS	*** -.449	*** -.437	.115
<u>BAS Scales</u>			
VR	*** -.694	*** -.695	*** .434
MLLF	*** -.593	*** -.602	.152
COP	*** -.723	*** -.703	*** .455
ENS	*** -.733	*** -.716	*** .387
WRD	*** -.373	*** -.360	.144
CPS	*** -.762	*** -.753	*** .428
<u>IE2 Factors</u>			
AD	*** -.561	*** -.556	*** .424
REW	** -.229	* -.206	.001
IE	-.112	-.124	.021
VRB	-.119	-.118	-.056

* $p < .05$; ** $p < .025$; *** $p < .001$

SS= PPVT Standard Score; CPS= BAS Composite; AD= attention/distraction; REW= Susceptibility to reward and punishment; IE= inhibition/excitation; VRB= Verbal expressiveness.

Table 7.6: Inter-correlations Between Variables Significantly Correlated with Discrimination Learning

	MA	SS	IQ	CPS	AD	REW
MA	/	*** .936	*** .922	*** .753	*** .426	.124
SS		/	*** .898	*** .646	*** .431	.009
IQ			/	*** .730	*** .504	.162
CPS				/	*** .590	* .224
AD					/	.000

* $p < .05$; ** $p < .025$; *** $p < .001$

SS= PPVT Standard Score; IQ= Ratio IQ; CPS= BAS Composite; AD= attention/distraction; REW= Susceptability to reward and punishment; IE= inhibition/excitation; VRB= Verbal expressiveness.

7.4.2 CA, PPVT MA, and PPVT IQ.

The first question addressed was whether both PPVT MA and IQ should be considered independantly in accounting for discrimination performance. (The low correlation of SS is likely to be a result of restriction in range of PPVT standard scores, where over half the sample received the score <20. Consequently, only ratio IQ was considered). Both MA and IQ were significantly negatively correlated with trials to criterion and number of errors ($p < .001$). Higher MA and IQ was associated with fewer trials to criterion and fewer errors during learning. CA was not significantly correlated with discrimination performance.

Following House and Zeaman (1960) partial correlation coefficients, in which either MA, CA, or IQ alone were held constant statistically, were computed to determine the independant effect of the remaining two variables on discrimination performance. The results with discrimination errors as the criterion variable are reported below. Identical correlations pertained when trials to criterion was the criterion variable.

The question to be answered from these partial correlations was whether MA and IQ were independently correlated with learning. The correlation between IQ and errors was reduced, though still significant, when MA was held constant ($r = -.31$, $p < .005$). However, the correlation between MA and errors was not significant when IQ was held constant ($r = .14$, $p > .10$). Controlling for the effect of CA did not significantly effect either the correlation between MA and errors ($r = -.58$, $p < .001$) or between IQ and errors ($r = -.59$, $p < .001$).

These results indicated that MA was not independently correlated with learning. That is, MA could account for little variance in errors that could not also be accounted for by IQ. However, IQ could account for additional variance in errors that could not be accounted for by MA. In quantitative terms, IQ accounted for 35% of the total variance in errors, while MA accounted for 28% of the total variance in errors. However, the two variables accounted for the same portion of the variance, such that the 28% of variance accounted for by MA was shared with ('contained within') the 35% of variance accounted for by IQ. IQ could therefore account for all the variance attributable to MA, plus an additional 7% unique variance.

PPVT MA and IQ were near perfectly correlated in the present sample ($r = .922$, $p < .001$). It was therefore considered necessary to include only one of these variables in subsequent analyses. Since IQ had the greatest raw correlation with learning scores, and MA made no independent contribution towards accounting for discrimination performance, only IQ was included in the following analyses.

7.4.3 BAS, PPVT IQ, AD, and REW.

A similar procedure to that described above was employed to evaluate the significant correlations between discrimination learning and BAS composite, AD, PPVT IQ, and REW. Four sets of partial correlations were computed. For each ID variable, the effect of each of the other variables alone was controlled in first-order partial correlations. The effect of controlling all three remaining variables simultaneously was also evaluated through third-order partial correlations. The results of the partial correlations with errors are presented in Table 7.7. An identical pattern of results was obtained when trials to criterion was employed as the

Table 7.7: Partial Correlation coefficients of BAS Composite, IQ, AD, and REW with Errors

<u>Constants</u> <u>a</u>	<u>IQ vs. Errors</u>
--	-.588 ***
REW	-.575 ***
AD	-.429 ***
BAS	-.085
REW,AD,BAS	-.058

<u>Constants</u> <u>a</u>	<u>AD vs. Errors</u>
--	-.556 ***
REW	-.568 ***
IQ	-.372 ***
BAS	-.210 *
REW, IQ,BAS	-.214 *

<u>Constants</u> <u>a</u>	<u>REW vs. Errors</u>
--	-.210 *
AD	-.247 *
IQ	-.139
BAS	-.057
AD, IQ, BAS	-.095

<u>Constants</u> <u>a</u>	<u>BAS vs. Errors</u>
--	-.753 ***
REW	-.741 ***
AD	-.633 ***
IQ	-.586 ***
REW,AD, IQ	-.498 ***

a. Zero-order (raw) correlation; * $p < .05$; *** $p < .001$

criterion variable.

The results indicated only BAS composite and the AD factor were independantly related to learning. Controlling for BAS composite in the correlations of IQ and REW reduced these correlations to non-significant levels (see Table 7.7). Controlling for BAS composite also reduced the correlation between AD and errors, however the correlation remained significant ($r = -.21$, $p < .05$). Thus, AD was the only variable to account for variance in errors that could not also be accounted for by BAS composite. Controlling for the effects of REW and IQ did not reduce the significance of the correlations between BAS and errors, or AD and errors.

BAS composite accounted for the largest portion of the total variance (57%). BAS composite also accounted for some unique variance in errors that could not be accounted for by any of the other variables. This was indicated not only from the minimal effect of the first-order partial correlations, when the effects of the other correlated variables were controlled successively, but by the observation that the correlation between BAS composite and errors remained significant in third-order partial correlations where the variance attributable to MA, AD, and REW was simultaneously removed ($r = -.498$, $p < .001$).

The above conclusions were also supported by the results of multiple regression analyses. The dependant variables selected were again trials to criterion and errors, and BAS composite, IQ, AD, and REW were entered as predictor variables. Backward elimination of variables with conventional removal criteria ($POUT = .1$) was employed. Only BAS composite and the AD factor were contained in the final multiple regression equation. Together, BAS composite and the AD factor accounted for 60% of the variance in errors,

($R = .77$, $F(2,74) = 52.38$, $p < .00001$).

In summary, BAS composite and AD scores were the only variables to independently account for a significant proportion of the variance in errors, when the influence of all correlated variables was controlled. Similar results were obtained when PPVT MA was substituted for PPVT IQ in the analyses, and when trials to criterion replaced errors as the criterion variable. Either IQ and REW control an entirely different portion of the variance in discrimination performance than BAS composite and the AD factor, or their variance is also accounted for by BAS composite and AD. The latter appears more reasonable given all the data. In short, PPVT IQ and REW are redundant variables, to the extent that the variance in discrimination performance may be more efficiently and comprehensively explained by BAS composite.

A final multiple regression equation was built in order to determine the subset of variables which would most efficiently predict discrimination performance. In this analysis BAS composite score was not entered, rather each of the BAS scales was eligible for independent entry. All other ID variables were also eligible for entry. Forward entry of variables ($PIN = .1$) was employed. The linear combination of variables that most efficiently predicted discrimination performance consisted of the Visual Recognition and Early Number Skills scales of the BAS, and the AD factor. ($R = .76$, $F(3,73) = 32.28$, $p < .00001$).

7.4.4 Dimensional Score and ID Variables

Six variables correlated significantly with number of dimensions (see Table 7.5). MA produced a low but significant correlation with dimensional

score ($r_s = .23$, $p < .05$). Higher correlations were found with three of the BAS scales, and with BAS composite (Visual Recognition: $r_s = .43$; Copying: $r_s = .46$; Early Number Skills: $r_s = .39$; and Composite: $r_s = .43$; $df = 61$, $p < .001$ in all cases). Finally, AD scores also correlated highly significantly with number of dimensions ($r_s = .42$, $p < .001$). Higher scores on all variables was associated with greater breadth of learning.

The above correlations were based upon the 61 children for whom dimensional scores were available. Fifteen children failed to acquire the discrimination, and a further four children failed to maintain correct responding to the S_+ compound during dimensional testing. Thus, 19 children had no score on the dimensions variable. Since these children may be expected to have the lowest scores on the ID variables, the correlations with dimensional score may suffer from attenuation in range on the ID variables. The mean score on the ID variables for the nineteen children who failed to acquire or maintain the discrimination, referred to as "weak discriminators", was computed to determine whether these children differed significantly from the other subjects.

While this was the major objective of the analysis, as a further comparison the children who successfully completed dimensional testing were split into two groups. Twenty-five children performed at a superior level, responding to multiple (2 or 3) cues during dimensional testing. These subjects were referred to as "multiple cue discriminators". These children were distinguished from the remaining 36 subjects, who by default were referred to as "single cue discriminators". Thus, three groups were identified: weak discriminators ($n=19$), single cue discriminators ($n=36$), and multiple cue discriminators ($n=25$).

Univariate analyses of variance (ANOVA) were computed for all ID variables, followed by comparisons of group means. These data are presented in Table 7.8. Significant overall differences were found for all variables, except CA, and the REW, IE, and VRB factors. Newman-Keuls comparisons of means revealed that Group 1 (weak discriminators) had significantly lower means than the other groups on MA, IQ, Visual Recognition, Matching Letter-like Forms, Copying, Early Number Skills, and the AD scale ($p < .01$ in all cases). The weak discriminators also differed significantly from the single cue discriminators in mean REW score ($p < .05$). The results also indicated that multiple cue discriminators (Group 3) had significantly higher mean MA, VR, COP, ENS, and AD scores, than single cue discriminators (Group 2) ($p < .01$ in all cases).

7.4.5. IE2 factors

AD scores correlated significantly with PPVT MA and IQ ($r = .43$, and $r = .50$ respectively, $df = 77$, $p < .001$). AD scores also correlated significantly with all scales from the BAS composite, and with composite score (VR: $r = .53$; MLLF: $r = .41$; COP: $r = .57$; ENS: $r = .60$; CPS: $r = .59$; $df = 75$, $p < .001$ in all cases). As detailed in Table 7.5, AD scores correlated significantly with trials to criterion ($r = .56$, $df = 75$, $p < .001$), errors ($r = .56$, $df = 75$, $p < .001$), and number of dimensions ($r = .42$, $n = 61$, $p < .001$). Children with higher AD score acquired the discrimination more rapidly, made fewer errors, and responded to more of the component dimensions. CA was not significantly correlated with AD score ($r = -.17$, $df = 75$, $p < .10$).

The REW scale did not correlate significantly with either CA, MA, or IQ (all $p < .10$). However, significant correlations with BAS composite ($r =$

Table 7.8: Mean and SD of Scores on the Individual Difference Variables for Weak Discriminators (Group 1), Single Cue Discriminators (Group 2), and Multiple Cue Discriminators (Group 3).

Variable	Group 1 (n=19)	Group 2 (n=36)	Group 3 (n=25)
CA	174.7 (32.3)	158.6 (27.6)	169.8 (28.0)
MA	31.3 (12.9)	52.5 (20.9)	64.8 (27.7)
IQ	18.5 (7.5)	33.3 (11.4)	38.1 (12.4)
<u>BAS Scales</u>			
VR	24.6 (23.2)	47.1 (25.4)	65.7 (20.7)
MLLF	12.5 (14.1)	29.2 (15.9)	34.3 (18.5)
COP	9.7 (19.5)	36.4 (23.4)	58.2 (21.3)
ENS	13.2 (18.4)	37.7 (24.9)	57.4 (17.0)
WRD	6.5 (13.6)	20.1 (23.5)	31.3 (28.8)
<u>IE2 Factors</u>			
AD	-.750 (.825)	-.108 (.862)	.720 (.839)
REW	-.433 (.882)	.177 (1.14)	.066 (.793)
IE	-.245 (1.01)	.097 (1.07)	.042 (.881)
VRB	-.266 (1.29)	.041 (1.04)	.139 (.626)

Note. VR= Visual Recognition; MLLF= Matching Letter-Like Forms; COP= Copying; ENS= Early Number Skills; WRD= Word Reading; CPS= BAS composite score; AD= attention/distraction; REW= Susceptibility to reward and punishment; IE= inhibition/excitation; VRB= Verbal expressiveness.

.22, $df=75$, $p<.05$) and the VR ($r= .26$, $df= 75$, $p<.05$) and ENS scales ($r= .24$, $df= 75$, $p<.05$) were found. In relation to discrimination learning, REW scores correlated significantly with both trials to criterion ($r= -.23$, $df= 75$, $p<.025$) and number of errors ($r= -.21$, $df= 75$, $p<.04$). Children with higher REW scores acquired the discrimination more rapidly and with fewer errors.

The only significant correlation involving IE was with CA ($r= -.25$, $df= 75$, $p<.05$). Older children were more likely to have higher inhibition scores than younger children. VRB also correlated significantly only with two variables, namely the Word Reading Scale ($r= .25$, $df=75$, $p<.025$) and PPVT IQ ($r=.28$, $df=75$, $p<.005$). Thus VRB scores were significantly associated only with the two verbal measures; one-word verbal comprehension (PPVT) and one-word expressive vocabulary (Word Reading).

Discussion

7.5.1 The Classroom Rating Scale

Factor Analysis

The factor analysis of the IE2 questionnaire revealed a significantly more complex factor structure than that reported by Evans (1975). Evans reported a two factor structure, with factors identified as attention/distraction (AD) and inhibition/excitation (IE) dimensions. However in the present analysis, which employed identical factor extraction criteria and factor rotation methods, four factors were extracted (AD, IE, REW, and VRB). Analysis of the first factor extracted (AD), clearly replicated Evans findings. The factor accounted for the largest amount of the total variance in both studies, and identical items loaded on this

factor. However, two main differences from Evans results were apparent.

First, a previously unreported factor, identified as susceptibility to reinforcing or punishing events in the classroom (REW), was extracted. Second, the integrity of Evan's IE factor was challenged, since the items Evans reported as loading heavily on this factor split over two separate factors in the present analysis. The new factor consisted of three of the four items pertaining to aspects of the child's speech (speaks at length, quickly, and decisively), and was therefore identified as a verbal expressiveness factor (VRB).

Regarding the REW factor, it is perhaps surprising that Evans did not extract such a factor, since he specifically states "certain other items were added to the I/E 2 that were thought to reflect susceptibility to reinforcing or punishing events in the classroom. These were items 5, 13, 17, 22, and 23" (Evans, 1975, p82). However, Evans did not report any analysis of these items. In the present analysis these five items did indeed form a separate factor, which accounted for 11.0% of the total variance. Evans' main preoccupation with constructing an IE scale may account for the absence of any further analysis of these items. Certainly, a subsequent factor analysis (Evans & Hogg, 1984) was based only on those items that had been identified as loading on the AD and IE factors.

As regards the VRB factor (items 8, 9, and 11), in the initial principle components analysis only item 8 failed to load significantly on the IE component as well as the VRB component. These loadings on the IE factor tended to be minimized following factor rotation. It may be argued, since the VRB factor accounts for a relatively small portion of the total variance (6.4%), that little significance should be attached to this factor. However, a significant correlation between the VRB scores and scores on the

BAS Word Reading Scale suggests this factor may have some validity (this will be further discussed below).

Attempts were made to evaluate the differences between our results and Evan's in terms of differences in the subject samples. Evans (1975) employed a sample of 186 severely mentally handicapped children, and subsequently replicated the two factor structure, although with slight differences in the items loading on these factors, with a second sample of 146 moderately mentally handicapped children. However, beyond this description no further details of the sample could be located (Evans, 1975). One aspect of interest would be the relative proportion of non-verbal subjects in the samples. In the present study eleven children were non-verbal, causing the sample size for the speech items to be reduced relative to other items. However, it is not clear what proportion of Evans sample were non-verbal. While the two populations could not be compared, it is possible that the pattern of results obtained in the two studies are specific to the populations studied.

Validity of the Factors

Attention/Distraction (AD). To date, the validity of the AD scale has been assessed only through correlation with age equivalents and standard scores derived from the EPVT. Evans and Hogg (1984) report significant correlations between AD scores and both measures ($p < .01$). The present study greatly extends these findings. Correlations between AD scores and age equivalents and standard scores derived from the PPVT again proved highly significant ($p < .001$). The present analysis also revealed that AD scores correlated significantly with six scales from the BAS, and with a composite score derived from four of these scales ($p < .001$ in all cases). AD scores may therefore reflect attentional abilities related to general cognitive

ability.

More importantly, from the point of view of the present study, AD scores correlated significantly with all three measures of discrimination learning; trials to criterion, number of errors, and number of dimensions ($p < .001$ in all cases, see Table 7.5). Furthermore, if the variance in both AD scores and errors that can be accounted for by ability measures (e.g., PPVT, BAS) is removed through partial correlation, a significant correlation between AD and discrimination learning is still found ($r = -.21$, $p < .05$). Thus, the AD scale measures some unique portion of the variance in learning that cannot be accounted for in terms of cognitive ability measures. For this reason, discrimination acquisition could best be predicted by a combination of BAS ability and AD scores, as indicated by multiple regression analysis (see Section 7.4.3).

The AD scale also correlated significantly with dimensional score ($r_s = .42$, $df = 59$, $p < .001$). This result is in contrast to results reported in the only previous investigation. Siegel et al., (1985) found no significant correlation between teacher rated inattention and number of dimensions (BOL), with their sample of 67 severely mentally handicapped children ($r = -.18$, $df = 65$, $p > .10$). Although significant correlations with PPVT MA and IQ were reported ($r = -.31$ and $r = -.30$, $p < .01$), replicating the above results, their measure also failed to correlate significantly with discrimination errors ($r = .15$). However, the measure of attention employed by Siegel et al., consisted of a single, dichotomously scored, item. The child's teacher was simply required to indicate the presence or absence of "inattention (e.g., short attention span, easily distracted)" (p390). The AD scale is a more differentiated measure of attention/distractability aspects of children's classroom behaviour. In the

present study individual differences as assessed through the AD factor correlated significantly with attention in discrimination learning. This convergence between assessments of 'attention' at different levels of inference strongly supports the validity of the AD scale. We may conclude that the AD scale measures more than a molar behavioural component of attention, and also measures a more cognitive or information processing component of attention.

The present results indicate that individual differences in the behaviour of severely mentally handicapped children can be reliably assessed through the AD scale, and furthermore these individual differences may be shown to relate to measures of ability (e.g., PPVT, BAS); to measure of discrimination acquisition (trials and errors to criterion); and to breadth of learning (number of dimensions).

Susceptibility to Reinforcing and Punishing Events (REW). Scores on the REW factor correlated significantly with the VR and ENS scales of the BAS, and with BAS composite, indicating the factor may also assess some general cognitive ability. REW factor scores also correlated significantly with discrimination acquisition (see Table 7.5). Thus, a measure of susceptibility to reinforcement and punishment derived from ratings of the child's behaviour in the classroom, correlated significantly with an experimental index (rate of discrimination learning) that may also be dependant upon such processes. Children who were rated as being relatively insensitive to reinforcing events required more trials to acquire a discrimination and made more errors, than children rated as being sensitive to reinforcing events. Since rate of acquisition of a discrimination will in part be determined by sensitivity to the reinforcing and non-reinforcing events contingent upon responses, this finding suggests some validity for the REW factor derived

from the classroom rating scale. It may be hypothesised that children who are responsive to praise, seek approval, upset by being told off, etc., may be more readily motivated by the reinforcing contingencies operating within the context of the learning task.

However, the correlations, while significant, are of a relatively low magnitude and suggest that the factor explains only a small proportion of the variance in discrimination performance. It is also possible (although causal interpretations cannot be confirmed from the correlation analysis), that the significant correlation with discrimination performance is mediated through REWs shared variance with ability measures, such as BAS composite, since when ability differences were controlled through partial correlation the resulting correlation was not significant.

Inhibition/Excitation (IE). In the present study, scores on the inhibition/excitation factor correlated significantly only with CA ($r = -.25$, $p < .05$). This finding partially replicates the results of previous studies, since Evans (1975) reported a similar negative correlation with CA for severely mentally handicapped children, and Evans and Hogg (1984) have reported that IE scores did not correlate with VA and VQ derived from the EPVT. However, Hogg and Evans (1975), Evans and Hogg (1975), and Evans (1982), have reported significant correlations between scores on an IE factor and indices of inhibition derived during successive discrimination learning. For example, Hogg and Evans (1975) report a significant correlation between IE scores and absolute number of errors for severely mentally handicapped subjects on their successive discrimination learning task ($r = .43$, $p < .05$), although the correlation was not significant when differences in CA were controlled through partial correlation.

The non-significant correlations between the IE and learning variables observed in the present study may be due to the discrimination training procedure employed, i.e., the present study investigated simultaneous discrimination training, while Evans and his associates employed a successive discrimination training procedure. In terms of conditioning-extinction theory, simultaneous discrimination training requires both excitation of responding to S+, and inhibition of responding to S-, simultaneously; hence the two processes are confounded. In contrast, the successive technique presents S+ and S- as discrete trials and separates these component processes; subjects are required to respond only during S+ trials and withhold responses during S- trials. Sharp and Evans (1981) have compared the performance of severely mentally handicapped children on simultaneous and successive discrimination tasks, and conclude the procedures are sensitive to different aspects of the processes involved in discrimination learning. The different discrimination training methodologies employed in the studies may therefore be a significant factor in accounting for the lack of significant correlation between IE scores and learning variables.

Verbal Expressiveness (VRB). Finally, the verbal expressiveness factor was also not significantly correlated with discrimination performance. Verbal expressiveness correlated significantly only with the two variables having a strong verbal content (PPVT IQ and Word Reading). Word Reading was the only BAS scale that required a verbal response, all other scales requiring pointing or drawing responses. The significant correlation with Word Reading, combined with the absence of significant correlations with the other scales, would appear to indicate some discriminant validity for the VRB factor.

This result also supports the division of Evans seven IE items into two groups, loading on separate IE and VRB factors. The results for the IE factor (items 10, 18, and 20) are congruent with the insignificant correlations between IE and the EPVT reported by Evans and Hogg (1984), while those items identified as loading on a separate VRB factor (items 8, 9, and 11) did correlate significantly with both the PPVT and with BAS Word Reading.

Summary

Four factors were extracted from the IE2 Questionnaire. The extraction of AD and IE factors replicated the results of a previous analysis (Evans, 1975) although the REW and VRB factors had not previously been identified. The differing results may indicate the factor structure was specific to the sample studied, although the absence of full description of Evans subjects made comparison of the samples problematic. Internal consistency coefficients indicated the four factors were reasonably reliable assessments. Assessment of the validity of the factors through correlation with criterion variables indicated; (1) the AD factor correlated significantly with cognitive ability (PPVT, BAS), simultaneous discrimination performance (trials and errors to criterion), and a measure of selective attention derived from discrimination performance (number of dimensions); (2) The IE factor correlated significantly only with CA. However, the lack of significant correlations with discrimination performance may have been due to the use of a simultaneous rather than successive discrimination training procedure; (3) The REW factor correlated both with measures of cognitive ability (BAS composite) and with discrimination performance. However, the correlations were low and accounted for only a small proportion of the variance in learning; (4) the VRB factor correlated significantly

only with the two variables with strong verbal components the (PPVT and BAS Word Reading). Since the latter variable was the only measure which required verbal responses, some validity for the verbal expressiveness factor was assumed.

7.5.2 Ability Measures and Discrimination Learning

It has frequently been assumed that intelligence tests measure learning ability (Rapier, 1962). However, as reviewed in Chapter 2, correlations between intelligence and learning have not produced the expected significance. In an influential review, Woodrow (1946) concluded "the ability to learn cannot be identified with the ability known as intelligence" (p148). In the light of these results, Zeaman and House (1967) argued that the relationship between intelligence and learning may be task specific. They hypothesised that high correlations with intelligence may be found within certain limited sets of learning situations, rather than the general class of all tasks requiring learning. Specifically, discrimination learning became the primary focus of research for these authors.

Zeaman and House (1967) reviewed 18 studies relating IQ to discrimination performance with MA controlled. These studies produced conflicting results, as nine studies reported no reliable differences among the various IQ groups (see section 2.1). The majority of these studies sought to assess the independent influence of IQ by comparing the performance of groups of normal intelligence children and mentally handicapped children, where groups were matched on MA. However, even where significant mean differences between normal intelligence and mentally handicapped groups are found, the relevance of such comparative research for individual differences within the mentally handicapped population may be

questioned. Very few studies have sought to directly assess the relationship between CA, MA, IQ, and discrimination learning within the mentally handicapped population through correlational techniques.

However, House and Zeaman (1960) have reported a significant correlation between IQ and errors on a simultaneous two-choice discrimination in a sample of 66 severely mentally handicapped children (mean CA 12:2, mean MA 4:1, mean IQ 37.0) ($r = -.51$, $p < .001$). This correlation remained significant when MA was controlled statistically ($r = -.28$, $p < .05$). The present study, employing a similar discrimination task and a comparable sample of severely mentally handicapped children, also revealed a significant correlation between IQ and discrimination errors ($r = -.59$, $p < .001$). The partial correlation between IQ and errors with MA controlled was also significant ($r = -.31$, $p < .005$).

The importance of assessing the relationship of IQ and learning independent of MA arises since it is IQ, rather than MA, that typically defines mental handicap (Fryers, 1987). However, the interpretation of the above results depends crucially upon a demonstration that CA is an irrelevant variable for learning. This is because, while theoretically IQ is independent of CA, in a population of equal MA (or where MA is held constant statistically) IQ will be negatively correlated with CA. The mathematical relations between CA, MA, and IQ demand that for a group of children of equal MA those with higher CA must of necessity have lower IQ. Therefore, a significant correlation between IQ and errors (with MA constant) may be ascribed to variation in either IQ or CA. However, the condition that CA is an irrelevant variable was confirmed since CA was clearly uncorrelated with errors ($r = .09$, $p > .10$). With CA eliminated as a relevant variable, the interpretation of the partial correlation becomes straightforward; IQ is

independantly related to discrimination performance.

In sum, the present results concur with those reported by House and Zeaman (1960). The results support the conclusion that, within a sample of severely mentally handicapped children, individual differences in discrimination learning ability are significantly correlated with individual differences in intelligence. However, PPVT IQ accounted for only 35% of the variance in discrimination performance. The majority of the variance in discrimination performance could not be accounted for by standardized scores on a norm-referenced test.

The variable which accounted for the greatest amount of variance in discrimination performance was not IQ or MA, but BAS composite. While MA and IQ correlated $-.53$ and $-.59$ respectively with errors, the correlation of BAS composite and errors exceeded both these correlations ($r = -.75$, $p < .001$). Thus, the variable accounting for the greatest amount of variance in errors (approximately 57%) was BAS composite score. Furthermore, when the variance attributable to BAS composite was removed through partial correlation, the correlation between IQ and errors was no longer significant ($r = -.09$, $p > .10$). Therefore, IQ does not account for any variance in errors that cannot also be accounted for by BAS composite (i.e., IQ is not independantly correlated with errors). Since a similar result was obtained for PPVT MA, which in common with BAS ability score is a direct transformation of the raw score without reference to CA, this result cannot be attributed to the correction for CA involved in PPVT IQ. Clearly, while IQ is a significant predictor of discrimination performance, the BAS scales are even better predictors. BAS composite not only accounts for more of the total variance than IQ (by dint of its larger overall correlation), but also accounts for all of the variance that would be predicted from IQ. Consequently, IQ does

not significantly increase the multiple correlation with errors when it is entered into a regression equation which already contains BAS composite (see section 7.4.3). In short, measures of general level of intellectual functioning appear redundant in predicting discrimination performance, when assessments of specific cognitive abilities are available. Identical findings were obtained when trials to criterion was employed as the criterion variable.

