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HUMAN LEARNING WHEN REINFORCEMENT IS DELAYED: THE EFFECTS OF RESPONSE MARKING

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ABSTRACT

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It has long been known that the impairment to discrimination learning caused by brief delays to reinforcement can be counteracted by the response-contingent presentation of a conditioned reinforcer during the delay interval following a correct response (Spence, 1947). More recently, it has been shown that reinforcement delay can also be overcome using response-marking procedures, in which the same stimulus contingently follows both correct responses and errors (e.g., Lieberman, McIntosh, & Thomas, 1979). This thesis examined the effects of response-marking procedures on human learning of conditional discrimination tasks with delayed reinforcement.

Experiments One to Three employed single case experimental designs (alternating treatments) to evaluate the effect of response marking during matching-to-sample tasks with delayed reinforcement, using children with autism as participants. Experiment One showed that both marking and conditioned reinforcement supported acquisition of conditional discrimination performance over a 5 s delay, although the latter appeared more efficient. Experiment Two, however, showed that—with more effective techniques-both procedures were equally effective, and that both were more effective than a control in which no response-contingent stimuli occurred during the delay. Experiment Three compared the standard marking procedure with a novel *marked-before* procedure in which all sample stimuli were marked before a matching response was made. Both procedures produced very similar acquisition rates, and both were more effective in establishing conditional discriminations than a delay only control.

Experiments Four to Seven employed group comparison designs to compare marking against conditioned reinforcement, delay and immediate reinforcement using adult humans in a laboratory version of the matching-to-sample task. Marking effects were found only in Experiment Seven, when the confounding effects of verbal behaviour were adequately controlled.

Overall, the findings indicated that response-marking procedures may be effective with human participants but that their effects are more reliable in applied settings with children than in laboratory settings with adults.

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1. THEORETICAL ACCOUNTS OF DELAY-STIMULUS FUNCTION

1.1 INTRODUCTION

A *positive reinforcer* is a stimulus whose presentation contingent on a response increases the subsequent frequency of that response (Skinner, 1938). A fundamental principle of behaviour is that of *positive reinforcement.* In the animal laboratory, for example, key pecking usually increases when a food-deprived pigeon's key pecks produces grain; bar pressing usually increases if a water-deprived rat's lever pressing produces water (e.g., Catania, 1992). In everyday life, our behaviour is also reinforced by its immediate consequences. Pressing a light switch becomes more probable when it produces light; turning a tap more likely if it produces water.

The effectiveness of a reinforcer is often affected by the *delay of reinforcement,* the time between the occurrence of a response and the occurrence of a reinforcer. Reinforcers usually lose their effectiveness as the delay increases. A tennis coach, for example, would not improve her pupil's backhand by praising him several minutes after the stroke occurred[1]. Similarly, studying in schools is often followed by good grades, but, for some children, these consequences may be too remote in time to function as effective reinforcers for newly acquired behaviours (Skinner, 1968).

Sometimes, however, our behaviours can be established and maintained despite relatively long delays to reinforcement. For example, we press a doorbell despite the need to wait for some time until someone comes to answer the door; we continue to press lift call buttons although we must always wait for the lift to arrive. In most such cases, however, the behaviour in question usually produces a momentary change in the environment which is correlated, after a delay, with reinforcement. For example, pressing a door bell usually produces the distant sound of the door bell ringing, previously associated with someone answering the door. When we press for a lift a light comes on and remains on until the lift arrives. Similarly, children may work well towards achieving good grades if they receive gold stars along the way (Kazdin & Bootzin, 1972). In each of these cases, an immediate response-produced stimulus functions somehow to link the response with the delayed reinforcer.

[1] Where singular pronouns are used, I will use his/her interchangeably

Empirically, delay-of-reinforcement is an important variable for both theoretical and applied concerns. Many difficulties that arise in clinical and educational settings stem from the fact that reinforcers are often inevitably delivered well after a target behaviour occurs. Thus, many theorists and practitioners seek to find effective ways to use response-produced cues to establish and maintain behaviour in the face of delayed reinforcement.

1.1.1 THESIS OVERVIEW

A delay to reinforcement can severely impair learning and performance in animals and humans. Such a deficit can be counteracted by response-contingent cues presented during the delay. A popular account of the function of response-produced cues is that they acquire reinforcing value through association with positive reinforcers. Another account is that a response-contingent cue provides information by highlighting that a response has been made. Support for this notion has come from research on the concept of marking, where the same cue follows both correct responses, which are reinforced, and incorrect responses which are not reinforced (e.g., Lieberman, McIntosh, & Thomas, 1979). Any marking effect is therefore independent of value. Lieberman, McIntosh, and Thomas (1979) and Lieberman, Davidson, and Thomas (1985) have shown that, with delayed reinforcement, such an arrangement can establish accurate discrimination performance in rats and pigeons. The aim of this thesis was to examine the effects of response-marking procedures on human learning of conditional discrimination tasks when reinforcement is delayed. Two parallel sets of studies were conducted, one using children with autism in an applied setting, the other adult humans in the laboratory. The chapters relevant to the applied work will be presented first, the laboratory studies second; this order of presentation is, however, arbitrary.

The first two chapters of this thesis introduce the literature on delayed reinforcement and address the general question of how the negative effects of delayed reinforcement can be alleviated. The present chapter reviews the experimental literature on the effects of delayed reinforcement on learning and performance, primarily in an operant conditioning context and also discusses the major theoretical approaches adopted by behaviour analysts trying to understand how response-produced cues can overcome the effects of delay. Chapter Two focuses on marking, reviewing the experimental literature on marking and summarising the factors which affect whether or not marking is effective. It also provides the basis for the four experimental studies reported in Chapters Three to Six. Finally, Chapter Seven contains a general discussion of the experimental findings and discusses how marking has furthered our understanding about how to reduce the negative effects of delayed reinforcement in humans.

1.2 BACKGROUND

Much early research on instrumental conditioning tested the impact of delay on the effectiveness of 'learning by consequences'. In 1934, Wolfe conducted a study in which rats were able to learn with a substantial delay to reinforcement. In this experiment the rats were required to solve a spatial discrimination problem in a T-maze, where food was always available in a specified goal box. Wolfe added delay boxes between the choice point and the goal box of a T-maze so that he could control the delay interval between the rats' choosing the correct path and food reinforcement by varying holding time in the delay box. With this preparation, rats could still learn the discrimination even when reinforcement was delayed for 20 min.

Hull (1943) proposed a new concept, "secondary reinforcement", as an explanation for this delayed reinforcement learning: When the rat was released from the delay box on the correct path, it received immediate food reinforcement. Thus any cues associated with the delay box (e.g., its colour or odour) acquired reinforcing value of their own through classical conditioning because these cues were contiguous with primary reinforcement (see Section 1.3.1). Eventually a rat entering the delay box would receive immediate secondary (i.e., conditioned) reinforcement, sufficient to strengthen the correct response with food.

Subsequently, experimenters tried to eliminate all sources of response-contingent cues from their experiments (e.g., Grice, 1948; Perkins, 1947). Grice (1948), for example, designed a unique visual discrimination maze in which were two alleys, one painted black and the other white, whose positions were alternated randomly over trials from left to right. After choosing either alley, the rats were kept in a grey delay box. After the delay, the rats were allowed into a goal box where they were fed if they had chosen the correct alley. Thus, whether the rat chose the black or the white alley, it received the same amount of exteroceptive (e.g., odour) or proprioceptive (e.g., from physical movement) conditioned reinforcement. Under these conditions, delays to reinforcement usually produced substantial deficits in learning, but interestingly some learning still occurred in the face of delay.

Spence (1947) argued that when such learning does occur, it can always be attributed to the presence of response-contingent cues of some kind (e.g., proprioceptive cues experienced by the rats as a result of their differential muscle movements) and that they become conditioned reinforcers through their association with primary reinforcement. Thus, Spence predicted, if all response-contingent cues could be eliminated, even a brief delay to reinforcement would prevent learning. This suggestion, however, has been difficult to test empirically, because any number of internal cues (such as sensory traces of the discrimination) can be proposed to exist within an organism.

It is also worth thinking about the relevance of this research to human behaviour. For example, the relation between a response and reinforcement is also relevant to the question of how humans develop language, or verbal behaviour (e.g., Horne and Lowe, 1996; Skinner, 1957). According to Skinner (1957) one of the most important verbal operants is the *tact,* where a response of some kind is evoked by a particular object or event (e.g., a child saying "dog" when they see a dog). In explaining how a child initially develops their tact repertoire, Skinner describes the role of *generalised conditioned reinforcers.* For example, if a parent presents a child with a cup and the child says "cup", the parent may reinforce this utterance in a variety of ways by smiling, or praising the child (e.g., saying, "good boy"). This approval (e.g., a smile, praise) serves as a generalised conditioned reinforcer because it characteristically precedes access to a wide range of other primary or already established conditioned reinforcers. Other forms of generalised conditioned reinforcers might also be important. For example, caregiver attention or feedback from the child's own behaviour might also acquire conditioned reinforcement properties.

In sum, Skinner's (1957) criterion for the development of a tact repertoire in humans relies on the relation between an object or event as a discriminative stimulus and the verbal response evoked by that object or event (e.g., saying, "cup" in the presence of a cup). This is supported by the child frequently receiving some sort of generalised conditioned reinforcement (e.g., approval, attention) immediately contingent on their verbal response.

In addition to its use as an interpretative device the concept of conditioned reinforcement has had a major impact on the design of interventions used in applied settings to counteract the negative effects of delay. For example, the analysis of *token reinforcement* has developed into one of the most important and widely used techniques in applied behaviour analysis (Kazdin, 1982b). A token economy is a set of contingencies based on token reinforcement; tokens are arbitrary items like poker chips, gold stars, points and tickets. The contingencies specify when, and under what conditions, particular forms of behaviour are reinforced with tokens. It is an economy in the sense that the tokens can be exchanged later for a variety of back-up reinforcers preferred by the individual, just like money can be in the domestic economy.

Token reinforcement has been successfully employed in a number of settings. In the classroom they can increase academic activities like study behaviour and also reduce bad behaviour (e.g., Robinson, Newby, and Ganzell, 1981; see O'Leary & Drabman, 1971, for a review). Tokens have also been awarded to psychiatric hospital patients to teach and maintain behaviours related to social responsiveness, work activities and self-help skills (e.g., getting dressed, self-feeding). For example, in a series of experiments, Ayllon and Azrin (1968) showed that the token economy was effective in increasing the frequency of basic work and self-help behaviours in chronic schizophrenics. The opportunity to engage in activities that were chosen with high probability when freely available (e.g., Premack, 1962) was a particularly effective back-up reinforcer. When the reinforcement procedure was discontinued and these activities were freely available, the desired adaptive behaviours declined sharply but returned to their prior level when token reinforcement was reinstated. The social interactions of chronic schizophrenics have also been improved through token economies designed either to decrease the frequency of aggressive behaviours (Steffy, 1969) or to increase social interaction (Schaefer & Martin, 1966).

Probably the most common type of reinforcer used in applied behaviour analysis is *social reinforcement*. Social reinforcers have been defined by Lieberman (2000) as "stimuli whose reinforcing properties derive uniquely from the behaviour of other members of the same species" (p.208). Thus, for humans, a major source of social reinforcement may be mediated by the behaviour of other people. Social consequences such as physical contact, attention, and verbal statements of approval have all been shown to function as social reinforcers for most people (e.g., Kazdin & Klock, 1973; LeBlanc & Ruggles, 1982). Although some of the reinforcing effects of social reinforcement are probably unconditioned (Baum, 1993, Vollmer & Hackenberg, 2001), there is an extensive literature to suggest that social reinforcers may acquire some of their facilitatory effect through being associated with a wide range of primary or other already established reinforcers (e.g., Skinner, 1953).

It is generally accepted that social reinforcers can help to establish and maintain a wide range of both adaptive and maladaptive behaviours. They may be a crucial component in our ability to develop language or verbal behaviour repertoires (e.g., Horne & Lowe, 1996; Skinner, 1957). Problem behaviour patterns may also be maintained by social reinforcers, particularly attention (Iwata et al., 1994). Social reinforcement can, however, be virtually ineffective in facilitating learning for many children with learning disabilities (Bijou & Baer, 1961; Cairns & Paris, 1972; Harter, 1977). Some attempts have been made to establish effective social reinforcers for these children through classical conditioning procedures (e.g., Lovaas et al., 1966). This research will be discussed in the introduction to Experiment One (Section 3.1) because the issues it raises lead to the rationale for this experiment.

Token economies and social reinforcement are widely used in applied settings to counteract the negative effects of delay and their usage is based on the assumption that conditioned reinforcement functions are acquired through classical conditioning. Given the ubiquitous use of conditioned reinforcement in applied settings, much depends on a complete understanding of the possible processes leading to its effects. There are, for example, several other kinds of theories that have been proposed to account for the facilitatory effects of response-contingent cues that don't rely on classical conditioning. These processes have rarely been considered by applied researchers, despite the fact that they may also help to influence the development of new interventions.

The main focus of this chapter will be the description of the different theoretical accounts of the function of response-produced cues. Two distinct kinds of theories have been proposed. I shall refer to these types as *value-based* and *contextual theories.* Researchers who support the more popular value-based theories generally agree that the cues are liked and become transituationally rewarding. They differ only on the factors that create this value. Other researchers, however, have supported contextual theories, suggesting that response-produced cues can guide action in the context in which they acquire significance. They may, for example, show the organism what to do next, or signal that the correct choice has been made.

Response-produced cues may, therefore, potentially serve a variety of different functions, increasing the salience of the relationship between responding and reinforcement in several different ways. Many researchers have assumed that the functions are mutually exclusive and have tried to show that one or other of the interpretations are correct. The implication of the literature, however, is that a response-produced cue can have a variety of different functions.

1.3 VALUE-BASED THEORIES

Two main conceptions have been proposed to explain how the relationship between the cue and reinforcer creates transituational value. The *pairing hypothesis* states that the simple pairing of a response-produced cue with a primary reinforcer imparts reinforcing strength or value to that stimulus through Pavlovian conditioning. This can be contrasted with the more relative theory; *the predictivity hypothesis,* which states that the cue which acquires most reinforcing value will be relatively a better predictor of reinforcement than another cue. Proponents of both hypotheses agree that cues that are positively related to reinforcement themselves acquire value and can function as conditioned reinforcers.

1.3.1 THE PAIRING HYPOTHESIS

The pairing hypothesis (after Hull, 1943) is the most widely cited explanation for the putative effects of response-contingent cues. Its basis is that an initially neutral stimulus acquires reinforcing value in its own right as a result of being paired with, or occurring very closely together in time with, a primary reinforcer (i.e., through Pavlovian conditioning). Subsequently, the cue functions as a conditioned reinforcer, supporting operant responding in the same way as a primary reinforcer. This hypothesis has been supported by a great many researchers using a variety of arrangements of response-produced cues.

Several studies using *simple operant schedules* have shown how delayed reinforcement can affect performance of the operant (see Appendix A for a description of the procedures). Researchers have generally found that unsignalled delays reduce the rate of schedule maintained responding compared to when reinforcement is delivered immediately (see Schneider, 1990 for a review of the literature). For example, Williams (1976) used such an unsignalled delay-of-reinforcement procedure, where the first peck after a reinforcer was scheduled triggered a delay interval (3, 5, 8 or 15 s), at the end of which food was delivered. No stimulus change signalled the delay interval and responses could occur during it. Response rate was reduced by 70 to 80% compared to an immediate reinforcement condition. Similarly, Sizemore and Lattal (1977) showed that the rate of key pecking in pigeons with a 3 s delay to reinforcement decreased and stabilised at levels well below those observed under a comparable immediate reinforcement baseline.

Several studies have also shown disparate effects on rate of responding between unsignalled and signalled delays to reinforcement. For example, Richards and Hittesdorf (1978) reinforced pigeons responding according to a VI schedule with a 10 s delay imposed between their required response and reinforcement. When the delay was signalled by illumination of a pilot light, responding was maintained at much higher rates than when it was unsignalled. Richards (1981) assessed the generality of this finding by comparing the effects of various durations of signalled and unsignalled delay. Delays of 10 s signalled by a pilot light had minimal detrimental effects, whereas unsignalled delays of 5 and 10 s produced large decreases in subjects' responding.