General versus Specific Abilities

While measures of general ability such as MA and IQ were correlated significantly with discrimination performance, the variance in learning was better explained by a composite of specific ability measures. How may these results be interpreted? One interpretation is that the four scales of the BAS composite assessed prerequisite skills for successful discrimination learning. In these terms, the greater correlation of discrimination performance with 'task-relevant' abilities, rather than general ability, appears justified.

Interpretation in terms of specific cognitive abilities has advantages over interpretation in terms of general ability, since discrimination performance can be evaluated in terms of specific processes presumed to underly successful performance on the individual scales. For example, individual differences in short-term visual recognition were significantly correlated with discrimination errors ($r = -.69$, $p < .001$). Individual differences in perceptual matching ability (Copying and Matching Letter-like Forms scales) also correlated significantly with discrimination errors ($r = -.70$ and $r = -.60$ respectively, $p < .001$ in both cases). Finally, non-identity matching and classification skills (Early Number Skills) also

correlated significantly with learning ($r = -.72$ with errors, $p < .001$).

However, the observed results are not incompatible with interpretation in terms of a single general ability factor. First, the comparatively low correlations (relative to the BAS scales) between PPVT MA/IQ and learning, may result because the PPVT is not an especially valid measure of general ability. Picture Vocabulary tests (such as the PPVT and EPVT) are frequently used to estimate general ability, since vocabulary measures are often found to be the most reliable indicator of final score in profile measures of verbal ability and general intelligence (Clark, 1974; Wheldall & Jeffree, 1974). Picture vocabulary tests are also frequently employed when assessing mentally handicapped students since no reading and no oral or written response is required of the child, and the instructions are simple and easily understood by mentally handicapped children.

However, there is some evidence to suggest that, especially with mentally handicapped populations, MA and IQ estimates derived from picture vocabulary tests and estimates derived from full-scale tests such as the Stanford-Binet and WISC, may differ significantly (e.g., Kaufman & Ivanoff, 1968; Burland & Carroll, 1971; Trivedi, 1977). While picture vocabulary scores are frequently interpreted as estimates of general ability (for the reasons given above), the test actually assesses a highly specific ability to comprehend single words. Several authors have criticised the use of such tests to derive general ability estimates (e.g., Burland & Carroll, 1971; Wheldall & Jeffree, 1974). These authors have argued that to the extent that scores on these tests measure any form of general ability, it is verbal ability only. The measures may therefore better be described as verbal age (VA) or verbal IQ (VQ). It remains to be seen, therefore, whether the present results would be replicated if MA and IQ were derived from

full-scale tests.

Second, obtaining pure measures of specific abilities is difficult to achieve. Thus, poor performance on the VR scale may be associated with the ability to hold and recognize visual images, but it may also be associated with inattention, or poor perceptual ability. Similarly, poor performance on the copying scale may indicate poor development of perceptual matching skills, or poor motor control. Thus, while the BAS scales do assess specific processes (e.g., short-term memory, perceptual matching, spatial imagery, etc.), high performance on the scales may also reflect the influence of some general factor.

Principle components analysis of the six scales (see section 7.3.2) did indeed extract only a single factor, which may be presumed to be a general ability factor. More specifically, this factor may be described as 'general visual ability', since the four scales which loaded most heavily on the factor (Visual Recognition, Copying, Matching Letter-like Forms, and Early Number Skills) all have strong visual, rather than verbal, content. The VR, COP, and MLLF scales are also three of the six BAS scales recommended for the calculation of Visual IQ (Elliot, 1983). An argument could be forwarded, therefore, that BAS composite score may be interpreted as a measure of 'general visual ability', possibly analogous to a short-form visual IQ.

In summary, the correlations between the VR, MLLF, COP, and ENS scales and discrimination performance may be interpreted in terms of the influence of a single factor; general visual ability. That the correlations between these scales and discrimination performance are higher than those of PPVT MA/IQ, may indicate only that visual ability is a better predictor of visual

discrimination performance than verbal ability. However, it may be noted that in their influential theories of the visual discrimination learning of mentally handicapped individuals, Zeaman and House (1963, 1979) have considered only the role of general IQ. Indeed, Zeaman and House (1967), and Zeaman (1978), explicitly reject distinctions between verbal and performance IQ on the basis that such factors have appreciable common variance. However, the present observation that assessments of visual abilities (perceptual matching, visual recognition, etc.) correlated more highly with all three measure of discrimination performance than measures of verbal abilities (VA, VQ, WRD), suggests a distinction between visual and verbal intelligence is relevant, and may have implications for correlational assessments of the relationship between intelligence and simple learning.

However, whether the results are interpreted in terms of general or specific abilities, this does not preclude attempts to identify the particular subset of variables that most efficiently predict discrimination performance. As reported in Section 7.4.3, a final multiple regression equation was built in which composite score was removed, and each of the BAS scales was eligible for independent entry, in order to determine the subset of scales which would most efficiently predict discrimination performance. A linear combination of Visual Recognition, Early Number Skills, and AD scores best predicted discrimination errors ($R = .76$, $F(3,73) = 32.28$, $p < .00001$).

Discrimination performance was therefore most efficiently predicted from individual differences in short-term visual recognition memory, visual matching and classification abilities, and in attention/distractability aspects of classroom behaviour. This latter result is of interest since it indicates that factors other than the child's cognitive abilities need to be

considered in assessing the probable outcome of discrimination training. These results may be important in (a) providing a basis for individualizing discrimination training, and (b) elucidating the processes underlying discrimination performance. These issues will be discussed further in Section 7.5.4.

7.5.3 Breadth of Learning

Breadth of Learning (BOL) was assessed by the number of component cues children responded to following acquisition of a discrimination with multiple relevant and redundant cues. The majority of subjects exhibited a restricted breadth of learning, since only eight subjects responded to all three component cues. The 61 children who completed dimensional testing (mean CA 13.6 yrs, mean MA 4.8 yrs, mean IQ 35.7) responded on average to only 1.5 components of a three-component stimulus complex.

Three previous studies have utilized a directly comparable discrimination task in assessing BOL (Kovattana & Kramer, 1974; Schover & Newsom, 1976; Rincover & Ducharme, 1987). However, only the first of these studies (Kovattana & Kramer, 1974) employed mentally handicapped subjects, and direct comparison with this study is not possible since Kovattana and Kramer fail to report either individual data or mean MA, IQ, or dimensional score for any of their groups. Several other studies have, as in the present study, employed a relevant and redundant cue paradigm in assessing BOL with severely mentally handicapped subjects (e.g., Wilhelm & Lovaas, 1976; Bailey, 1981). However, in these studies the S⁺ stimulus complex consisted of separate visual components, rather than multiple dimensions of single visual stimulus. For example, in the Wilhelm and Lovaas (1976) study S⁺ was a card containing pictures of an Indian, a sun, and a tepee; while

S- was a card containing pictures of a girl, a lamp, and a parrot. While these studies may therefore differ from the present study in important respects (these differences will be commented on shortly), the estimates of BOL derived are broadly comparable. For example, Wilhelm and Lovaas (1976) found a sample of 10 severely mentally handicapped children (mean CA 15.8 yrs, mean MA 6.2 yrs, mean IQ 39.2) responded on average to only 1.6 cues of a three-component stimulus complex.

Most recently, BOL has achieved prominence in the context of research concerning 'stimulus overselectivity', primarily with autistic populations. (n.b., in the present report the term restricted BOL is preferred to stimulus overselectivity, although both terms refer to the control of responses by one or a restricted number of components of a complex stimulus). Initially, (Lovaas et al., 1971; Lovaas and Schreibman, 1971) restricted BOL was considered a stimulus control deficit specific to the autistic population, and some authors still maintain this position (e.g., Frankel et al., 1984). However, the present results clearly demonstrate that severely mentally handicapped children also evidence restricted BOL. In the present study 61 severely mentally handicapped children completed a BOL assessment. The size of this sample, more than three times that of the largest previously reported sample, suggests restricted BOL is likely to be a common observation with severely mentally handicapped children.

Previous studies (Wilhelm & Lovaas, 1976; Schover & Newsom, 1976; Bailey, 1981) have reported that BOL is more directly related to developmental level than diagnostic category, all studies reporting a positive relationship between BOL and MA. In the present study, a weak but statistically significant correlation between BOL and MA was observed ($r_s = .23$, $df = 57$, $p < .05$). This generally supports the observation that as

mental age increases, BOL increases. However, the small magnitude of the correlation indicates that little of the variance in BOL may be accounted for by MA. In accord with observations made by Bailey (1981), there is enough variability in the data to indicate that the relationship with MA may be a weak one.

It is notable that, as for measures of discrimination acquisition (trials to criterion and errors), BOL correlated more highly with the BAS scales than with MA. The Visual Recognition, Copying, and Early Number Skills scales were all significantly correlated with dimensional score (all p 's $< .001$, see Table 7.5). All these scales require careful visual inspection and comparison of stimuli for successful performance. High scores on these scales therefore reflect, at least in part, the ability to perceive and respond on the basis of multiple aspects of complex visual stimuli (Elliot, 1983). It may be hypothesised that strong 'attentional' control over responding may be more directly reflected in high scores on the BAS scales than on the PPVT, since success on the PPVT primarily requires verbal skills, in addition to visual attention skills.

Breadth of learning in this study has been viewed as an outcome or dependant variable. For example, the research was concerned to evaluate the relationship between individual differences on the AD scale and BOL, as discussed in section 7.5.1. However, several authors (e.g., Lovaas et al., 1971, 1979; Schreibman, 1975; Koegel & Rincover, 1976) have viewed BOL as an independant variable that may help to 'explain' a child's poor performance on discrimination learning tasks. These authors have argued that autistic children's failure to acquire discriminations may result from the child's tendency to respond only to a restricted number of cues of a complex stimulus. The child may not therefore 'attend' to cues relevant for

discrimination acquisition.

In the present study, dimensional score did correlate significantly with trials to criterion ($r_s = -.44$, $p < .001$); children who responded to a greater number of stimulus dimensions also acquired the discrimination more rapidly and made fewer errors. However, this result was somewhat surprising, in that all three dimensions assessed during dimensional testing were relevant and redundant; only position was an irrelevant dimension. Therefore, the task could theoretically be acquired equally rapidly whether the child responded on the basis of only one or all three of the relevant stimulus dimensions during acquisition. It is likely that the correlation between rate of acquisition and dimensional score was mediated through the correlation of both variables with cognitive ability (BAS, MA). More able children acquired the discrimination more rapidly, and also responded to a greater number of dimensions; the correlation between rate of acquisition and dimensional score may therefore be a result of the correlation of both variables with cognitive ability.

In the context of the present results, it would be inappropriate to attempt to forward hypotheses concerning causal relationships between BOL, cognitive ability, and discrimination performance. Further research might investigate childrens subsequent performance on additional discrimination tasks, since the generality of the results may be questioned where measures of BOL and measures of discrimination acquisition are derived from one and the same task.

Before leaving the results of the correlation analysis, it may be noted that nineteen subjects had no score on the dimensions variable, since they either failed to acquire the discrimination, or failed to maintain correct

responding to the stimulus compound during dimensional testing. This is not an unusual outcome in research with severely mentally handicapped children: Siegel et al., (1985) also had to eliminate 15 of their 82 subjects from their dimensional testing procedure, since these children did not acquire a simple pre-training discrimination. As a consequence however, there was a tendency for children with extreme scores in the lower range of the independent variables to be excluded from the correlations; for example, the six children with the lowest MAs had no dimensional score (see section 7.4.4 for further analyses). It is possible, therefore, that the correlations with dimensional score may suffer from attenuation of range, and higher correlations may exist with BOL for an unrestricted range of AD, MA, and BAS scores.

How may restricted BOL be accounted for? Recently, Anderson and Rincover (1982), Rincover, Feldman, and Eason (1986), and Rincover and Duchmare (1987), have proposed a 'tunnel vision' hypothesis to account for the restricted BOL observed with their autistic subjects. These authors hypothesise that the degree of stimulus control acquired by each cue in a multiple cue discrimination is determined by the distance of these cues from each other. Rincover and Ducharme (1987) trained eight autistic, and eight intellectually average children, on two simultaneous discrimination tasks where stimuli differed on relevant and redundant form and colour dimensions.

In a 'within-stimulus' condition, S⁺ and S⁻ forms were also of different colours, e.g., blue triangle vs. yellow circle. In a second 'extra-stimulus' condition, S⁺ and S⁻ forms were white, and the colour cue was a horizontal strip presented above each stimulus. In this condition the form and colour cues were both still relevant, but spatially separated. Following acquisition of the discrimination BOL was assessed through stimulus generalization tests across the form and colour dimensions.

Rincover and Ducharme report a significant group X condition X dimension interaction, and suggest the only significant difference was for the autistic children in the extra-stimulus condition, who responded significantly more often to the form cue than the colour cue. They conclude that only the autistic children showed overselectivity, and that this occurred only when the component cues were spatially separated.

These results demonstrate that overselective responding may be determined by stimulus variables, and is therefore valuable in cautioning against any rigid interpretation of restricted BOL as an endogenous stimulus control deficit. However, the results of the present study reveal that 'tunnel vision' is not a necessary condition for the occurrence of overselective responding, at least for our subjects. In the present task all cues were components of a single visual stimulus, and distance between cues was not a relevant variable: Yet the majority of subjects did respond to a restricted number of component cues. Similarly, both Kovatanna and Kramer (1974), and Schover and Newsom (1976), who employed similar tasks to the present discrimination, have reported restricted responding to component cues by autistic and mentally handicapped subjects.

From the present observations we can conclude that restricted BOL appears to be a reflection of the general cognitive developmental delay shown in mentally handicapped children. It does not appear to be specific to any one developmentally-impaired population, since many (but not all) autistic and moderately to severely mentally handicapped children demonstrate overselective responding (e.g., Koegel & Wilhelm, 1973; Lovaas et al., 1979). Given this degree of variability, both between and within populations of developmentally-impaired individuals, an important objective is a more precise specification of those children who are likely to

demonstrate overselective responding. Such identification may be important since overselective responding has been hypothesised as a factor that may influence a child's failure to transfer from prompt to training stimuli in extra-stimulus or NCR fading programmes (e.g., Koegel & Rincover, 1976). Similarly, Gersten (1980) in a review of over a decade of research into stimulus overselectivity, concludes "Clearly, precise methods are needed to ascertain which types of children display specific learning deficits, and for which type of children specific teaching procedures (such as within-stimulus prompts) are effective" (p61).

The present research may claim to have made a start on the first of these aims. The research has identified significant covariates of restricted BOL in severely mentally handicapped children, specifically individual differences in Attention/Distraction scores, and performance on specific cognitive ability scales. The latter aim, essentially that of specifying aptitude-treatment interactions, is more complex issue to evaluate. However, the next section will include some (admittedly speculative) comments on possible aptitude-treatment interactions in programmed training procedures.

7.5.4 Implications of Results

This study has clearly demonstrated that variation in the discrimination performance of severely mentally handicapped children could be meaningfully related to stable (reliable) dimensions of individual difference. Results showed that individual differences in verbal abilities (VA, VQ, and WRD), short-term visual recognition memory (VR), visual matching abilities (MLLF, COP, ENS), sustained attention (AD), and susceptibility to reinforcing events (REW) all correlated significantly with trials to criterion and

errors during discrimination acquisition.

There are two approaches to the interpretation of these results. First, the high intercorrelations between the ID variables may be assumed to lend empirical validity to interpretation in terms of a single general factor. For example, in Section 7.5.2 it was suggested that the extraction of a single factor from a principal components analysis of the BAS scales may imply a general ability factor. If a similar interpretation is placed upon the significant intercorrelations between all the above ID variables, the concept of 'g' then specifies the major (and single) individual difference parameter.

Alternatively, the variables may be interpreted as assessments of specific abilities. Thus, a profile of abilities are identified, e.g., sustained attention, short-term memory capacity, perceptual matching abilities, verbal abilities, etc. This profile of abilities then specifies several relevant individual difference parameters.

In this analysis, the latter approach is preferred. Other authors have also favoured this approach to individual differences and discrimination learning, although little research with mentally handicapped students has been reported (Conners and Detterman, 1987). The significant correlations observed between individual differences in cognitive and attentional abilities and discrimination performance may provide more detailed information about the learner, as well as about the process of learning.

Some Abilities Underlying Discrimination Performance

Conners and Detterman (1987) administered a battery of seven basic

cognitive tasks to a sample of 19 severely mentally handicapped children. Performance on these tasks was then correlated with performance on a previously administered word learning task, in which subjects were trained to point to written representations of spoken words. Connors and Detterman report that three tasks (a match-to-sample task, a probed recall task, and a simple paired-associate learning task) correlated significantly with trials to criterion on the word learning task. Measures of choice reaction time, relearning, long-term recognition memory, and tachistoscopic-threshold did not correlate significantly with learning. The authors conclude that individual differences in basic cognitive abilities can be identified that affect rate of learning.

In section 7.5.4 the BAS scales were interpreted as indicating some of the cognitive abilities that may underly discrimination performance. It may be noted that the Matching letter-Like Forms and Visual Recognition scales employed in the present study parallel the match-to-sample and probed recall tasks employed by Connors and Detterman, which were assumed to assess 'ability to encode and discriminate stimuli' and 'short-term memory capacity' respectively. In both studies, these variables were significantly correlated with learning. In general, two sets of processes, attentional and retentional, would appear to be implicated.

The importance of short-term memory capacity in discrimination acquisition was indicated by the significant correlation with the Visual Recognition scale. The number of dimensions which subjects responded to during dimensional testing also correlated with VR scores. This observation may be interpreted in terms of stimulus trace theory (Ellis, 1963). This theory proposed that mentally handicapped children had inferior STM due to extra-fast stimulus trace decay. Interposing a delay between stimulus and

response had an appreciable negative effect on the performance of mentally handicapped subjects, but not on the performance of normal intelligence subjects. In a subsequent analysis, Ellis (1970) replicated the poor STM performance of mentally handicapped children, although the deficit was attributed to a deficiency in rehearsal strategies, such as verbal encoding or grouping strategies, rather than directly to rapid trace decay. More recent reviews (Cohen, 1982) have concluded that there is evidence for both types of deficiencies in the STM performance of mentally handicapped individuals, which may be manifested differentially depending upon the demands of the task. Thus, poor discrimination performance may be associated with rapid loss of reward associations regarding the various cues. This may be due either to poor organization of the information through inadequate rehearsal strategies, or directly attributable to the storage mechanism per se. Whatever the interpretation of the mechanism underlying the performance of mentally handicapped children on STM tasks, STM performance was clearly correlated with all measured aspects of discrimination performance.

Other variables correlated with discrimination performance in the present study (e.g., Copying, Matching Letter-like Forms, the AD scale, breadth of learning) appear to involve attentional rather than retentional capabilities. This may be a significant observation since the most frequently cited theory concerning the discrimination learning of mentally handicapped individuals (Zeaman and House, 1963) explains the learning difficulties of the mentally handicapped in terms of defects in attention. The theory was presented in some detail in Chapter 2. To briefly recap, Zeaman and House postulate a chain of two responses for discrimination learning; first, an attentional response to the relevant stimulus dimension; and second, a correct instrumental response to the positive cue on the

correct dimension. The poor discrimination performance of mentally handicapped individuals was ascribed to their low initial probability of observing certain relevant stimulus dimensions, rather than poor ability to learn which of two observed cues is correct. For example, mentally handicapped children may have a higher probability of initially attending to position, which is generally an irrelevant dimension, than to form or colour. That position is a highly salient dimension for mentally handicapped children was clearly demonstrated in Chapter 5, where position perseveration and alternation biases were frequently identified.

Many reviews have considered attention to be a multibehavioural process (e.g., Alabiso, 1972; Mercer & Snell, 1977; Stankov, 1983), and distinctions may be drawn between 'behavioural' as well as 'cognitive' components of attention (Wood, 1988). In attention theory, emphasis is placed upon a cognitive or information processing component (the ability to scan or sample the available stimuli, and to subsequently select relevant stimuli). High scores on the Copying and Matching Letter-Like Forms scales for example, appear dependant on such capabilities. However, behavioural aspects of attention are also important since the individual must, in order to process relevant stimuli, also maintain attending behaviour over extended spans of time. This gross capacity of 'sustained attention' may be one element assessed in the behavioural items composing the attention/distractability scale, and may give rise to the significant correlation with discrimination performance. The AD scale may also, however, assess cognitive aspects of attention. For example, the number of dimensions a subject 'attended to' in discrimination learning also correlated significantly with the AD scale.

That this latter attentional variable (number of dimensions) was also itself correlated with rate of discrimination acquisition may at first

appear suprising, in that successful acquisition of the task required attention to only one of the three relevant stimulus dimensions (see Section 7.5.3). However, while the task did not demand attention to multiple dimensions, it may measure a 'preferred breadth of attention' (Zeaman & House, 1979, p115). Children who consider more rather than fewer stimulus dimensions may have a greater probability of initially attending to a relevant rather than irrelevant dimension. Later formulations of attention theory (Zeaman & House, 1979) have explicitly forwarded breadth of attention as a possible covariate of intelligence. Indeed, they note that such a variable appears a stronger candidate for relation to intelligence than direction of attention, since direction of attention (i.e., the dimension to which a subject attends) is so readily changed by training. (For example, the fading programmes reported in earlier chapters have clearly demonstrated the ease with which childrens attention can be modified through the addition of highly salient prompt dimensions). The present results, showing significant correlations between breadth of learning and cognitive ability (espically the BAS scales), may support an interpretation of breadth of learning as a covariate of intelligence.

In summary, the correlations observed in the present research may implicate both attentional and retentional processes in learning, and these observations are congruent with theoretical models which emphasise the role of these processes in discrimination learning (Ellis, 1963, 1970; Zeaman & House, 1963, 1979).

Some Possible Implications for Discrimination Training

It has been argued that where individual differences in cognitive and attentional abilities are identified that correlate with discrimination

performance, these individual differences may be used as a basis for individualizing instruction (Conners and Detterman, 1987). Parameters of discrimination training programmes may be varied for individual learners, in order to capitalize on strengths and compensate for weaknesses in these abilities. At the present stage of investigation such suggestions must be speculative and in the nature of hypotheses only, but some suggestions are detailed below.

First, the classroom rating scales may serve as appropriate assessment devices for determining those children who might benefit immediately from a particular type of educational programme, and those who might experience more difficulty. The AD and REW scales may highlight the need for intervention prior to instigation of discrimination training programmes. Subjects with low scores on attention/distractibility aspects of behaviour may benefit from pre-training of on-task behaviours, such as visual-fixation of discriminative stimuli (e.g., Maler & Hogg, 1974; Martins & Powers, 1967; Ross & Ross, 1981) since such attending skills are essential pre-requisites for successful learning. It was also suggested that the REW scale may reflect the influence of individual differences in motivation on rate of learning. Low scores on the REW factor may indicate the necessity for a reinforcement selection procedure to maximize motivation where sensitivity to reinforcement appears low.

In terms of programme manipulation, students whose short-term recognition ability is poor might benefit from decreased inter-trial intervals. Alternatively, subjects may be given overt verbal rehearsal training, such as verbal labelling of stimulus dimensions (Whiteley, Zaparniuk, and Asmundson, 1987; Crawford & Siegel, 1982). Although such techniques are likely to be beneficial for all subjects, subjects with

relatively good visual recognition memory and high verbal scores may already employ such strategies for recall.

Students with relatively poor perceptual matching ability might benefit from extended fading sequences, that commence with steps of extreme discriminability. Students with superior perceptual skills might benefit from shorter instructional sequences, where some of these early steps could be eliminated allowing the child to progress more quickly to the target discrimination. Such manipulations of programmed sequences were considered in Chapter 5, where standard and revised fading procedures were compared.

Individual differences in BOL may also have important implications for training. It was noted in Chapter 5 that extra-stimulus and NCR manipulations may sometimes prove ineffective, and the prompt cue may come to overshadow the training cue. However, Experiment 8 revealed an individual difference factor, since some subjects were capable of transferring from the NCR prompt cue to the training discrimination (e.g., from intensity to size) while others were not. If these results are reanalysed in the light of the subjects dimensional score, it appears that the variation in programmed success may be related to individual differences in BOL. All children who had responded to multiple cues during dimensional testing were successful in transferring from the NCR cue: those children who had responded to only a single cue at testing were more likely to exhibit difficulties in transferring from the NCR cue.

While CR programmes may circumvent some of these problems, and may therefore benefit all subjects, many CR manipulations (such as stimulus shaping procedures) are extremely costly in terms of the construction of materials, and require extensive stimulus manipulation. Etzel and LeBlanc

(1979) have argued that shaping is accomplished only at the cost of a great deal of time and effort, and that such programmes should only be employed where fading programmes fail to accomplish successful transfer. Clear benefits would arise if it were possible to match programmed techniques to a child's abilities, both in saving the cost involved in developing shaping programmes where the individual might benefit from less costly fading techniques, and in avoiding the potentially detrimental effects of exposing the child to experiences of failure where fading procedures are unlikely to be effective. However, such programme specification is clearly dependant upon the assumption that overselective responding is a "trait", or at least a fairly stable mode of responding, that can therefore be reliably assessed.

To date, no research has assessed the reliability of assessments of BOL. Indeed, some research has suggested that overselective responding may be task-specific, and may vary dependant upon the stimulus materials employed (Rincover & Ducharme, 1987).

Clearly, these observations can be forwarded as tentative hypotheses only. Extensive further research will be required to support any specific recommendations. To date, little research has evaluated such potential aptitude-treatment interactions, although studies such as Connors and Detterman (1987) are encouraging. A clear precursor to any attempt to specify interactions between aptitude and treatment is the identification of dimensions of individual difference that are relevant to discrimination performance. The present research has identified several such dimensions. However, further research to investigate the validity of these dimensions is clearly required. One obvious requirement is to expand the analysis over a more varied selection of learning situations. In the present study, performance on a simple two-choice visual discrimination task was employed as the criterion variable. The results may not be replicated when

attempting to analyse performance on more complex learning tasks (e.g., visual-auditory discriminations, conditional discriminations) or in classroom learning situations. However, the positive results of the present study should encourage follow-up research.

7.6 Summary of Results

1. Variation in the discrimination performance of severely mentally handicapped children was shown to correlate significantly with reliable dimensions of individual difference.
2. PPVT MA and IQ, but not CA, were significantly correlated with discrimination performance. Results suggested that IQ rather than MA was the better predictor of discrimination performance.
3. Discrimination performance was, however, better predicted from a composite of specific ability measures (BAS scales) than by global ability measures such as PPVT MA/IQ.
4. Factor analysis of a teacher completed classroom rating scale extracted four rather than two factors (Evans, 1975). The extracted factors were shown to be both reliable and to have acceptable validity. Such assessments of pupils' classroom behaviour were also significantly correlated with discrimination performance. Specifically, attention/distractability aspects of behaviour (AD) and susceptibility to reinforcing and punishing events (REW) both correlated significantly with discrimination performance.
5. Inhibition/excitation (IE) aspects of behaviour did not correlate significantly with discrimination performance, in contrast to previous

reports (Evans, 1975, 1982). However, these findings may be interpreted in terms of the differing response requirement of successive and simultaneous discrimination training procedures.

6. The linear combination of variables which most efficiently predicted discrimination performance consisted of Visual Recognition, Early Number Skills, and Attention/Distraction scores (multiple $r = -.76$, $F(3,73) = 32.28$, $p < .00001$). Results were interpreted as indicating the importance of perceptual, attentional, and retentional processes in discrimination learning.

7. The results did not support the hypothesis that restricted BOL is a function of 'psychopathology', specific to autism (Frankel et al., 1984). BOL was found to correlate significantly with cognitive ability, and restricted BOL may be more closely associated with low developmental level.

8. BOL was correlated significantly with the molar measure of attention derived from teacher ratings of classroom behaviour (AD Scale). This convergence between 'behavioural' and 'cognitive' components of attention was assumed to validate assessments of attention derived from teacher rating scales.

CHAPTER 8

General Conclusions

Chapter 8

General Conclusions

It is appropriate at this stage to extract some general trends for implementing discrimination training techniques in a natural environment. In this context, some general conclusions concerning the effectiveness of various discrimination training procedures are discussed. The results are then considered in terms of the theoretical processes presumed to underly discrimination learning. Consideration is also given to the role of individual differences in determining discrimination performance. Finally, some educational implications of the research are discussed.

8.1 Comparing Discrimination Training Procedures

Programmed versus Trial-and-Error Training

The superiority of programmed over trial-and-error training in facilitating the discrimination learning of severely mentally handicapped individuals was demonstrated in several experiments (Experiments 1, 2, 4, 7, and 8). While in some experiments the programmed procedures and trial-and-error training were not found to differ significantly (Experiments 3 and 5), whenever significant differences were found trial-and-error training was always the less effective procedure.

Trial-and-error training frequently gave rise to perseverative error strategies that interfered with learning. Particularly, position

perseveration and position alternation biases were often observed in the performance of subjects receiving trial-and-error training. Such biases were only rarely observed when subjects received programmed training. The effectiveness of programmed training in preventing the development of perseverative response biases can be explained by the fact that the responses of subjects are very quickly controlled by the discriminative stimuli. By contrast, the performance of subjects receiving trial-and-error training was clearly controlled by sources of stimulation other than the discriminative stimuli per se (e.g., position).

However, it was noted that where the training task was extremely complex, programmed training was not always ultimately effective in eliminating such perseverative error patterns. In the three experiments including the complex opposing 45° line tilt task (Experiments 2, 5, & 6) position biases were not exhibited during fading sequences. However, when there was no longer any obvious feature of the prompt cue to control responding, as at the end of a fading sequence where the prompt cue was completely attenuated, subjects frequently reverted to position-based response strategies. We conclude that position is a highly salient dimension for mentally handicapped persons. While such strategies may be supplanted where a highly salient prompt dimension is added, if the training cue is a complex one subjects may simply revert to a position-based strategy at the cessation of fading.

Programmed procedures may also be less successful when the child has acquired a history of unsuccessful trial-and-error training on the task. For example, in Experiment 8, a CR fading programme was successful in retraining children who had failed to acquire tasks with a NCR fading procedure, but markedly less effective in retraining those children who had

initially received trial-and-error training. We may conclude that programmed training may prevent the development of perseverative error strategies, but may not always be successful in eliminating them once they develop.

In summary, these results support the conclusion that programmed procedures are to be preferred over trial-and-error instruction in teaching discriminations to severely mentally handicapped children, although the effectiveness of the programmed procedures may be influenced both by the difficulty of the training task, and by the child's immediate prior training history.

Comparing Programmed Training Procedures

Following from the conclusion that programmed training is more effective than trial-and-error training, it may be asked whether any one programmed procedure is more effective than another. An answer to this question is not immediately apparent, since differences between various programmed procedures were generally minimal in comparison to the large differences observed between programmed and trial-and-error procedures.

Programmed procedures may be contrasted in terms of their underlying procedural parameters. For example, in Experiment 1 two programmed procedures (which were equally superior to trial-and-error training), could be contrasted on various dimensions (e.g., within-stimulus versus extra-stimulus manipulations, S₊ versus S₋ manipulation, etc.). The approach adopted in the present research was to attempt to evaluate some of these basic procedural parameters within experimental situations where the influence of other confounding factors could be controlled.

For example, Experiments 2 through to 4 investigated the effect of manipulating either S⁺ or S⁻ during programmed training. Previous research is equivocal on the issue of differential effectiveness of S⁺ or S⁻ manipulation (Schreibman & Charlop, 1981; Zawlocki & Walls, 1983; Stella & Etzel, 1986). However, Schreibman and Charlop (1981) have theorized that S⁺ manipulation should prove superior to S⁻ manipulation. They hypothesise that a changing S⁺ stimulus will remain novel and therefore more functional in learning, serving to direct the subjects attention to the relevant (S⁺) stimulus. In contrast, a changing S⁻ may serve only to direct the subjects attention to the incorrect (S⁻) stimulus.

In Experiment 2, S⁻ manipulation during superimposition and fading did appear less effective than S⁺ manipulation. In this experiment, the effect of S⁻ manipulation was to heighten the perceptual salience of S⁻, by manipulating a colour cue superimposed upon S⁻. It was argued that some severely mentally handicapped children appeared to have difficulty in inhibiting responses to the prompted S⁻. However, in Experiment 4 manipulation of S⁻ during stimulus fading appeared more effective than S⁺ manipulation, since more subjects acquired the difficult B and Q between-case letter matches with S⁻ than with S⁺ fading. It appeared that reinforcing responses to the terminal form of S⁺, before introducing competing S⁻ stimuli, was more effective than manipulating S⁺. In this experiment, although both programmed procedures increase the perceptual salience of S⁺, it was argued that the occurrence of a 'form vs. no form' baseline in the latter procedure proved maximally effective in highlighting the salience of S⁺.

The main conclusion to arise from Chapter 4 was that manipulation of S⁺

or S- per se., did not appear to significantly effect the outcome of training. The superiority of S+ over S- manipulation, predicted from Schreibman and Charlops theory of the role of stimulus novelty in graduated stimulus change procedures, was not confirmed. The crucial factor appeared to be the extent to which the stimulus manipulations increased the perceptual salience of S+ over S-. We conclude that S- manipulation may prove equally effective to S+ manipulation, providing the net effect of the manipulations is to increase the salience of S+. Programmed procedures should therefore aim to maximize S+ salience, irrespective of whether S+ or S- stimuli are manipulated.

In a similar manner, Chapter 6 compared the effectiveness of programmed procedures involving either CR or NCR stimulus manipulations. Results revealed that CR manipulations were more effective than NCR manipulations in facilitating discrimination acquisition. This effect was observed while controlling for the effects of important confounding variables (e.g., within-stimulus vs. extra-stimulus manipulations, number and size of fading steps, task difficulty). Not only did subjects acquire tasks faster with CR fading, but those children who failed to acquire tasks with NCR fading subsequently acquired the tasks when retrained with the CR procedure.

However, the experiment showed that NCR manipulations are not invariably ineffective, since NCR fading was superior to trial-and-error training. Indeed, over the series of experiments reported in the present research, NCR fading procedures have generally proved superior to trial-and-error training (see Experiments 1, 2, 4, and 7). Although a few studies with contrary findings have frequently been cited in the research literature (e.g., Koegel & Rincover, 1976), in general the results of NCR fading compare favourably with trial-and-error training (Sidman & Stoddard,

1967; Touchette, 1968; Gold & Barclay, 1973; Zawlocki & Walls, 1983; Richmond & Bell, 1983; Strand & Morris, 1986; Lancioni & Smeets, 1986). It may be concluded that the transfer of stimulus control from the dimension manipulated to the one relevant for the discrimination, is not as difficult as studies such as Koegel and Rincover (1976) would suggest.

One of the major variables influencing the effectiveness of the programmed procedures was task difficulty. For the opposing 45° line tilt task employed in Experiments 2, 5, and 6, all procedures were largely ineffective in producing task acquisition. Neither extra-stimulus distinctive-feature manipulation (Experiment 2); within-stimulus non criterion-related manipulation (Experiment 3; Experiment 5) nor within-stimulus criterion-related manipulation (Experiment 6) proved successful in facilitating acquisition of the task for the majority of the children. Although the overall lack of success of the programmed procedures was disappointing, trial-and-error training proved equally ineffective in training this task. (It may be noted, however, that four of five children who did acquire the task in Experiments 2 and 3 received programmed training).

The influence of task difficulty on programmed training will be considered in detail in section 8.2. However, for the present this observation raises a general point concerning the extent to which it is possible to specify a universally successful training procedure. Discrimination performance will be the product of many variables, and few researchers would expect any one procedure to be uniformly effective when applied to any task, or with any subject. Since individual variability in discrimination performance is so frequently observed, even within the severely mentally handicapped population (see Chapter 7), the effectiveness

of any programmed procedure in training a particular task to a particular child must ultimately remain an empirical issue.

For example, as mentioned above a CR orientation fading programme was not effective in teaching the opposing 45° line tilt task (see Experiment 6). Analysis suggested that subtle and unexpected aspects of the stimuli, such as the relative 'height' of the upper ends of the S+ and S- lines, may have come to control responding. This observation is made to indicate that, even when conditions are carefully arranged for establishing control of the relevant cue, seemingly trivial and easily overlooked features may acquire inappropriate control over responding.

Some authors have argued that research into programmed training - focussing on the process of establishing appropriate stimulus control - is essentially analytic rather than predictive in nature (Sidman, 1978, 1979; Ager, 1983). Therefore, while some broad generalizations concerning the effectiveness of particular procedures can be made (for example CR stimulus manipulations are likely to be more effective than NCR manipulations), such research may more directly guide us to discover where an individuals specific difficulties lie, rather than necessarily allowing us to predict this a priori.

8.2 Theoretical Interpretations

Programmed versus Trial-and-Error Training

The only theory forwarded to specifically account for the success of errorless learning is the 'aversive S-' theory proposed by Terrace (1966a,

1972). Terrace hypothesises two different types of learning in discrimination acquisition with and without errors. In trial-and-error learning, non-reinforced responses to $\underline{S-}$ result in frustration, producing negative emotional responses in the presence of $\underline{S-}$ (e.g., turning away from the key, pulling back from the key, wing flapping, etc.). Importantly, such responses are antagonistic to the response to $\underline{S+}$ (e.g., turning away from the key is incompatible with keypecking), and are presumably strengthened by the avoidance of frustration. This process establishes $\underline{S-}$ as an aversive stimulus, and $\underline{S-}$ acquires inhibitory control over responding. In support of this hypothesis, Terrace (1971) demonstrated that pigeons who had the opportunity to escape from $\underline{S-}$ during discrimination training, emitted escapes responses only if they had been trained under a trial-and-error procedure. Terraces also discusses several phenomena indicative of inhibitory control (e.g., inverted generalization gradients, peak shift, behavioural contrast), which he claims are observed only following trial-and-error learning.

In contrast, the absence of non-reinforced responses to $\underline{S-}$ during errorless learning results in an absence of frustration. $\underline{S-}$ functions as a neutral rather than aversive stimulus, and does not acquire inhibitory control over responding. The emotional responses to $\underline{S-}$ observed following trial-and-error training are not observed following errorless learning. Terrace therefore explains the difference between learning with and without errors in terms of the neutral or inhibitory properties acquired by $\underline{S-}$ during the course of training, and views the behavioural mechanism underlying the success of errorless training as the absence of competing and incompatible emotional responses which interfere with learning.

However, Terrace's theory of the neutral value of $\underline{S-}$ following

errorless learning has been challenged. Subsequent research (Karpice & Hearst, 1975; Rilling & Kaplan, 1975; Lambert, 1977; Evan & Hogg, 1982) has determined that S- may exercise inhibitory control even after errorless or near errorless training. Karpice and Hearst (1975) conclude that a negative correlation between the presentation of a stimulus and the delivery of reinforcers, which occurs even when learning occurs with little or no responding to S-, is the crucial factor in producing an inhibitory S- stimulus.

Therefore, in common with other authors (e.g., Lambert, 1980), we do not believe we are in the presence of two different types of learning, as Terrace claims. Errorless learning and acquisition with errors may be interpreted within a common conceptual framework. However, whatever the conclusion concerning the neutral or inhibitory value of S- in learning without errors, the absence of negative emotional responses during programmed training has been observed in the present research, and by other authors working with mentally handicapped individuals (e.g., O'Brien, 1968).

We conclude that the absence of such competing emotional responses remains a viable source of facilitation in programmed versus trial-and-error training.

As stated above, Terrace is the only author to forward a specific theory of errorless learning. However, the facilitation observed with programmed training may be related to other more general theories of discrimination learning, such as 'attention theory' (Zeaman & House, 1963). The overt goal of these authors has been to develop an "explicit quantitative model" of discrimination learning, and as such they tend to emphasise different issues to those focussed on here. For example, a major concern is to compare mentally handicapped and normal intelligence groups,

and importantly the role of programmed training in discrimination learning is not addressed. However, their central premise - that discrimination performance is "related to attentional differences rather than those of other subprocesses such as learning or extinction" - is pertinent for the current analysis.

For example, the responding of children following trial-and-error training was characterized by position perseveration or alternation biases, an observation consistent with attention to an irrelevant (position) dimension. The initial facilitative effect of adding prompt cues to the criterion discrimination may also be derived from the theory. Increasing the number of relevant dimensions by adding redundant prompt cues may increase the probability that the child will attend to a relevant stimulus dimension, and therefore assist the learning process by facilitating the first (attentional) link of the discriminative chain. We will return to this important theory later.

Finally, other more general sources of facilitation in programmed training can be posited. We noted in Section 8.1 that with programmed training the responses of subjects very rapidly became controlled by the discriminative stimuli, in contrast to the performance of subjects receiving trial-and-error instruction. In this regard, it is notable that programmed procedures provide greatly increased density of reinforcement vis a vis trial-and-error training, particularly in the early stages of training. It may be that general 'on-task' or precursor behaviour is more rapidly conditioned, e.g., conditioning of attention to the stimulus display.

In conclusion, the above interpretations are not incompatible, and it may be that increased density of reinforced experience with S+, the lack of

competing emotional responses that arise from non-reinforced experience with S-, and the direction of attention towards relevant stimuli all have a role in accounting for the superiority of programmed over trial-and-error instruction.

Comparing Programmed Training Procedures

A further concern of the present research has been to identify factors influencing the effectiveness of programmed training procedures in developing appropriate stimulus control. The major framework for the interpretation of programmed training in this context has concerned overshadowing. This analysis was most clearly expounded in Chapter 5. The role of overshadowing was suggested by the observation that the major feature of non-acquisition following programmed instruction was perseveration in responding to the prompt cue. It was argued that this observation reflected the overshadowing effect of the prompt cue upon the criterion cue during discrimination training. More generally, it was suggested that overshadowing provided a mechanism to interpret both successful and unsuccessful fading sequences, where outcome was viewed largely (although not exclusively) as a consequence of success or failure in attenuating the effects of overshadowing.

The analysis may be briefly reviewed. The addition of a prompt cue to the training cue forms a compound stimulus with multiple relevant cues. Initially, the prompt cue must be more discriminable than the training cue in order to facilitate correct responding. Thus, at the onset of training the prompt cue is an overshadowing agent by dint of its greater discriminability (Lovejoy & Russell, 1967; Sutherland & Mackintosh, 1971). The systematic relation between the magnitude of the overshadowing effect

and the discriminability of the overshadowing cue demonstrated by Miles and Jenkins (1973), allows the forwarding of an explanation of the effectiveness of fading in terms of changes in cue discriminability. Where the overshadowing cue remains easily discriminable during training, the overshadowing effect is observed (e.g., Terrace, 1963b). However, if the more salient cue is reduced in discriminability via fading, the less salient cue may come to acquire control as the discriminability of the component cues converge.

We may conclude that fading is a necessary condition for the successful transfer of stimulus control. However, it is also apparent that fading is not a sufficient condition for such transfer. It is suggested that subjects who failed to acquire discriminations with programmed training may have learnt to discriminate the prompt cue to the detriment of the criterion cue, observing increasingly subtle differences between S⁺ and S⁻ along the fading dimension to the exclusion of the criterion dimension. This process is presumed to result in the ^epers_Nerative responding to the prompt cue sometimes observed in the present research (see for example Figures 4.3, 4.6, and 6.4).

The emphasis placed on overshadowing in the current account is congruent with most theories of selective attention. In Zeaman and Houses (1963) theory, the attentional probabilities for each of the stimulus dimensions must sum to unity, i.e., the more learned about one dimension the less learned about another, when both dimensions are relevant and redundant.

For example, if attention to colour is directly reinforced on a trial, attention to form is indirectly extinguished. As the probability of attention to colour approaches 1 over successive reinforced trials, the probability of attention to form must inversely decline towards zero. This

has been termed the 'inverse hypothesis'. A similar assumption characterizes other theories of 'selective attention' (Sutherland & Mackintosh, 1971). In sum, the theories predict that the presence of one cue will reduce the extent to which a subject can attend to and hence learn about a concurrent second cue.

Other theories, although clearly quite distinct from theories of selective attention, may still be seen to explain stimulus selection by appeal to an 'inverse hypothesis'. For example, while modified non-continuity theory (Rescorla & Wagner, 1972) does not view stimuli as competing for a limited attentional capacity, stimuli are presumed to compete for a limited amount of associative strength conditionable by a given reinforcer. The control that one cue can acquire will be reduced to the extent that a concurrent second cue brings the strength of the entire compound closer to the asymptotic value for the reinforcer, thus limiting the conditioning of one cue.

It may be asked why the extra-stimulus and NCR prompting procedures employed in the present research were frequently effective in facilitating discrimination acquisition, given that the inverse hypothesis implies that learning about the prompt cue should detract from learning about the criterion cue. However, it must be remembered that both theories of selective attention and modified non-continuity theory have only addressed tasks in which the values of the discriminative stimuli are invariant over successive trials. The theories have not been applied to tasks in which fading procedures are applied. As we suggested earlier, fading procedures, viewed as systematic changes in the discriminability of the overshadowing cue, may prove an effective means of attenuating the overshadowing effect, allowing the less discriminable cue to acquire control.

More recently, Mackintosh (1975) has summarized a large body of data that conflict with the inverse hypothesis. He observes the overshadowing effect is only reliably obtained when one cue is 'stronger' than another; that is where one cue of the compound is either better correlated with reinforcement, or more discriminable, than the concurrent second cue. Since the latter is clearly the case in programmed training, Mackintosh's results do not conflict with our interpretation of the role of overshadowing in programmed procedures. However, he concludes that overshadowing is not the generalized and ubiquitous phenomena implied by the inverse hypothesis, suggesting that overshadowing may not be due to any simple competition between stimuli for attention.

This has, in part, led to the rejection of the inverse hypothesis in a recent reformulation of attention theory (Zeaman & House, 1979). Although attention remains selective, in that the subject makes an initial choice of dimensions for attention, the degree of selection (breadth of attention) varies in the revised model. The indirect extinction of observing responses is relaxed, as the theoretical probabilities of attention no longer need to sum to unity. i.e., attention to one dimension is independent of attention to any other dimension. This position is not without its own associated problems, since, as Mackintosh states, rejection of the inverse hypothesis requires the specification of alternative rules that can predict overshadowing where one cue of the compound is 'stronger' than the other, and Zeaman and Houses (1979) model fails to specify such rules. Mackintosh himself considers overshadowing may more parsimoniously be considered a consequence of subjects learning to ignore stimuli that signal only the occurrence of a reinforcer already predicted by other stimuli. For example, attention to the criterion cue may decline to the extent that the criterion

cue signals no change in reinforcement from the level predicted by the prompt cue alone.

Since programmed training procedures fulfil Mackintosh's requirement for the occurrence of overshadowing (one component of the compound is 'stronger' than the other), our interpretation of the role of overshadowing is less compatible with the revised theory than with the original formulation. However, it may be argued that, by theoretically allowing that attention to the prompt dimension does not of necessity inversely reduce attention to other dimensions, the revised model may be more congruent with our observation of the frequent effectiveness of extra-stimulus and NCR fading procedures. Subjects may theoretically learn something about a second (criterion) cue, even while their performance is largely controlled by the overshadowing (prompt) cue.

The present research does not provide a basis for determining conclusively which of the two models is the more appropriate formulation. This is because - while highly suggestive - our data cannot unambiguously confirm the occurrence of overshadowing. Because a maximum of 175 trials to criterion was employed in the present experiments, we can only state that trial-and-error and programmed training were sometimes equally ineffective in facilitating acquisition; we cannot necessarily state that programmed subjects learnt less about the criterion cue than the trial-and-error subjects. However, overshadowing appears a compelling explanation for the failure of fading, since it is clear that for some (predominantly complex) tasks, subjects receiving programmed training learnt only about the prompt cue, and learnt nothing about the criterion cue (see for example Figures 4.3, 4.6, and 6.4).

We have argued that overshadowing provides a plausible explanation for the failure of programmed training. However, the resulting prolonged perseveration to the prompt cue is not an inevitable outcome of extra-stimulus or NCR fading procedures. What factors appear to exacerbate the prolonged perseveration in responding to the prompt cue? All the theories outlined above assume that any control that might be acquired by the less salient cue will be determined by the amount of control exerted by the overshadowing cue. Consequently, experiments reported in Chapter 5 attempted to determine whether reducing the starting discriminability of the prompt cue would facilitate acquisition of the criterion discrimination. However, Experiments 5 and 7 did not find that reduced starting prompt intensities facilitated acquisition relative to a standard fading procedure; in Experiment 7 both programmed procedures proved equally superior to a trial-and-error training control. It is not possible to conclude therefore that reducing the initial discriminability of the prompt cue will reduce the degree of perseverative responding to the prompt cue, although this was the case for three of the five sets of matched subjects compared. Further research, possibly consisting of a controlled factorial study with large numbers of subjects, will be required to resolve the issue.

The research has clearly indicated, however, that the discriminability of the criterion cue is a significant variable affecting the degree of perseverative responding to the prompt cue. Mention has been made in section 8.1 that programmed procedures were less effective in training complex rather than simple discrimination tasks. Experiment 8 provided a controlled manipulation of training cue discriminability, by employing tasks in which discriminability was manipulated only through small variations in

the value of S+. During identical fading sequences, transfer from the prompt cue to the training cue occurred more readily when the training cue was more discriminable (larger size or intensity differences between S+ and S-) than when the training cue was less discriminable (smaller size or intensity differences between S+ and S-).

We conclude that as the fading cue becomes less discriminable, the criterion cue, if highly discriminable, is more likely to become effective in controlling responding. However, if the fading and criterion cues are both low in discriminability, which may obtain at the final stages of a fading sequence, the fading cue continues to control responding until it is removed. Thus, the disadvantage of a prompt cue being drawn from a different dimension to the criterion cue may be overcome where the criterion cue is relatively discriminable. This may explain why extra-stimulus and NCR procedures frequently proved effective. Further support for this interpretation may be drawn from Experiment 8, where it was observed that the difference between NCR and CR fading procedures was less pronounced when the criterion cue was relatively easy to discriminate. The inferiority of NCR fading relative to CR fading was most pronounced during acquisition of the more complex (low discriminability) tasks.

This latter experiment, which directly compared CR and NCR stimulus manipulations, provides the most substantial support for the overshadowing analysis. The overshadowing analysis clearly predicts that fading a CR cue will be superior to fading a NCR cue. With CR fading there is no competition between relevant cues, upon which overshadowing is predicated, since prompt and training cues are drawn from the same stimulus dimension. Only where NCR prompts are employed are subjects required to transfer to a

new cue during fading. As described earlier in section 8.1, this prediction was clearly confirmed and supports the overshadowing interpretation.

This superiority of CR over NCR fading - a natural consequence of our 'overshadowing' analysis - is not immediately deducible from attention theory. Zeaman and House (1963) hypothesise that learning is mediated through attention to stimulus dimensions, rather than directly to discriminative stimuli per se. Since the theoretical role of the attention response is to transform the attended stimulus dimension to the cues of that dimension, any demonstration that cue differences can in turn help determine attention to stimulus dimensions presents a paradox of backward action in time. However, Zeaman and Houses (1979) reformulation of attention theory recognizes this paradox, and incorporates a feedback loop into the model. The 'effective' probability of attention to a dimension is seen as a product of both the initial probability of attending to the dimension, and information concerning cue-significance. In the revised model, therefore, the presence of large cue differences on a stimulus dimension may directly increase the likelihood of attending to that stimulus dimension, via a feedback loop to the attention selector. Thus, the revised theory can incorporate our results concerning the importance of cue differences, whilst maintaining a dimensional analysis of discrimination learning.

In conclusion, the 'overshadowing' analysis presented in this section appears largely to be supported by the available data. This interpretation of fading in terms of changes in cue discriminability is compatible with an attentional analysis of learning, although it is not clear which formulation of attention theory (Zeaman & House, 1963, 1979) most closely accords with the present data. Ultimately, since neither model considers the influence

on performance of changes in cue discriminability over successive trials, our data concerning fading procedures cannot differentiate between the two models. It is also notable that the theoretical interpretation of overshadowing is not exclusively the preserve of attentional theories, and modified non-continuity theory (Rescorla & Wagner, 1972) can also cope with most aspects of the data. In sum, the present analysis, while compatible with aspects of both theories, is clearly unique in the role assigned to changes in cue discriminability during the course of discrimination training.

8.3 Individual Differences and Discrimination Training

Wide individual differences in learning among severely mentally handicapped persons are frequently observed (e.g., Brooks and Baumeister, 1977; Berkson & Landesman-Dwyer, 1977; Haywood et al., 1982; Ellis, et al., 1982) although only rarely are attempts made to identify sources of such variability (see Chapters 2 and 7). In the present research it was found that individual variability in discrimination performance was significantly correlated with individual differences in MA and IQ. While this observation may have important theoretical implications (see Chapter 7, section 7.5.4) the practical relevance of such a finding is less clear. A major criticism of approaches that seek to interpret performance differences simply in terms of IQ is that norm-referenced scores, such as those derived from the PPVT, are seldom prescriptive, i.e., the results are not especially useful for determining the programme needs of individual children (Baumeister, 1967; Brooks & Baumeister, 1977).

In support of such an argument, it may be noted that while PPVT MA was predictive of outcome ($r = -.53$ with errors), PPVT MA could account for less than 30% of the variance in discrimination performance. Variance in discrimination performance could better be accounted for in terms of specific assessments of short-term recognition memory, visual matching skills, and attention/distractability aspects of classroom behaviour ($R = .76$, $p < .0001$). Therefore, where the aim of assessment is to provide information pertinent to the child's discrimination performance, the present results suggest that specific assessments of basic cognitive and attentional capabilities may be more useful than norm-referenced tests scores, such as PPVT MA/IQ.

In addition to the PPVT and BAS assessments of cognitive ability (e.g., short-term visual recognition memory, perceptual matching performance, visual matching and classification skills), aspects of the child's classroom behaviour, as measured by teacher ratings, also correlated significantly with subsequent discrimination performance. Factor analysis of the teacher rating scale extracted four factors. Two of these factors - identified as attention/distractability aspects of classroom behaviour, and susceptibility to reinforcing and punishing events in the classroom - correlated significantly with performance in a subsequent simultaneous discrimination task. These findings, previously unreported, suggest behavioural dimensions of individual difference, in addition to individual differences in cognitive ability, may have a significant effect on the outcome of discrimination training.

The research reported in Chapter 7 investigated the relationship between individual difference dimensions and the child's discrimination

performance in the absence of any specific programmed assistance. However, the present research has demonstrated that programmed procedures may be an effective means of reducing such individual variability. For example, in Experiment 1, while there was marked individual variability in performance within the trial-and-error group, individual variance in performance within the two programmed groups was virtually eliminated, with all subjects acquiring the tasks with the minimum, or near minimum, number of errors and trials to criterion.

We hesitate to suggest, however, that programmed training procedures can totally eliminate individual variability in performance. For example, in later studies wide individual variability within the programmed groups was observed (e.g., Experiments 2 and 7). In Experiment 4, individual differences were also observed in overall improvement between pre-testing and post-testing. Finally, where tasks were not acquired, individual differences were noted in the highest step that children attained within a programmed sequence (see Experiment 6).

It is notable that little attention has been paid to individual differences in the theories reviewed in section 8.2. These theories have predominantly been concerned with identifying a general locus for the 'learning deficit' of mentally handicapped individuals, and individual differences within the mentally handicapped population are rarely considered. As Brooks and Baumeister (1977) note in discussing Zeaman and Houses (1963) theory (among others) "it should be emphasised that these are basically nomothetic theories, more concerned with generalizations across individuals than with individual by situation interactions - interactions that we believe are crucial to understanding retarded behaviour" (p408). A

similar view is expressed by Gärsten (1980), whose review concludes "precise methods are needed to ascertain which types of children display specific learning deficits, and for which types of children specific teaching procedures . . . are effective" (p61).