The length of the signal relative to the length of the delay has also been shown to determine rate of responding. For example, Schaal and Branch (1988, Experiment One) showed that when delays were signalled by a brief 0.5 s change in key colour (which was response-dependent and temporally contiguous with a peck) and delays were relatively short (i.e., 1, 3, and 9 s); response rates were similar to that maintained with immediate reinforcement, decreasing to low levels only with a 27 s delay. When a delay interval of only 1 s was unsignalled, however, responding was much lower than the 1, 3 or 9 s signalled delays.

In sum, response rates of pigeons under VI schedules of signalled delayed reinforcement are reliably higher than rates obtained under comparable schedules without signals. Such experiments have frequently been cited as evidence that the signal acquires reinforcing value though being paired with primary reinforcement, subsequently serving as a conditioned reinforcer that maintains responding (e.g., Ferster, 1953; Schaal & Branch, 1988). This interpretation is supported in part by Schaal and Branch (1990) who studied the effects of delay-signal duration on rate of responding. Using a single VI 60 s with reinforcement delayed by 27 s, they examined the effects of gradually increasing the delay-signal durations (See Figure 1-1, for results from one subject). They showed that low response rates observed under a VI 60 s schedule with a 27 s delay signalled by a response-contingent 0.5 s change in key colour increased gradually as the duration of the delay signal was increased (from 0.5 s to 27 s across phases). This was replicated with other subjects, suggesting that responding is an orderly function of the proportion of the delay signalled. According to the pairing hypothesis, performance would be disrupted in (say) the 1 s brief signal condition because the end of the signal is separated by 26 s from food delivery, thereby causing a considerable reduction in the degree of conditioned value. Other interpretations of this study, however, are possible (see Section 1.2.3).

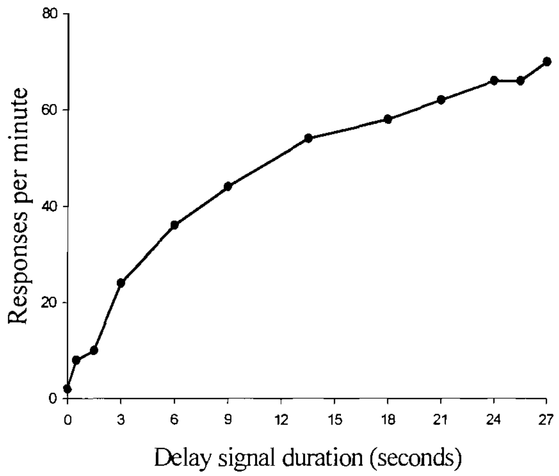

Figure 1-1. Rates of key pecking for one subject under each delay-signal duration for a 27 s delay to reinforcement, as depicted by Schaal and Branch (1990).

In addition to studies of performance, simple operant schedules have also been used to study acquisition of a simple operant response. These *operant acquisition* procedures may also support the pairing hypothesis. For example, Dickinson, Watt, & Griffiths (1992) used an unsignalled delay-of-reinforcement procedure to study the effects of delay-of-reinforcement on the acquisition of free-operant lever pressing, using a FI 1 s schedule, where the first lever press in each second produced a food pellet after a fixed delay. Responding during the delay was non-functional. For different groups of rats, the delay interval ranged from 2-64 s. The results demonstrated that the speed of learning to press the lever deteriorated rapidly with increases in the delay of reinforcement, and that no learning occurred with a 64 s delay-of-reinforcement (see Figure 1-2).

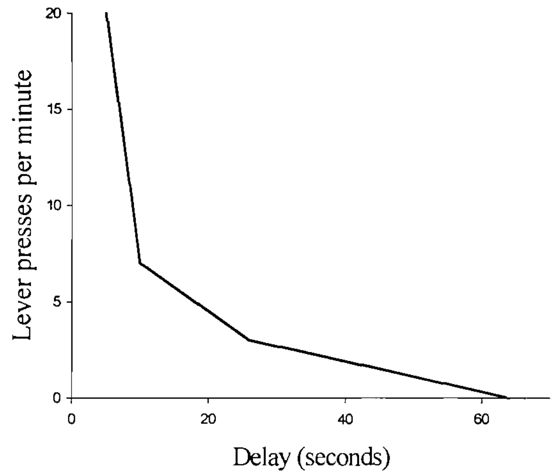

Figure 1-2. Effects of delay-of-reinforcement on acquisition of lever pressing in rats, as studied by Dickinson, Watt and Griffiths (1992).

The fact remains, however, that some instrumental learning was still possible with a delay of 30 s, albeit that lever pressing occurred only at very low rates. Similar patterns of acquisition have been found in pigeons acquiring a key-pecking response (Lattal & Gleeson, 1990). According to Hull (1943), if learning does occur despite a delay, response-contingent cues of some kind must be present (see Section 1.2). Thus, in the Dickinson et al. (1992) study, response-contingent cues could be identified as auditory feedback emitted by the mechanical operanda used in the study (e.g., key pecks produced the sound of a beak striking plastic, the lever pressing the sound of the lever moving on its hinges). This response-produced stimulation may have acquired conditioned value through its contiguity with primary reinforcement and subsequently facilitated response acquisition, despite the delay to reinforcement.

To control for this confound, Critchfield and Lattal (1993) investigated acquisition of an operant response when no mechanical operandum was involved. The operant–breaking the beam of a photocell–did not involve contact by the animal and was thus free of any auditory feedback. Even with a photo beam-break response, however, the response was still acquired and maintained with 30 s delayed reinforcement. The authors concluded that delayed reinforcement can produce operant acquisition and that their findings prompt scepticism towards traditional assumptions that substantial reinforcement delay prevents acquisition (e.g., Grice, 1948).

Nevertheless, proprioceptive or visual stimulus changes were not eliminated and may still have accompanied the response, conceivably contributing to acquisition of the response (e.g., Spence, 1947).

Experiments using *chain schedules* (see Appendix B for a description of the procedures) also support the pairing hypothesis. In a two-component chain schedule cues associated with the terminal-link stimulus are believed to function as effective conditioned reinforcers of initial link responding because of their contiguity with primary reinforcement at the end of the chain (e.g., Ferster & Skinner, 1957; Gollub, 1958; Kelleher & Gollub, 1962). Thus, in a chain VI 2 min FI 2 min schedule with green and blue lights in the first and second components (see Figure 9-2, Appendix B) responding under the green light is said to occur because the blue light has acquired conditioned value through its relation with primary reinforcement.

One drawback of using chain schedules to study the effect of response-contingent cues is that the effects of the primary reinforcer and the response-contingent cue may be confounded. Responding in the initial link of the chain could be controlled by the primary reinforcement obtained upon completion of the entire chain instead of by the response-contingent cue presented at the end of the initial link. This problem can be addressed by comparing performance on a chain FI 60 s FI 60 s with performance on an equivalent *tandem* FI 60 s FI 60 s schedule (e.g., Gollub, 1958). Response requirements on the two schedules are identical, but on the tandem schedule the links of the chain are not signalled (in other words, the tandem schedule is an unsignalled chain schedule). Any difference in rate of responding in the first link of the two schedules must therefore be due to the response-contingent cue at the end of that link.

Several studies have shown the average rate of responding is very similar for the two schedules (e.g., Malagodi, Deweese, & Johnston, 1973) but that the temporal patterns of responding can differ substantially. For example, Gollub (1958) demonstrated that on the tandem FI 60 s FI 60 s schedule, performance resembled the typical scallop pattern observed on a FI 120 s schedule. That is, the pigeons paused after each food delivery but accelerated in response rate as they got closer in time to the next reinforcement. On the chain FI 60 s FI 60 s, however, two FI scallops were produced: the pigeons' responding accelerated during the first FI until the response-contingent cue was produced; then slowed before accelerating until food was obtained. A widely held view is that the response-contingent cue functions as a conditioned reinforcer and reinforces responding in the initial link. If responding in the initial link was controlled exclusively by the food at the end of the chain, the pattern of responding should be equivalent to that found with the tandem schedule.

Researchers have also suggested that the pairing hypothesis is supported by research on chain schedules with two or more links (*"extended chain schedules,"* Kelleher & Gollub, 1962). For example, Gollub (1958) examined rates of key pecking on chain schedules with 2, 3, 4, and 5 links, when each link of the chain was associated with a FI 30 s schedule of reinforcement. He showed that the average rate of responding was a function of the number of links which occurred before food presentation: when the pigeons were presented with the five-link chain, response rate in the initial link was low (only 0.3 responses per minute), much less than the rate of responding during the first 30 s of a FI 150 s schedule where the same signal was present throughout. This well-documented difficulty in sustaining behaviour in extended chain schedules suggests that the facilitatory effects of response-contingent cues may operate only for the later links of the schedule which are nearer to food presentation (see also Catania, Yohalem, & Silverman, 1980; Thomas, 1967).

An explanation for these findings comes from research on higher-order conditioning, where an initially neutral stimulus is paired with a previously conditioned stimulus. Pavlov (1927) showed that conditioning was impossible with anything above third-order conditioning. Thus, in chain schedules, higher-order conditioning may attenuate the transfer of conditioned value in the early links of the chain, causing the characteristic graded response rates across the different links. Stimulus changes in extended chain schedules may therefore only have some conditioned value, mostly in the later links, which are closer to food delivery (e.g., Catania, 1992).

The chains which have been described thus far are often called *homogenous* chains, because the same response topography (e.g., key pecking) is required throughout the chain. Sometimes, however, different response topographies are required in each link of the chain, these are called *heterogeneous* chains. For example, Wolfe (1936), trained chimpanzees to pull a handle to get a token which had to then be deposited in a slot machine to get a grape. The chimpanzees responded just as fast to get a token as they did to get immediate primary reinforcement. When Wolfe arranged a delay between acquisition of the token and the opportunity to insert it into the machine, the delay did not slow down the chimp's lever pressing. One explanation for these results is that the tokens, to which the chimpanzees were initially indifferent, took on the properties of reinforcement through being repeatedly paired with it (e.g., Rachlin, 1976b). As such, the chimpanzee's behaviour was reinforced as much by the sight of the tokens as it was by receiving the grapes (but for alternative conceptualisations, see Section 1.4.4).

Concurrent chains (see Appendix C for a description of procedures) have also been widely cited as evidence for the pairing hypothesis (e.g., Williams, 1994b). A study by Williams and Fantino (1978) provides a good example of the concurrent-chains approach. The initial links were concurrent VI 60 schedules arranged on two response keys. In cued conditions, the two terminal links were signalled by different changes in colour on the left and right response keys. Two different FI schedules were correlated with each colour in the terminal link. Pigeons showed large preferences for the initial link leading to the shorter of the two terminal link FI schedules. In an uncued condition, there was no change in key colour to indicate which of the two FI schedules was available. Preference for the initial link leading to the shorter terminal link was substantially reduced in this uncued condition (see also Alsop, Stewart, & Honig, 1994, Experiments One and Two). In this standard concurrent chains paradigm, the key-lights are often believed to acquire value through their contiguity with primary reinforcement, subsequently reinforcing pecking on one or other of the white keys in the initial links (e.g., Mazur, 1993). The distribution of behaviour in the initial links is assumed to reflect the relative conditioned value of the two terminal-link stimuli.

Some support for the pairing hypothesis also comes from studies using *second-order schedules of brief-stimulus presentation* (see Appendix D for a description of procedures). In one study Kelleher (1966) scheduled food presentation to pigeons under FR 30 (FI 2 min: light) and FR 15 (FR 4min: light), where light was a change in key colour presented upon completion of the first-order schedule. Under both schedules the minimum time between food presentations was 60 min. The overall rate of responding was generally greater with the schedules of brief stimuli presentations than under comparable tandem schedules with the same interfood interval, but no brief-stimulus presentations. Kelleher argued that the brief stimuli occurring at the end of each component acquire value because they were intermittently paired with primary reinforcement (see also Kelleher & Gollub, 1962.

There is evidence, however, that increases in responding can be just as large when the brief stimuli are not paired with the primary reinforcer (see Gollub, 1977, pp.302-305 for a review). For example, Stubbs (1971) compared two second-order schedules, one in which the brief stimulus was directly paired with a primary reinforcer and one where it was not. He showed that paired and unpaired stimuli produced comparable overall response rates for a wide range of schedules (see also, Cohen & Stubbs, 1976; Stubbs & Cohen, 1972, Stubbs & Silverman, 1972). Moreover, both paired and unpaired stimuli produced similar response rates to primary reinforcement, even when they were not directly paired with the primary reinforcer. If pairings are not required to increase responding, it seems unlikely that the enhancements of response rate seen with brief stimuli in second-order schedules are in fact due to conditioned value (see Section 1.4.4 and Section 2.2.3 for alternative explanations).

The evidence described above to support the pairing hypothesis mostly involves free-operant schedules of reinforcement in which response rate or preference has been the measure of the degree of effectiveness of the response-contingent stimuli. The evidence of delayed learning in *instrumental discrimination learning* however may also support this hypothesis. Since the classic study of Grice (1948, see Section 1.2), a number of researchers have studied the speed of acquisition of discrete-trial discriminations. In these procedures, choice responses are separated from the trial outcomes by a delay, and a response-contingent cue is present during the delay.

In *simple discrimination learning procedures* two discriminative stimuli are presented simultaneously and the organism is required to respond to one or the other stimulus (e.g., the left or right arm in a T-maze, stimuli on one of two pigeon response keys). As discussed previously (Section 1.2), learning the correct path in a T-maze is substantially reduced when there is a delay between a choice response and reinforcement, but this can be alleviated by a response-contingent cue being presented during the delay.

Simple discrimination learning with pigeons can also be affected by whether or not a response-contingent cue is inserted during the delay. For example, Cronin (1980) showed that pigeons could not learn a simultaneous two-key (red-green) visual discrimination task when there was a 60 s delay to reinforcement. However, when correct and incorrect responses were immediately followed by different coloured houselights which remained on throughout the delay interval, the pigeons soon learned the discrimination. In a similar study, Williams and Dunn (1994) showed that pigeons could learn to discriminate between horizontal and vertical bars with an 8 s delay interval, provided that they received differential stimuli during the delay immediately following correct versus incorrect responses.

Some studies have also used *conditional discrimination procedures*, in which the reinforcement of responding during a stimulus is conditional upon other stimuli. In matching-to-sample procedures, for example, a given comparison response is reinforced depending on the sample stimulus. Williams (1994a, see also Section 2.5) trained rats on a conditional discrimination in which either a light or a noise cued whether the left or right lever was the correct choice. During training there was a 30 s delay interval. Faster learning occurred when a signal (an overhead houselight) was inserted during the first 5 s and last 5 s of the delay, than when there was no signal (see also Williams & Dunn, 1991b, Williams, 1991).

Many other studies of instrumental discrimination learning under delayed reinforcement contingencies have also reported this major facilitation in the rate of delayed learning when a response-contingent cue is present during the delay. The most popular interpretation for these results is that the choice of the S+ (i.e., the correct stimulus) has the immediate effect of producing the stimulus that precedes the food on the trials on which the S+ is chosen. Indeed, Williams (1994a) concluded that the results can only be interpreted as showing that the response contingent cue possesses considerable value in its own right through pairing with the primary reinforcer.

1.3.2 PREDICITIVITY

The pairing hypothesis stipulates that response-produced cues acquire reinforcing value through temporal contiguity with primary reinforcement. Proponents of the *predictivity* account suggest that contiguity alone is not sufficient for conditioning to occur but that the value of a response-produced cue is also influenced by its capacity to predict (or provide *information* about) when reinforcement is due. Thus, a cue which acquires most reinforcing value will be relatively a better predictor of reinforcement than another cue.

Consider the following experiment by Egger and Miller (1962), who conditioned rats by pairing two different stimuli (S_1 and S_2) with food (see Figure 1-3). In condition A, S_1 came on and S_2 was presented half a second later. During an extinction phase, when bar pressing was not reinforced by food, the rats pressed more times to get S_1 than S_2, indicating that S_1 had greater conditioned value. In condition B, however, S_1 and S_2 were presented as before, but S_1 was occasionally presented alone. Food was never given when S_1 occurred by itself. Under these conditions only S_2 was demonstrated to be an effective conditioned reinforcer.