For example, 'stimulus overselectivity' models (e.g., Lovaas et al., 1979) interpret the 'learning deficit' of developmentally impaired children in terms of a tendency to overselect when presented with a compound stimulus, attending to only one component of the stimulus complex (see Chapter 2). In the present research, such behaviour has been termed restricted breadth of learning (BOL). On the basis of the overselectivity model, it has been predicted that NCR and extra-stimulus fading procedures, which require attention to both prompt and training cues, may prove largely ineffective in training developmentally impaired children (Lovaas et al, 1979).

In contrast, the present research suggests BOL may be a dimension upon which mentally handicapped individuals differ, and aptitude-treatment interactions may be influential in determining the success of programmed training procedures (see Chapter 7). For example, in Experiment 8 some children were successful in transferring from a NCR prompt cue to the training cue, while others perseverated in responding to the prompt cue. In reinterpreting this data in the light of the child's BOL, it was apparent that all children who responded to multiple cues during dimensional testing were successful in transferring from the NCR cue; those children who exhibited a restricted BOL (responded to only a single cue on the dimensional tests) were more likely to exhibit difficulties in transferring from the NCR cue.

In conclusion, a major task facing theoretical accounts of the discrimination learning of mentally handicapped individuals concerns the incorporation of individual differences parameters into the proposed models.

In general, it may be concluded that further research is necessary to more clearly articulate how characteristics of the individual may interact with programmed procedures to effect outcome. The example given above highlights the possible nature of such aptitude-treatment interactions, and further suggestions were forwarded in Chapter 7, section 7.5.4. While the present research cannot provide definitive statements concerning aptitude-treatment interactions, the research may claim to have contributed to the initiation of this process by identifying dimensions of individual difference in mentally handicapped children that are significant covariates of discrimination performance.

8.4 Educational Implications

The long term objectives of any basic research involving mental handicap individuals is to develop methods or procedures for teaching that can be used in everyday practice. To apply the technology of errorless learning in the classroom, the apparatus and the design of the programme must be within the reach of the teachers. To date, programmed procedures have required complex and costly specialized equipment, which has undoubtedly hindered the widespread use of such techniques. The present research suggests two manners in which the application of fading procedures may be increased in everyday practice.

First, the research has demonstrated that stimulus fading procedures may be effectively implemented using microcomputers. Such demonstrations of effective applications, allied with the reliability, flexibility, and availability of modern microcomputer technology (microcomputers are now available in all special needs schools), may increase the potential application of fading techniques in the classroom. Microcomputers offer several specific advantages for discrimination training, including an increased range of reinforcers (e.g., tones, graphic displays), automatic recording and storage of data, and the opportunity for individualized instruction without the need for constant supervision from the teacher. Indeed, interacting with the computer in itself proved an extremely strong motivator for the children. Further technological advances, such as the development of relatively inexpensive touch sensitive screens, may further increase the widespread use of fading techniques.

Second, a graded prompt fading programme (see Experiment 1), involving the fading of physical, gestural, and verbal prompts delivered by a trainer, also proved an extremely effective training procedure. In contrast to microcomputer applications, the advantage of the graded prompting procedure may lie in the interactive nature of the training. For students with whom on-task behaviour is difficult to maintain without supervision, or who react primarily to social reinforcement, the procedure offers a readily applied programmed technique without the necessity for stimulus manipulation. Hence, the procedure can readily be employed in many varied training contexts.

However, the present research has been concerned with training relatively simple two-choice simultaneous visual discriminations. The

effectiveness of fading procedures in teaching more complex tasks has yet to be conclusively demonstrated, and this may limit the applicability of programmed techniques. It may be encouraging, however, to note that the early negative results concerning the effectiveness of programmed procedures in facilitating conditional discriminations (Gollin & Savoy, 1968), and generalization across stimuli (Gurnalick, 1975), have not been substantiated in more recent studies (Schilmoeller, Schilmoeller, Etzel, & LeBlanc, 1979; Aeschleman & Higgins, 1982).

Finally, throughout this research the occurrence of errors during learning has consistently been assumed to have negative consequences. However, some authors have questioned whether there may be negative by-products of a history of learning without errors. For example, Lambert (1980) writes "let us suppose a child could acquire all the basic discriminations without errors. What would be the reactions of this child when faced with a non-programmed situation? We can imagine that a child who has had no experience with failure would be unable to solve the problem . . . it might be that reducing the opportunities to emit errors will increase the dependence of the person." (p125).

There is little research relevant to this issue. The vast majority of investigations into programmed training have only evaluated performance on single discrimination tasks. Stoddard and McIlvane (1986) have highlighted the absence of repeated acquisition designs as "an important gap in discrimination learning research" (p174). However, the first experiment reported in the present research is pertinent here, as performance was evaluated across four successive discrimination tasks, and the study also directly evaluated the effects on subsequent unassisted performance of a

history of programmed training versus a history of trial-and-error training.

The results of the experiment did not reveal any adverse effects of prior errorless learning on subsequent trial-and-error training performance.

Indeed, results indicated that three of five subjects who initially received stimulus fading acquired the unassisted task more rapidly than any of the subjects who received only trial-and-error training.

Experiment 1 was restricted to performance over a series of highly similar discrimination tasks, and it remains to be seen what the broader 'secondary' effects of a history of errorless discrimination training may be. For example, it may ultimately prove necessary to fade assistance across successive tasks in a manner analogous to the fading of assistance within a single task.

However, for severely mentally handicapped children who present a non-adaptive history of discrimination learning, it is of primary importance to design and implement procedures that will permit the establishment of adequate behaviours. Thus, we consider the benefits associated with programmed training procedures to be of more immediate concern than any putative 'adverse secondary effects' of a history of learning without errors. However, it is apparent that more data will be required before the trial-and-error issue may finally be laid to rest.

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APPENDIX A

Appendix A, Part 1.

The IE2 Questionnaire (after Evans, 1975).

CHILD'S NAME: _____ IDENTIFICATION No.: _____

As you have watched at home or in the classroom and at play you will have gradually built up a picture of how she/he generally behaves. Obviously no child acts in exactly the same way on every occasion, but most children show certain characteristics that you feel are typical for that child. Although a child may not be very active all the time, he may tend to be so on the whole.

In order to enable us to take a clear record of your impressions of the above child we should like you to indicate your opinions on rating scales. To do this we have arranged various statements that have been made about mentally handicapped and ask you to indicate how much this applies to the child. As an example we might have the statement:

He/she likes painting:

Always	Frequently	Quite often	Sometimes	Infrequently	Very rarely	Never

If the child always likes painting then you would put a cross in that box:

Always	Frequently	Quite often	Sometimes	Infrequently	Very rarely	Never
X						

If the child likes painting infrequently then the cross would be placed appropriately:

Always	Frequently	Quite often	Sometimes	Infrequently	Very rarely	Never
				X		

If before filling in the booklet you would prefer to observe the child for a short period each day bearing in mind these questions please do so. Try to treat each scale in its own right. If some seem similar do not worry. Obviously there are no right or wrong answers, it is your assessment that is important.

In using the rating scales do not confine yourself only to the end categories or to the middle category. Use these by all means when you feel this is applicable, but try to use all categories in order to make the distinctions between children clear.

1. He/she requires additional stimulation to continue a task:

<input type="checkbox"/>	Always
<input type="checkbox"/>	Frequently
<input type="checkbox"/>	Quite often
<input type="checkbox"/>	Sometimes
<input type="checkbox"/>	Infrequently
<input type="checkbox"/>	Very rarely
<input type="checkbox"/>	Never

<input type="checkbox"/>

54

2. His/her concentration is:

<input type="checkbox"/>	Extremely good
<input type="checkbox"/>	Moderately good
<input type="checkbox"/>	Slightly good
<input type="checkbox"/>	Neither one nor the other
<input type="checkbox"/>	Slightly poor
<input type="checkbox"/>	Moderately poor
<input type="checkbox"/>	Extremely poor

<input type="checkbox"/>

55

3. His/her capacity for work is:

<input type="checkbox"/>	Extremely low
<input type="checkbox"/>	Moderately low
<input type="checkbox"/>	Slightly low
<input type="checkbox"/>	Neither one nor the other
<input type="checkbox"/>	Slightly high
<input type="checkbox"/>	Moderately high
<input type="checkbox"/>	Extremely high

<input type="checkbox"/>

56

4. His/her movements are generally co-ordinated:

<input type="checkbox"/>	Extremely well
<input type="checkbox"/>	Well
<input type="checkbox"/>	Fairly well
<input type="checkbox"/>	Neither one nor the other
<input type="checkbox"/>	A little poorly
<input type="checkbox"/>	Poorly
<input type="checkbox"/>	Extremely poorly

<input type="checkbox"/>

57

5. His/her performance on a task tends to be disrupted by failure:

	Not at all
	To a very small extent
	To a slight extent
	To a moderate extent
	To a considerable extent
	To a great extent
	To a very great extent

58

6. His/her reaction to a problem (though not necessarily an appropriate reaction) is:

	Extremely fast
	Moderately fast
	Slightly fast
	Neither one nor the other
	Slightly slow
	Moderately slow
	Extremely slow

59

7. He/she perseveres for a long time:

	Not at all
	To a very small extent
	To a slight extent
	To a moderate extent
	To a considerable extent
	To a great extent
	To a very great extent

60

8. He/she speaks. Leave blank if child is not verbal:

	Extremely decisively
	Moderately decisively
	Slightly decisively
	Neither one nor the other
	Slightly indecisively
	Moderately indecisively
	Extremely indecisively

61

9. He/she speaks at length: leave blank if child is not verbal:

	To a very great extent
	To a great extent
	To a considerable extent
	To a moderate extent
	To a slight extent
	To a very small extent
	Not at all

62

10. In his/her actions he/she is:

	Extremely restrained
	Moderately restrained
	Slightly restrained
	Neither one nor the other
	Slightly impulsive
	Moderately impulsive
	Extremely impulsive

63

11. He/she speaks: leave blank if child is not verbal:

	Extremely slowly
	Moderately slowly
	Slightly slowly
	Neither one nor the other
	Slightly quickly
	Moderately quickly
	Extremely quickly

64

12. The co-ordination of his/her movements tends to vary when doing the same task on different occasions:

	Not at all
	To a very small extent
	To a slight extent
	To a moderate extent
	To a considerable extent
	To a great extent
	To a very great extent

65

13. His/her performance on a task improves with success:

<input type="checkbox"/>	To a very great extent
<input type="checkbox"/>	To a great extent
<input type="checkbox"/>	To a considerable extent
<input type="checkbox"/>	To a moderate extent
<input type="checkbox"/>	To a slight extent
<input type="checkbox"/>	To a very small extent
<input type="checkbox"/>	Not at all

66

14. He/she listens to instructions well:

<input type="checkbox"/>	Never
<input type="checkbox"/>	Very rarely
<input type="checkbox"/>	Infrequently
<input type="checkbox"/>	Sometimes
<input type="checkbox"/>	Quite often
<input type="checkbox"/>	Frequently
<input type="checkbox"/>	All the time

67

15. He/she works well towards a set objective:

<input type="checkbox"/>	To a very great extent
<input type="checkbox"/>	To a great extent
<input type="checkbox"/>	To a considerable extent
<input type="checkbox"/>	To a moderate extent
<input type="checkbox"/>	To a slight extent
<input type="checkbox"/>	To a very small extent
<input type="checkbox"/>	Not at all

68

16. He/she speaks: leave blank if child is not verbal:

<input type="checkbox"/>	Extremely loudly
<input type="checkbox"/>	Moderately loudly
<input type="checkbox"/>	Slightly loudly
<input type="checkbox"/>	Neither one nor the other
<input type="checkbox"/>	Slightly softly
<input type="checkbox"/>	Moderately softly
<input type="checkbox"/>	Extremely softly

69

17. He/she is responsive to praise:

<input type="checkbox"/>	Not at all
<input type="checkbox"/>	To a very small extent
<input type="checkbox"/>	To a slight extent
<input type="checkbox"/>	To a moderate extent
<input type="checkbox"/>	To a considerable extent
<input type="checkbox"/>	To a great extent
<input type="checkbox"/>	To a very great extent

18. He/she is:

<input type="checkbox"/>	Extremely excitable
<input type="checkbox"/>	Moderately excitable
<input type="checkbox"/>	Slightly excitable
<input type="checkbox"/>	Neither one nor the other
<input type="checkbox"/>	Slightly calm
<input type="checkbox"/>	Moderately calm
<input type="checkbox"/>	Extremely calm

19. He/she is:

<input type="checkbox"/>	Extremely easy to distract
<input type="checkbox"/>	Moderately easy to distract
<input type="checkbox"/>	Slightly easy to distract
<input type="checkbox"/>	Neither one nor the other
<input type="checkbox"/>	Slightly difficult to distract
<input type="checkbox"/>	Moderately difficult to distract
<input type="checkbox"/>	Extremely difficult to distract

20. He/she is:

<input type="checkbox"/>	Extremely uninhibited
<input type="checkbox"/>	Moderately uninhibited
<input type="checkbox"/>	Slightly uninhibited
<input type="checkbox"/>	Neither one nor the other
<input type="checkbox"/>	Slightly inhibited
<input type="checkbox"/>	Moderately inhibited
<input type="checkbox"/>	Extremely inhibited

☐ 70

☐ 71

☐ 72

☐ 73

21. To get his/her attention for a new task is:

<input type="checkbox"/>	Extremely difficult
<input type="checkbox"/>	Moderately difficult
<input type="checkbox"/>	Slightly difficult
<input type="checkbox"/>	Neither one nor the other
<input type="checkbox"/>	Slightly easy
<input type="checkbox"/>	Moderately easy
<input type="checkbox"/>	Extremely easy

☐

74

22. He/she is upset by being told off:

<input type="checkbox"/>	To a very great extent
<input type="checkbox"/>	To a great extent
<input type="checkbox"/>	To a considerable extent
<input type="checkbox"/>	To a moderate extent
<input type="checkbox"/>	To a slight extent
<input type="checkbox"/>	To a very small extent
<input type="checkbox"/>	Not at all

☐

75

23. He/she actively seeks approval:

<input type="checkbox"/>	Always
<input type="checkbox"/>	Frequently
<input type="checkbox"/>	Quite often
<input type="checkbox"/>	Sometimes
<input type="checkbox"/>	Infrequently
<input type="checkbox"/>	Very rarely
<input type="checkbox"/>	Never

☐

76

Appendix A, part 2.

Factor Scores on the IE2: Varimax rotation (N=77)

VARIABLE	FACTOR 1	FACTOR 2	FACTOR 3	FACTOR 4
1	.80565	-.03724	.17112	.04046
2	.78507	.15696	.07195	.21694
3	.78927	-.14437	.10723	.24843
4	-.38371	-.32023	-.34759	-.17353
5	-.17164	-.04036	.59204	-.03976
6	.69848	.32558	-.02987	-.05212
7	.81930	-.11148	.15023	.06315
8	.27853	-.09258	-.04367	.77400
9	.17346	.13157	.18240	.84482
10	-.01997	.89437	-.02881	.12325
11	.22874	.29494	.14867	.50631
12	-.41271	.16144	-.01630	.04787
13	-.25598	-.14515	-.82871	.07237
14	.65530	.28227	.32228	.21238
15	.63982	-.12038	.48450	.18499
16	.01570	.31122	.00959	.39649
17	.12388	.01164	.82379	.08309
18	-.25692	.78456	.07136	-.09477
19	.78181	-.29643	.00256	.05073
20	-.20749	.70353	-.19052	.36132
21	.77239	-.20316	.10546	.30577
22	-.03455	.28594	-.61792	-.04959
23	-.19721	.00071	-.72866	.16524

Appendix A, Part 3.

Factor Scores on the IE2: Oblique Rotation Pattern Matrix (N=77)

VARIABLE	FACTOR 1	FACTOR 2	FACTOR 3	FACTOR 4
1	.80921	-.00175	-.10221	-.03868
2	.78185	.16634	.00521	.14268
3	.73085	-.15366	-.02493	.19538
4	-.32492	-.30192	.30803	-.12200
5	-.28844	-.06145	-.61280	-.03594
6	.75454	.34420	.09329	-.13464
7	.83062	-.06442	-.08198	-.01479
8	.11401	-.19487	.10846	.80276
9	.00155	.04097	-.13298	.86192
10	.05971	.89679	.02782	.07786
11	.17282	.27198	-.11501	.48456
12	-.34487	.20979	-.03484	.06269
13	-.20694	-.20519	.83093	.14384
14	.55689	-.28797	-.25749	.17027
15	.53498	-.12335	-.42478	.12893
16	-.07476	.22797	.01766	.40884
17	.01381	.03511	-.82759	.04379
18	-.16161	.81132	-.10622	-.12865
19	.77151	-.27625	.07046	-.00263
20	-.21319	.63382	.19456	.37189
21	.71443	-.20405	-.02581	.25674
22	.04596	.24308	.63242	-.03474
23	-.08748	-.01534	.72081	-.12720

APPENDIX B

Appendix B

Correlation Matrix for all Variables abc

	MLLF	COP	ENS	BDL	WRD	CPS	CA	MA	SS	IQ	TRLS	ERRS	DIM	AD	REW	IE	VRB
VR	*** 669	*** 779	*** 812	** 462	*** 475	*** 910	*** 092	*** 653	*** 551	*** 657	*** -694	*** -695	*** 434	*** 528	* 255	-102	077
MLLF	/	*** 745	*** 675	*** 498	*** 471	*** 825	*** 141	*** 668	*** 615	*** 646	*** -593	*** -602	*** 152	*** 409	*** 142	028	077
COP		/	*** 871	*** 613	*** 592	*** 943	* 214	*** 714	*** 599	*** 658	*** -723	*** -703	*** 455	*** 570	*** 159	-029	116
ENS			/	** 483	*** 598	*** 937	*** 148	*** 707	*** 599	*** 696	*** -733	*** -716	*** 387	*** 604	*** 243	* -060	162
BDL				/	* 350	*** 573	*** 142	** 460	** 447	*** 445	* -323	* -299	* 207	* 384	052	007	-076
WRD					/	*** 592	*** 146	*** 402	** 311	*** 362	*** -373	*** -360	*** 144	** 295	003	023	253*
CPS						/	166	*** 753	*** 646	*** 730	*** -762	*** -753	*** 428	*** 590	*** 224	* -052	121
CA							/	** 278	166	-088	078	092	192	-174	-055	-248*	-165
MA								/	*** 936	*** 922	*** -553	*** -529	* 225	*** 426	124	-179	181
SS									/	*** 898	*** -449	*** -437	*** 115	*** 431	009	-144	168
IQ										/	*** -609	*** -588	*** 148	*** 504	162	-082	279**
TRLS											/	*** 995	*** -439	*** -561	* -229	-112	-119
ERRS												/	*** -402	*** -556	* -206	-124	-118
DIM													/	*** 424	001	021	-056

- a. All correlations are Pearson product-moments, except DIM (Spearman's rho).
- b. Decimal point omitted for all correlations.

c. Correlations between IE2 Factors omitted as factors were orthogonal (i.e., $r=.000$).

VR= Visual Recognition; MLLF= Matching Letter-Like Forms; COP= Copying; ENS= Early Number Skills; BDL= Block Design Level; WRD= Word Reading; CPS= BAS Composite; SS= PPVT Standard Score; TRLS= Trials to criterion; ERRS= Errors; DIM= Dimensional Score; AD= Attention/distraction; REW= Susceptability to reinforcing and punishing events in the classroom; IE= Inhibition/excitation; VRB= Verbal expressiveness.

*= $p<.05$; **= $p<.01$; ***= $p<.001$

APPENDIX C

Appendix C.

This appendix contains:

Strand, S. C., and Morris, R. C. (1986). Programmed training of visual discriminations: A comparison of techniques. Applied Research in Mental Retardation, 7, 165-181.

Programmed Training of Visual Discriminations: A Comparison of Techniques

S. C. Strand and R. C. Morris

Plymouth Polytechnic

The efficiency of three discrimination training procedures was compared for mentally handicapped children trained on a shape discrimination presented via a micro-computer. Each of three groups received one of the following training procedures: (1) graded stimulus fading; (2) graded prompt fading, a procedure approximating behavior modification prompting techniques; (3) trial-and-error training. The stimulus fading and graded prompting procedures were equivalent in terms of the number of steps and criteria for fading. Results showed the two programmed techniques did not differ significantly, but both were significantly superior to trial-and-error learning in terms of number of children reaching criterion, number of trials to criterion, and number of errors. The training procedures were continued for subjects from each of the three groups for an additional two problems, followed by a trial-and-error test problem. Over the additional training problems the pattern of differences between the groups in number of errors remained significant, however differences between the groups in number of trials to criterion decreased. There were no significant differences in any of the measures on the trial-and-error test problem. Results are discussed in relation to the literature on errorless learning techniques, and the implications for applied training procedures are elucidated.

In the last quarter century, the experimental study of discrimination learning has been strongly influenced by the application of the training procedure known as "stimulus fading." The early studies were conducted by Terrace (1963a, 1963b); a red-green discrimination was established by having the reinforced stimulus ($S+$) differ greatly from the unreinforced stimulus ($S-$) in several ways. Initially, $S+$ differed from $S-$ in terms of brightness and duration, as well as color. Gradually differences were eliminated, or "faded out,"

Requests for reprints and copies of the micro-computer programs may be sent to Dr. R. C. Morris, Dept of Psychology, Plymouth Polytechnic, Plymouth PL4 8AA, England.

until the only difference remaining was color. Terrace found that pigeons learned the discrimination faster and with fewer errors than animals trained with the traditional trial-and-error method. Indeed the process of acquisition under such procedures is often described as "errorless" since there is little or no responding to $S-$.

Subsequent research with humans has shown that difficult discriminations seemingly unattainable by conventional procedures may be achieved with fading. Examples with children of normal intelligence include discriminations between complex angular orientations (Moore & Goldiamond, 1964); letters of the alphabet (Egeland, 1975); and colors (Powers, Cheney, & Agostino, 1970). The technique has also been used effectively with mentally handicapped children in training discriminations between positions (Touchette, 1968); colors, sizes, shapes, and weights (Cullen, 1978); and coins (Joyce & Thorpe, 1981; McIvor & McGinley, 1983). However, fading procedures have not proved the most effective for training some complex tasks such as conditional discriminations (Gollin & Savoy, 1968), although a related procedure termed "stimulus shaping" (Sidman & Stoddard, 1967) has been shown to be successful (Schilmoeller, Schilmoeller, Etzel, & LeBlanc, 1979).

Despite the effectiveness of the procedure, stimulus fading apparatus can be quite complex and costly in terms of time and materials. However, the advent of micro-computers, available in most special education schools, provides a potential tool for the inexpensive, efficient, and flexible application of fading procedures. This technology was employed in the present experiment.

In contrast to the experimental work using stimulus fading, prompting procedures involving physical guidance, gestural, and verbal cues, are the most widely used instructional aids employed in practice with mentally handicapped children. In principle such an approach can also be used to produce "errorless" learning, although typically prompts have been used only in a corrective fashion, contingent upon the occurrence of errors (e.g., Lowry & Ross, 1975), and with mild prompts (verbal, gestural) being delivered before more intrusive prompts (physical contact) until a correct response is produced. This situation is also the case in many experimental comparisons of prompting with other training programs (e.g., Mosk & Bucher, 1984). However, in order to emulate stimulus fading procedures, at least in the amount of help available, prompts must (1) be available before a response is produced, and (2) faded in order of their intrusiveness (i.e. physical to gestural to verbal), so as to guide the student through the instructional sequence with a minimum of errors.

Schreibman (1975) utilized fading of a gestural (pointing) prompt in training visual discriminations with autistic children. The procedure proved ineffective, though a stimulus fading program was extremely successful. However, Glendenning, Adams, and Sternberg (1983), using combinations of prompts obtained results suggesting that, in terms of generating self-initiated responses,

a prompting sequence that combined verbal prompts with lessening amounts of physical assistance was superior to physical assistance or verbal prompts presented alone. A more comprehensive approach then, involving the simultaneous presentation and fading of multiple prompts, both physical, gestural, and verbal, may prove more effective. Such an approach is described in the Education of the Developmentally Young (EDY) behavioral methods training course (Trainee Handbook, Unit 4; Foxen & McBrien, 1981). This procedure is suitable for use with mentally handicapped children while potentially fulfilling the requirements of an errorless training procedure. Interestingly, no empirical studies investigating the efficacy of such a procedure in training visual discriminations can be found. Therefore, the present experiment was designed to determine the effectiveness of the graded prompt fading procedure in facilitating discrimination learning, compared both to traditional trial-and-error training and stimulus fading.

A second question concerns the relative efficacy of programmed fading versus trial-and-error training over a series of discrimination problems. In the majority of previous research demonstrating the superiority of programmed training, the procedures have been applied only to a single discrimination problem. One study that did address the question of extended training, Bricker, Heal, Bricker, Hayes, and Larsen (1969), found no evidence for a facilitative effect of stimulus fading compared to trial-and-error training on the development of learning set (a progressive improvement in rate of learning over a series of similar discrimination problems). In their study only one programmed fading procedure was employed, so it is not yet clear how other fading procedures compare with trial-and-error training over a series of discrimination problems.

A further question concerns the relative efficacy of programmed and trial-and-error training on the learning of subsequent trial-and-error problems. Will repeated success under programmed training conditions facilitate learning of subsequent problems presented without programmed assistance? Robinson and Storm (1978) found that first-grade children who originally acquired a red-green discrimination with few or no errors using either verbal instruction or graded choice training made fewer errors during subsequent trial-and-error reversals than subjects who learned the original discrimination by trial-and-error. However, their study addressed only reversal learning. Therefore, the final aim of this experiment was to determine whether trial-and-error training, although possibly inferior as a method of training an initial discrimination, would remain inferior to stimulus fading and graded prompting in terms of subsequent learning of a novel problem by trial-and-error.

In summary, the aims of the experiment were: To compare the effectiveness of; (a) an automated stimulus fading procedure, presented and controlled by a micro-computer; (b) a training program based on the gradual fading of physical, gestural, and verbal prompts, and (c) a trial-and-error procedure,

in (i) an initial discrimination problem, (ii) over a series of additional problems using the same training procedures, and (iii) in a subsequent trial-and-error problem.

METHOD

Subjects

Twenty-one children, 9 girls and 12 boys, attending an ESN(S)¹ School for the mentally handicapped participated in this study. Subjects were drawn from a pool of 31 children aged seven to fourteen years who were all administered scales from the short-term memory, perceptual matching, and spatial imagery process areas of the British Ability Scales (BAS) (Elliot, Murray, & Pearson, 1978). Each subject was individually matched with two others on the basis of total score on the three scales, producing seven sets of matched subjects. Within each set subjects were randomly assigned to the experimental conditions forming three matched groups of seven subjects each. Table 1 gives the sex, chronological age, and BAS total score of each subject. All children were diagnosed as severely mentally handicapped and had IQ scores below 50, this being one criterion for education in special schools. None of the subjects had any previous experience with discrimination problems of this kind.

Apparatus

The tasks were presented using a 48K Apple II micro-computer, double disk drives, and color monitor. The screen measured 21 cm in height and 27.5 cm in width. Fitted beneath the screen was a two-button response box (38.5 cm long, 8 cm high, and 10.5 cm wide) connected to the computer. The response buttons were raised 1.5 cm from the surface of the box and spaced 6 cm apart, divided in the middle by a parallel bar. Stimuli presented on the screen appeared directly above the response buttons. All data were automatically recorded and saved at the end of each session. The screen and response box were set on a table at the child's seated height, and the micro-computer and other equipment positioned away from the subject.

Stimuli and Problems

Eight colored shapes, approximately 7.5 cm high by 8.0 cm wide, were presented on the screen in either green, violet, yellow, or blue. Four pairs of shapes, presented on white backgrounds, constituted the discrimination prob-

¹Educationally Sub-Normal Severe (ESN(S)) Schools are special day schools designed to serve children defined by the Mental Health Act (1959) as severely subnormal in intelligence with IQ's of less than 50.

TABLE 1.
Descriptive Characteristics of Subjects

Subject Number and Group	Sex	Chronological Age	BAS Total Score
Graded Prompting			
1	F	13:6	149
2	F	12:10	130
3 ^a	M	11:8	116
4	M	11:4	97
5	M	12:1	70
6	M	11:4	61
7 ^a	F	10:7	21
Mean		11:11	92
SD		1:0	44.3
Stimulus Fading			
8	M	12:2	148
9	M	13:6	139.5
10 ^a	F	14:3	98
11	F	12:11	97
12	F	12:2	68
13	M	7:1	61
14 ^a	M	11:4	30
Mean		11:11	91.1
SD		2:4	41.8
Trial & Error			
15	M	13:9	146.5
16	F	13:1	141.5
17 ^a	M	13:9	97
18	M	14:8	97
19	F	14:0	63
20	M	11:7	61
21 ^a	F	13:7	37
Mean		13:6	91.9
SD		1:0	41.4

a. The subject completed Problem 1 only.

lems (see Figure 1). The training tasks were two-choice simultaneous discrimination problems. Each problem used two stimulus dimensions; shape, which was relevant to solution of the problem so that choice of one shape ($S+$) was always reinforced while choice of the other ($S-$) was never reinforced, and color, which was irrelevant. Each problem used two colors. On every trial one shape was of one color and the other was of the other color of the pair. Each color appeared equally often in $S+$ and $S-$ with the constraint that no shape remained the same color for more than three successive

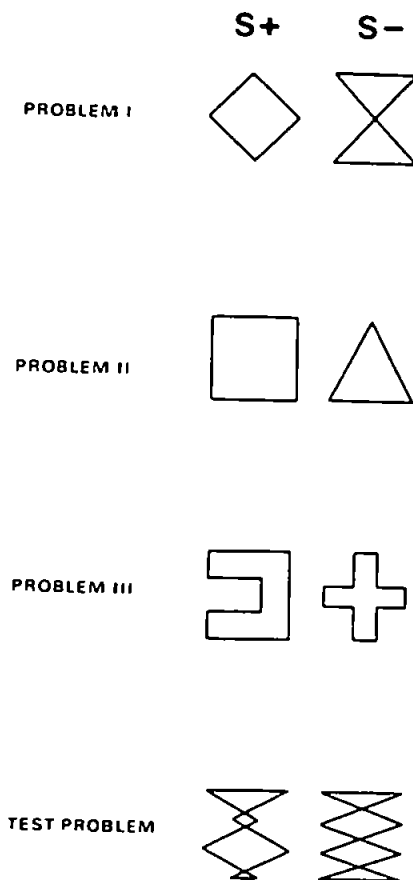


FIGURE 1. Task stimuli used in the four discrimination problems. Color pairs used in the discriminations were: Problem I, blue/violet; Problem II, green/yellow; Problem III, blue/green; test problem, yellow/violet. The different colors appeared equally often in $S+$ and $S-$.

trials. The pair of colors employed was varied between problems. For example, in Problem II selection of the square regardless of its color always resulted in reinforcement, while selection of the triangle, again regardless of the color, never resulted in reinforcement.

The position of $S+$ and $S-$ on the screen (left or right) was randomly determined by the computer, with the constraint that a shape could not be presented in the same position on more than three consecutive trials.

Procedure

All sessions were conducted in a quiet experimental room away from the classrooms and occurred once daily on consecutive weekdays. The criteria for ending a session were; (a) 80 trials completed; (b) 20 minutes had elapsed; or (c) the learning criterion for the problem was reached, whichever occurred first. Additionally, if the child stood up, or expressed the desire to leave, the session was discontinued and restarted the next day.

Apart from the six subjects who received only Problem I the criterion for advancement to the next problem was; (a) the learning criterion for the problem was reached; or (b) 160 trials were completed, again whichever occurred first.

The experiment was conducted in two stages. The first stage was aimed at assessing the effectiveness of the training procedures in facilitating the acquisition of a visual discrimination. Twenty-one subjects, seven per condition, completed the first discrimination problem and comparisons between groups were planned.

The second stage of the experiment was aimed at assessing the effects of extended programmed and trial-and-error training over a series of similar discrimination problems. Five of the sets of matched subjects, randomly selected before the start of the experiment, were given an additional two problems using the same training procedures they received in the first problem, and a final trial-and-error test problem. These discriminations were different shapes and color combinations but were otherwise the same as the first discrimination problem.

Pre-training. A pre-training procedure was employed to familiarize the children with the apparatus and the correspondence of the positions of the stimuli on the screen and the buttons beneath them. A single white square was presented randomly on either the right or left of the screen. A correct response (selection of the button beneath the stimulus) produced a tune from the computer and was rewarded with a small edible and verbal praise. An incorrect response produced no consequences. A non-correction procedure was used so that every response terminated that specific trial. Initially the experimenter modelled the correct response and provided extra physical, verbal, and imitative prompts whenever necessary. The criterion for successful completion of the problem was 20 consecutive, unprompted, correct responses.

Training. At the start of each session the child was given the following directions. "Now (child's name) we are going to play a game, this game is called play the tune. We will see some pictures on the television, one will be a winning picture which will play the tune and the other will be a losing picture. Your job is to find out which is the winning picture and play the tune every time."

The child was shown the response buttons. Any button press blanked the screen and all correct responses were reinforced with computer tunes and extensive verbal praise. In addition a small edible reward was initially provided for every correct response and later for three consecutive correct responses. If the child failed to respond within six seconds, or attempted to elicit a direction from the experimenter before responding, one non-directional prompt such as "Which picture will play the tune? Where is the winning picture?"

etc. was used. If the child still failed to respond an error was scored. The screen was blank during each six second inter trial interval. The learning criterion for all problems was set at 10 consecutive, unprompted, correct responses.

Graded Prompting Program (Group 1)

Three types of prompts were employed; physical guidance, gestural, and verbal (see Table 2). Initially a combination of all types of prompts, at maximum level, was delivered which precluded the occurrence of errors. Subsequently each component prompt was gradually faded, beginning with the physical guidance prompts and then the gestural prompts; finally the verbal prompt was removed, giving eight steps in all. The final fading step, where no prompts were given, was identical to trial-and-error training conditions.

A criterion of two consecutive correct responses were required to advance to the next step, and a back-up procedure was employed whereby an error returned the subject to the previously mastered step. No step could be advanced though, even on a second or third attempt, until the criterion had again been fulfilled. Once two consecutive correct responses were made in the absence of prompting (Step 8), the program was completed and any subsequent errors failed to reinstate the program. The learning criterion was at-

TABLE 2.
Graded Prompting Procedure

Fading Step	Type of Prompt		
	Verbal	Gestural	Physical Guidance
1	It's the Left/Right hand picture, look.	Full point to the picture.	Subjects hand brought up to touch picture, and then down to button.
2	"	"	Subjects hand brought up to touch picture only.
3	"	"	Subjects hand moved up and half-way to the picture.
4	"	"	Subjects hand started upward.
5	"	Finger moved half-way between picture and centre of screen & angled to point.	No prompt.
6	"	Finger moved to centre of screen & angled slightly.	No prompt.
7	"	No prompt.	No prompt.
8	No prompt.	No prompt.	No prompt.

tainable only after the prompting program had been successfully completed.

On each trial the computer presented a number corresponding to the fading step at the center bottom of the screen, thus precluding the potential problem of error on the part of the experimenter in level of prompt delivered.

Stimulus Fading Program (Group 2)

The program consisted of eight steps that differed in the level of prompt presented along the dimension of intensity. Initially $S+$ was presented at full intensity with a blank space as $S-$ to enhance the probability that subjects would respond to $S+$. Subsequently the intensity of $S-$ was gradually increased (i.e., faded in) by systematically incrementing the number of lines composing the shape, while $S+$ remained at full intensity. This sequence continued until Step 8 where both stimuli were at full intensity, and was identical to Step 8 in the graded prompting program and to the trial-and-error training condition. An example of this sequence for the first discrimination problem is presented in Figure 2.

The criteria for step advancement and the back-up procedure were identical to the graded prompting program, and controlled automatically by the micro-computer. Again the learning criterion was attainable only after the program had been successfully completed.

Trial-and-Error Training (Group 3)

This procedure followed the traditional simultaneous discrimination procedure and was identical to the preceding training programs except that both stimuli were presented at maximum intensity and no prompts were delivered by the experimenter.

RESULTS

Problem 1

Figures 3 and 4 present the number of errors and trials to criterion for each child for the first discrimination problem.

The distribution of scores were neither normal nor homogeneous, therefore non-parametric statistics were used throughout. An analysis of the number of children reaching or failing the learning criterion across the three groups proved significant, (Cochran's $Q = 8.00$, $p < .02$), all four non-learners were in the trial-and-error group. Additionally a Friedman analysis of variance of ranks showed significant overall differences between the three matched groups in both number of errors ($S = 12.27$, $p < .001$) and trials ($S = 7.143$, $p < .027$). Planned orthogonal comparisons between groups using the Wilcoxon test (Kirk, 1968) showed significant differences in favor of the graded prompting and stimulus fading treatments when compared to trial-and-error training,

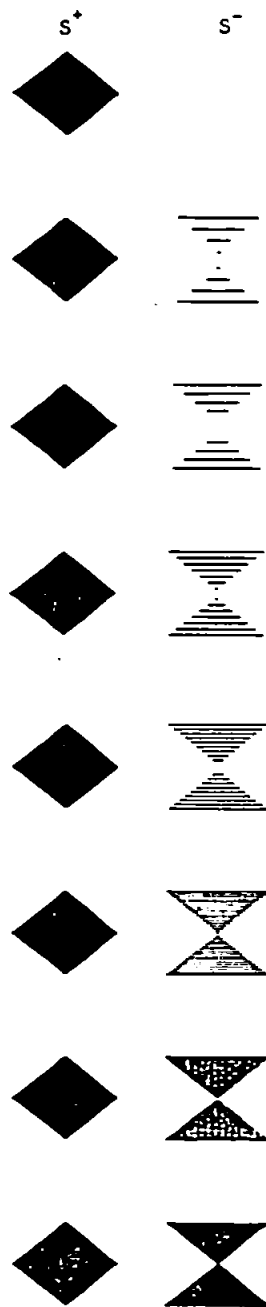


FIGURE 2. Illustration of the steps involved in the stimulus fading program for Problem 1. S^+ remains at full strength throughout, while S^- is faded in.

both for errors ($W=0$, $p<.01$ one-tailed, in both cases) and trials ($W=1$, $p<.025$ one-tailed, in both cases). The stimulus fading group required slightly more trials to criterion and produced a few more errors than the graded prompting group. However there was considerable overlap, the occurrence of ties reducing N to five, and the results did not differ significantly.

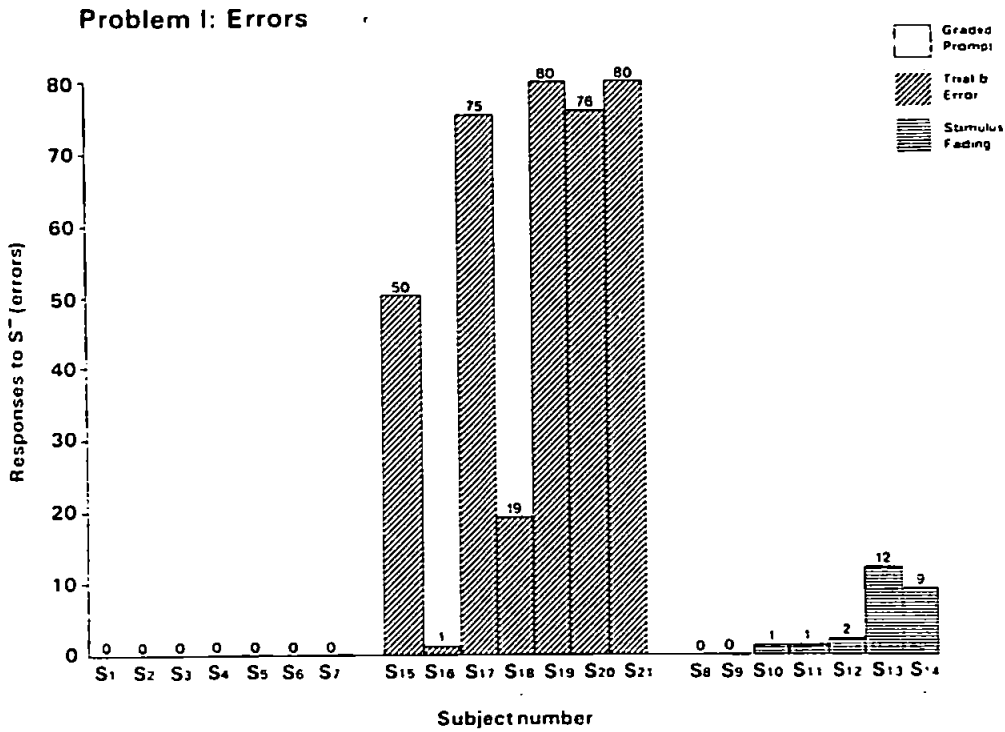


FIGURE 3. Responses to S^- (errors) emitted by each child for the first discrimination problem.

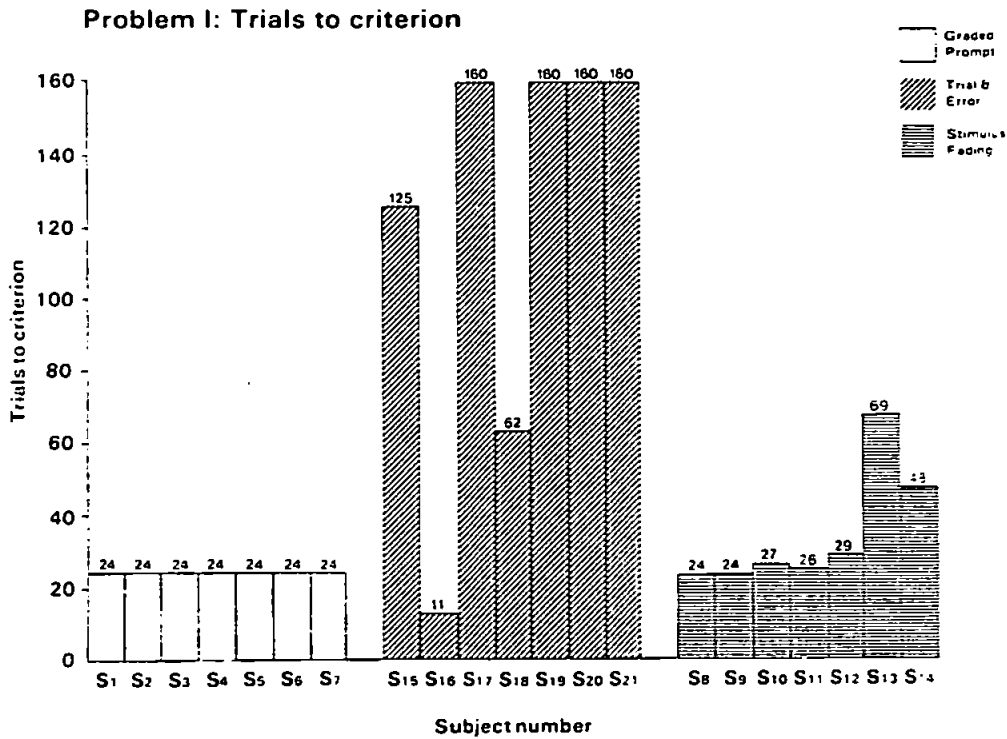


FIGURE 4. Number of trials to criterion for each child for the first discrimination problem. Training was discontinued after a maximum of 160 trials.

Problems II and III

Table 3 presents the number of errors and trials to criterion for each individual child who completed the series of all four problems.

Subjects in the two programmed training conditions continued to perform at a high level on Problems II and III, making few or no errors. Freidman tests for overall group differences in number of errors (see Table 3) proved significant for Problem II ($S = 7.6$, $p < .024$), and was marked but not statistically significant for Problem III ($S = 5.7$, $p < .09$). Group 1 (graded prompting) made fewer errors than Group 3 (trial-and-error) in both problems ($W = 0$, $p < .05$ in each case). Group 2 (stimulus fading) also made significantly fewer

TABLE 3.
Number of Errors and Trials to Criterion for Subjects Completing all Four Discriminations

Subject Number and Group	Number of Errors For Each Problem				Number of Trials For Each Problem				
	Graded Prompt	I	II	III	Test	I	II	III	Test
1		0	0	0	4	— ^a	—	—	18
2		0	0	0	34	—	—	—	65
4		0	0	0	40	—	—	—	80 ^c
5		0	1	0	39	—	32	—	80 ^c
6		0	0	0	42	—	—	—	80 ^c
Total		0	1	0	159	120	128	120	323
Stimulus Fading									
8		0	0	0	44	—	—	—	80 ^c
9		0	0	0	16	—	—	—	30
11		1	0	0	0	26	—	—	10
12		2	0	1	10	29	—	34	28
13		12	0	8	44	69	—	52	80 ^c
Total		15	0	9	114	172	120	158	228
Trial & Error									
15		50	62	10	57	125	160 ^b	32	80 ^c
16		1	3	2	15	11	21	17	39
18		19	9	22	41	62	25	63	80 ^c
19		80	87	84	37	160 ^b	160 ^c	160 ^b	80 ^c
20		76	38	2	12	160 ^b	109	12	53
Total		226	199	120	162	518	475	284	332

a. Dash indicates criterion was met in the minimum of 24 trials.

b. Subject failed to meet criterion in the maximum of 160 trials.

c. Subject failed to meet criterion in the maximum of 80 trials.

errors than Group 3 in Problem II ($W = 0, p < .05$), and fewer errors on Problem III, although the latter difference did not reach statistical significance. The two programmed training groups did not differ significantly in either problem.

In terms of number of trials to criterion both programmed procedures again continued to be effective, with the majority of these subjects reaching criterion in the minimum number of trials. However no significant comparisons between these groups and the trial-and-error group were found, probably due to increased variability produced by some subjects solving the trial-and-error problems rapidly, and due to the small number of subjects involved. It must be noted, however, that programmed training continued to be effective for all subjects, even the lowest functioning ones, while some trial-and-error subjects still failed to learn. In addition, three out of five trial-and-error subjects required a substantially greater number of trials than their matched programmed companions on Problem II, and similarly, although to a lesser extent, on Problem III (see Table 3).

Test Problem

A Friedman test was computed on performance data from the test problem. No significant differences were found between the three groups in either trials to criterion or number of errors. Since the programmed training procedures masked any trends over the initial three problems in Groups 1 and 2, a subsidiary analysis was conducted on data from Group 3 (trial-and-error) to evaluate any trend towards more efficient learning across the initial three problems.² Pages *L* trend test failed to show significant change over problems in either trials to criterion or errors. There is no evidence then of a significant improvement in learning rate over the three problems for the trial-and-error group.

DISCUSSION

The results of this experiment can be summarized as follows:

1. Both programmed training procedures resulted in all subjects acquiring the trained discriminations, and doing so faster and with few or no errors compared to trial-and-error training, under which some subjects failed to learn the problems. However, the superiority of the programmed procedures was most marked in the first problem, and only error data achieved statistical significance in the two subsequent discrimination problems.

²The test problem was excluded from this analysis as it was conducted to a ceiling of 80 and not 160 trials.

2. The two programmed training procedures did not produce significant differences in performance on any of the training problems.
3. No significant differences appeared between the groups in performance on the final test problem where all groups received trial-and-error training.

The results confirm previous findings concerning the efficacy of stimulus fading procedures in facilitating the errorless acquisition of visual discriminations (e.g., Powers et al., 1970; Cullen, 1978), and also demonstrate the effectiveness of an errorless procedure based on the gradual fading of physical, gestural and verbal prompts.

Group comparisons for trials to criterion between the programmed training and the trial-and-error training groups on the two subsequent training problems did not reach statistical significance, this may indicate that the principal advantage of prompting and stimulus fading techniques lie in facilitating performance on highly novel initial problems rather than in subsequent problems using the same stimulus dimension. However, it should be noted in comparing the training procedures that the number of steps in the stimulus fading and graded prompt fading programs were arbitrarily determined from a survey of previous research. Optimization via variations in the number and size of steps might produce more marked and durable advantages for the programmed fading procedures.

It is interesting that while some subjects in the trial-and-error group made large gains in performance over successive problems (e.g., S20), others failed to benefit at all (e.g., S19). One of the strongest arguments in favor of the programmed training procedures was the elimination of this variance in performance, such that all subjects, whatever their abilities as measured by the BAS, acquired these problems in the minimum, or near minimum, number of trials throughout all the problems using the programmed procedures.

Problems in transfer of stimulus control from prompts to training stimuli have been noted with both intensity fading (Koegel & Rincover, 1976) and manual prompts (Wolfe & Cuvo, 1978). It is impossible to guarantee that a subject will attend to the relevant stimulus, and not simply respond to the additional prompt provided by the stimulus display or the trainer, yet this did not appear to be a problem in the present study as transfer from the prompts to the unprompted criterion level discrimination invariably occurred errorlessly in Group 1, and near errorlessly in Group 2. However, the difficulty of the discrimination is one factor that has been implicated in problems of transfer from prompted to unaided trials; such transfer may occur more readily when the discrimination is easy (Russo, 1976). The present tasks were simple 2-choice discriminations and it remains to be seen whether similar results would be obtained with more complex tasks.

With regard to the question of facilitating later trial-and-error learning, prior programmed training failed to facilitate performance on the trial-and-error test problem relative to subjects with a history of trial-and-error training alone. Equally, however, the performance of the programmed groups was no worse than that of the trial-and-error group. This result is in accord with the finding of Bricker et al. (1969). It is possible that the lack of any detectable facilitation by programmed training was due to too rapid a transition between the conditions of training and testing, the programmed training subjects being faced with the sudden removal of all prompts. This interpretation may be indicated by the rapid appearance of position habit and color preference strategies among the programmed training subjects on the trial-and-error test problem, where no such strategies had been exhibited during programmed training. In Group 1 (graded prompting) S2, S4, and S6 rapidly developed color preferences and S5 a position habit (both strategies being defined as deviations from chance responding significant at the 5% level, chi-squared). Slightly fewer subjects developed such strategies in Group 2 (stimulus fading); S13 developed a color preference and S8 exhibited both color preference and position habit strategies. This is in contrast to Group 3 (trial-and-error) in which such strategies were also apparent during their prior training problems as well as the test problem. The method of transition from programmed fading procedures to trial-and-error training is open to question at present, it may be that prompts should be gradually eliminated *across* problems in a manner parallel to fading within a single problem.

At present the mechanism by which programmed fading facilitates learning compared to trial-and-error training is not clear. Possibilities include increased density of reinforced experience with S+, lack of competing emotional responses due to non-reinforced experience with S-, direction of attention towards the relevant stimuli, or a combination of these. A fuller understanding of these factors could contribute towards optimization of fading programs both within and across problems.

Finally, the results may also have significance for the classroom application of programmed procedures with mentally handicapped students. With the advent of micro-computer facilities, the stimulus fading program could be used for individualized instruction with relevant material such as coins without the need for constant supervision from the teacher, since the program provides response feedback and automatically adjusts the level of difficulty (i.e., level of fading) as appropriate. Conversely, the advantage of the graded prompting procedure may lie in the interactive nature of the training. For students with whom on-task behavior is difficult to maintain without supervision, or who react primarily to social reinforcement, the procedure offers a readily applied errorless technique without the necessity of stimulus manipulation. Hence the procedure can readily be employed in many varied training contexts.

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APPENDIX D

Appendix D.

This appendix contains:

Strand, S. C., and Morris, R. C. (1988). Criterion-related versus non-criterion-related prompt fading with severely mentally handicapped children. Journal of Mental Deficiency Research, 32,137-151.

Criterion-related versus non-criterion-related prompt training with severely mentally handicapped children

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ABSTRACT. Thirty-three severely mentally handicapped children were involved in a study to evaluate the effectiveness of three training programmes in teaching visual discriminations. Three matched sets of subjects each received both a size and an intensity discrimination with either: (1) size prompting; (2) intensity prompting; or (3) no prompting (trial-and-error training). The prompted groups therefore received both criterion-related (CR) and non-criterion-related (NCR) training. Order of presentation of the discriminations was counterbalanced across subjects. There was a significant main effect of training group with both size and intensity prompting groups making significantly fewer errors than the trial-and-error group ($P < 0.05$ in both cases), but not differing significantly from each other. Significant linear trends for increasing errors across CR, NCR and trial-and-error training programmes were found for both the size discrimination ($P < 0.01$), and intensity discrimination ($P < 0.05$). More children acquired the discriminations when trained with a CR prompt than with a NCR prompt or trial-and-error procedure, and all four children who failed to acquire discriminations with NCR prompts subsequently acquired them when trained with a CR programme. The results are discussed in relation to cue discriminability and theoretical explanations involving overshadowing are considered.

INTRODUCTION

A major concern in applied learning research over the last 2 decades has been the development and evaluation of training programmes for teaching visual discriminations to mentally handicapped people (for example, Touchette, 1968; Etzel & LeBlanc, 1979; Smeets *et al.*, 1984). Spurred by the failure of some prompting procedures to facilitate the acquisition of the trained discriminations (Terrace, 1966; Gollin & Savoy, 1968; Schwartz *et al.*, 1971), one area of subsequent research focussed on the nature of the prompt cue employed and its relation to the training discrimination. Several studies (Schreibman, 1975; Koegel & Rincover, 1976; Wolfe & Cuvo, 1978) have suggested that a distinction may be drawn between 'within-stimulus prompting' (WSP) and 'extra-stimulus prompting' (ESP). ESP involves the addition of a prompt cue spatially separate from the location of S+ (for example, Rincover, 1978). In contrast, with WSP the prompt is usually superimposed upon one of the stimuli and is often an exaggeration of a feature present in S+. Wolfe & Cuvo (1978) found that fading of colour prompts highlighting distinctive features of letter pairs (WSP) led to greater post-test letter recognition than fading of an experimenters

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finger point cue (ESP) with their mentally handicapped subjects. A similar superiority for WSP over ESP was reported by Schreibman (1975) with autistic subjects. Indeed, Koegel & Rincover (1976) suggest that ESP may be even less efficient than trial-and-error training.

A further distinction between prompting procedures has been proposed by Schilmoeller & Etzel (1977) who distinguish 'criterion-related' from 'non-criterion-related' prompts. A criterion-related (CR) prompt is one drawn from the same dimension that the training (or criterion) discrimination will be based upon, whereas a non-criterion-related (NCR) prompt is drawn from a different dimension.

Schilmoeller & Etzel (1977) trained eight subjects of normal intelligence on two complex discriminations using either CR prompts, or both CR and additional NCR prompts. Correct responding on post-tests for the tasks trained with CR prompts was higher than for those tasks trained with additional NCR prompts. The authors conclude that CR prompting is more effective than NCR prompting. Richmond & Bell (1983) also report that profoundly mentally retarded students acquired a size discrimination with significantly fewer errors when trained with a CR cue (increasing size of S-), than either a NCR cue (a trainer's finger point to S+) or trial-and-error training.