The degree to which S_2 predicted reinforcement in each situation can help to explain the results. In condition A, when S_1 and S_2 were equally correlated with food, but S_2 followed just after S_1, S_2 was largely redundant because it was no more predictive than S_1 alone; consequently it was not an effective conditioned reinforcer. In condition B, however, S_2 was more predictive than S_1 (e.g., the rats were always fed in the presence of S_2 but only sometimes in the presence of S_1) and was therefore a more effective conditioned reinforcer (See Egger & Miller, 1963, and Seligman, 1966 for similar results and Thomas, Berman & Serednesky, 1968; Borgealt, Donahoe & Weinstein, 1972, for some limits to its generality).

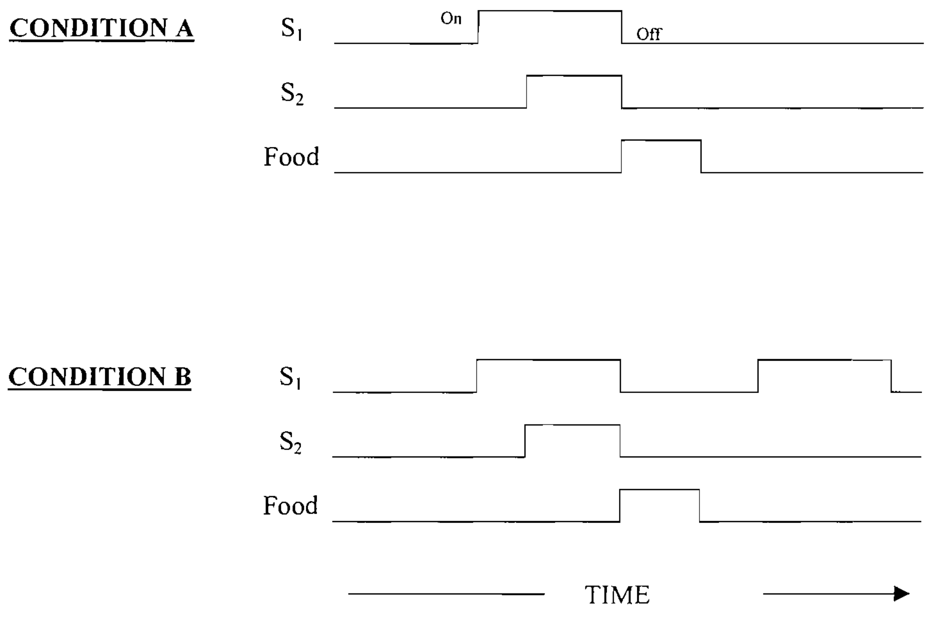

Figure 1-3. Schematic diagram of Egger and Miller's (1962) experiment using the extinction method to test for conditioned reinforcement. In condition A, S_2 does not predict reinforcement and is not a conditioned reinforcer. In condition B, S_2 predicts reinforcement and has high value as a conditioned reinforcer.

Using a concurrent-chains procedure, Schuster (1969) demonstrated similar results. Pigeons were required to choose between one of two conditions (see Figure 1-4) In condition A, pecking a key on a VI schedule occasionally produced a stimulus that was always immediately followed by food. In condition B, pecking sometimes produced extra stimuli that were not followed by food.

Schuster argued that if the pairing hypothesis was correct and the stimuli had acquired conditioned value, pigeons should have preferred condition B, which had more stimulus presentations than condition A. If, however, the brief stimulus presentations were only valuable if they reliably predicted food, the pigeons should have preferred condition A, in which the contingency relationships between the stimulus and the food were stronger. In condition B, the extra stimuli would be expected to reduce the informativeness of the stimuli that did precede food. Results showed that preference for condition B was substantially reduced compared to condition A, indicating that the stimuli were only valuable if they reliably predicted food.

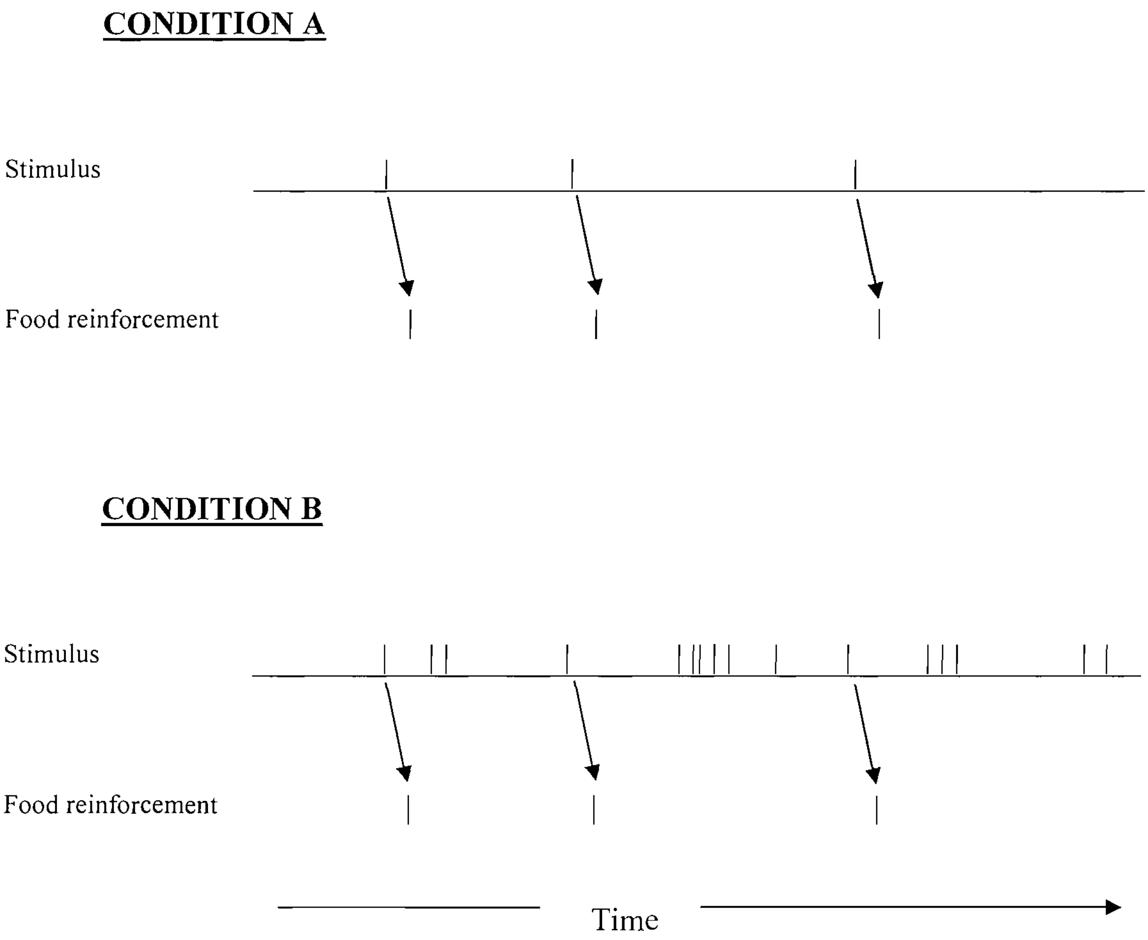

Figure 1-4. **Schematic diagram of Schuster's (1969) concurrent-chains procedure, as depicted by Rachlin (1976a). Pigeons were required to choose between two conditions. In condition A, each reinforcer was preceded by a stimulus. In condition B, each reinforcer was preceded by a stimulus with extra presentations as well.**

Taken together, the results from Egger and Miller (1962) and Schuster (1969) suggest that a stimulus will only become a conditioned reinforcer if it is predictive of when reinforcement is due. It is important to note that in these experiments, the cues are assumed to acquire transituational value (i.e., they acquire value in one experimental situation but their function is tested in a *different* context). Predictive cues, however, can also acquire value which is relevant only in the context in which they are encountered (cf. the information hypothesis for observing responses, Section 1.4.1). An important question therefore is whether predictiveness makes a cue transituationally rewarding or whether it is reinforcing only in the situation in which it is encountered.

1.4 CONTEXTUALLY-BASED THEORIES

The effects of response-produced cues may occur for reasons other than the cue acquiring transituational reinforcing value in its own right. This section will review the literature supporting five separate functions, each of which may guide action in the context in which they are experienced. The *contextual value account for observing* states that observing responses (see Appendix E for a description of procedures) are maintained because cues acquire value by giving information about when reinforcement is due. These cues, however, only have value in the context in which they are encountered. In everyday terms, the *delay-reduction hypothesis,* states that the effectiveness of a cue is a function of the relative reduction in time to reinforcement that it signals; the *bridging* hypothesis states that the cue's effects derive from its function as a bridging stimulus, increasing the likelihood that an organism will detect that a response is linked to a reinforcer. Similarly, the *directing* account emphasises that the function of the response-produced cue is to signal to the organism what to do next. Finally, the cues may also have a *feedback* function, increasing the salience of the to-be-reinforced response.

1.4.1 THE CONTEXTUAL VALUE ACCOUNT OF OBSERVING

Predictive cues might either acquire value which is transituational (Section 1.3.2) or they might function only in the context in which they are encountered. The latter is exemplified by the *information hypothesis* which has been offered as an explanation for observing responses.

In one experiment, Bower, McLean, and Meacham (1966) trained pigeons to peck two keys for food. On each key a FI 10 s schedule alternated with a FI 40 s schedule. If the pigeon pecked one of the keys, that key turned red when the FI 40 s schedule was in effect or green when the FI 10 s schedule was in effect (i.e., mult FI 10 s FI 40 s). If the pigeon pecked the other key, however, the schedules were not signalled (i.e., mix FI 10 s FI 40 s). The pigeons showed a strong preference for the key that provided information, suggesting that they pecked this key to "observe" which contingencies were currently in operation.

Several theories have been proposed to explain how the observing response is maintained, when the information it provides has no effect on the occurrence of reinforcement. According to the contextual value account of observing, subjects perform observing responses to obtain information about reinforcement availability, but the informativeness of a stimulus does not have to depend on whether it is directly correlated with reinforcement (e.g., cues bringing either "good news" or "bad news"). Both may acquire value because both reduce the uncertainty about when reinforcement is available (e.g., Badia, Culbertson, & Harsh, 1973; Lieberman, 1972; Schaub & Honig, 1967).

Many researchers, however, have supported the idea that "good news" only functions as conditioned reinforcement. According to this account, the stimulus correlated with positive reinforcement (the S+) acquires reinforcing value because it is sometimes contiguous with food when presented. Subsequently it can conditionally reinforce observing responses (see Dinsmoor, 1983; and Fantino, 1977, for reviews). Stimuli not associated with reinforcement (the S-), however, are not reinforcing, and may even acquire conditioned aversive properties which suppress responses which produce them.

Dinsmoor, Browne and Lawrence (1972) separated out the reinforcing effects of S+ (good news) and S- (bad news) to see which better maintained observing. Pigeons were first trained to peck a key on a VI 30 s schedule of reinforcement that alternated with unpredictable periods of extinction. The birds could perform an observing response that turned on a green light (the S+) when reinforcement was in effect or a red light (the S-) correlated with extinction. Next, the reinforcing effects of S+ and S- were separated out. In some sessions, observing responses produced only the S+ (when the extinction schedule was in effect observing was ineffective), in others, only the S-. Thus, observing produced either S+ or S-, but not both. When observing resulted in the S+ only, the pigeons pecked at a high rate. In contrast, when the S-was in effect, observing was completely eliminated. When both S+ and S-were available, observing behaviour was maintained only at an intermediate rate, raising the possibility that production of the S-, had in fact, been punishing. Thus, according to this study, good news functions as conditioned reinforcement, but bad news does not (see Section 1.4.4 for other explanations).

1.4.2 DELAY REDUCTION THEORY

The pairing hypothesis is often used to explain the effects of terminal-link stimuli in concurrent-chain schedules (see Section 1.3.1). The assumption is that contiguity alone determines the conditioned value of these stimuli, and that any stimulus perfectly contiguous with a primary reinforcer, i.e., with 0 s between the offset of the stimulus and the onset of the primary reinforcer, should be maximally effective as a conditioned reinforcer.

In the Williams and Fantino (1978) study (see Section 1.3.1), however, a key light associated with a shorter terminal link appeared to be more valued that a key light associated with a longer terminal link, even though both were perfectly contiguous with primary reinforcement (i.e., both stayed on until such time as primary reinforcement was delivered). Thus, a more viable measure of contiguity may be to take into account the overall temporal context of reinforcement in which the terminal link stimulus occurs, that is, the overall rate of reinforcement in the situation.

Delay-reduction theory (e.g., DRT-Fantino, 1977) provides an explanatory framework for understanding these context effects, and can be illustrated by Fantino's (1969) experiment. He presented six pigeons with a concurrent-chains procedure where terminal-link stimuli were always set at VI 30 s for the left key and VI 90 s for the right. So that the average delay interval between food presentations varied, he used three different initial-link schedules over the course of the experiment: VI 40 s, VI 120 s, and VI 600 s. The schedules in the initial links were always the same for both alternatives.

The important question was whether the pigeon's preference for the shorter VI 30 s terminal link changed as time was increased in the initial link of the chains. Results showed that when the initial link schedule was relatively short (e.g., chain VI 30 s VI 30 s on the left and chain VI 30 s VI 90 s on the right), pigeons responded almost exclusively in favour of the shorter terminal-link on the left key. When the initial link schedules were increased (e.g., VI 120 s VI 30 s on the left and VI 120 s VI 90 s on the right) the pigeons spent approximately 75% of their time responding on the left key. When time in the initial links was increased to VI 600 s, the pigeons showed no preference for either alternative. These changes in preference were despite the absolute values of the terminal link schedules remaining unchanged throughout the experiment. The pairing hypothesis would not be able to distinguish between these cases.

DRT predicts, however, that the relative value of the terminal-link stimuli should vary strongly as a function of the average inter-reinforcement interval. Indeed, Fantino (1969) developed an equation to predict the extent to which a terminal link stimulus correlated with a greater reduction in time to primary reinforcement can acquire more value than the stimulus in the concurrent chain:

$$\frac{R_L}{R_L + R_R} = \frac{T - t_{2L}}{(T - t_{2L}) + (T - t_{2R})}$$

R_L and R_R represent the rate of responding on the left and right keys, respectively, measured in the concurrently available initial links. T is the average overall time to primary reinforcement, and is calculated as the sum of the average time in the initial links and the sum of the average time in the terminal links; and t_{2L} and t_{2R} are the average delays to primary reinforcement during the terminal links on the left and right keys, respectively. The terms $(T-t_{2L})$ and $(T-t_{2R})$ represents the degree to which a terminal link stimulus on the left and right keys, respectively, is a function of its relative reduction in time to primary reinforcement. Thus, an important feature of DRT is that the predictions of the equation are based on scheduled values that can be specified precisely before any obtained values are collected (See Pierce & Epling, 1995, for an example of how these predictions work out).

1.4.3 BRIDGING

Another explanation for the facilitatory effects of response-contingent cues is that a stimulus can signal that a reinforcer is about to occur by somehow serving to connect (or bridge) a response with a delayed reinforcer (Rachlin, 1976b). Williams's (1994b) illustrated the difference between conditioned value and bridging by using an example of a teacher responding to a child's behaviour by saying ‘good’ and, after a delay giving them a sweet. According to the concept of conditioned value, the child would feel a warm glow of positive affect whenever they heard the word “good” again and this feeling would make the word an effective reinforcer for a range of behaviours on subsequent occasions. According to the bridging concept, however, the word 'good' would not be valued for its own sake, but instead would function only to signal that a sweet would eventually be delivered. The behaviour would be maintained only because the word has bridged the temporal gap between the response and eventual delayed reinforcement.

Rescorla (1982) supported the concept of bridging in a series of experiments on classical conditioning. It is known that inserting a delay between a CS and US can be detrimental to conditioning, but that this effect can be reversed if another stimulus intervenes between the end of a CS and US (e.g., Kaplan & Hearst, 1982; Pearce, Nicholas, & Dickinson, 1981). Typically this facilitation is attributed to second-order conditioning (Pavlov, 1927). The intervening stimulus becomes strongly associated with the US because of its temporal contiguity to it, and in turn acquires value so that it can support second-order conditioning to the immediately preceding trace CS (Pavlov, 1927).

Using an autoshaping procedure with pigeons, however, Rescorla (1982, Experiment Four), showed that responding to a trace CS by an intervening stimulus occurred in circumstances which could not be explained by second-order conditioning. In this experiment (see Table 1-1), two separate target CSs (A and B) were followed on 50% of trials by food delivered after a 5 s delay. For stimulus A on food trials, however, an intervening stimulus, X, was inserted throughout the delay between the CS and food, but on non-food trials the delay interval remained blank. Conversely, for stimulus B, on food trials the delay between the CS and food was left blank, but stimulus X was inserted throughout the delay on non-food trials.

CS	Delay Interval	US
A	X	Food
A	Blank	No food
B	Blank	Food
B	X	No food

Table 1-1. **The four types of trials in Rescorla (1982, Experiment Four). Each of two CSs appeared on half of the trials, with food after a 5 s delay on 50% of the CS presentations. The CSs differed only in terms of whether the intervening stimulus, X, occurred on food or non-food trials.**

Pigeons responded far more to stimulus A, the CS for which the interval was bridged by X with food on the same trial. Rescorla argued that the stimulus X could not have acquired value and facilitated responding through second-order conditioning because both CSs were followed by X and food with equal frequency. There should, therefore, have been no difference in the level of responding they omitted (for criticisms of the procedure, however, see Honey, Schachtman, & Hall, 1987; Thomas, Robertson, Cunniffe & Lieberman, 1989). Rescorla (1982) concluded that the most likely explanation was that stimulus X somehow acted as a "catalyst" which facilitated the learning of the CS-US association, and also that the catalytic effect was a perceptual mechanism: "....events which are bridged in time by a third event appear to go together" (p. 140).

If this bridging account is true, many effects traditionally explained in terms of conditioned value (e.g., the effects of chain schedules) might be interpreted as being due to a bridging function. For instance, Rachlin (1976b) suggested that, in Wolfe's (1936) study with chimpanzees (see Section 1.3.1), the token, which itself was invariably followed by a reward, may have served as a sort of promissory note for the chimpanzee- a signal that the grape was coming, thereby maintaining responding independently of conditioned value. Furthermore when a delay was introduced between the acquisition of a token and the opportunity to insert it into the machine, the delay had little detrimental effect on responding, provided that, the chimp could hold onto the token throughout the delay. Responding decreased dramatically, however, when the chimp had to wait throughout the delay with no token in its hand. This finding is also consistent with a bridging account; the token may have functioned to bridge the temporal gap between response and reinforcement.

1.4.4 DIRECTING

Response-produced cues may also, or alternatively, have a behaviour directing function, signalling to the organism what to do next. In chain schedules, for example, a stimulus correlated with each link of the chain has been said to function both as a discriminative stimulus (S^D) setting the occasion for the behaviours required in the next component, but also as a conditioned reinforcer for behaviours in a preceding component (Ferster & Skinner, 1957; Keller & Schoenfield, 1950; Kelleher & Gollub, 1962).

Consider, for example, a three-link component schedule with green, yellow and blue stimuli correlated with the different links of the chain (Figure 1.5). In such a schedule the critical issue has been the status of yellow, the middle link stimulus, in controlling responding during blue and the status of blue in controlling responding during yellow.

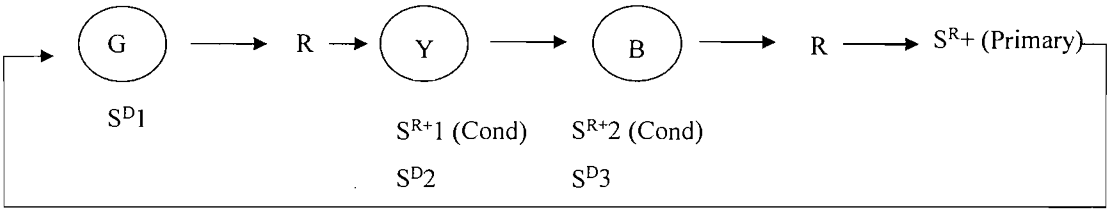

Figure 1-5. **A schematic diagram of a three-component chain schedule of reinforcement, VI 60 s FR 50 FI 120 s. The green (G) light only has a S^D function, while the yellow (Y) and blue (B) lights have at least two functions, including S^D and S^R (cond).**

The traditional interpretation of chain schedule performance relies on the backward transmission of conditioned value via higher-order conditioning as the underlying mechanism (see Section 1.3.1). Thus, yellow key responding would be maintained only because blue has acquired value through being paired with food, and green key responding would be maintained only because yellow has acquired value through being paired with blue.

According to a dual functionality account, however, the blue light is both a conditioned reinforcing stimulus for pecking under the yellow light, but also an S^D, cueing the operant responding on which primary reinforcement will be contingent Similarly, the yellow light serves as an S^D cueing that responding will earn conditioned reinforcement (the blue light), but also acquires value because of its association with the blue light, via the process of higher-order conditioning. Responding during the green light occurs because of the contingency between responding and the onset of the yellow light. The green light should only function as an S^D and not a conditioned reinforcer (e.g., a separate response is not required to produce it as the green light automatically comes on). This interpretation, however, could only be tested empirically if another link was added.

Stimuli in heterogeneous chains may also have dual functionality. For example, Fantino and Reynolds (1975) trained a rat to perform a complicated sequence of behaviour, including climbing ladders, operating lifts and pressing levers to receive one food pellet at the end of the chain. Pierce and Epling (1995) suggested that in animal training acts such as this the behaviours in each link of the chain may conditionally reinforce preceding responses but also function as an S^D for the behaviour required in the next component. Similarly, the token in Wolfe's (1936) experiment may have functioned both as a conditioned reinforcer for the responding that preceded it (pulling a lever) but also as an S^D for responding reinforced by food (exchanging the token for a grape).

The reinforcing effects of tokens have also been attributed to their discriminative properties. When Kelleher (1958, see Appendix D) arranged a second-order FR50 (FR 125: token) schedule, chimpanzees typically paused for more than 2 hours before they started to respond. If, however, they were given a number of tokens at the start of the session independently of responding, they responded rigorously. Kelleher argued that the chimps had learned that they had to earn a large number of tokens before food became available and that it was the discriminative properties of a substantial number of tokens, cueing the availability of food, which determined rate of responding.

The terminal-link stimuli in *concurrent chains* might also serve a discriminative function in addition to any reinforcing function; setting the occasion for pecking the key in the terminal links of the two chain schedules, but also conditionally reinforcing pecking one or other of the white keys in the initial links, or choice phase of the experiment (e.g., Pierce & Epling, 1995). That is, reinforcement for pecking in the choice phase is the onset of the stimuli (S^D and S^r) associated with primary reinforcement in the terminal links.

Further evidence to support the directing function comes from studies on *observing responses*. Like the information hypothesis, the directing account of observing states that the S+ and S- cues provide information about when reinforcement is due and that this information is contextually relevant. It adds, however, that this information is functional because it signals to the animal what it should do next.

Evidence to support this interpretation comes from Badia, Culbertson, and Harsh's (1973) study where rats were given a choice of receiving an electric shock without warning or having each shock preceded by a signal. Each time they pressed a lever they were given three minutes of exposure to signalled instead of unsignalled shock, pressing the lever had no effect on the rate of shock. Results showed that the rats preferred the signalled shock even when it was several times as powerful, several times as long in duration or several times as frequent as unsignalled shocks, suggesting that they preferred aversive events to be signalled.

The directing functions of the signals, according to preparatory response theory (Perkins, 1955), cue escape or avoidance responses. The S- may, for example, signal to the rat that they should perform a response geared to withstanding shock, such as freezing, as this may make the shock less aversive. In addition, preparation for shock need only occur when shock is likely.

Similar reasoning has been applied to positive reinforcement. When Wyckoff (1952) demonstrated that pigeons would perform an observing response to find out whether a FI 30 s schedule or a period of extinction was in effect (see Appendix E), the information from the observing response may have been reinforcing because the pigeon could budget its time more efficiently (Rachlin, 1976b). For example, the S+ was correlated with the reinforcement of pecking responses; the S-, on the other hand, which signalled non reinforcement of pecking, meant that they could perform other species-specific responses such as preening and scratching. Pecking would presumably be wasted if food did not come.

Despite these studies, however, there is still much contradictory evidence regarding whether bad news supports observing (e.g., Fantino, 1977; Jenkins & Boakes, 1973; Mulvaney, Dinsmoor, Jwaideh, & Hughes, 1974). Several studies show that animals will respond only for a stimulus correlated with a shock-free period, but not for information about shock (e.g., Badia, Harsh, Coker, & Abbott, 1976; DeFran, 1972). Overall, the weight of the evidence suggests that good news functions as conditioned reinforcement but that bad news does not. In fact, considerable evidence indicates that S- presentations are aversive, actually suppressing the observing response (e.g., Dinsmoor, Browne, & Lawrence, 1972). For this reason, the good news hypothesis has been generally supported (see Dinsmoor, 1983 for a review) as the mere informativeness of a stimulus seems not to be the basis for conditioned reinforcement.

1.4.5 FEEDBACK

Another mechanism suggested by Rachlin (1976a) as an alternative to conditioned value is that a stimulus presentation contingent on a response may define that response as a significant event by highlighting its occurrence. Many technological devices (e.g., mobile phone keypads, cockpit instruments) provide feedback for this purpose. Support for this general notion comes from research on *feedback stimuli*. In experiments with pigeons, for example, key-pecks are typically followed by feedback clicks that occur only when a peck has sufficient force. The click is thus a consequence only of the successful responses that are a requirement for primary reinforcement. Such stimuli can strengthen the relationship between the response and reinforcer by providing feedback that a required response has just occurred, independent of conditioned value.

Effects previously interpreted in terms of conditioned value may instead arise because of a feedback function. For example, the effects of brief stimuli in second-order schedules cannot be interpreted unambiguously as being due to conditioned value because they maintain a facilitatory effect even when they are not directly paired with reinforcement (see Section 1.3.1). According to Rachlin (1976a), the brief stimuli may have a feedback function; each stimulus providing information that a response unit has just been completed, consequently maintaining responding even when not paired with reinforcement (see also, Reed, 1994).

In humans, biofeedback from an outside source can be used to enable an individual to modify its physiological functioning. For example, if the reading on a meter or the loudness of a tone is made proportional to the electrical activity of a muscle, an individual may learn to control levels of muscle tension and relaxation (e.g., Davis, Eschelman, & McCay, 1995). It is unlikely that biofeedback cues acquire value and become rewarding in themselves. They may, however, guide action in the context in which they are effective, not because they have value beyond that context but because they provide feedback as to what has been done or indicate the best subsequent course of action. Thus, biofeedback cues may provide information (e.g., a tone indicates that muscles are tense) and also signal what to do next (e.g., relax muscles). Such feedback procedures are also useful because they provide information about the relation between a response (e.g., relaxing muscle tension) and later contingencies of reinforcement (e.g., pain reduction).

Support for the notion that a signal can define a response as a significant event has also come from research on the concept of *marking* (see Chapter Two). This procedure has been developed in a series of studies in which the presentation of brief salient signals are contingent on choice responses in a two-choice discrimination task where there is a delay between the choice response and reinforcement (e.g., Lieberman, Davidson, & Thomas, 1985; Lieberman, McIntosh, & Thomas, 1979). The critical feature of the marking procedure is that a brief stimulus occurs after both correct and incorrect choice responses. If the conditioned reinforcement theory was correct and the marking stimulus had acquired reinforcing properties of its own it should strengthen both correct and incorrect responses equally. The resulting response competition would slow down the rate of acquisition of the correct response. Nevertheless, marking procedures have been shown to substantially facilitate the rate of acquisition, even after a 1 min delay to reinforcement which would otherwise prevent learning from occurring (e.g., Lieberman et al., 1979).

Given that conditioned value is not a sufficient explanation of marking effects; an important question is whether marking can explain procedures conventionally interpreted in terms of conditioned value. This will be the focus of Chapter Two.

2.4 SUMMARY AND CONCLUSIONS

Several types of response-produced cues have been described (stimuli in simple and concurrent chain schedules, stimuli produced by observing responses and so on); all have in common an association with primary reinforcement. Evidence has been reviewed showing that generally such stimuli reduce the detrimental effects of a delay to reinforcement in various instrumental learning paradigms.

Experimental research with animals has identified many different explanations for how a response-produced cue overcomes the detrimental effects of delay to reinforcement. One of the most widely cited explanations is based on the value account; that is, that the stimulus acquires transituational reinforcing value in its own right because of its contiguity with a primary reinforcer. Another explanation is that cues can guide action in the context in which their function is established, by providing feedback as to what has been done or indicating the best subsequent course of action.

Although researchers have tried to show that one or other of the functions are correct, unambiguous conclusions are impossible as there is considerable support for each account. Research has demonstrated that cues can acquire conditioned value in their own right, subsequently becoming conditioned rewards; but they may also, irrespective of conditioned value, provide information, and signal what to do next or provide feedback showing that the right response has been made.

Many researchers have failed to acknowledge the multi-functionality of response-contingent cues, often assuming the conditioned value interpretation. Future research would benefit from investigating each of the alternative functions in more detail. To this aim, Chapter Two will review in detail the literature on the marking function of response-contingent cues. This chapter will form the basis for the experimental studies on marking in humans, which is the focus of this thesis.

2. THE MARKING HYPOTHESIS

2.1 INTRODUCTION

The concept of marking was introduced briefly in the previous chapter. The aim of the current chapter is to examine in more detail the empirical evidence that supports or contradicts marking as an explanation for the role of a signal in a delay-of-reinforcement interval. This will help to provide a context in which the research outlined in this thesis can be better understood. Additionally the chapter will review several distinct methodologies that have been employed by animal researchers exploring the marking effect, of these, the most widely cited studies use instrumental (e.g., T-maze) discrimination learning tasks (e.g., Lieberman, et al., 1979) but the research has also adopted Pavlovian conditioning tasks (e.g., Thomas, et al., 1987). Historically, most of this research on marking has been carried out by Lieberman and his colleagues, with later contributions by Urcuioli and Kasprow (1988) and Williams (1991, 1994b). The chapter will conclude with a description of some human research on marking.

2.2 T-MAZE DISCRIMINATION TASKS

Marking was first introduced into the animal learning literature by Lieberman et al. (1979) to explain a series of experiments in which rats learnt a spatial discrimination in a T-maze with delayed reinforcement. The initial aim of their research was to replicate Lett's (1975) finding that rats could learn such discrimination, provided that they were removed immediately from the maze after each choice response and returned to the home cage for the duration of the delay.

Lett (1975) proposed that her findings supported Revusky's *situational relevance* theory (e.g., Revusky, 1971), that organisms will easily associate events that occur in the same physical environment, but not those occurring in different environments. For example, if a rat is given food in a T-maze, it would be likely to associate that food with previous responses in the maze. If, however, the rat is moved outside the maze, it would be less likely to associate the food with any subsequent responses. Thus, in Lett's (1975) study, the rats would be able to learn the response-reinforcer association because home cage removal reduced the interference created by other responses during the delay. In other words, any home cage responses made during the interval would be unlikely to become associated with food and hence would not interfere with learning.

One problem with Lett's (1975) study, however, was that the rats were always reinforced in the same place that they made their choice response. Thus, the area may have acquired conditioned reinforcing properties irrespective of where the rats spent the delay. A second problem was the absence of a control group in which the rats were picked up immediately after each choice response but immediately returned to the maze instead. Thus, it was not possible to see if maze removal or being picked up was the critical variable.

To explore these possibilities further, Lieberman et al. (1979, Experiment One) used an apparatus and procedure similar to those used by Lett (1975) but changed the apparatus to include a separate start box (see Figure 2-1). The start box and the choice box were painted grey, but the side arms were painted either black (on the left) or white (on the right).

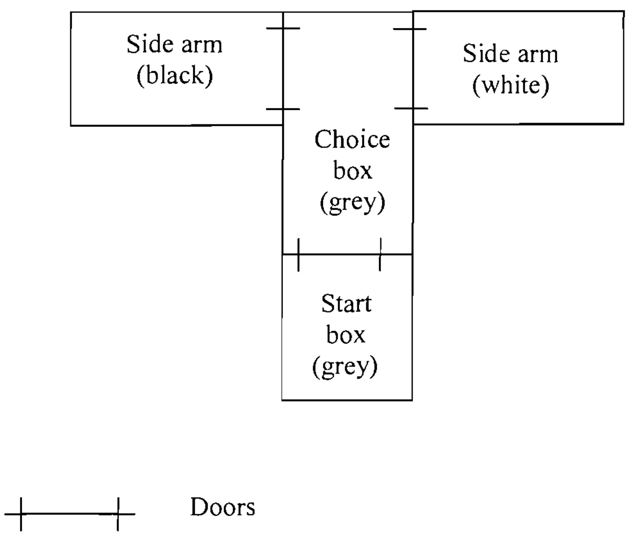

Figure 2-1. Ground plan of the maze used in Lieberman et al. (1979, Experiment One).