These distinctions emphasize important qualities of prompt and training cues that must be considered when designing effective training programs. The CR/NCR distinction is an appealing one due to the availability of a theoretical mechanism to explain the effectiveness of training with CR cues. It is hypothesized that CR fading may be more effective than NCR fading since, as both cues are drawn from the same stimulus dimension, it does not necessitate the transfer of stimulus control from the prompt cue to the training cue (Terrace, 1966; Etzel & LeBlanc, 1979). The failure of some prompting programmes to facilitate task acquisition, and the success of others, has frequently been ascribed to the use of NCR or CR prompt cues (Smeets *et al.*, 1984; Schreibman, 1975; Wolfe & Cuvo, 1978). However, the present study contends that additional controls are required to conclusively isolate the effect of the CR/NCR variable from other confounding factors.

In the present study, size and intensity prompt fading programmes were each applied to discriminations based upon either size or intensity cues. The relation of the prompt cue to the criterion discrimination could, thus, be systematically varied. Specifically, four combinations were examined; size prompt/size discrimination (CR), size prompt/intensity discrimination (NCR), intensity prompt/intensity discrimination (CR), and intensity prompt/size discrimination (NCR). Both discriminations were also trained using a trial-and-error procedure to provide a baseline for comparison with the prompting conditions. Several factors prompted the adoption of the above design.

In Schilmoeller & Etzel's (1977) study, the tasks were extremely complex, making manipulation of the CR variable in some respects arbitrary. Although NCR cues were indeed clearly unrelated to the criterion discriminations, it is less clear, for example, whether fading on a dimension of colour is unambiguously CR to a complex four-colour configuration and colour sequence criterion. Employing physical dimensions of difference between stimuli (specifically size and intensity) as cues for both prompt

and criterion discriminations, means that whether a prompt cue is CR or NCR is relatively unambiguous.

Furthermore, with a factorial investigation, the main effect of dimension of prompting can be separated from the CR/NCR variable. For example, Richmond & Bell's (1983) study demonstrates that size cues are more effective than finger-point cues in training a size discrimination. However, to conclusively isolate the effect of the CR variable, it is necessary to control for the main effect of prompt dimension. Strong confirming evidence would also demonstrate that size cues are *less* effective than finger-point cues on a second task in which finger-point cues are CR and the size cue is NCR. While developing a task in which finger-points are CR is problematic, with size and intensity dimensions such a counterbalanced design can be readily constructed and the main effect of type of prompt can be controlled.

Finally, a major consideration in the design of this study was the apparent problem of confounding between NCR and extra-stimulus variables. For example, the NCR prompts in the Schilmoeller & Etzel (1977) study were also extra-stimulus (for example, adding a red rectangle encircling the correct stimulus), while the CR prompts were within-stimulus (for example, the use of a stimulus shaping procedure for a form discrimination). Similarly, in Richmond & Bell's (1983) study the CR prompt was within-stimulus (increasing size of S-), while the NCR prompt was extra-stimulus (finger-point). Control of this variable is essential given the inferiority of extra-stimulus compared to within-stimulus prompting demonstrated in the studies reviewed earlier. Therefore, within-stimulus fading was employed in all cases, i.e. the whole of the stimulus was manipulated on either a size or intensity dimension.

In summary, further systematic and controlled analysis of the CR/NCR variable appears warranted. It was hypothesised that prompt fading would be more effective than trial-and-error training, and that significant linear trends of increasing errors over CR, NCR and trial-and-error training would be revealed on each task, with size prompting more effective than intensity prompting in training the size discrimination and the reverse for training the intensity discrimination.

METHOD

Subjects

Thirty-three children attending two special schools for children with severe learning difficulties (SLD)¹ participated in this study. Subjects were selected from a pool of 80 children who were all administered four selected scales from the British Ability Scales (BAS) (Elliot *et al.*, 1978). These scales were (with process areas in brackets): matching letter-like forms and copying (perceptual matching); visual recognition (short-term memory); and early number skills (retrieval and application of knowledge). A composite score for each subject was derived by summing the total scores for each of the scales. Eleven sets of three subjects each were selected, each subject being matched with two others having the same or closest composite score. Within each set, subjects were randomly assigned to each of the three experimental

¹ Under the Education Act (1981), severe learning difficulty (SLD) replaces the term educationally sub-normal severe (ESN(S)).

Table 1 Descriptive characteristics of subjects

Matched set	Group 1 size prompt				Group 2 intensity prompt				Group 3 trial-and-error			
	S ^a	Sex	CA ^b	BAS ^c	S	Sex	CA	BAS	S	Sex	CA	BAS
1	1	M	13:9	278	12	M	13:10	288	23	M	17:5	289
2	2	F	10:1	213	13	M	11:9	227	24	F	13:3	213
3	3	M	16:5	203	14	F	15:8	200	25	F	14:10	189
4	4	M	12:5	191	15	M	12:5	184	26	M	10:10	196
5	5	M	14:7	194	16	M	17:2	185	27	M	16:3	190
6	5	M	11:1	162	17	F	14:7	163	28	M	13:1	175
7	7	F	13:5	116	18	M	12:6	121	29	M	13:9	129
8	8	F	13:1	96	19	M	11:10	92	30	M	12:7	86
9	9	F	12:1	85	20	F	11:7	81	31	F	8:9	86
10	10	M	16:9	59	21	M	17:0	68	32	F	16:5	64
11	11	F	9:3	69	22	M	8:0	63	33	M	15:7	49
Mean			13:1	151.5			13:4	152.0			13:11	151.5
SD			2:4	70.7			2:8	73.0			2:7	74.4

^aSubject number.^bData given in years and months.^cBAS=British Ability Scales composite score.

groups. Descriptive characteristics of the subjects are presented in Table 1. As an approximate indication of the degree of handicap the mean chronological age of the sample was 13 years and 5 months (SD: 30.0 months), while mean mental age (Peabody Picture Vocabulary Test-Revised) equalled 4 years and 1 month (SD: 12.3 months).

Apparatus

The tasks were presented using a 32K BBC(B) micro-computer, single disc drive and colour monitor. The screen measured 21 cm in height and 27.5 cm in width. Fitted beneath the screen was a two-button response box (38.5 cm long, 8 cm high and 10.5 cm wide) connected to the computer. The response buttons were raised 1.5 cm from the surface of the box and spaced 6 cm apart, divided in the middle by a parallel bar. Stimuli presented on the screen appeared directly above the response buttons. All data was automatically recorded and saved at the end of each session.

The screen and response box were set on a table at the child's seated height, and the micro-computer and other equipment positioned away from the subject. All sessions were conducted in a separate, quiet experimental room adjoining the classrooms and lasted approximately 20–25 min. Sessions were conducted once daily on consecutive weekdays.

Design

A mixed factorial design was employed in the study. Prompt type (size, intensity and

no prompt) was a between-subjects variable with separate groups each receiving one of the above types of prompting. The within-subjects variable was discrimination task (size and intensity). Each subject received both discriminations, the order of presentation being counterbalanced across subjects.

Stimuli and the CR/NCR manipulation

Progressive manipulations along the size and intensity dimensions generated values for seven levels of size and seven levels of intensity, respectively. This involved the gradual increase of diameter for the size dimension and of pixel density for the intensity dimension.² The values selected are presented in Table 2.

Values at levels 1–6 were employed in the manipulation of *S*– during fading on either the size or intensity dimension. Level 7 values were employed *only* for *S*+ in order to produce the criterion discriminations. The criterion tasks employed only one relevant cue, the values of the second cue being identical in both *S*+ and *S*–. The criterion size discrimination was between levels 6 and 7 on the size dimension, with intensity held constant at level 6, and the criterion intensity discrimination was between levels 6 and 7 on the intensity dimension, with size held constant at level 6. Figure 1 presents the criterion size and intensity discriminations.

Size prompting on both the size and intensity tasks involved increasing *S*– through size levels 1 to 6. Similarly, intensity prompting on both the size and intensity tasks

Table 2 Stimulus values employed in the fading programmes

Level ^a	Size (diameter cm)	Intensity (percentage of pixels on)
1	— ^b	—
2	1.6	0.0
3	2.4	12.5
4	3.2	25.0
5	4.0	50.0
6	4.8	75.0
7	5.3 ^c	87.5 ^c
	5.4	100.0
	5.6	

^aValues at levels 1–6 were used in fading *S*–. Level 7 values were used only for *S*+.

^bDash indicates *S*– was a blank space on the initial step.

^cDifficulty of the discrimination was manipulated by varying the *S*+ values.

² A pixel is the smallest definable unit of the micro-computer graphics screen. The pixel can be defined as 'on' or 'off', i.e. lit or unlit, against a black background. Gradations in intensity were produced by defining tones on a 4×4 pixel grid. With all 16 pixels switched on, intensity was maximum (100%). By reducing the number of pixels switched on in the grid to 14, 12, 8, 4, 2 and 0, gradations in intensity of 87.5%, 75%, 50%, 25%, 12.5% and 0% respectively were formed. The tone-generating program was written by Mr Peter Sandford and published in the January 1985 issue of *Acorn User*.

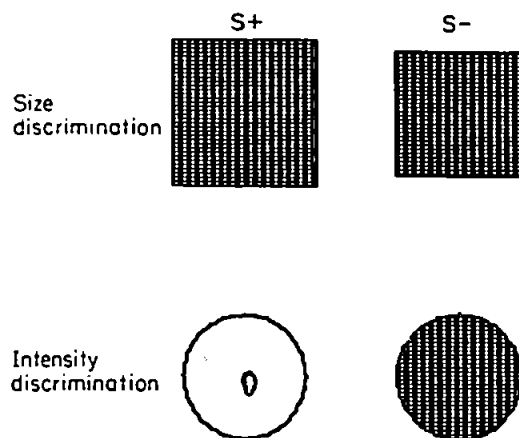


Fig. 1 Size and intensity criterion discrimination tasks.

involved increasing $S-$ through intensity levels 1 to 6. This process is most clearly illustrated by reference to Figure 2 which presents the size and intensity fading programs for each of the discrimination tasks.

For the purpose of comparison between CR and NCR programmes, it is important to stress that the stimulus values involved in the fading of the size prompt were identical whether the size cue was CR or NCR. Similarly, intensity prompting involved fading through an identical set of values in both CR and NCR intensity fading programs (Fig. 2).

CR and NCR prompting thus differ only in the relation of the prompt cue to the final discrimination. CR prompting involved initially exaggerating and then fading the cue which ultimately would form the basis of the discrimination. For the size discrimination, this was an exaggeration of size and, for the intensity discrimination, an exaggeration of intensity. NCR prompting involved adding a cue that was unrelated to the dimension on which the discrimination would ultimately have to be made, i.e. a size cue for the intensity discrimination and an intensity cue for the size discrimination.

In both CR and NCR prompting, the addition of the prompt cue should make the discriminations easy to solve in the early stages. However, the programmes differed as successful acquisition after NCR prompting would require the transfer of correct responding from the prompt to criterion cue, while this was not required by CR prompting since prompt and criterion cues were drawn from the same dimension.

Procedure

Pre-training. A pre-training procedure was employed to familiarize the children with the apparatus and the association between the position of the stimuli on the screen and the buttons beneath them. A single white square was presented randomly on either the right or left of the screen. A correct response (selection of the button beneath the stimulus) produced a tune from the computer and was rewarded with a small edible

and verbal praise. An incorrect response produced no consequences. A non-correction procedure was used so that every response terminated that specific trial. Initially the experimenter modelled the correct response, and provided extra physical, verbal and imitative prompts whenever necessary. The criterion for successful completion of the task was 20 consecutive, unprompted, correct responses.

Training programmes. At the start of each session the child was given the following

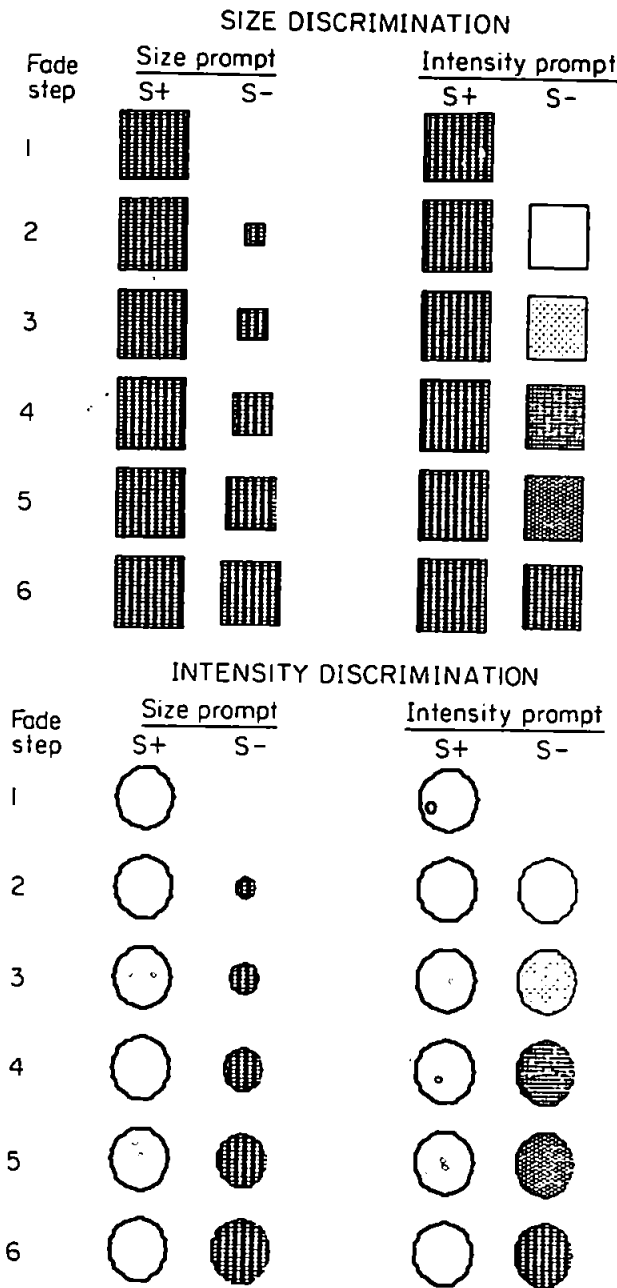


Fig. 2 Illustration of the steps involved in the size and intensity fading programmes for both the size discrimination (upper figure) and intensity discrimination (lower figure).

directions. 'Now (child's name) we are going to play a game, this game is called "play the tune". We will see some pictures on the television, one will be a winning picture which will play the tune and the other will be a losing picture. Your job is to find out which is the winning picture and play the tune every time'.

The child was shown the response buttons. Any button press blanked the screen and all correct responses were reinforced with computer tunes and extensive verbal praise. In addition, a small edible reward was initially provided for every correct response and later for three consecutive correct responses. If the child failed to respond within 6 s, or attempted to elicit a direction from the experimenter before responding, one non-directional prompt such as, 'Which picture will play the tune?' or 'Where is the winning picture?' was used. If the child still failed to respond, an error was scored. The screen was blank during each 6-s inter-trial interval. The learning criterion for both problems was 10 consecutive, unprompted, correct responses. Training was discontinued if the criterion was not achieved after a maximum 175 trials.

Size fading (group 1)

The procedure involved six steps that differed in the level of prompt presented along the dimension of size. Initially $S-$ was a blank space to enhance the probability that subjects would respond to $S+$. Subsequent steps progressively increased the size of $S-$ while $S+$ remained constant throughout. This six-step sequence was identical for both size and intensity discriminations (Fig. 2).

A criterion of two consecutive correct responses were required to advance through each fading step and a back-up procedure was employed whereby any two errors on a step returned the subject to the previously mastered step. No step could be advanced through, even on a second or third attempt, until the criterion had again been fulfilled. Once five consecutive correct responses were made in the absence of prompting (Step 6), the programme was completed and any subsequent errors failed to reinstate the programme. The learning criterion was attainable only after the prompting programme had been successfully completed. The final fading step, where no prompts were given, was identical to trial-and-error training.

Intensity fading (Group 2)

The programme consisted of six steps which progressively increased the intensity of $S-$, while $S+$ remained at constant intensity throughout training. Initially, $S-$ was a blank space to enhance the probability that subjects would respond to $S+$. Subsequently, the intensity of $S-$ was gradually increased by systematically incrementing pixel density in $S-$. The fading sequence was identical for both size and intensity discriminations (Fig. 2).

The final fading step (Step 6) was identical to both Step 6 in the size-fading programme and to the trial-and-error training condition. The criteria for step advancement and the back-up procedure were the same as those adopted in the size fading programme, and the learning criterion attainable only after the programme had been successfully completed.

Trial-and-Error training (Group 3)

This procedure followed the traditional simultaneous discrimination procedure and was identical to the preceding training programmes except that no prompts were added to the training stimuli.

Task difficulty

There was considerable variation in mean BAS composite ability scores between the matched sets of subjects, ranging from 285.0 (Set 1) to 60.3 (Set 11). Training tasks of a single level of discriminability were considered inappropriate due to potential problems of both ceiling and floor effects. Therefore, the difficulty of the discriminations was varied between two sub-groups comprising Sets 1-5 (mean BAS 216.0) and Sets 6-11 (mean BAS 98.0).

Difficulty of the size discrimination was manipulated by variation in the diameter of S+. For the more able subjects (Sets 1-5), the diameter of S+ equalled 5.3 cm. A less complex discrimination was presented to Sets 6-11 by increasing S+ to 5.4 cm or 5.6 cm. For the intensity discrimination, the value of S+ was manipulated so that Sets 1-5 again received a more complex criterion discrimination (87.5% *vs* 75%) than Sets 6-11 (100% *vs* 75%).

RESULTS

A 3 (treatment) X 2 (task) X 2 (complex *vs* simple discrimination) mixed analysis of variance for number of errors, revealed that significantly more errors were emitted on the complex discriminations ($F(1,27)=7.67$, $P<0.025$) and produced a significant

Table 3 Number of errors for each subject on each discrimination

Size discrimination				Intensity discrimination		
Set number	Size prompt	Intensity prompt	Trial-and-error	Size prompt	Intensity error	Trial-and-error
1	1	0	1	56 ^a	38 ^a	3
2	3	0	94 ^a	4	5	2
3	1	18	68	6	7	82 ^a
4	1	5	2	52 ^a	29	86 ^a
5	1	52 ^a	88 ^a	59 ^a	20	101 ^a
6	3	9	0	3	2	11
7	1	13	6	0	2	4
8	3	39	84 ^a	3	0	8
9	6	17	30	7	25	6
10	17	1	5	8	0	13
11	11	3	19	1	0	37
Mean	4.4	14.2	36.1	18.1	11.6	32.1
SD	5.2	16.8	39.1	24.3	13.8	38.5

^aThe subject failed to meet the learning criterion in the maximum of 175 trials.

main effect of treatment ($F(2,27)=6.53$, $P<0.01$). No interaction terms reached significance. Newman-Keuls multiple comparisons for the treatment effect showed size prompting and intensity prompting groups did not differ significantly, but both produced significantly fewer errors than trial-and-error training ($P<0.05$ in both cases). Table 3 presents the number of errors for each subject on each discrimination.

The treatment main effect demonstrates the superiority of prompt fading over trial-and-error training, but confounds CR and NCR training. However, planned parametric trend tests showed the predicted linear trends for increasing errors with CR, NCR and trial-and-error training were significant for both the size discrimination ($F(1,27)=9.12$, $P<0.01$) and intensity discrimination ($F(1,27)=4.28$, $P<0.05$). Figure 3 presents this data graphically.

The learning criterion was not attained in six cases where discriminations were trained with a trial-and-error procedure, four cases of training with NCR prompting and for one case of CR prompt training. Hence, CR prompting was the most effective procedure in facilitating acquisition of the tasks. Instances of unsuccessful training were evenly distributed across the first and second training tasks the subjects received.

If the learning criterion was not attained following NCR prompting or trial-and-error training, the discrimination was subsequently trained with a CR prompt programme. All four subjects who initially failed to acquire discriminations with NCR prompting acquired the discriminations when subsequently trained with CR prompts. Five subjects failed to acquire discriminations with trial-and-error training (S27 failed to acquire both discriminations). Subsequent CR prompting resulted in successful acquisition in four of these six cases. Table 4 presents the results for all subjects receiving additional CR prompt training.

After 175 trials of training without successful acquisition, the discriminations were

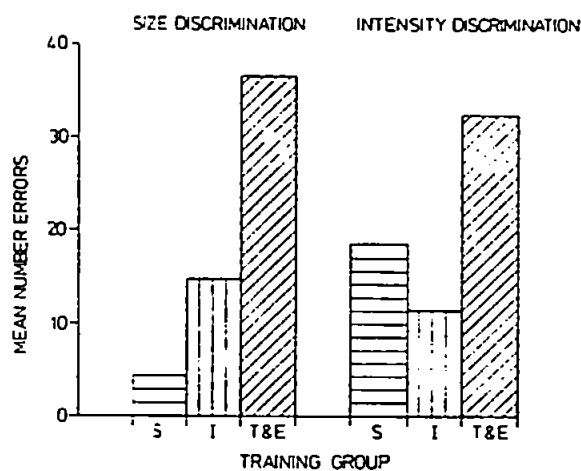


Fig. 3 Mean number of responses to S- (errors) emitted by each group on the two discrimination tasks. (S=Size fading; I=Intensity fading; T&E=Trial-and-error training.)

Table 4 Results of retraining with criterion-related prompting (CR) following failure to acquire discriminations with non-criterion-related prompting (NCR) or trial-and-error training (T&E) during initial 175 trials

Subject number	Initial training	Task ^a	Second training	Criterion ^b acquired	Trials	Errors
16	NCR	S	CR	1	49	13
1	NCR	I	CR	1	20	0
4	NCR	I	CR	1	83	22
5	NCR	I	CR	1	29	1
24	T&E	S	CR	1	23	2
27	T&E	S	CR	1	39	6
30	T&E	S	CR	0	175	58
25	T&E	I	CR	1	62	19
26	T&E	I	CR	1	130	39
27	T&E	I	CR	0	175	60

^aS=Size; I=Intensity.

^b1 indicates the learning criterion was acquired; 0 indicates the learning criterion was not acquired.

often acquired extremely rapidly upon introduction of the CR programme. This is clearly illustrated in the trial-by-trial analyses of performance for S5 (NCR size fading/CR intensity fading) and S16 (NCR intensity fading/CR size fading) presented in Figure 4.

However, subjects who had first received trial-and-error training had greater difficulties acquiring the task with CR prompts (mean number of trials: 100.7; mean number of errors: 30.7), than those subjects who were first trained with NCR prompts (mean number of trials: 45.3; mean number of errors: 9.0).

DISCUSSION

The results of this study can be summarized as follows:

(1) Size prompting and intensity prompting groups did not differ significantly in overall number of errors but both produced significantly fewer errors than the trial-and-error training group.

(2) There were significant linear trends for increasing number of errors across CR, NCR and trial-and-error training on both the size discrimination ($P < 0.01$), and intensity discrimination ($P < 0.05$).

(3) Less failures to acquire the discriminations were observed following CR prompting than either NCR prompting or trial-and-error training. Furthermore, in all cases where discriminations were not acquired with NCR prompting subsequent CR training resulted in successful and often rapid acquisition.

The results of this study suggest that prompt fading is a more efficient procedure than trial-and-error training in reducing errors during discrimination learning,

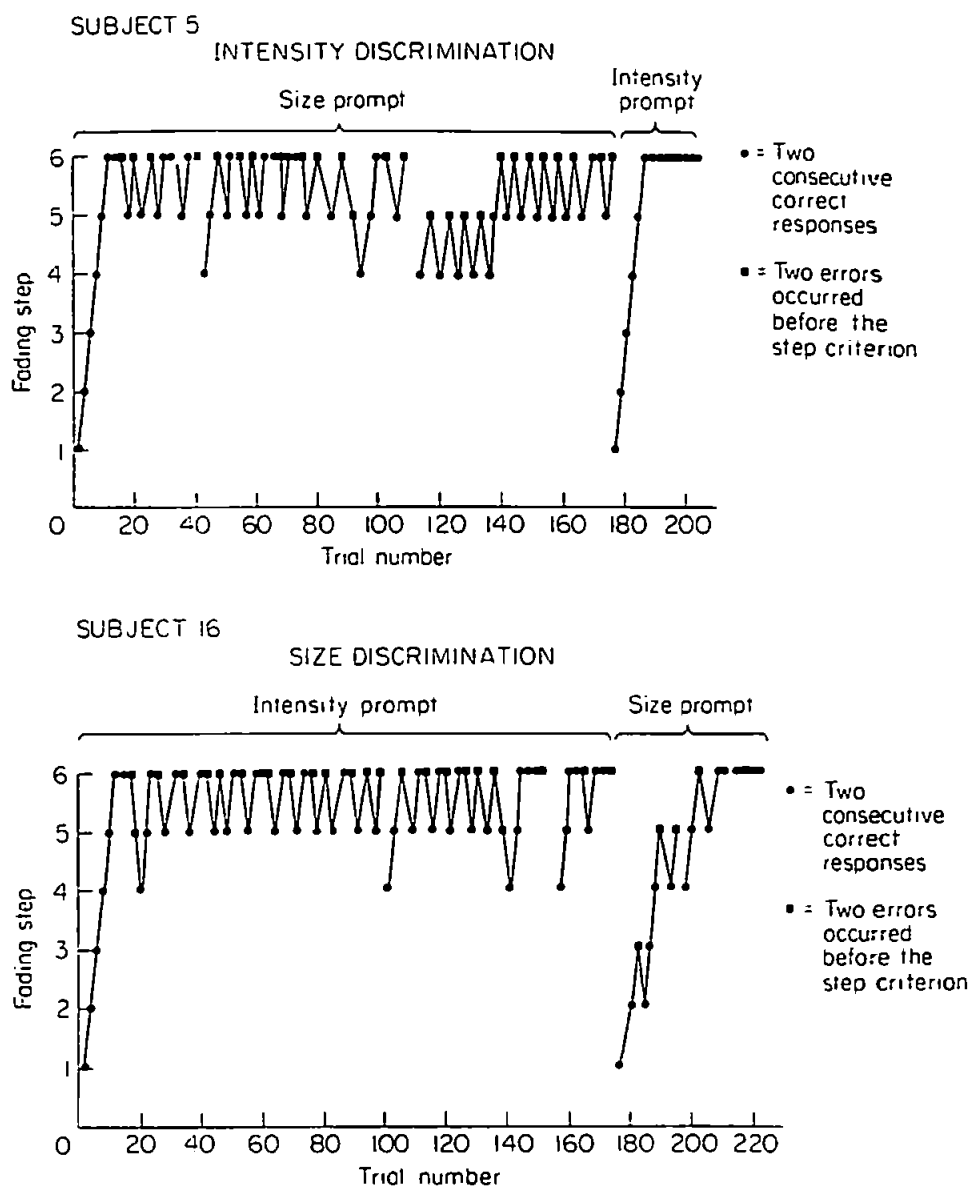


Fig. 4 Trial-by-trial performance of Subject 5 (upper figure) and Subject 16 (lower figure) during first (NCR) and second (CR) training phases.

confirming previous research concerning the efficacy of programmed training techniques (for example, Strand & Morris, 1986).

The present results also indicate the superiority of CR over NCR prompting in teaching visual discriminations to severely mentally handicapped children. Fading sequences were significantly more effective when the faded cue was CR rather than NCR and, importantly, this superiority was consistent across all combinations of prompt and task dimensions. Furthermore, since within-stimulus fading procedures were employed in all prompting programmes, the results cannot be ascribed to

confounding with the ESP variable. The results, therefore, substantiate the conclusions drawn from previous research (Schilmoeller & Etzel, 1977; Richmond & Bell, 1983).

It is interesting that subjects who received prior trial-and-error training were less successful during subsequent CR retraining than subjects who first received NCR prompting (Table 4). It was hypothesized that the failure of S27 and S30 to acquire tasks with retraining might be attributed to perseverative error strategies developed as a result of prior trial-and-error training. However, while both subjects did exhibit position perseveration during CR retraining, they had not previously exhibited such strategies. Furthermore, all the subjects who did exhibit perseverative error strategies during initial trial-and-error training (S25 and S26 showed position perseveration, and S24 showed an alternation bias) subsequently acquired the tasks during CR retraining. While the mechanism underlying the facilitative effect of NCR fading compared to trial-and-error training is unclear, it is congruent with the significant linear trends observed in the main analyses and with results reported by Richmond & Bell (1983).