They trained two groups of rats to choose one of the alleys when there was a 1 min delay to reinforcement. Rats in the home cage group were picked up immediately after both correct and incorrect choices and placed in their home cage throughout the delay; control subjects were picked up and placed in the choice box. At the end of the delay, all subjects were returned to the start box where they received reinforcement for correct responses.

Both groups showed equally rapid acquisition even with a 1 min delay to reinforcement. This replicated Lett's (1975) results in the sense that the rats in the home cage group were able to learn but did not support Lett's interference interpretation. Intervening events in the maze should have produced greater interference than events in the home cage, resulting in reduced learning in the control group. Lieberman et al. (1979) have since proposed the marking hypothesis as an alternative explanation for Lett's (1975) findings (see Section 2.2.1).

In a later study, Urcuiloi and Kasprow (1988) examined whether Lieberman et al's (1979) findings could be easily replicated using comparable training procedures. They also trained different groups of rats on a left-right/ black-white discrimination in the T-maze with a 1 min delay to reinforcement, but compared several variations of where the rats spent the delay. In Experiment One, four groups were picked up immediately after each choice response and held above the choice alley that they had just entered for 1 s. One of these groups was placed in the stem of the maze during the delay (thereby replicating Lieberman et al's, 1979 control group), another in the home cage, and the remaining two groups in either the same arm they had just entered or the opposite, unchosen arm. A control group was left in the arm they had chosen. After the delay, rats in all groups were removed from their respective delay locations, held over the stem for 1 s, and returned to the start box, where food was available for correct responses.

Overall, results showed that handling actually impaired learning relative to a control group in which no handling occurred, leading Urcuioli and Kasprow (1988) to conclude that, contrary to Lieberman et al's (1979) findings, handling does not facilitate learning of a T maze discrimination. Methodological criticisms of this study, however, will be reviewed in Section 2.4.

2.2.1 THE MARKING HYPOTHESIS

In the Lieberman et al. (1979) studies, rats learnt the correct alley to food, provided that they were picked up immediately after each choice response and returned to their home cage or to the stem of the maze. To explain these effects Lieberman et al. (1979) drew upon research on Kamin's (1968, 1969) "surprise" analysis of classical conditioning. This suggests that the presentation of a US does not automatically produce classical conditioning, but rather triggers a search through memory to identify which cues reliably predict the US. Specifically, he proposed that only a surprising US causes subjects to search their memories for predictors. If, however, the US is expected, then, by definition, cues predicting the US must be reliably present, and a backward scan is not necessary.

Lieberman et al. (1979) proposed that a similar process could be applied to instrumental learning situations, and that, "[any] salient and unexpected stimulus [not just a US]...leads the subject to search its memory in an attempt to identify causal responses." (p. 240). They further supposed that during the memory search, organisms examine both stimuli and responses as potential predictors. According to this analysis, being picked up in a maze (Lieberman et al., 1979, Experiment One) would surprise the rat, causing a backward search through memory to identify possible predictors of that salient event. Because being picked up occurred immediately after a choice response, rats would be especially likely to identify that response as its most reliable predictor. Thus, they suggested that being picked up would strengthen or "mark" the choice response in memory. They did not, however, specify, what would happen after many trials. Presumably, handling would eventually come to be expected at the choice point, making a backward scan through memory superfluous (see Section 7.5).

To explain what happens when correct responses are reinforced at the end of the delay, they likewise suggested that this would trigger a search through memory for possible predictors. This search would identify the most memorable contiguous event, which, because of the extra processing already received, would probably be the marked choice response. In consequence the rats would be more likely to associate this choice response with reinforcement. Lieberman et al. (1979) recognised that events other than the marked correct choice response could be considered as possible predictors of reinforcement, but argued that the marked correct response would be more strongly associated with reinforcement because it has the best correlation with it. Furthermore, they suggested that incorrect responses would also be marked in memory but not strengthened because they do not lead to reinforcement.

This backward-scan analysis was based in part upon a consideration of research on recall in other contexts. Lieberman et al. (1979) cite research on verbal memory in humans and the *von Restorff effect,* which demonstrates that items which are particularly distinctive at the time of their initial presentation are more likely to be recalled subsequently (e.g., von Restorff, 1933; Hunt, 1995). For example, when participants are presented with a string of items which can be recalled in any order, they usually report being able to recall a particular item more easily and accurately if it is printed in a different colour to the other items in a list (e.g., Baddeley, 1976). Baddeley (1976) suggested that the easier recall reflects the extra attention or rehearsal that the (surprising) item received when presented (see also Green, 1956; Jenkins & Postman, 1948).

There are, however, alternative explanations for the facilitatory effects found in Lieberman et al. (1979, Experiment One) which do not rely on a backward scan mechanism. These have been explored by Lieberman et al. (1979, Experiments 2, 3 and 4) and Thomas, Lieberman, McIntosh and Ronaldson (1983), and will be discussed below.

2.2.2 ALTERNATIVE EXPLANATIONS

Lieberman et al. (1979) acknowledged the possibility that handling the subjects might have functioned as a source of immediate *conditioned reinforcement;* food presentation was always immediately preceded by the rats being transferred from the choice box to the start box, so handling might have acquired reinforcing properties of its own. Nevertheless, a critical feature of marking is that a stimulus is presented after both correct and incorrect choice responses. If the marker had acquired reinforcing properties of its own it would have strengthened both correct and incorrect choices equally. Thus, a reinforcement explanation cannot explain any *differential* strengthening of the correct response.

Another possibility that Lieberman et al. (1979) explored was that the expectations of the experimenter may have influenced the way in which the subjects were handled (see, Rosenthal & Fode, 1963, for a detailed description of how experimenter behaviour can affect a rat's performance in a maze). If subjects were handled more gently following correct choices than incorrect choices (and being handled gently is reinforcing and being manhandled is aversive), this could have contributed to the facilitatory effects.

Lieberman et al. (1979), however, were doubtful about this explanation because care was taken to reduce variations in handling from the outset of the experiment. In addition, the results from their first experiment were completely unexpected; they found learning in the control group where they did not expect learning. If the results *were* influenced by their expectations they should not have found any learning. Nevertheless, Lieberman et al. (Experiment Three and Four) sought to develop more automated procedures for studying marking. A ground plan of the maze used in this experiment is shown in Figure 2-2.

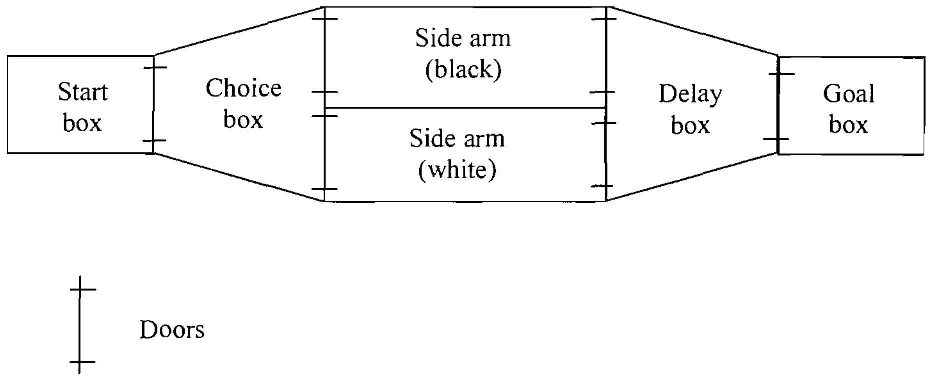

Figure 2-2. Ground plan of the maze used in Lieberman et al. (1979, Experiments 3 and 4) and Thomas, Lieberman, McIntosh & Ronaldson (1983).

Subjects in a *handling* group were picked up immediately after they had entered their chosen alley and placed in the delay box for 2 min. Following the delay interval, they were picked up again and placed in the goal box and, if they had chosen correctly, fed. Rats in the *white noise* and *light* groups received 2 s of noise or light immediately after choosing. They then entered the delay box where they were confined for 2 min, after which they could enter into the goal box and, if correct, receive reinforcement. On entering the goal box they received a second marker. Subjects in the control group were treated the same as the rats in the marked groups, except no markers were presented.

To reduce experimenter effects, the duration of both the light and the white noise were controlled with an electronic timer. Lieberman et al. (1979) supposed that if the backward-scan hypothesis was correct these new markers would still facilitate learning. If, however, the results from previous experiments were due only to variation in handling following correct and incorrect choices, only the subjects in the handled group would learn.

All three experimental groups (handling, noise, or light) learned the discrimination but the control group could not. Handling in previous experiments

(Lieberman et al., 1979, Experiments 1, 2 and 3), therefore, probably functioned as a marker. The results also demonstrated the generality of the marking phenomenon; light and noise could also act as a marker, not just handling. It could be argued; however, that one source of experimenter bias still remained because the experimenter was responsible for initiating the marker by pressing a button. Subsequently, Lieberman and his colleagues developed fully automated procedures for studying marking (see Section 2.3).

Another alternative explanation discussed by Lieberman et al. (1979) stems from research on the effect of *punishment* in maze learning with rats. Muenzinger and Wood (1935) demonstrated that rats whose correct choice responses were followed by shock learned the correct path to food significantly faster than control subjects who were not shocked. In a slightly later study, Muenzinger and Newcomb (1936) found that another form of punishment (jumping a gap) could also facilitate discrimination learning in rats. They observed, however, that in both the shock and the jump conditions subjects waited longer at the choice point than the control group did, perhaps because they were frightened of both punishers. Muenzinger and Newcomb concluded that this increased exposure to the discriminative stimuli at the choice point may have contributed to their enhanced learning of the discrimination (see Fowler & Wischner, 1969 for a discussion of Muenzinger's research).

If handling is considered aversive, the animals in Lieberman et al's marked groups may also have paused longer at the choice point than the controls and as a result learned more rapidly. Nevertheless choice latencies for the different groups in each experiment revealed no differences between marked and control groups, so this hypothesis cannot be supported.

Another possibility that Lieberman et al. (1979) explored was whether the marking cue (e.g., handling) increased the subject's level of *arousal* which in turn facilitated learning, irrespective of the contiguity between the marking cue and the choice response. Evidence that increases in arousal level can improve learning in humans has been provided by research on the effects of noise on *paired-associative learning* (e.g., Berlyne, Borsa, Hamacher and Koenig, 1966; Hamilton, Hockey and Quinn, 1972). Hamilton, Hockey & Quinn (1972), for example, gave two groups of subject a list of paired associates (e.g., window-glass) to memorise. Subjects whose initial exposure to the list occurred in the presence of a continuous white noise were found to recall significantly more words than a control group during subsequent testing (see also Craik & Blankenstein, 1975). The authors concluded that the white noise may have increased arousal (and subsequently attention to the lists of words) which in turn facilitated recall. In another experiment, Kleinsmith & Kaplan (1963) presented participants with eight words. The arousing effect of each word was measured using the galvanic skin response (GSR) and the words divided into two sets, those above and those below the average in GSR. When tested after a delay of several minutes, words which produced a strong emotional response (e.g., vomit, rape) were more likely to be recalled than neutral words (e.g., dance, swim).

Studies using animals as subjects have also found that increases in arousal caused by drug administration can improve learning (e.g., McGaugh, 1973). Berlyne (1967), for example, reviewed two studies which showed an improvement in discrimination learning in rats if they were aroused by the injection of stimulants (Doty & Doty, 1966; Rensch & Rahmann, 1960).

This research supports the idea that marking may have increased arousal (and subsequent attention to cues in the environment) which in turn facilitated recall, irrespective of the contiguity between the marking cue and the choice response. To test this hypothesis, Lieberman et al. (1979, Experiment Two, see also Thomas et al., 1983, Experiment Two) ran an additional group in which the marker was delivered 30 s after the choice response. If the arousal hypothesis were true, learning in this delayed marker group should have been at least as good and possibly better than that in the immediate marker group (better performance might be expected as the delay in marker would probably result in the subject being more aroused at the time of reinforcement). In fact, in both experiments subjects receiving a marker immediately after their choice responses showed significant learning, whereas those for whom the marker was delayed did not.

In another experiment Thomas et al. (1983, Experiment 3) altered the maze so that discriminative cues were present only on the doors leading to the alleys. Thus, once the rats entered an alley and received a marker no cues were available to identify the alley. If the arousal hypothesis was true, and marking facilitated recall by improving attention to cues in the environment, learning should not have occurred because there were no discriminative cues for the subject to attend to. Nevertheless, a strong marking effect was still obtained. Thomas et al. concluded that markers do not simply focus attention on subsequent events through increased arousal levels and that a backward scan hypothesis remains the most likely explanation.

In the experiments reported by Lieberman et al. (1979) all subjects received two markers, one immediately after the choice response and the other at the end of the delay, just prior to reinforcement. The use of two markers suggests another alternative to marking. Perhaps the presentation of the second marker immediately before food acted as a *retrieval cue*. That is, if the first marker had become associated with the choice response, presentation of the second marker might have served to activate the memory of the first marker, which in turn activated the memory of the choice response. Thus, despite the delay, the memory trace of the choice response might still have been available upon food delivery.

Evidence for this hypothesis is provided by a number of researchers who have suggested *memorial reinstatement theory* to explain delayed-reinforcement learning (e.g., Cronin, 1980; Lett, 1979; Spear, 1978). Lett (1979), for example, suggested that when subjects make a choice response in a T-maze and enter either the black or white alley, the information on the response just made (i.e., the colour of the alley) would be stored in memory. When the rat is placed in the start-box at the beginning of the delay, memories of the choice response would be retrieved. Finally, when the animal is fed in the start box at the end of the delay the retrieved memories and the presence of reinforcement would occur at the same time and so become associated. Thus by a process of memorial reinstatement through retrieval cues the animal is able to learn the discrimination.

Evidence to support the retrieval cue hypothesis has also come from research on human memory studies where retrieval has been shown to play a role in improving recall of memory for words (e.g., Tulving & Pearlstone, 1966; Tulving & Osler, 1968). For example, Tulving and Osler (1968) paired a list of target words with weak associates during training (e.g., cold-GROUND). During testing participants were presented with the associates and asked to recall the target words. Target words were recalled better during testing if they were accompanied by the associate or retrieval cue. The authors suggested that the presence of these cues during testing reminded the participants of their earlier presentation which in turn led participants to the target word with which it had become associated during learning. They concluded that memory is a cue dependent process where current events and experiences can bring to mind past memories, even memory of distance events that appear to be forgotten.

Thomas et al. (1983) explored the possibility that marking stimuli may have functioned as retrieval cues. The retrieval cue analysis is clearly dependent upon a second marker so Thomas et al. (1983, Experiment 1) set out to investigate whether two markers are necessary to facilitate learning or only one. In this experiment they used a maze similar to that employed by Lieberman et al. (1979, Experiment 4- see Figure 1.2) and found no difference in rate of acquisition between the one-marker and two-marker groups. Both marked groups, however, learned significantly faster than a non-marked control group. Thomas et al. (1983) concluded that it was unlikely that the facilitation effects observed could have been due to the second salient stimulus acting as a retrieval cue in the manner outlined above because the second marker was not necessary for learning.

One final feature of the marking phenomenon which Thomas et al. (1983) identify concerns the question of whether or not markers facilitate memory for subsequent as well as preceding events. This will be described in detail in Chapter Six.

In conclusion, Lieberman et al. (1979) and Thomas et al. (1983) argued that any facilitation effects found in marking experiments are due to a backward scan through memory, and that alternative explanations such as experimenter bias, conditioned reinforcement, increased stimulus exposure, increased arousal and retrieval cues cannot be supported.

2.2.3 IMPLICATIONS

If true, the marking hypothesis might offer a framework for explaining other phenomena. It could, for example, explain Muenzinger and Wood's (1935) finding that *response-contingent shock* facilitated rather than depressed learning (see also Muenzinger, 1934). If shock marked the correct choice response in memory it could increase the likelihood of recall when food is eventually delivered.