Failures of acquisition after NCR prompting were characterized by perseveration in responding to the prompt cue. This is seen clearly in Figure 4. For both S5 and S16, correct responding is high throughout attenuation of the NCR prompt (Steps 1-5), but with complete removal of the prompt (Step 6) performance is disrupted and many errors are emitted. The difficulty appears to be located in transferring correct responding from the prompt to training cue. The efficiency of CR prompting in effecting this transfer can be seen in the CR phases of Figure 4 where introduction of the CR prompt resulted in rapid acquisition of the previously unacquired discriminations. Similar results were observed for S1 and S4 (Table 4).

Theoretically, such failures may be interpreted in terms of 'overshadowing' (Pavlov, 1927). In the case of instrumental discrimination, learning overshadowing occurs when the control exerted over the discriminative response by one cue (a pair of stimulus values) is reduced by the presence of a concurrent second cue, and has been demonstrated in both successive (Eckerman, 1967) and simultaneous (Lovejoy & Russell, 1967) discrimination training procedures.

Discriminations trained with CR prompts contained only a single relevant cue, as prompt and training cues were drawn from the same dimension. Hence there was no competition between relevant cues, upon which overshadowing is predicated (Sutherland & Mackintosh, 1971). In contrast, the stimuli in the discriminations trained with NCR prompts contained multiple relevant cues, i.e. the cue distinguishing the training stimuli and the additional prompt cue. This prompt cue must be highly discriminable in order to facilitate initial correct responding. Thus, at the onset of training the values of the prompt cue were designed to be more readily discriminable from one another than the values of the training cue. In situations in which cues are of unequal strength, overshadowing is most likely to occur (Sutherland & Mackintosh, 1971).

Overshadowing is a problem to the extent that subjects are required to transfer to a new cue at the cessation of fading; this is required only after NCR fading. The subjects who failed to acquire discriminations trained with the NCR method may,

therefore, have learnt to discriminate the prompt cue to the detriment of the training cue, observing increasingly subtle differences in the prompt cue during fading to the exclusion of the training stimuli. This interpretation is supported by Doran & Holland (1979), who observed that unsuccessful NCR training was characterized by exclusive control by the fading cue, while successful NCR training resulted in both prompt and training cues acquiring control during fading.

However, the NCR method was not invariably ineffective. One factor influencing successful transfer from NCR prompts was the difficulty of the discrimination, since all subjects who failed to acquire the tasks received the complex size and intensity discriminations (see Table 3). Koegel & Rincover (1976) have also reported that fading of colour cues was more effective in training simple rather than complex form discriminations. However, further research is necessary to determine why some subjects in the present study were successful in transferring responding from the prompt to the complex training cue, while others were not. With increasing confidence in the significance of the overall effects of training procedures, future research might investigate the interaction of training methods with individual difference variables.

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APPENDIX E

Appendix E

This appendix contains:

Strand, S. C. (1989). S+ versus S- fading in teaching visual discriminations to severely mentally handicapped children.

Journal of Mental Deficiency Research, in Press.

S+ versus S- Fading in Teaching Visual Discriminations to Severely
Mentally Handicapped Children.

Steve. C. Strand

Department of Psychology

Plymouth Polytechnic

Running Head: S+ versus S- Fading

Requests for reprints and copies of the micro-computer programmes may be sent to Steve Strand, who is now at the Assessment and Evaluation Unit, Education Department, London Borough of Croydon, Taberner House, Park Lane, Croydon, CR9 1TP, England. The author wishes to express his appreciation to the headteacher, staff, and pupils of Mill Ford special school for their generous help in supporting the reported research.

Abstract

Twenty-seven severely mentally handicapped children in three matched groups were trained on both a complex and a simple visual discrimination task with either; (1) prompt fading on S⁺; (2) prompt fading on S⁻; (3) no prompting (trial-and-error training). On the complex discrimination task, differences between groups were obscured by a floor effect. Only one subject from each group acquired the discrimination. However, on the simple discrimination task all nine S⁺ fading, eight S⁻ fading, and six trial-and-error training subjects attained criterion. Both S⁺ and S⁻ fading groups made significantly fewer errors than the trial-and-error group, but did not differ significantly from each other.

Sixteen children who failed to acquire the complex discrimination in Experiment 1 also participated in Experiment 2. Subjects received additional training on the task by one of four procedures. Neither continued trial-and-error training, continued S⁺ and S⁻ fading, reversals of the prompt between S⁺ and S⁻, or intensity fading resulted in acquisition of the task. Results are discussed in terms of overshadowing and task difficulty.

S+ versus S- Fading in Teaching Visual Discriminations to Severely Mentally Handicapped Children.

Prompt fading is a facilitative technique employed in training visual discriminations with mentally handicapped people. Fading procedures involve adding a more discriminable prompt cue to a complex training cue in order to facilitate initial correct responding. The prompt cue is subsequently faded (made less discriminable) until finally the child is responding to the training stimuli alone (e.g., Sidman & Stoddard, 1967; Touchette, 1968).

Prompting can be achieved by either the addition to the reinforced stimulus (S+), or subtraction from the non-reinforced stimulus (S-), of values on the prompt dimension. Both operations heighten the discriminability of the stimuli, although the stimulus manipulated during fading differs. In practice, whether S+ or S- is selected for manipulation frequently depends upon the stimulus dimension from which the prompt cue is drawn. Colour and size prompting procedures predominantly highlight and then fade colour or size cues superimposed upon S+ (e.g., Egland, 1975; Wolfe & Cuvo, 1978). Conversely, intensity fading procedures predominantly manipulate S-. The intensity of S- is initially reduced relative to S+, with subsequent increments in S- intensity (e.g., Sidman & Stoddard, 1967). However, recent research (Schreibman & Charlop, 1981; Zawlocki and Walls, 1983; Stella & Etzel, 1986) has focussed directly upon how either S+ or S- manipulation in graduated stimulus change procedures may affect the process of discrimination acquisition.

Schreibman & Charlop (1981) trained eight autistic subjects on

two complex visual discrimination tasks, employing either S+ or S- intensity fading in a counter-balanced design. Seven out of eight subjects acquired discriminations faster and with fewer errors when the relevant component of the S+ rather than the relevant component of the S- was faded first. However, although fading was initially conducted on either S+ or S-, subsequent training phases manipulated both S+ and S- to attain the terminal discrimination. Stella & Etzel (1986) note that "no empirical data exist to indicate which of two simultaneously presented stimuli (S+ or S-) should be manipulated in programmes that manipulate only one stimulus" (p.138). Stella & Etzel investigated stimulus shaping procedures involving either S+ or S- manipulation. While the results of their study also suggested that fewer errors may result from S+ manipulation, differences in number of errors between conditions were minimal. Although four out of five normal intelligence pre-school subjects made fewer errors during S+ rather than S- shaping, S+ and S- conditions differed by only two or three errors for all subjects. Interestingly, all discriminations had first to be established by S- fading to ensure reliable correct responding to S+.

These results contrast with those presented by Zawlocki & Walls (1983), and Cheney & Stein (1974). Zawlowki & Walls (1983) trained size as well as numerosity discriminations to twelve severely mentally handicapped children. They report no significant differences between size or numerosity fading on S+, on S-, or on both S+ and S- simultaneously, although all fading procedures were more successful than trial-and-error training. However, these results were based upon a combination of 40 fading and 40 test trials in each condition. Analysis of the fading trials independantly suggested that S- fading

was superior to S+ fading. Furthermore, Cheney & Stein (1974) compared saturation and fading of colour cues on either S+ or S- in teaching an oddity learning task to normal intelligence preschool children. While the procedures produced no significant differences in task acquisition, S- manipulations led to greater transfer of observation to the relevant shape dimension.

In summary, comparison of S+ and S- manipulation in fading programmes appears to warrant further investigation. The present study aims to employ S+ fading, S- fading, and trial-and-error training with a sample of severely mentally handicapped children to determine whether: (i) prompt fading is a more effective procedure than trial-and-error training; and (ii) S+ and S- fading procedures differ in facilitating task acquisition.

Method

Subjects

Twenty-seven children attending a special school for children with Severe Learning Difficulties participated in the study. Subjects were selected from a pool of 35 children who were administered four selected scales from the British Ability Scales (BAS) (Elliot, Murray, & Pearson, 1978). These were matching letter-like forms, copying, visual recognition, and early number skills. A composite score for each subject was derived by summing the total scores on each of the scales. Nine sets of three subjects each were selected, each subject being matched with two others having the same or closest composite score. Within each set subjects were randomly allocated to the training conditions, producing three groups of nine subjects each.

Table 1 presents descriptive characteristics of the subjects. The mean chronological age of the sample was 12 years 11 months (Range 7:11-16:2, SD 22.9 months). The mean Mental Age of the sample (Peabody Picture Vocabulary Test- Revised) was 5 years 9 months (range 3:1-12:10, SD 30.0 months).

 Insert Table 1 about here

Apparatus

The tasks were presented using a 32K BBC(B) micro-computer, single disk drive, and colour monitor. The screen measured 21cm in height and 27.5cm in width. Fitted beneath the screen was a two button response box (38.5cm long, 8cm high, and 10.5cm wide) connected to the computer. The response buttons were raised 1.5cm from the surface of the box and spaced 6cm apart, divided in the middle by a parallel bar. Stimuli presented on the screen appeared directly above the response buttons. All data was automatically recorded and saved at the end of each session.

The screen and response box were set on a table at the child's seated height, and the micro-computer and other equipment positioned away from the subject. All sessions were conducted in a separate, quiet experimental room adjoining the classrooms and lasted approximately 20-25 minutes. Sessions were conducted once daily on consecutive weekdays.

Stimuli

Two discrimination tasks were employed in the study. Both discriminations differed on only one relevant component, and were

white line forms presented on black backgrounds. Task 1 consisted of two manikins (approximately 8cm by 13cm) with 'arms' angled at 45 degrees to the right of vertical (S+) or 45 degrees to the left of vertical (S-). Task 2 consisted of two "X" shapes, approximately 8cm by 8cm. On S+ a horizontal bar joined the upper left and right corners of the figure. On S- the line joined the lower left and right corners (see Figure 1).

 Insert Figure 1 about here

Procedure

Pre-training. A pre-training procedure was employed to familiarize the children with the apparatus and the association between the position of the-stimuli on the screen and the buttons beneath them. A single white square was presented randomly on either the right or left of the screen. A correct response (selection of the button beneath the stimulus) produced a tune from the computer and was rewarded with a small edible and verbal praise. An incorrect response produced no consequences. A non-correction procedure was used so that every response terminated that specific trial. Initially the experimenter modelled the correct response, and provided extra physical, verbal, and imitative prompts whenever necessary. The criterion for successful completion of the problem was 20 consecutive, unprompted, correct responses.

Training programmes. At the start of each session the child was given the following directions. "Now (child's name) we are going to play a game, this game is called play the tune. We will see some pictures on the television, one will be a winning picture which will

play the tune and the other will be a losing picture. Your job is to find out which is the winning picture and play the tune every time."

The child was shown the response buttons. Any button press blanked the screen and all correct responses were reinforced with computer tunes and extensive verbal praise. A small edible reward was also initially provided for every correct response and later for three consecutive correct responses. If the child failed to respond within six seconds, or attempted to elicit a direction from the experimenter before responding, one non-directional prompt such as "Which picture will play the tune? Where is the winning picture?" etc. was used. If the child still failed to respond an error was scored. The screen was blank during each six second inter trial interval. The learning criterion for both tasks was 10 consecutive, unprompted, correct responses. All subjects initially received training on Task 1, and subsequently on Task 2.

S+ and S- Fading Programmes (Groups 1 and 2).

The prompt used in these programmes was an exaggeration of the non-common elements of the stimuli, i.e. the diagonal line in Task 1, and the horizontal bar in Task 2 (see Figure 1). Prompting involved increasing the size of the relevant element sevenfold and highlighting it in blue. S+ and S- fading programmes were identical except that fading was conducted on a prompt added to S+ or S- respectively. The S+ fading programme for Task 1 is presented in Figure 2. An identical procedure was followed for Task 2 except that the fading operations were conducted on the horizontal bar.

Insert Figure 2 about here

The fading programmes consisted of eight steps. Steps 1 to 4 faded the size of the prompt in 2cm width stages, until at Step 4 the prompt was at criterion size in both S+ and S-. Steps 5 to 8 faded colour saturation. At Step 8 all colour was faded and both S+ and S- were white. This final fading step was identical to trial-and-error training.

A criterion of two consecutive correct responses were required to advance each step, and a back-up procedure was employed whereby an error returned the subject to the previously mastered step. No step could be advanced through, even on a second or third attempt, until the criterion had again been fulfilled. Once five consecutive correct responses were made in the absence of prompting (Step 8) the programme was completed and any subsequent errors failed to reinstate the programme. The learning criterion could be attained only after the prompting programme had been successfully completed.

Trial-and-Error Training (Group 3).

This programme followed the traditional simultaneous discrimination training procedure and was identical to the preceding training programmes except that no prompts were added to the training stimuli.

Results

Task 1

A one-way related ANOVA revealed significant differences between groups in number of errors emitted during training ($F(2,16) = 8.24$, $p < .01$). The number of errors emitted by both the S+ group (mean = 26.1, $SD = 9.9$) and the S- group (mean = 29.4, $SD = 9.4$), were significantly lower than the trial-and-error group (mean = 46.9, $SD = 13.2$) ($t_s = 3.78$ and 3.17 respectively, $df = 16$, $p < .01$). S+ and S- groups did not differ significantly ($t = 0.60$, $df = 16$, $p > .05$). However, of the 27 subjects only S4 (S+ fading), S14 (S- fading), and S19 (trial-and-error training) acquired the discrimination in the maximum 100 trials.

Analysis of individual performances revealed distinctive patterns of responding. The majority of both S+ and S- fading subjects failed to transfer correct responding from the final prompted step to unprompted trials. Overall, the mean proportion of errors on fading trials was extremely low (.09 for S+ fading; .16 for S- fading) while the number of errors on criterion level trials approached 0.5 (chance level) for both groups. These differences were highly significant for both S+ and S- groups ($t_s = 8.51$ and 5.62 , respectively, $df = 8$, $p < .0005$). Illustrative data for S8 and S10 are presented in Figure 4.3.

Insert Figure 3 about here

In this figure, the fading steps are presented on the ordinate. (These steps correspond to those in Figure 2). Consecutive trials are

plotted along the abscissa. A circle represents two consecutive correct trials, and an I indicates an incorrect trial. As stated before, when the child made two consecutive correct responses he advanced a step through the programme, and when he made an error he was returned to the previous step, where he again needed two consecutive correct responses to be advanced to the next step. It can be seen that S8 (S+ fading) progressed errorlessly through the size fading steps. Some errors were emitted upon initial fading of the colour component of the prompt (Step 5), although the subject then responded errorlessly through to the last fading step. Subsequently, an alternating pattern of predominantly error free responding at Step 7 and frequent errors at Step 8 was observed. A similar pattern was observed for S10 (S- fading), although in common with the majority of S- fading subjects some errors were emitted through initially responding to the prompted stimulus. At the end of the training session, this alternating pattern of error-free responding at Step 7 with frequent errors on Step 8, had become a stable mode of responding for all but two of the 24 subjects who failed to attain the learning criterion.

In conclusion, neither S+ nor S- fading facilitated acquisition of the discrimination, since subjects failed to transfer correct responding from the prompt to the training cue. However, questions may still be asked concerning the relative effectiveness of prompting either S+ or S- during the fading trials. As noted above, two subjects failed to respond reliably to the prompt cue at the penultimate level of fading (step 7). S13 progressed errorlessly through the size fading steps, and consistently responded correctly on Step 4 (size cue eliminated). However, she failed to maintain correct responding when

attenuation of the colour cue was initiated, and repeatedly failed Step 5. The performance of S16 was more variable, but again he rarely responded correctly above Step 4. Both these subjects received S- fading. S+ and S- fading groups were also compared for number of trials to first criterion level trial (an index of speed of progress through the fading programme), and number of errors on fading trials (Steps 1 to 7) (an index of the efficiency of the prompt in precluding errors). The S+ group required fewer trials to reach their first criterion level trial than the S- group (means= 22.2 and 39.6, SDs= 9.9 and 28.0, respectively, $t = 1.79$, $df=8$, $p<.06$), and made fewer responses to S- on fading trials (means= 5.6 and 12.0, SDs= 5.6 and 10.9, respectively, $t = 1.62$, $df= 8$, $p<.07$).

Task 2

All S+ fading subjects acquired the discrimination in the maximum 175 trials. Three subjects in the trial-and-error group, and one in the S- fading group, failed to attain the learning criterion. Number of errors and trials to criterion for each subject are presented in Table 4.2.

Insert Table 2 about here

A one-way related ANOVA revealed significant differences between groups in number of errors ($F(2,16) = 5.96$, $p<.025$). Planned t-tests revealed both the S+ group ($t = 3.29$, $df= 16$, $p<.005$) and the S- group ($t = 2.55$, $df= 16$, $p<.025$) made significantly fewer errors than the trial-and-error group. The two fading groups did not differ significantly ($t = 0.75$, $df= 16$, $p>.05$). However, the S+ group again required significantly fewer trials to reach their first criterion

level trial than the S⁻ group (means= 15.7 and 20.9, SDs= 1.4 and 6.7, respectively, t= 2.66, df= 8, p<.05) and made significantly fewer errors on fading trials (means= 1.1 and 4.7, SDs= 2.1 and 5.7, respectively, t= 2.04, df= 8, p<.05).

Discussion

Differences between groups on Task 1 were obscured by a floor effect, since only three subjects (one from each training group) acquired the task. However, 17 of 18 subjects (94.4%) from the S⁺ and S⁻ fading groups acquired Task 2, compared to only 6 of 9 subjects (66%) who received trial-and-error training. The fading groups also both made significantly fewer errors than the trial-and-error group. The results of the present study therefore confirm the superiority of programmed training over trial-and-error instruction in teaching visual discriminations to severely mentally handicapped children (e.g., Strand & Morris, 1986).

While there was a clear trend towards increasing number of errors and trials to criterion across S⁺ fading, S⁻ fading, and trial-and-error groups on Task 2 (see Table 4.2), the difference between S⁺ and S⁻ fading groups was not significant. However, on both tasks the S⁺ fading group progressed through the fading sequence faster, and made fewer errors on fading trials, than the S⁻ fading group. Furthermore, the performance of individual subjects does provide some data favouring S⁺ fading. The two subjects (S₁₃, S₁₆) who exhibited the greatest difficulty during fading of the prompt cue in Task 1 received S⁻ fading. In addition, the only programmed subject who failed to acquire Task 2 (S₁₈) also received S⁻ fading.

The results therefore suggest that the most extreme difficulties were manifested following $\underline{S}-$ rather than $\underline{S}+$ fading.

However, the present experiment has clearly illustrated a potential problem with programmed training procedures. During the training of the manikin task, many subjects perseverated in responding to the prompt cue, and failed to transfer correct responding to the criterion cue once the prompt was removed (see Figure 3). For this reason training of Task 1 was not extended beyond 100 trials. However, Experiment 2 involved extended training of the task, and was concerned to further elucidate the conditions controlling perseverative responding to the prompt.

Experiment 2

The purpose of the experiment was to determine whether the prompt perseveration exhibited by subjects in the training of Task 1 could be ameliorated. Sixteen children who failed to acquire Task 1 were involved in the experiment. The efficacy of four training procedures was investigated; (i) continued trial-and-error training; (ii) continued $\underline{S}+$ and $\underline{S}-$ prompt fading; (iii) reversals of the prompt between $\underline{S}+$ and $\underline{S}-$; and (iv) $\underline{S}-$ intensity fading.

Trial-and-error training, $\underline{S}+$ prompt fading, and $\underline{S}-$ prompt fading were continued as controls to determine whether subjects would acquire the task without additional remedial intervention. The two novel procedures were attempts to eliminate perseverative responding to the prompt.

First, the prompt reversal programme was predicated upon research

suggesting that, in a discrimination involving multiple cues, the cue that best predicts reinforcement is more likely to overshadow the second cue (Sutherland & MacKintosh, 1971). It was hypothesised that if the prompt cue was subject to a number of reversals between S+ and S-, subjects may be encouraged to search for other aspects of the stimulus display which were positively and consistently correlated with reward (i.e. line tilt).

Second, the effectiveness of fading an intensity cue was evaluated. In Experiment 1, although subjects successfully progressed through fading of the size component of the prompt they perseverated in responding to the faded colour cue. Suchman & Trabasso (1966), and Corah (1964), have charted developmental changes in colour and form preference in children of normal intelligence. Suchman & Trabasso (1966) report younger children predominantly preferred colour and older children form, with the median transition age at 4 years, 2 months. It may be hypothesised that for discriminations where form and colour are relevant and redundant cues, a similar preference for colour over form may be demonstrated by mentally handicapped children of similar developmental level. To evaluate whether prompt perseveration in the present task was specific to the use of a colour prompt, the discrimination was also trained employing fading on an intensity dimension.

Method

Extended trial-and-error training. Two children were chosen randomly from the trial-and-error group for extended training. These subjects received an additional 100 trials with the traditional simultaneous

discrimination training procedure.

Extended Prompt Fading. Two S+ and two S- fading subjects were selected at random, and received an additional 100 trials of training with the prompt fading programmes, as described in Experiment 1.

Prompt Reversals. Two S+ fading and two S- fading subjects were again selected randomly for the reversal programme. Four further subjects received reversal training following extended prompt fading. Subjects initially continued to receive S+ or S- fading before the first prompt reversal was initiated. For those subjects initially receiving S+ fading the prompt was subsequently placed on S-, and vice versa for S- fading subjects. Hence, the reinforcement contingencies for the prompt cue were reversed. However, the reinforcement contingencies for the training cue remained unchanged: S+ was always the stimulus containing the 135° tilted line, while S- was always the stimulus containing the 45° tilted line.

After either 40 or 60 trials a second reversal was conducted which returned the prompt to the original stimulus for a further 30 trials. During the initial reversal the back-up procedure by which errors returned subjects to previously mastered steps was discontinued. The purpose of this procedure was to prevent the prompt from rapidly returning to full colour saturation and exaggerated size as a result of initial errors.

Intensity Fading Training. Three S+ fading and three S- fading subjects were randomly selected for the intensity fading programme. The programme consisted of nine steps which differed in the level of prompt presented along the dimension of intensity. Only S- was manipulated during training for all subjects. Initially S+ was

presented at full intensity with a blank space as \underline{S}^- to enhance the probability that subjects would respond to \underline{S}^+ . Subsequently the intensity of \underline{S}^- was gradually increased by systematically incrementing the number of dots composing the lines. \underline{S}^+ remained at full intensity throughout. This sequence continued until Step 9 where both stimuli were at full intensity. Step 9 was identical to Step 8 in the prompt fading programmes and trial-and-error training. The criteria for step advancement and the back-up procedure were identical to the prompt fading programmes and the learning criterion attainable only after the programme had been successfully completed.

Results and Discussion

Neither of the two subjects receiving continued trial-and-error training acquired the discrimination after 200 trials of training. For both subjects correct responding remained at chance level. Similarly, of six subjects given extended prompt fading only $\underline{S}1$ (\underline{S}^+ fading) acquired the discrimination after over 200 trials of \underline{S}^+ or \underline{S}^- prompt fading. For the other five subjects the perseveration in responding to the prompt cue observed in Experiment 1 continued throughout subsequent training.

The two remedial procedures were also unsuccessful in teaching the discrimination. During the prompt reversal programme two patterns of responding predominated. First, four of eight subjects perseverated in responding on the basis of the original prompt contingencies, and showed little if any correct responding to the training cue. This is clearly illustrated by $\underline{S}9$ (initial \underline{S}^+ fading) whose data are presented in the upper portion of Figure 4. (n.b., the format of this figure is as

described for Figure 3, except that the back-up procedure was discontinued during the first reversal, as described in the method section). The subject invariably responded to the prompted stimulus despite reversals, producing 60 consecutive errors during the first reversal, although none of the responses were reinforced. Similar results were observed for S11 (initial S- fading) who perseverated in responding to the non-prompted stimulus on every reversal trial, even though this again resulted in a total absence of reinforcement.

 Insert Figure 4 about here

Second, the remaining subjects demonstrated rapid acquisition of the reversed reinforcement contingencies for the prompt cue. This pattern of responding is illustrated by S6 (initial S+ fading) in the lower portion of Figure 4. Although the subject emitted some errors immediately following both reversals, she rapidly learned to respond on the basis of the new reinforcement contingencies. Similar rapid acquisition of the reversed contingencies for the prompt cue was observed for S13 (initial S- fading).

Clearly, reversal training revealed marked contrasts in performance between subjects. Four subjects perseverated in responding on the basis of the original (pre-reversal) prompt contingencies, while the others showed rapid learning compatible with the reversed contingencies for the prompt. However, for all subjects, including those in the latter group, the discriminative response was still under the exclusive control of the prompt cue rather than the training cue, since in no case was correct responding maintained when the prompt cue was totally removed (step 8).

It may be argued that making the prompt an irrelevant cue varying randomly between S+ and S-, rather than instigating discrete reversal phases, would have proved more effective in facilitating transfer to the criterion cue. However, such a procedure would not have facilitated the performance of the four subjects who continued to make non-rewarded responses either to the prompt (initial S+ fading), or away from the prompt (initial S- fading) on every trial during the first reversal (e.g. S9, see Figure 4). For these subjects prompt responding was placed in extinction during reversal; making the prompt an irrelevant cue would in effect have maintained responding to the prompt on a VR2 schedule, since at least 50% of responses to the prompt would result in reinforcement.

The intensity fading programme was also unsuccessful in shifting control from prompt to training stimuli. Of the six subjects trained, only S10 acquired the discrimination. The problem again appeared to be a failure to transfer correct responding from the prompt cue (in this case intensity) to the training cue. As in the original fading programme few errors were made on prompted trials, significantly more errors being produced on unprompted trials ($t=10.84$, $df=5$, $p<.0005$). Perseverative responding to the prompt on this task was therefore not specific to the use of a colour cue.

General Discussion

The results of the present study may be summarized as follows:

1. S+ and S- fading did not differ significantly in overall number of errors or trials to criterion, but both were more effective than trial-and-error training.

2. Perseveration in responding to the prompt and failure to transfer correct responding to the training cue was observed predominantly on the complex rather than simple discrimination.
3. Prompt perseveration was extremely resistant to change during reversal shifts, and was not ameliorated by introducing a new prompt cue.

S+ versus S- Manipulation

As noted in the discussion of Experiment 2, S+ manipulation significantly facilitated the performance of subjects in the early stages of fading where the prompt cue was prominent, although the observed reduction in total number of errors to criterion relative to S-fading (see Table 2) was not statistically significant. However, if errorless learning is defined as the acquisition of a discrimination with less than 10% errors (Lancioni & Smeets, 1986), seven S+ fading subjects acquired Task 2 errorlessly, compared to only four S- fading subjects. Furthermore, the two subjects (S13, S16) who exhibited the greatest difficulty during fading of the prompt cue on Task 1, and the only programmed subject to fail to acquire Task 2 (S18), all received S-fading. Experiment 2 also provided further support for this observation, since the only subject (S1) to acquire the task with extended S+ or S-fading received S+ fading.