Marking might also explain the phenomenon which Neuringer and Chung (1967) termed "*quasi-reinforcement.*" In Neuringer and Chung's experiment, pigeons were trained to peck a key according to a second-order schedule in which several FI components were required before food presentation. Removing the second-order stimulus (a 1 s blackout) halved the average rate of responding. The blackout could not have functioned as a conditioned reinforcer because it was never paired with primary reinforcement. Lieberman et al. (1979) argued that the blackout may have functioned as a marker, effectively identifying a preceding response sequence as a unit. Subjects would be more likely to recognise that food followed a preceding unit, hence increasing the likelihood it would be strengthened. This analysis relates marking to the feedback function of response-contingent stimuli discussed in Section 1.4.5.

Thomas et al. (1983) extended this analysis by proposing that marking might play a role in *any* delayed-reinforcement situation in which a response produces distinctive feedback. For example, presenting a click immediately after every bar press can facilitate acquisition, an effect usually attributed to conditioned reinforcement (e.g., Skinner, 1938). Thomas et al., however, proposed that some or all of the facilitatory effect could be the results of the marking process:

> When the click occurs it helps the rat to remember the bar press as a functional unit, or alternatively, it may direct attention to the critical segment of the response (e.g., the bar's downward movement). Rather than directly strengthening the response, in other words, the click may be helping the rat to remember the critical units in its execution so that when food is presented subsequently the rat will be better able to identify these units and thus reproduce them. One important function of feedback stimuli, in other words, may be to mark the preceding response in memory" (p. 409)

Marking might also explain how delay affects behaviour maintained by simple VI schedules of reinforcement (see Appendix A). Usually lower rates of behaviour are maintained with unsignalled delays than when a signal is inserted during the delay interval and this is interpreted in terms of conditioned reinforcement (e.g., Richards and Hittesdorf, 1978, Section 1.3.1).

Although Schaal and Branch (1988, Section 1.3.1.) demonstrated that a brief signal (0.5 s) at the onset of 1, 3 and 9 s delay intervals was sufficient to maintain high rates of responding, even when not paired with food, there was little difference in response rate between a brief stimulus condition and a condition in which a continuous signal extended throughout a 9 s delay. If the conditioned reinforcement hypothesis were true, acquisition should have been slower in the brief signal condition because the end of the signal was separated by 8 s from food delivery, thereby reducing its contiguity with (and predictiveness of) primary reinforcement. The failure to find such an effect suggests the possibility that marking rather than conditioned reinforcement may have been the proper interpretation (but see Schaal & Branch, 1990).

The marking phenomenon demonstrates how inserting a stimulus into a delay-of-reinforcement interval can facilitate learning. This effect, however, contradicts research in other areas, particularly models of information processing developed to account for human memory. According to Wagner's rehearsal model (Wagner, 1978, 1981; Wagner, Rudy & Whitlow, 1973), for example, an event must be rehearsed in short-term memory before a permanent representation of it can be formed in long-term memory. The capacity to process information is presumed to be limited, so presenting a response-contingent cue during a delay interval should reduce rehearsal of a preceding response, and consequently the likelihood that it would be remembered (e.g., Pearce & Hall, 1978; Tranberg & Rilling, 1980; but see Tarpy, Roberts, Midgley & Lea, 1984). For example, in a study by Pearce and Hall (1978), rats were trained to press a lever on a VI schedule, with reinforcement delayed for 0.5 s following the operant response. Subjects who received a light flash during the delay responded at a significantly lower rate than did control subjects not given the light (see also Hall, 1982, for similar results with pigeons). According to Wagner's model, the light would have competed with the bar press for processing in short-term memory, thereby reducing the likelihood of the bar press being remembered when reinforcement was eventually delivered. In contrast, Lieberman et al. (1979) demonstrated that presentation of a brief stimulus following a response actually *enhanced* learning with a 2 min delay to reinforcement. This discrepancy in results can perhaps be explained by considering differences in the salience of stimuli used in the experiments (Section 2.4.4) or differences in the length of the delay interval (Section 2.4.3).

In conclusion, if the marking hypothesis is correct, it would have important potential implications. Empirically, marking might function in a number of learning situations and could account for many previously puzzling aspects of learning. At a theoretical level, the marking hypothesis suggests that memory may have an important role in determining the effects of delayed reinforcement. Marking may also represent an additional function to those traditionally assigned to a stimulus during a delay (cf. Lieberman et al., 1979); those of value, bridging or directing (see Chapter One). Essentially, marking is a form of feedback stimuli, which occurs after both correct and incorrect responses (see Section 1.4.5). Finally, marking suggests that a salient stimulus can enhance learning, rather than impairing it in the manner suggested by many researchers of short-term memory (see Thomas et al., 1983, for further discussion).

2.3 PAVLOVIAN CONDITIONING AND TRACE AUTOSHAPING

To validate the backward-scan hypothesis and to explore its generality as a process in new learning situations, Thomas, Robertson and Lieberman (1987) used a Pavlovian trace conditioning paradigm to compare the rate of pecking on one of two keys. On one of the keys a 5 s illumination of a light (CS_1) was followed after a 5 s delay by access to reinforcement; illumination of a different coloured light (CS_2) on a second key, was not reinforced. In a marked CS-group, both CSs were followed immediately by a light flash; any second-order conditioning effects of the marker should, therefore, have affected CS_1 and CS_2 equally. A control group received no presentations of the marker. The results showed that pigeons in the marked group pecked more to the reinforced CS_1 than to the nonreinforced CS_2 than did subjects who received a marker in the middle of the interval between successive trials (an ITI group) or control group who did not receive a marker. Thomas et al. (1987) concluded that a marker presented immediately after a trace CS can trigger a memory search that focuses attention on the CS, thereby increasing the likelihood that it would be remembered when food (the US) followed.

In sum, Thomas et al. (1987) demonstrated that acquisition of responding to reinforced CSs in a Pavlovian trace conditioning procedure is facilitated when a marker follows those cues. Thus, marking effects appear not to be restricted to instrumental conditioning paradigms.

2.4 METHODOLOGICAL CONSIDERATIONS

The series of studies from Lieberman's laboratory in general support the marking phenomenon. They suggest that marking effects can be observed with rats in a T-maze (Lieberman et al., 1979; Thomas et al., 1983), with pigeons learning an operant discrimination (Lieberman, Davidson & Thomas, 1985) and also with pigeons in a Pavlovian trace conditioning paradigm (Thomas, Robertson, & Lieberman, 1987, 1990). In addition, they showed that a wide range of stimuli could function as markers (Lieberman et al., 1979; Thomas et al., 1983). Against this background of successful replications, however, Urcuiloi and Kasprow (1988), failed to find marking effects (see Section 2.2) despite using very similar procedures to Lieberman et al. (1979, Experiments One and Two). Thomas and Lieberman (1990), however, have argued that procedural differences between Urcuiloi and Kasprow (1988) and Lieberman et al. (1979, Experiments One and Two) could explain the differences in results, and these will be discussed below.

2.4.1 OVERSHADOWING

One difference was that in the Lieberman et al. (1979) study, the rats spent the delay period either in the straight alley leading to the choice point, or in the home cage, whereas in Urcuiloi and Kasprow's (1988, Experiments 2A and 2B) study, all subjects (both marked and unmarked) spent the entire delay period in the alley that they had chosen. Thus, distinctive stimuli from the correct choice alley always preceded food.

Thomas and Lieberman (1990) suggested that handling did mark choice responses in Urcuiloi and Kasprow's (1988) experiments, but that the marked choice response was not associated with food. If the correct choice alley stimulus (e.g., the colour of the side arm) always preceded food, and the marked response occurred 1 min earlier, the choice-alley stimuli would be identified very early on as a reliable predictor of food. If this were the case, subjects may not have searched for further predictors; that is, the choice alley stimulus may have *overshadowed* the learning of the association between the marked choice response and food. Although Urcuiloi and Kasprow attempted to remove all choice-alley visual cues in Experiment 2B, Thomas and Lieberman (1990) suggested that the procedure merely reduced overshadowing effects because distinctive side-arm imperfections still remained (cf. implausibility of removing all sources of conditioned reinforcement, Section 1.2).

2.4.2 TEMPORAL CONTIGUITY

Temporal contiguity between the event-to-be remembered and the marker may also determine marking effects. Using a Pavlovian conditioning paradigm, Thomas et al. (1987, 1990) demonstrated that, when the CS-US interval was 10 s, marking effects were completely abolished when a marker was delayed following a target CS by as little as 5 s. Moreover, Thomas and Lieberman (1990) speculated that results from Lieberman et al. (1979, Experiment Four) demonstrate the importance of temporal contiguity between marker and choice response. For example, the rats in the noise and light groups learnt slightly faster than the group which was handled, possibly because there was a slight delay between their choice responses and being picked up compared to the more immediate light and noise groups.

In Experiments 1A and 1B of Urcuioli and Kasprow's (1988) study, the marking effect was also not found. In these experiments, however, Thomas and Lieberman (1990) noted that there was a 3-5 s delay between the choice response and marker, whereas in the Lieberman et al. (1979) studies the handling procedure was initiated more immediately after subjects had made their choice (see Thomas and Lieberman, 1990, for further discussion). It is possible; therefore, that Urcuiloi and Kasprow's (1988) failure to replicate a marking effect may have been because of lack of temporal contiguity.

2.4.3 THE DURATION OF THE DELAY-TO-REINFORCEMENT INTERVAL

The duration of the delay interval may also determine whether or not a marker facilitates or hinders learning. For example, marking substantially enhanced learning using an operant conditioning paradigm when reinforcement delays were 7 s or more (e.g., Lieberman, Davidson, & Thomas, 1985), but interfered with learning in similar studies (e.g., Pearce & Hall, 1978) when the delay was only 0.5 s. Williams and Heyneman (1982) also showed that inserting a stimulus during the delay to reinforcement interval facilitated learning when the gap was 3 s, but interfered when the gap was only 0.5 s.

To explain these results, Lieberman, Davidson, & Thomas (1985) speculated that when a marker is presented its initial effect may be to attract attention which in turn, interferes with the processing of other events in short-term memory. If sufficient time, however, is available for the marking stimulus to be identified, a search should still be initiated to identify preceding causal factors. They stated, "The effect of a marker, in other words, may depend crucially on whether the reinforcer arrives when the subject is still focusing exclusively on the marker or after the subject has begun to search for events that might have caused it" (Lieberman et al., 1985, p. 623).

Perhaps the length of delay can explain those studies which are usually cited as evidence for Wagner's (1981) rehearsal model (e.g., Pearce & Hall, 1978). An added stimulus may cause a detriment in learning, not because the stimulus interferes with rehearsal of the preceding response in short-term memory, but rather because the response-reinforcer gap is too short, so there is not time for the stimulus to focus attention on (i.e., mark) the response.

2.4.4 SALIENCE OF MARKERS

The *salience* of a marker may also determine its effectiveness. Thomas, Robertson, and Lieberman (1990) proposed that it is unlikely that every stimulus encountered by an organism elicits a search for possible causes, because the processing load would be prohibitively heavy, and that only salient (and unexpected) stimuli function as markers.

They suggested that in the Lieberman et al. (1979) maze experiments, being handled startled the rats because they had little previous experience of being handled, but that in the Urcuioli and Kasprow's (1988) experiments the rats were more used to being handled which possibly reduced the effectiveness of handling as a marker.

The lights and noises presented as markers (Lieberman et al., 1979; Thomas et al., 1983) were also observed to produce a noticeable startle response for all subjects. In contrast, other stimuli associated with the experimental task (e.g., stimuli associated with different alleys) were considered by Thomas et al. (1987) to be subjectively much less salient.

Although the markers in the Lieberman et al. (1979) study produced startle responses, this is not necessarily a prerequisite for a successful marker. In their operant experiments with pigeons, for example, Lieberman et al. (1985) found facilitation effects when the marker was simply a change in key colour. In the Pavlovian discrimination procedure, however, a 1 s presentation of a different key colour at similar brightness to keylight CSs was not an effective marker (Fuller, 1981). Thomas and Lieberman (1990) also reported that in pilot studies neither houselight illumination nor presentation of a short burst of white noise had any effect on the acquisition of discriminated autoshaped responding in pigeons. Thomas et al. (1987) eventually found that a brief flash of light from a photographic flash gun located above the response keys produced reliable marking effects.

In a later study, Thomas et al. (1990, Experiment One) demonstrated that a stimulus projected onto a keylight could be effective as a marker in a Pavlovian trace autoshaping procedure, provided it was more intense than the preceding CS. In their first experiment they compared four groups of subjects: Group *cm* received a dim CS, followed by a dim marker; Group *Cm* received a bright CS, followed by a dim marker; Group *cM* received a dim CS followed by a bright marker; and group *CM* received a bright CS followed by a bright marker. They found that marking illumination of a response key could only facilitate conditioning to the key light CS associated with reinforcement when the light used as a marker was brighter than the lights used as CSs (i.e., the *cM* group). There were no marking effects when the CS and marker were of similar intensity (e.g., the *cm* and *CM* group) or when the marker was less intense than the CS (e.g., the *Cm* group).

The pattern of results from these experiments led Thomas et al. (1990) to conclude that a marking stimulus does not have to be startling, just sufficiently salient and unexpected relative to other stimulus changes which the experiment entails (e.g., CS presentation or occurrence of the to-be-remembered response). Perhaps, Pearce and Hall (1978, Section 3.2.3) failed to find a facilitatory effect of response-contingent cues because they were not salient enough relative to the general level of ambient stimulation in the experimental session.

2.5 MARKING VERSUS CONDITIONED REINFORCEMENT

This chapter has focussed on how a stimulus intervening in a delay-of-reinforcement interval can facilitate behaviour through the marking effect. Williams (1991) extended this research to compare the power of the effect of marking with that of conditioned reinforcement and bridging. He trained rats on a series of reversals of a two-choice conditional discrimination procedure, with delays ranging from 3 to 6 s. Pilot light and white noise presentation acted as conditional discriminative stimuli. For example, at the start of a session, a pilot light was correlated with reinforcement for responses to the left lever and responses to the right lever were not reinforced. During presentations of white noise, responses to the right lever were reinforced and responses to the left lever were extinguished. When this discrimination was learned to criterion (e.g., 10 consecutive correct trials), the two conditional stimuli were reversed and the problem was again learned to criterion (the within-subject serial reversal procedure was chosen to avoid the confounding effects of intersubject variability associated with between-subject studies of acquisition). The critical variable in this experiment were the events occurring during the delay interval (see Table 2-1).

Experimental Condition	After S+ choice	After S-choice
No Signal	-	-
Conditioned Reinforcement	Continuous tone	-
Brief Conditioned Reinforcement	1 s tone	-
Marking	1 s tone	1 s tone
Bridging	Continuous tone	Continuous tone

Table 2-1. Stimulus conditions occurring after correct responses (R+) or incorrect (R-) choices in Williams (1991) experiment.

In all conditions, choice responses were followed by the termination of the conditional stimulus (e.g., light/ noise) and the removal of the response levers. In the *no signal* condition these were the only contingencies in operation. In the *conditioned* *reinforcement* condition, only correct responses (R+) were followed by a tone that continued throughout the delay, incorrect choices (R-) had no consequence. In the *brief conditioned reinforcement* condition, the contingencies were the same except that the tone occurred only briefly after R+ but was turned off for the remainder of the delay interval. When the delay interval was 3 s, the tone lasted for 0.5 s but was increased to 1 s for 6 and 12 s delays. In the *marking* condition, the brief tone (with the same durations as above) occurred after both R+ and R- but was also turned off for the remainder of the delay. Finally, in the *bridging* condition, the tone followed both S+ and S- responses and remained on throughout the delay.

Each condition was presented until 4 consecutive reversals had been learned to criterion (see Table 2-2 for order of conditions). The results showed that the number of trials to criterion increased with the longer delay values across all conditions. There were also significant differences across conditions regardless of the length of the delay. Both conditioned reinforcement conditions substantially reduced trials to criterion compared to the no-signal control.

The difference between the two conditioned reinforcement conditions was not significant. In contrast, neither the bridging nor marking conditions facilitated learning; the number of trials to reach criterion in these conditions was approximately equal to that of the no-signal control condition.

	Delay (seconds)		
Condition	3	6	12
No Signal	1/6	7/12	13/18
CR*	2	8	14
Bridging	3	9	15
Marking	4	10	16
Brief CR*	5	11	17

*CR -Conditioned reinforcement

Table 2-2. Order of conditions for all subjects in Williams (1991). Numbers indicate order of testing.

Williams (1991) concluded that neither marking nor bridging could replace conditioned reinforcement as the process by which signals facilitate learning. The same stimuli were used for all of conditions, however, so it is possible that the repeated-acquisition procedure may have given them multiple functions which interacted to produce confusing results. If, for example, stimulus value was established during the conditioned reinforcement conditions and this function transferred to the marking and bridging conditions, incorrect as well as correct responses would be strengthened. This would have a detrimental effect on learning, obscuring any facilitation that marking or bridging might otherwise have had.

Another possibility is that marking effects were obscured because the marking stimulus was not more salient than the responses it followed (see Section 2.4.4). For example, the tone serving as the marker was used for a long series of conditions. According to Williams (1991) its consecutive presentation for so many trials may have produced substantial habituation until it no longer functioned as a salient event. It is possible that salience was not so critical for the conditioned reinforcement conditions (where the same tone was also presented for several trials).

Williams (1994a) addressed these concerns by using a *between-subject* design and rats as subjects to compare the effects of conditioned reinforcement and marking on the rate of acquisition of a simple operant task (lever pressing) with a 30 s delay to reinforcement. In the *conditioned reinforcement* condition, an overhead houselight was lit during both the first and last 5 s of the delay (e.g., just prior to food presentation). In the *marking* condition, the houselight was lit only during the first 5 s of the delay. In the *no signal* condition the houselight was not presented during the delay. At issue was whether the stimulus had to be paired with food to facilitate acquisition. Figure 2-3 shows the results: both marking and conditioned reinforcement procedures supported learning, compared to a no-signal control condition. During the first six sessions the rate of learning was considerably faster in the conditioned reinforcement condition. This superiority, however, had completely dissipated by the end of the tenth training session.

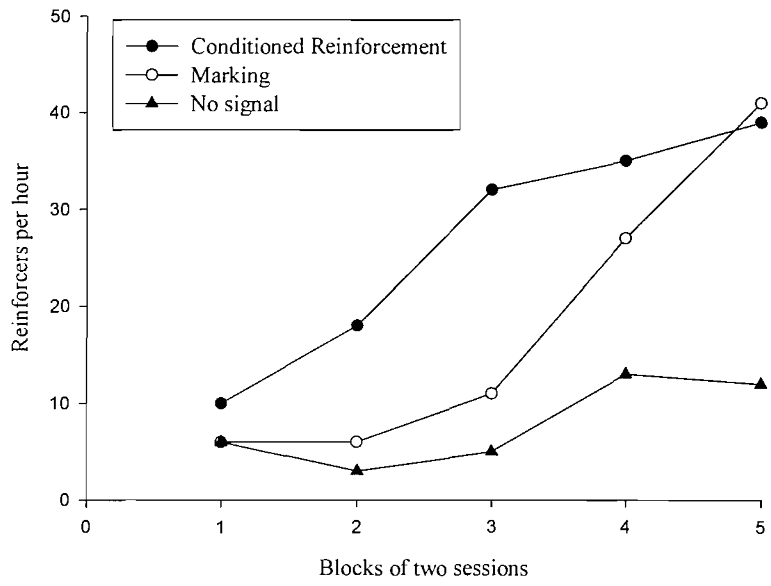

Figure 2-3. Mean rate of reinforcers for subjects trained with a 30 s delay of reinforcement, in Williams (1994a). The conditions varied with respect to the stimulus conditions during the delay interval.

Williams (1994a) concluded that the facilitatory effects of conditioned reinforcement are more powerful than those of marking, but acknowledged that the marking effect was still quite strong, because the difference between it and conditioned reinforcement had dissipated over time. This confirms that, at least in some situations, marking stimuli can facilitate learning despite a delay to reinforcement.

2.6 HUMAN STUDIES

Although the majority of research on marking has been carried out with animals, Reed (1998), explored whether the marking hypothesis could be extended to account for effects found in human memory tasks. Using a between-participants design, he assessed the extent to which recall of a word presented in the middle of a serially presented list could be enhanced by a salient cue being presented alongside or after it. His first experiment compared four conditions; in the *control* condition participants were shown a list of nine four-letter words, each presented for 0.5 s, with a 1 s interword interval (IWI); in the *salient* condition, the 5th word was dissimilar to the rest of the words in the list; in the *with* condition all words in the list were similar, but a box of asterisks surrounded the fifth word; and in the *after* condition, the box of asterisks was presented for 0.5 s immediately after the offset of the fifth word, and its offset was followed by a further period of 0.5 s before presentation of the next word (making a total IWI of 1 s). Thus the *salient* and *with* conditions tested the von Restorff effect, using within stimulus or extra-stimulus cues, and the *after* condition tested the marking hypothesis.

After the words had been presented participants were asked to type the words they recalled into the computer. In Experiments 2a, 2b, and 2c, a further *remember* condition was included in which participants were presented with the instruction "remember the last word you saw" immediately after the offset of the fifth word in the list. This condition was intended to test whether participants were capable of remembering the previous item when they were instructed to do so. The salience of the cue used in the *after* condition was also gradually increased across these experiments. All other conditions were the same as Experiment One. The results demonstrated that, compared to the control condition, recall of the fifth word was enhanced when it was not homogenous with the rest of the list (*salient*), when it was followed by the instruction *(remember)* and when the salient stimulus was presented alongside it (*with)*. Recall was, however, significantly impaired when the stimulus occurred after the item (*after)*. Therefore the results supported only the von Restorff effect and not marking, even when the salience of the marking cue was systematically increased. In fact, the results from the *after* groups are consistent with Wagner's information processing account (e.g., Wagner, Rudy & Whitlow, 1973) that an added stimulus can disrupt rather than enhance recall for an item.

One explanation for the failure to find a marking effect may have been the short IWI of only 1 s. Such a short IWI may not have allowed participants enough time to focus attention on the preceding word. To control for this possibility, Reed (1998, Experiment Five) increased the IWI to 3 s. Although Williams and Heyneman (1982) had shown that, using an operant conditioning paradigm, an added stimulus facilitates learning when a response-reinforcer gap is 3 s but interferes when the gap is only 0.5 s, Reed could find no evidence of improved recall with the longer IWI.

Reed (1998) also explored the possibility that a backward scan facilitation effect may only be provoked in humans if they believe that some aspect of the experimental context (e.g., a response) caused the marker to appear. To this end, Experiments Three to Five included an *active-signal* condition in which participants had to press the space bar to move through the list. Termination of the fifth word was immediately followed by presentation of a marking stimulus. Using this procedure, recall for the marked item in the active-signal condition was no better than in the control, but recall was still greater in both of these groups than in the *after* condition.

In sum, stimuli presented alongside a target word could facilitate recall compared to a no cue control, but stimuli presented after a preceding word (i.e., a situation analogous to a marking procedure) could not. Reed (1998) concluded that the generality of the backward-scan mechanism to humans is brought into question by his set of experiments, but acknowledged that the instrumentality of the task may have contributed to the lack of an effect. When the participants had to respond to produce the marking stimulus, the decrement in recall that would otherwise have been produced by that stimulus was abolished. This is consistent with the marking hypothesis in the sense that it is based on the premise that participants will only direct processing at those events which are likely to be causally responsible for the occurrence of the marker (see Section 7.4.3).

Although marking has been subject to few direct studies with humans, it may help us to understand other human experiments that have been explained in terms of second-order conditioning. It may, for example, help to explain previous research on human causality judgments. Shanks, Pearson, and Dickinson (1989) is typical of human causality judgment experiments. In their first two experiments, they employed a free-operant schedule, where participants were asked to press a space bar on a computer keyboard as many times as they liked. This action sometimes caused an outcome (an ambient tone and a triangle lighting up on a computer screen for 0.1 s) which occurred either immediately or with varying degrees of delay. In actuality 75% of the actions caused the outcome, regardless of the delay interval. After either a fixed period of time (Experiment 1A) or after a fixed number of responses (Experiment 1B), participants rated their belief in the action-outcome relationship on a scale of 0-100. Ratings were substantially lower than 75% when responding produced a delayed rather than immediate outcome (e.g., Reed, 1992; Shanks, 1989; Shanks, Pearson, & Dickinson, 1989).

Several studies have shown that a signal can ameliorate this delay-induced deficit in ratings of causal effectiveness (e.g., Reed, 1992; Shanks, 1989). Actions followed by a signalled outcome delay are rated as more effective than those followed by an unsignalled outcome delay. Reed (1992), using a free-operant schedule, found that the mean ratings of the causal effectiveness of pressing the space bar (to make a triangle appear) was 90% for when the outcomes immediately followed responses but

20% when a 5 s unsignalled delay occurred after the bar press response. However, when the 5 s delay was signalled by the presentation of a row of four “X”s (i.e., XXXX) presented 1 cm below where the triangle was due to appear on the computer screen, the causality rating increased to 50%. Again, in reality, 75% of the responses were programmed to produce the outcome. Together, these findings suggest that humans may find it difficult to judge if their behaviour causes an outcome when there is a delay between their behaviour and the outcome, but that this affect can usually be alleviated if a signal of some kind is presented during the delay. This is a striking parallel to the previously reviewed animal research (Chapter One). The conventional explanation for these effects is that the delay stimulus, because of its correlation with the outcome, acquires the properties of the outcome (i.e., second-order conditioning occurs). The delay stimulus can then mediate the association between the response and outcome thereby enhancing the judgment of causality (e.g., Reed, 1999).

If, however, the stimulus ‘marks’ the preceding response in memory, so that it can be more easily recalled when the outcome is finally presented, participants might be more likely to associate that response with the outcome, again increasing the perceived causality of the response. It still remains uncertain, however, how best to interpret stimulus effects in human causality judgment research, because these two explanations (conditioned reinforcement and marking) have never been directly compared.

2.7 RATIONALE FOR APPLIED RESEARCH ON MARKING

The animal literature has reliably shown that a marking cue can facilitate learning when reinforcement is delayed and that this effect cannot be explained by conditioned reinforcement (e.g., Lieberman et al., 1979; 1985, Lieberman & Thomas, 1986; Thomas et al., 1983, 1987,1990). Applied researchers, however, have only examined the conditioned reinforcement function of response-contingent cues (Section 1.2). For example, in clinical intervention using discrete-trial procedures, and in many other applied settings, cues such as tokens, photographs and praise are frequently established as conditioned reinforcers through pairing with a primary reinforcer and are commonly used to abolish the effects of inevitable delays to reinforcement (see Section 3.1 for a more detailed description of these procedures). The widespread use of such a powerful behavioural principle may, however, have subtly discouraged further investigation, even though more recent findings from the animal literature, many highly relevant to behavioral intervention (Stromer, McComas & Rehfeldt, 2000) are now available.

In the early 1980's, criticisms of this kind began to be voiced by those who were concerned about the way in which ABA was developing (e.g., Deitz, 1978; Epling & Pierce, 1983; Hayes, Rincover, & Solnick, 1980; Michael, 1980). Several analysts argued that ABA was applying only a small part of the conceptual knowledge produced by the experimental analysis of behaviour and would advance more rapidly if this were not the case (e.g., Deitz, 1978; Hayes, Ricover & Solnick, 1980; Epling & Pierce, 1983). Previously, in early applied research (e.g., Lovaas et al., 1965; Wolfe et al., 1965) the emphasis was placed on investigating the conceptual variables of which changes in socially important behaviour were a function. Effectiveness was of course socially important, but the analysis of behavioural principles and functional relationships was the purpose of the research. However, many behaviourists feel that the purpose of ABA gradually changed so that the procuring positive changes in dependent variables were considered more important. Azrin (1977) stated, "As applied psychologists, however, our guiding principle is outcome, or in more familiar language 'cure'" (Azrin, 1977, p. 141). He continued, "Thus outcome-oriented research strategy places the emphasis on the benefit resulting from treatment rather than on the conceptual variables." (Azrin, 1977, p.145). Thus, although there was no shortage of research reporting the apparent success of particular interventions, there was a shortage of more analytic work aimed at developing behaviour analysis in applied contexts (Remington, 1991). The idea that ABA had become increasingly separate from the experimental analysis of behaviour was also upheld by data reported by Hayes, Rincover and Solnick (1980) who analysed articles published in *The Journal of Applied Behavior Analysis* from 1968 through 1978.

It is possible that the lack of impact of basic research on applied research was because ABA analysts were relatively unfamiliar with the conceptual development in experimental analysis. Michael (1980) suggested that, unlike the founders of the field, most new applied behaviour analysts in recent decades were never experimental analysts and that they may have neglected the conceptual dimension of ABA because they were not well trained in basic laboratory research findings and procedures. Whatever the reason, it is clear that the lack of impact of basic research means that the tools of intervention in applied settings are many years behind developments in the basic field.

Research on delayed reinforcement provides one of the clearest and most immediate relevant examples of an area where, consideration, replication and extension of basic research with animals might benefit the applied area. It is not unreasonable to suppose that marking procedures might also be an effective way to facilitate learning in applied settings when reinforcement is delayed. For example, a different approach to improving performance in discrete trial training might be to draw a child's attention to every response, whether correct or incorrect. This may increase the likelihood that, during a long series of discrete trials, children will continue to attend to the act of choosing. Marking may generate a self-directed observing response that, by drawing attention to behavior just emitted, facilitates acquisition of the relation between correct responses and later reinforcement.

If marking can be demonstrated to be as effective as the traditional conditioned reinforcement procedure, it may provide teachers with an alternative or supplement to conditioned reinforcement that can also be used to improve their tutees' performance on a range of learning tasks, especially when primary reinforcement cannot be delivered immediately.

2.8 THE PRESENT THESIS

The present thesis aimed to investigate further whether marking has the potential to occur in humans when conditional discrimination procedures are employed. In doing so, the thesis used a paradigm more analogous to previous studies on marking which used instrumental discrimination learning procedures. Two parallel sets of studies were conducted, one using children with autism in an applied setting, the other adult humans in the laboratory. The chapters relevant to the applied work will be presented first, the laboratory studies second; however, this order of presentation is arbitrary. The first three experiments contained in this thesis, described in Chapters Three to Five, examine the effect of marking procedures on the learning of children with autism in an applied setting. The final experiments, described in Chapter Six, explore the generality of the marking effect to human participants in the laboratory.

3. EXPERIMENT ONE: EFFECTS OF CUE-VALUE AND RESSPONSE-MARKING PROCEDURES DURING DISCRETE-TRIAL TRAINING FOR CHILDREN WITH AUTISM[2]

The introduction that follows will serve as a general introduction to Experiments One to Three.

3.1 INTRODUCTION

The laboratory research reviewed in Chapter One is often justified in terms of its relevance to learning in applied settings where practical constraints frequently limit the immediacy with which behaviours can be reinforced. Indeed, in a recent manual of teaching techniques, Lovaas (2003) indicated that delaying reinforcement for only a few seconds during discrete-trial training for children with autism can impede learning, possibly because a behaviour other than the "correct" response is being strengthened. Consequently, basic research methods for studying the impact of response-contingent cues have been widely used in applied settings to design interventions that can be used when reinforcement is delayed. The most widely used interventions in applied settings are token economies (e.g., Kazdin & Bootzin, 1972), chain schedules (e.g., McClannahan & Krantz, 1999) and social reinforcement (e.g., LeBlanc and Ruggles, 1982). As mentioned previously, all presume the conditioned reinforcement function of response-contingent cues.

Token economies and chain schedules can facilitate acquisition of new operants for most people. Some individuals, however, lack the sensitivity to social reinforcement that may provide the basis for learning important skills like verbal behaviour (see Section 1.2). For example, Ferster (1961) suggested that much of children with autism's failure to acquire appropriate behaviour can be viewed as a failure of the environment to acquire motivational meaning for them because it contains few effective social reinforcers (see also Rimland, 1964). If social reinforcement plays such an important role in the development of effective verbal behaviour repertoires (finding ways to establish effective social reinforcers in children with autism is a matter of high priority.