These results may be interpreted in terms of the differing inhibitory demands of the procedures. Adding a highly discriminable prompt to a stimulus may increase the salience of that stimulus for learning, since Trabasso and Bower (1968) observe the more salient or noticable a stimulus the more likely it is to be selected as functional

in learning. Therefore, in contrast to S+ fading, an initial approach-avoidance conflict may be assumed to exist in the discrimination in which the prompted stimulus is negative (S- fading). Responses to the salient stimulus are not reinforced, and subjects are required to inhibit approaches to the highly discriminable prompted stimulus. This proved extremely difficult for some subjects. Zeaman and House (1962) have reported data suggesting that, early in learning, approach tendencies are formed more rapidly than avoidance tendencies (although once the discrimination is established approach and avoidance tendencies may have approximately equal strength). We may conclude therefore that faster learning may be achieved by initially prompting approach to S+ rather than avoidance of S-. However, it must be noted that prompting avoidance of the negative stimulus, by superimposing and fading a prompt upon S-, still proved significantly more effective than trial-and-error training.

Perseverative Responding to the Prompt Cue.

In Experiment 2, the majority of subjects continued to demonstrate perseverative responding to the prompt cue and failed to transfer to the training cue. This represented a continuation of the response patterns observed in Experiment 1, and demonstrated that simply extending training with the same procedures was unlikely to result in task acquisition.

The results of prompt reversal training also demonstrated this control was extremely resistant to change. All subjects perseverated in responding to the prompt cue (colour) and failed to transfer to the training cue. Additionally, four of eight subjects also perseverated in approaching or avoiding the stimulus containing the prompt (initial S+

and S- fading respectively) even when such responses were placed in extinction during reversal training. Fading on a novel prompt dimension (intensity) was also largely ineffective, since only one of six subjects acquired the task following S- intensity fading. Had intensity fading been employed before the child acquired a history of errors through unsuccessful colour fading, it may have proved more effective. However, perseverative responding to prompts was clearly not specific to the colour dimension. Perseveration to other types of prompts (e.g., trainer finger points) has also been reported (Schreibman, 1975; Wolfe & Cuvo, 1978).

Alteration of other parameters of the fading programme, such as step size or number of steps, may have proved more effective. However, the cue values employed in fading were identical for Task 2, in which only S18 exhibited prolonged prompt perseveration. An important factor influencing the success of fading was therefore the discriminability of the training cue. The difficulty of a discrimination between lines tilted at 45° and 135° for both normal intelligence and mentally handicapped subjects has also been observed in other studies (e.g., Stoddard, 1968). It would appear that when presented with a difficult training cue, perseveration in responding to prompts is more likely to occur. Koegel and Rincover (1976), and Smeets and Lancioni (1981), have also reported fading to be a more effective procedure in training simple rather than difficult discriminations.

The lack of success with fading in these cases may be interpreted as an example of 'overshadowing'. Pavlov (1927) found that a stimulus which would condition a response when presented singly failed to become a conditioned stimulus when presented in a compound with a stronger one. He referred to the stronger stimulus as overshadowing the weaker one. In

the case of instrumental discrimination learning, overshadowing occurs when the control exerted over the discriminative response by one cue is reduced by the presence of a second concurrent cue. In the present experiment, it would appear that the more discriminable prompt cue (colour or intensity) overshadowed the less discriminable training cue (line orientation) during learning, so that little was learned about the training cue. Certainly, subjects responding was characterized by the exclusive control of the prompt cue (see for example, Figures 3 and 4).

The problem of overshadowing might, however, be circumvented by employing a criterion-related (CR) cue. Research reported by Schilmoeller & Etzel (1977), and Strand & Morris (1988), suggests CR cues (cues drawn from the same dimension as the training cue) may be more effective than non criterion-related cues (NCR) (cues drawn from a different dimension) in facilitating task acquisition, since CR fading does not necessitate the transfer of stimulus control from the prompt to training cue. Further research is planned to investigate whether fading a CR cue, such as progressive manipulation along a dimension of line orientation, would prove effective in training this task.

While the failure of fading procedures in training the manikin task is disappointing, trial-and-error instruction was equally ineffective in facilitating task acquisition. The present study has shown that fading is, in general, superior to trial-and-error training, although the success of the fading procedures may depend upon the relative discriminability of the prompt and training cues. In summary, while the manipulation of either S+ or S- during fading appeared to exert some effect on programme outcome, factors such as the dimension that prompts are faded on (CR or NCR), procedural aspects of the fading programme (size and number of steps), and the discriminability of the training

cue, may be even more significant in determining the success of programmed training.

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Table 1
Descriptive Characteristics of Subjects

S+ Fading (Group 1)				S- Fading (Group 2)				Trial-and-Error (Group 3)			
a	b										
S	Sex	CA	BAS	S	Sex	CA	BAS	S	Sex	CA	BAS
1	M	182	295	10	F	172	293	19	F	149	297
2	F	175	287	11	F	167	282	20	M	156	291
3	F	164	260	12	M	172	263	21	M	175	259
4	F	129	250	13	F	142	258	22	M	170	241
5	F	156	222	14	M	122	221	23	M	150	233
6	F	165	216	15	M	146	214	24	F	181	209
7	M	175	190	16	M	186	185	25	M	155	194
8	F	141	116	17	M	146	129	26	M	95	115
9	F	137	96	18	M	131	86	27	M	123	92
Mean		158.2	214.7			153.8	214.6			150.4	214.6
SD		18.6	70.2			21.4	70.4			26.9	71.6

a. Subject number.

b. Chronological age in months.

Table 2
Number of Trials to Criterion and Errors for Task 2

Matched Set	Number of Trials			Number of Errors		
	S+ Fading	S- Fading	Trial & Error	S+ Fading	S- Fading	Trial & Error
1	24	124	11	0	25	1
2	24	24	17	0	0	6
3	24	27	73	0	1	32
4	29	109	175 ^a	1	26	94
5	24	25	92	0	1	41
6	27	34	175 ^a	1	1	83
7	60	51	27	11	11	7
8	147	62	69	29	10	19
9	29	175 ^a	175 ^a	2	41	78
Mean	43.1	70.1	90.4	4.9	12.9	90.4
SD	40.6	53.8	68.9	9.70	14.6	36.2

a. The subject failed to meet the learning criterion in the maximum of 175 trials.

Figure Captions

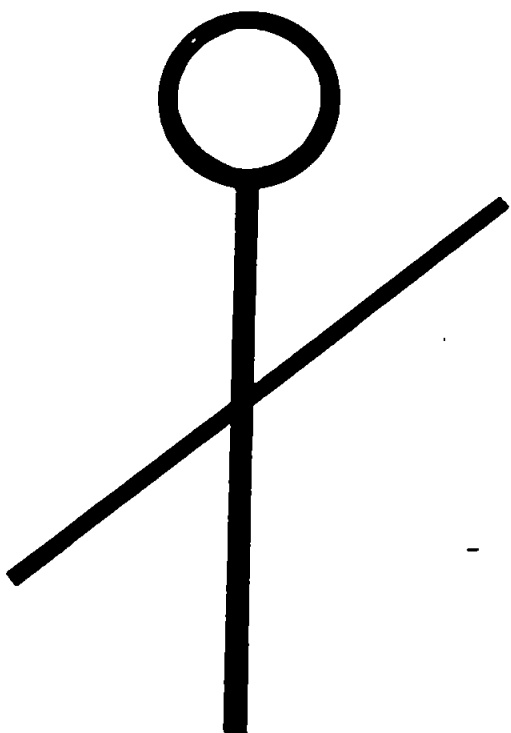
Figure 1. Stimuli employed in the two visual discrimination tasks.

Figure 2. Illustration of the eight steps involved in the S+ prompt fading program for Task 1. Steps 1 to 4 involve fading a size cue, while Steps 5 to 8 fade a colour cue.

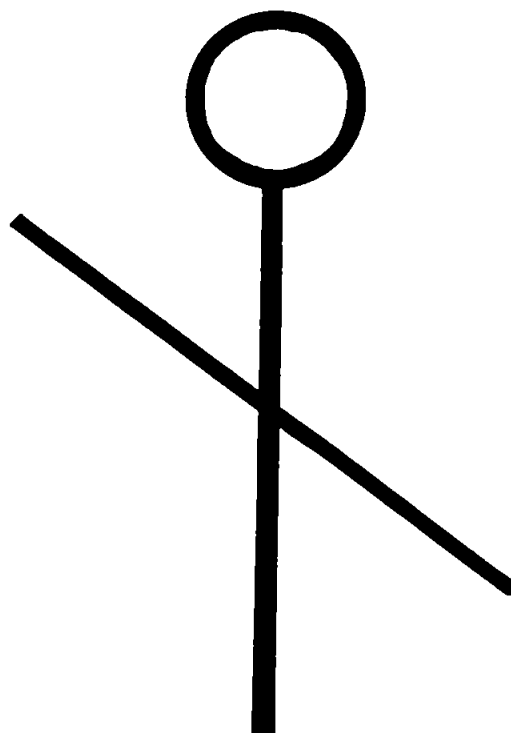
Figure 3. Trial by trial performance of S8 (top figure) and S10 (bottom figure) during the first training session of Task 1. I=incorrect response; O=two consecutive correct responses.

Figure 4. Trial by trial performance of S9 (top figure) and S6 (bottom figure) during prompt reversal training. I=incorrect response; O=two consecutive correct responses.

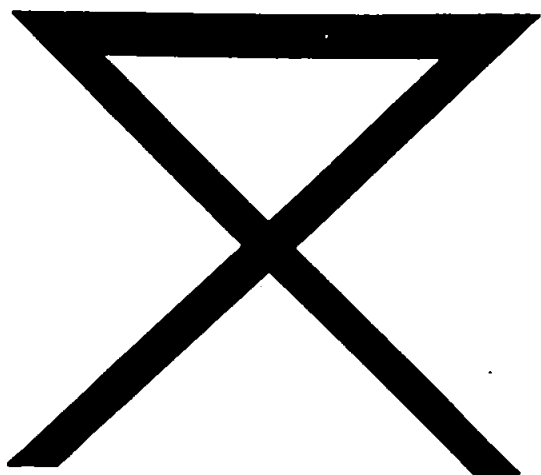
S+



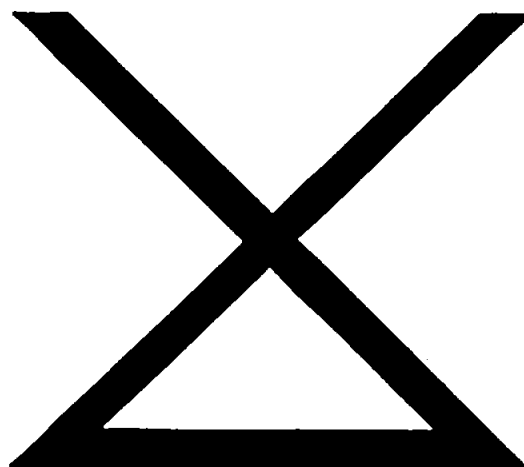
S-



VS

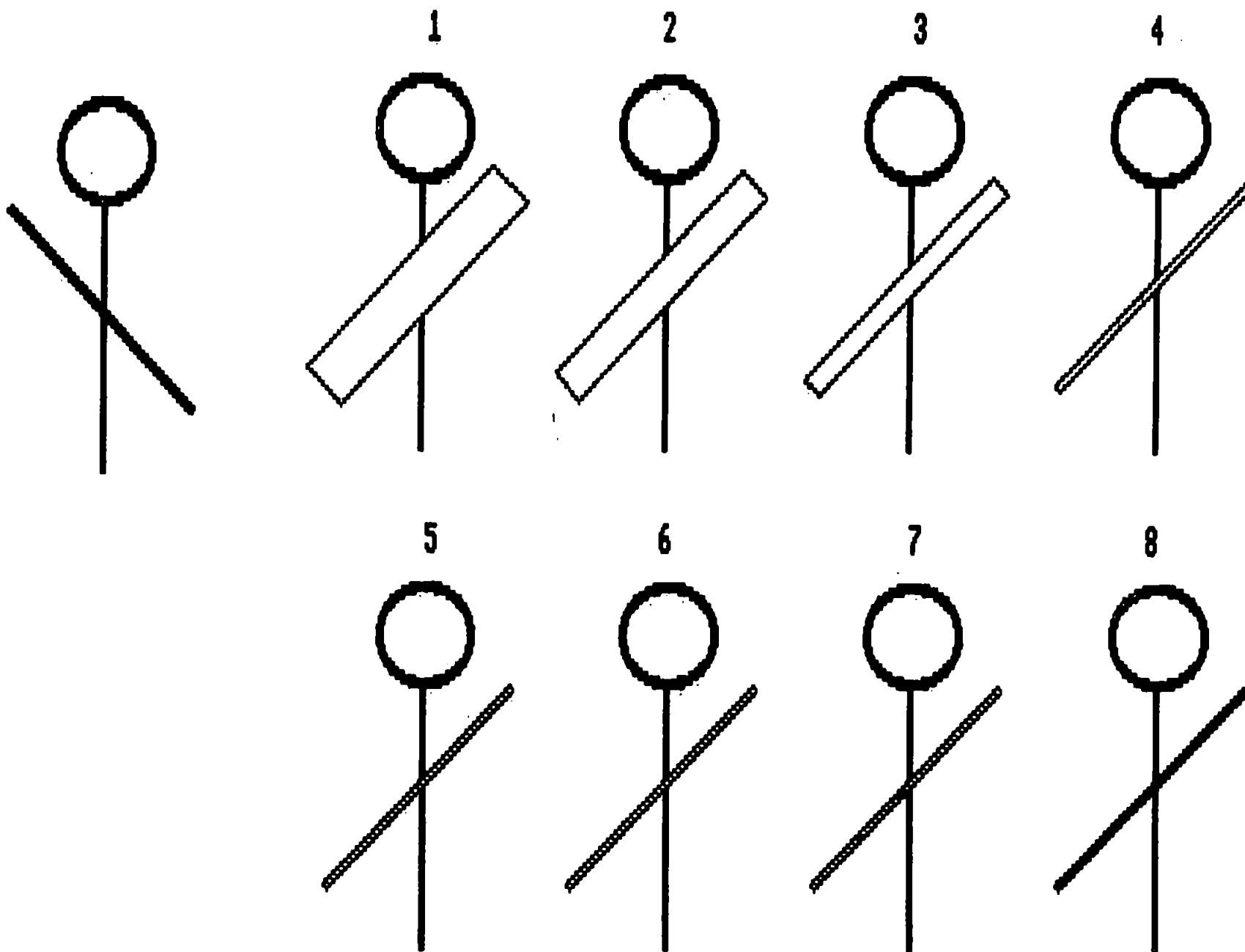


VS

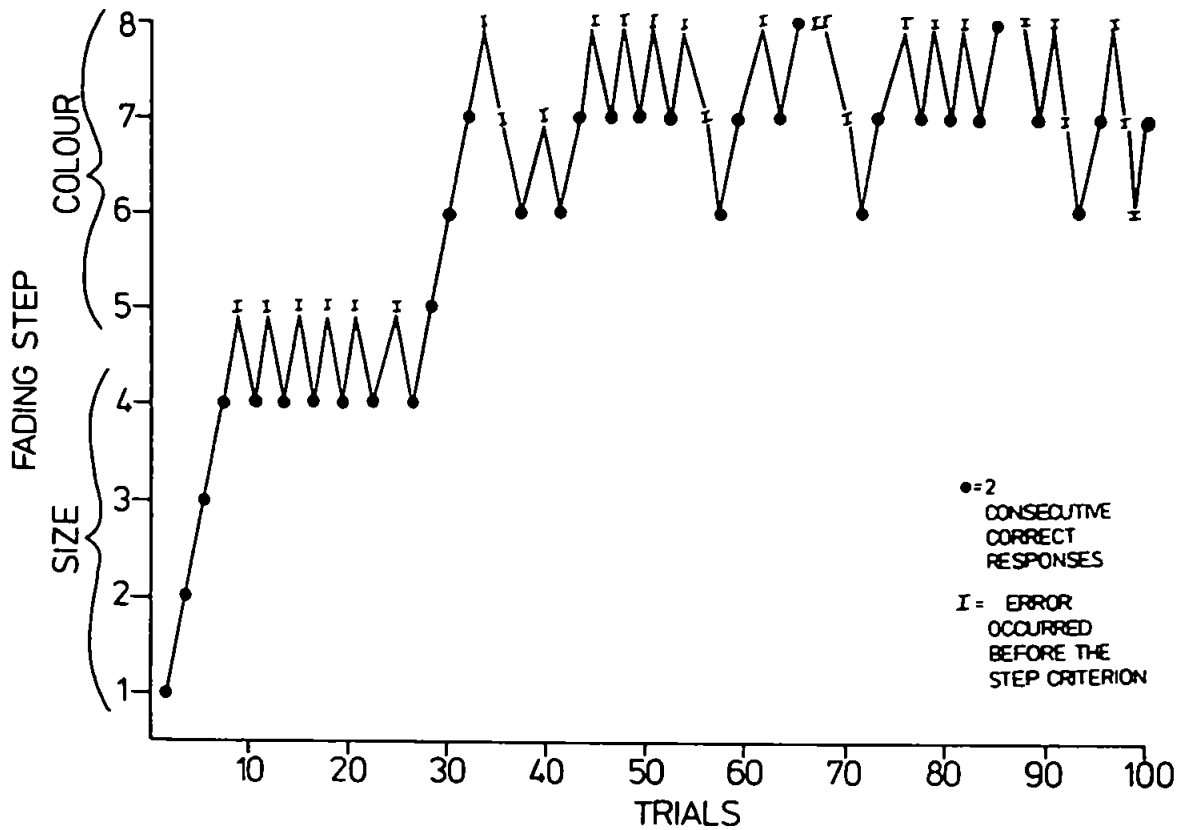


S-

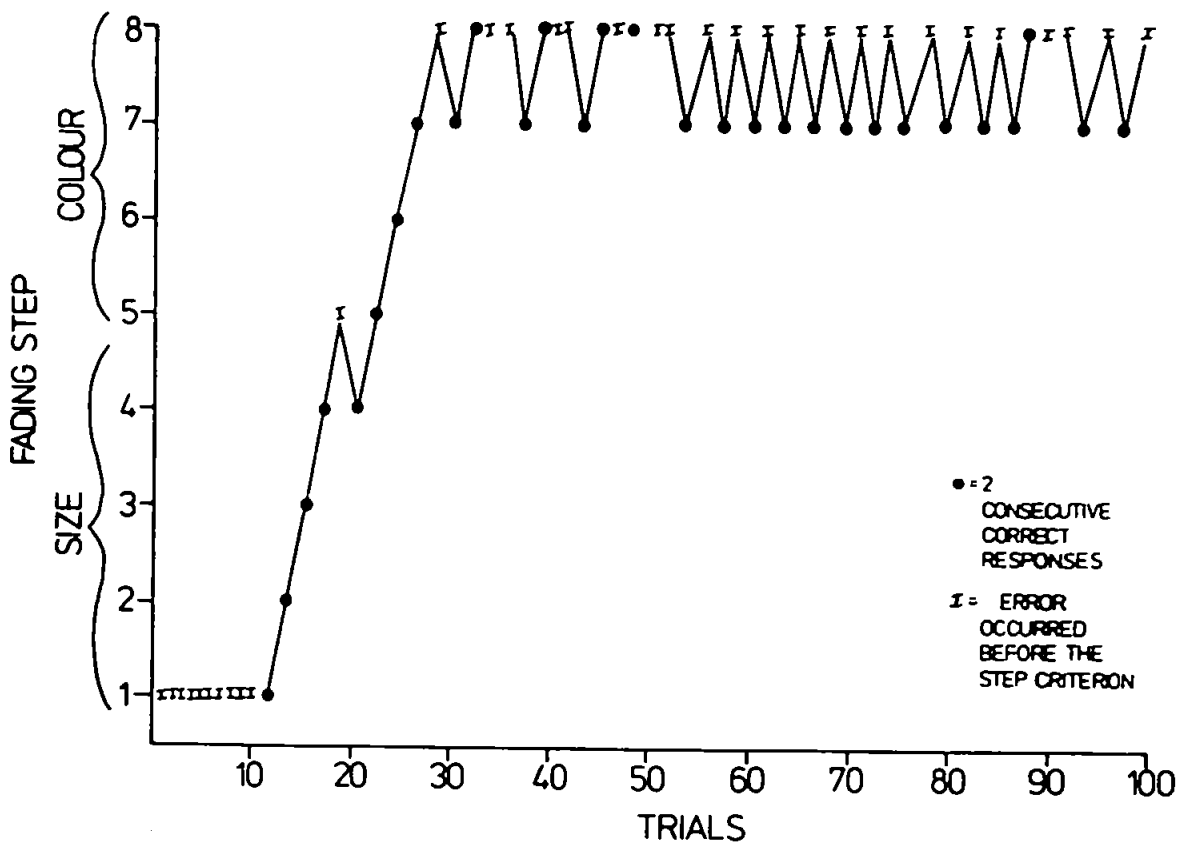
S+ Fading Step



Subject 8



Subject 10



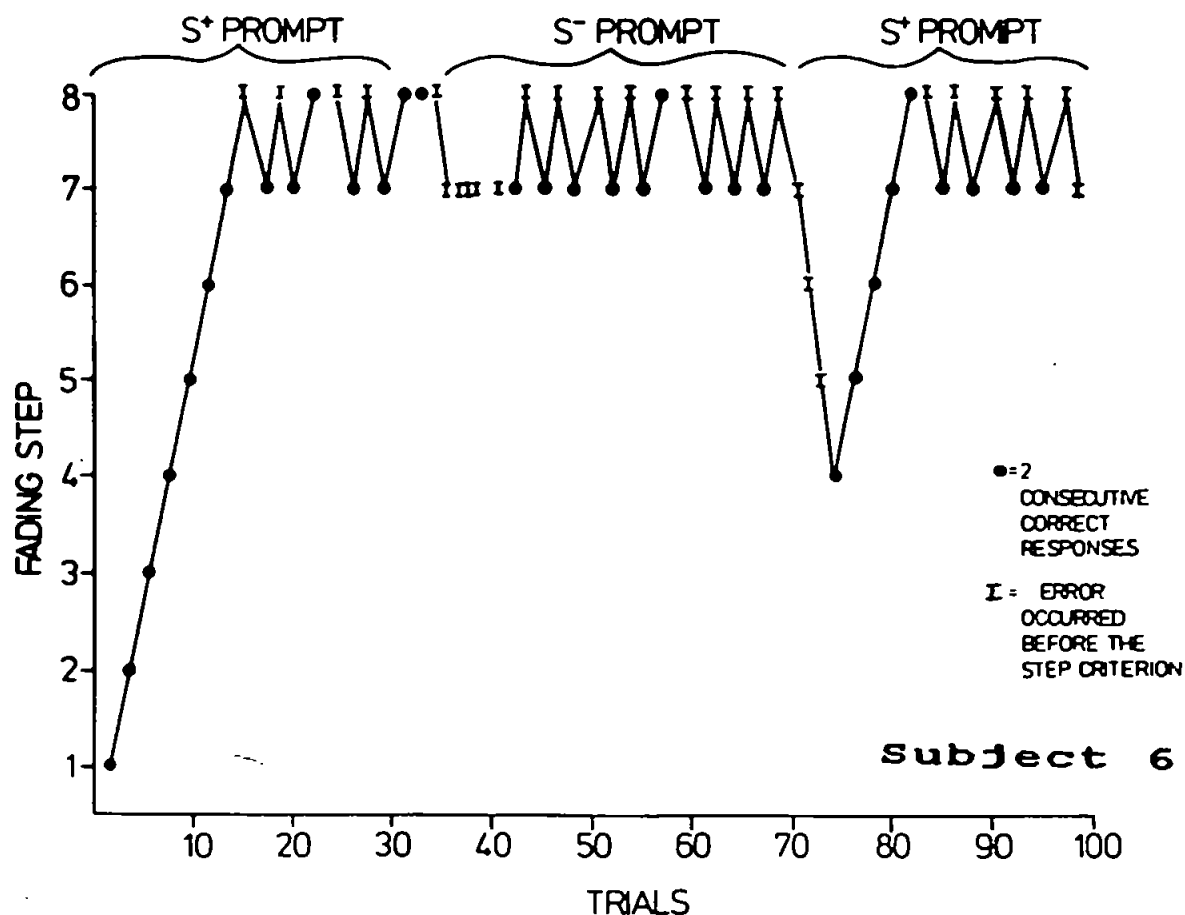
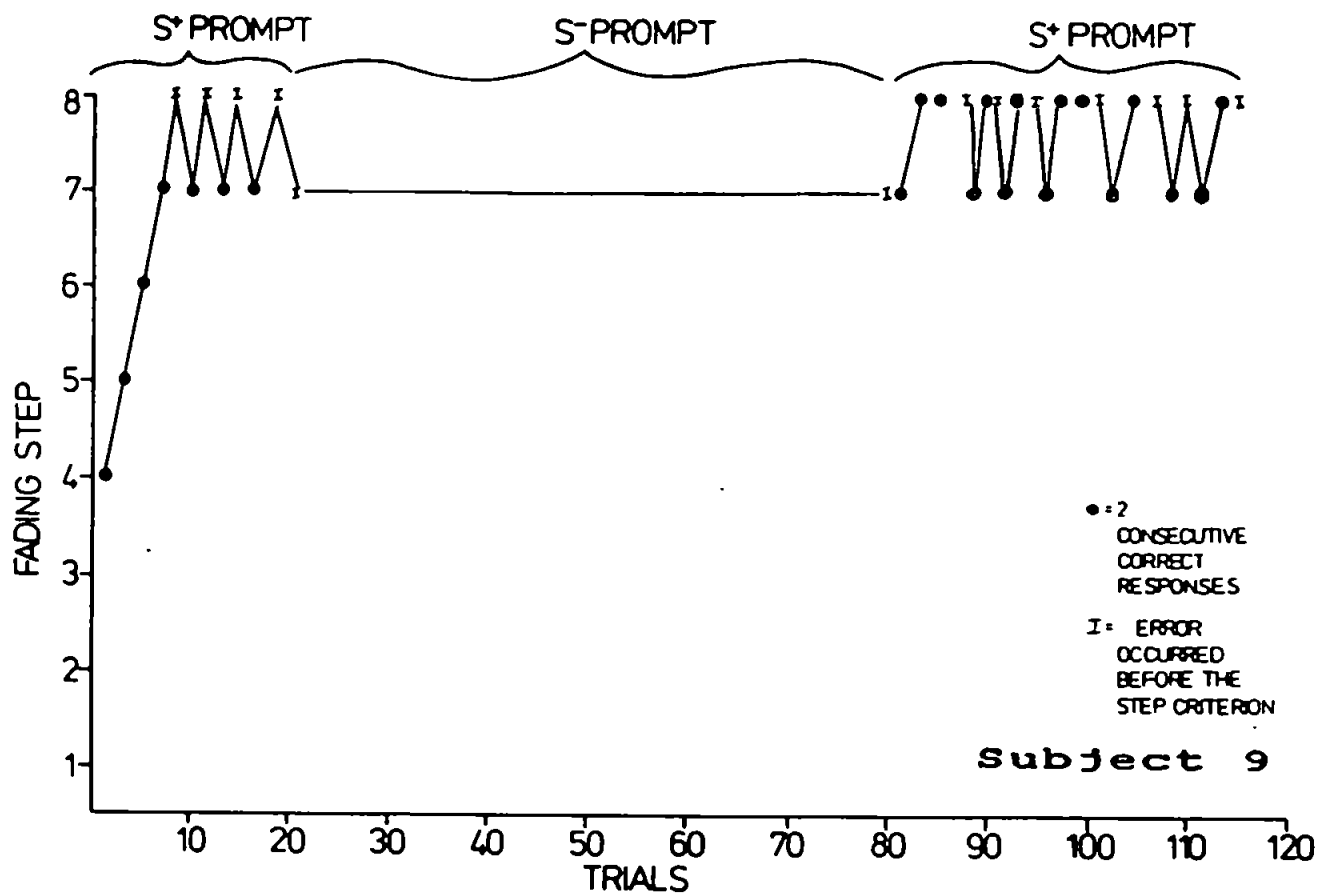


Figure 4: Trial-by-trial performance of g9 (top figure) and g6 (bottom figure) during prompt reversal training. I= incorrect response; •= two consecutive correct responses.