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[2] A report of this experiment was published as:
Grindle, C, F., & Remington, B. (2002). Discrete-trial training for autistic children when reward is delayed: A comparison of conditioned cue value and response marking. *Journal of Applied Behavior Analysis, 32,* 187-190

In the 1960s some researchers tried unsuccessfully to establish effective social reinforcers for children with autism through classical conditioning procedures (Bernal, 1965; Lovaas et al., 1966; Lovaas, Schaeffer, & Simmons, 1965). Bernal (1965) for example, failed to establish a social stimulus as a reinforcer by pairing it with food delivery (e.g., saying "good" at the same time as giving a child a bite of food). Lovaas et al. (1966) similarly failed to establish the word "good" as a social reinforcer in two children with autism. They stated:

> We did pair, in several hundred trials, the word "good" with food delivery...Subsequent tests of "good" for secondary reinforcing properties were negative; there were no modifications in the child's behaviour when that behaviour was accompanied by "good". In fact, despite all these pairings, he behaved as if he had never heard the word; he did not attend to, or otherwise respond to our behaviour. (p. 111)

Lovaas et al. (1966) observed that the children did not orient (attend) to the neutral stimulus (see also Bernal, 1965; Maltzman & Raskin, 1965), and suggested that this was responsible for the ineffectiveness of classical conditioning. They also identified the suppression of self-stimulatory and aggressive behaviour as necessary for classical conditioning to occur. Subsequently they developed a procedure which first established the social stimulus as discriminative of food, before making use of its reinforcing properties (cf. Dinsmoor, 1950). In the first part of the experiment, participants were trained to walk across the room to the experimenter whenever they heard the word "good", only then were they given the edible reinforcer. Once the social stimulus was functioning as an S^D, reinforcement was delivered only intermittently in its presence. The second part of the experiment tested the social stimulus to see if it had acquired reinforcing properties. The results showed that, when a VI 4 mins schedule was employed, the social reinforcer was able to establish and maintain a simple bar pressing operant for the duration of the study. In fact, even after approximately 15,000 responses, the social reinforcer showed no signs of losing its effectiveness. Unfortunately, no follow-up study was conducted to see if the social reinforcer maintained its properties outside of the training context.

Although simply pairing social praise with primary reinforcement through classical conditioning procedures did not establish effective conditioned reinforcers in Lovaas et al's (1966) experiment, this conditioned value account is now routinely used in discrete-trial training with children with autism. For example, Lovaas (2003) stated:

> Always pair effective reinforcers [such as food] with social reinforcement. For example, smile and praise the student (e.g., by saying "Good!" or "Super!") each time you give him more desired reinforcers (e.g., food or leaving a stressful situation). By doing so you help the student learn to value social praise as a reward if he does not already do so. (p. 64)

Although many effective clinical practices have been based on early behavioural research on conditioned reinforcement, more recent findings on this topic, many highly relevant to behavioural intervention (Stromer, McComas, & Rehfeldt, 2000) are now available. Notably, a body of evidence has accrued to show that response-contingent cues can be functional in the acquisition of behaviour through processes other than that suggested by the cue-value account of conditioned reinforcement (Section 1.4). One idea, response marking (Chapter Two), has been shown to support accurate discrimination performance in animals, even when primary reinforcement is delayed (e.g., Lieberman, McIntosh, & Thomas, 1979). The critical difference between cue-value and response-marking procedures is that, in the former, a cue only follows to-be-reinforced responses whereas in the latter, the same cue follows both correct and incorrect responses: Any marking effect is therefore independent of cue value.

In a recent review, Williams (1994a) found strong evidence for the cue-value hypothesis but also indicated that there was substantial evidence to show that response-marking procedures are effective in at least some situations. He argued that the fundamental issue is not whether marking stimuli can affect behaviour, because it is clear that they do, but whether it is possible to identify the contribution of marking relative to that of cue value. In a subsequent study using a between-subjects design with rats as subjects, Williams (1994a) compared value and marking on the rate of acquisition of a simple operant task (lever pressing) with a 30 s delay to reinforcement (see Section 2.5). The critical issue was whether or not the response-contingent cue had to be paired with food in order to facilitate acquisition of the response. Compared to a no-cue control condition, both procedures supported learning and the initial superiority of the cue-value procedure had completely dissipated by the end of the tenth training session.

Evidence such as this suggests that response-marking procedures might facilitate learning in applied settings when primary reinforcers cannot be delivered immediately. The aim of Experiments One and Two was to compare cue-value and response-marking procedures (cf. Williams, 1994a) using a discrete-trial receptive labelling procedure with delayed reinforcement and children with autism as participants. Experiment One was intended as a preliminary examination of the usefulness of examining marking effects with this population. Experiment Two improved on Experiment One by using additional controls and better procedures. Experiment Three compared the standard marking procedure with a novel *marked-before procedure* in which all sample stimuli were marked before a matching response was made. The design considerations for these three experiments were fairly similar and will be described before detailing Experiment One.

3.2 DESIGN CONSIDERATIONS

3.2.1 RATIONALE FOR USING SINGLE-CASE DESIGNS

Two general experimental procedures can be adopted in treatment evaluation. The first involves *between-group* comparisons. In such experiments, individuals in one group are treated differently from those in another group (or groups), and obtained differences in the performance of the groups are attributed to their differential treatment.

The tradition of applied behaviour analysis, however, usually favours *single-case,* or within-participant designs, where individual differences rather than group comparisons are of major importance. These designs are characterized by repeated measures of the behaviour of a relatively small number of participants, in contrast to most between-group designs, where the behaviour of interest is usually measured only once in each of a large number of individuals. Also in contrast to most between-group designs, where individuals in a particular group are exposed to only one value of the independent variable, typical single-case designs expose every individual to all types of the independent variable. The disadvantages of using between-group designs in behaviour analysis have been discussed by several authors (e.g., Barlow, Hayes, & Nelson, 1984; Kazdin, 1982a). Briefly, the main issues are concerned with the practical and ethical problems of a group design approach, and the difficulties in averaging group data.

The first three studies in this thesis used a population of children with autism. Acquiring, and matching, a large number of children with autism, necessitated by the group design approach, would clearly have posed significant practical problems. Moreover, there is the problem of withholding treatment from a no-treatment control group. Although withholding treatment is a necessary requirement for both experimental approaches, participants in single-participant designs are denied treatment only on a short-term basis. Further, the risk of continuing a treatment that has a detrimental effect on the participant is more likely during group designs because, unlike single case designs which require measures to be taken continuously, they frequently only involve one measure at post-test. Single case designs allow the opportunity of changing the treatment mid-course (see Section 3.4.2), should this prove to be necessary.

There is also the possibility that individual responses to treatment may be obscured through the grouping of data which commonly occurs with between-participant designs. For example, when Bergin (1971), in a psychotherapy outcome study, compared group differences on a depression measure between a pre-therapy mean score and a post therapy mean score, he found a slight average improvement associated with the therapy under investigation. This overall positive change, however, concealed the fact that, although most clients improved, a significant minority actually deteriorated. Based on the above considerations the single-case alternating treatments design was used for the first three studies in this thesis.

3.2.2 THE ALTERNATING TREATMENTS DESIGN

The basic feature of an alternating treatments design (Barlow & Hayes, 1979) is the alternation of two or sometimes three different treatments or conditions with the same participant. Since the studies in this thesis involved either a comparison of two teaching procedures (Experiment One) or three teaching procedures (Experiments Two and Three), this design was considered the most appropriate to use. To ensure that the differences in outcome can be attributed to the different treatment conditions, any extraneous factors are counterbalanced across the training conditions. For example, in the present thesis an attempt was made to avoid sequencing effects by counterbalancing the daily order of the training conditions (e.g., ABC, CBA, BAC).

3.2.3 THE MULTIPLE PROBE CONTROL

Although the alternating treatments design is an effective way to compare two or three training procedures, it cannot exclude the possibility of some extraneous variables, like maturation effects or additional teaching experience, coinciding with the training phase and leading to the behaviour change. Consequently, multiple baseline controls were built into the alternating treatments design for the first three studies, to control for these possibilities.

During a multiple baseline across behaviours control (e.g., Baer & Guess, 1971; Clarke, Remington & Light, 1988), a series of probe trials are used to evaluate changes in a number of behaviours. First baseline measures are taken for all of the target behaviours. Next, the experimenter applies the treatment variable to one of the responses, until that response reaches a predetermined mastery criterion level. At this point, further probes are taken of both to-be-trained and the trained responses and the experimenter subsequently applies the same treatment variable to a second behaviour. This process is continued until the treatment variable has been applied to all of the target responses. This procedure helps to confirm that any changes in behaviour occur only after a treatment has been applied.

3.3 METHOD

3.3.1 PARTICIPANTS

Andrew, Claire, and Steven, three children with autism (respectively, 4, 5 and 8 years old), participated. All attended an ABA school and had thus previously received intervention based on discrete-trial training. All could understand and comply with simple requests in discrete-trial procedures, including pointing to some familiar objects when they were named (receptive labelling).

3.3.2 SETTING

All experimental sessions were conducted by the same teacher in a corner of the child's classroom. All children had frequently received one-to-one instruction in this setting prior to the study. The teaching location was equipped with a table and two small chairs. All sessions were video-recorded for later analysis.

3.3.3 MATERIALS

Training stimuli were 12 photographs of toys mounted on card and laminated. Each photograph was 12 cm x 10 cm and was taken against the same background and from the same angle. Photographs of toys were chosen by the children's regular class teacher because she wanted to expand their understanding in this area.

Two 1 s response-contingent compound audio-visual stimuli (green light/buzzer, and red light/high pitch tone), generated by two visually discriminable table-mounted displays, could be delivered using a foot pedal.

3.3.4 DESIGN

The present experiment involved three phases: pre-testing, training with interpolated probes, and post-tests. The pre-testing phase (a) ensured that the response-contingent cues to be used in the experiment did not function as reinforcers and (b) assessed receptive labelling performance. The training phase involved teaching receptive labelling. An alternating treatments design (Barlow & Hayes, 1979) allowed the effects of training receptive labels to be compared across the value and marking conditions. Each child participated in a daily morning and afternoon training session, each lasting 15 min and separated by a 4-hour interval, with treatments counterbalanced to control for order effects.

A multiple-probe design was also used in each condition. A block of probe trials (i.e., 4 trials each of both trained and to-be-trained labels) was conducted before teaching began and after each label had reached criterion. Thus, the training phase of the study consisted of an alternating treatments design, with a multiple probe control procedure built into each treatment condition. Post-tests of receptive labelling performance were conducted for each child after 1 month.

3.3.5 PROCEDURE

3.3.5.1 Phase 1: Pre-tests

Pre-testing response-contingent cues

The response-contingent cues to be used in the marking condition were a 1 s green light/ buzzer contingent on both the S+ (i.e., the correct response) and the S- (i.e., the incorrect response); in the value condition a red light/ high pitched tone was contingent on the S+ only. Two pre-tests, conducted in the same setting as training, were used to assess whether these compound stimuli had sensory reinforcing properties prior to the training phase of the study. In each pre-test, participants were offered a pair of toys that differed only in colour (e.g., a red and a blue car). When the child chose the toy pre-designated for reinforcement (e.g., the red car), the test stimulus was delivered. A clear preference over 10 trials for the toy associated with the stimulus indicated a sensory reinforcement effect. None of the children showed such a preference, indicating that the response-contingent cues initially functioned as neutral stimuli.

Pre-testing receptive labelling performance

Children were tested on their receptive labelling skills by requiring them to select from an array of three photo-cards of familiar everyday objects suggested by the class teacher. Performance on this test was satisfactory for all children, allowing identical tests to be carried out on photographs of toys believed to be unknown to the children. For each child, this pre-test identified 12 photographs of toys as targets for teaching on the basis that they were not identified accurately on more than one of four test trials. Six of the 12 photo-cards so identified were then randomly assigned to either training condition. During pre-test trials, the teacher neither modelled nor prompted correct responses. To maintain compliance and interest in the task, established reinforcers such as physical contact (e.g., tickles, physical games) and social praise were delivered between trials independent of correct performance using a VR3 schedule.

3.3.5.2 Phase 2: Training with interpolated probes

Identifying primary reinforcers

Before teaching begun, a brief questionnaire was given to each child's class teacher and parents asking them to list up to 7 edible items that the child enjoyed, and up to 7 toys or sensory items that the child liked to play with. On the basis of this information, a few items were selected for each child and were consequently used as reinforcers throughout the teaching sessions.

Overview of training

An alternating treatments design was used to compare the effects of the marking and value conditions on the speed of learning the receptive labels. A different set of six items was trained in each condition. The comparison required that each child participated in two sessions, held at the same time each day, each lasting approximately 15 min, separated by at least 4 hours. Conditions were counterbalanced across sessions to control for order effects. Each session contained either a block of approximately 40 training trials or a block of 24 probe trials *and* a block of approximately 20 training trials.

Participants were trained to label the photographs using the following procedure. Three pictures of objects were placed on the table in front of the child. Training trials for each receptive label were initiated by the teacher saying, "Touch [pictured object]". A correct response was defined as the child touching the correct photograph within 3 s of the start of a trial. If the child was incorrect for two consecutive trials, he was prompted using a least-to-most hierarchy of prompts (positional, pointing, hand over hand). These prompts were withdrawn as soon as possible. In both treatment conditions, prompted responses were always immediately reinforced with established reinforcers like physical contact or with social praise. All unprompted correct responses were reinforced only after a 5 s delay with items chosen semi-randomly from the pre-determined selection. Following incorrect responses, no reinforcement was delivered and the trial was repeated after 5 s. A mastery criterion of ten consecutive correct unprompted responses was used throughout training.

Although there was a 5 s delay to reinforcement for unprompted correct responses for *both* treatment conditions, the response-contingent stimulus procedure differed between conditions. In the cue-value condition, the 1 s compound red light/tone stimulus was presented twice following each correct response, once immediately and after the 5 s delay (i.e., contiguously with food reinforcement). In the response-marking condition, the 1 s compound green light/buzzer stimulus was presented immediately after both correct and incorrect responses but not after the 5 s delay (i.e., not contiguously with food reinforcement on correct trials). In both conditions, incorrect trials were repeated.

Teaching routine

Regardless of treatment condition, the receptive labelling teaching procedure was based on the following routine. Each child was initially taught to identify only one photograph. At first, the teacher manually prompted the child to select the S+ (i.e., the correct card) from the array of three, although these prompts were faded as soon as possible. Training continued until the child selected the S+ correctly for two consecutive trials when the positions of the cards remained constant. At this point, S+ position and comparison S- cards were randomized between trials until the ten-trial mastery criterion was reached.

Next, the second label was taught using the same procedures. When this had been learned to criterion, the second label was interspersed with the previously mastered item. The choice of label and the position of S+ and S- photographs were rotated randomly between trials. From this stage on the 10-trial mastery criterion included both new and previously trained words. Next, the child was taught to match a third label, first in isolation and then intermixed with previously trained items, in a ratio of two to one.

The remaining three to-be-taught labels were introduced in the same way, each label being intermixed with previously mastered items in a ratio of two to one.

Interpolated probes

The probe trials were carried out in the same location as the training. For each condition, a baseline block of 24 trials (four probe trials for all six target labels) was conducted prior to training. Similarly, and after each target label reached criterion in both treatment conditions, a block of 24 probe trials for that condition was conducted. During these trials a procedure similar to the pre-testing matching-to-sample phase was used (i.e., the teacher neither modelled nor prompted the correct response and physical reinforcers or social praise were delivered non-contingently between trials on a VR3 schedule). No response-contingent cues followed correct or incorrect responses.

3.3.5.3 Post-test

To establish whether the labels trained were retained in the absence of further specific teaching input, two follow-up test sessions were conducted approximately 1 month after the end of training. Eight trials were conducted for each label in both conditions. The testing procedure used was identical to that used in the probe trial blocks.

3.3.5.4 Reliability

Reliability scores were acquired by having an independent observer separately rate 25% of videotaped sessions for response reliability (agreement that a response was correct or incorrect) and consequence reliability (agreement that response-contingent stimuli were delivered appropriately).

3.4 RESULTS

3.4.1 RELIABILITY

Inter-observer agreement was calculated by using Cohen's Kappa statistic. There was 100% agreement for responses ($K = 1.00, p < .005$) and a high level of agreement for consequences ($K = .84, p < .005$).

3.4.2 RATE OF ACQUISITION

The analysis revealed an advantage for the cue-value condition. Figure 4-1 shows that all three children acquired the first three receptive labels trained in the cue-value condition faster than in the response-marking condition. The total trials to criterion in the value and marking conditions respectively were: Andrew: 72, 314; Steven: 109, 253; Claire: 72, 123. Given the strength of this effect, the procedure was modified so that the last three labels assigned to the response-marking condition were taught using the value procedure. Figure 3-1 shows that, under the revised procedure, total trials to criterion for two of the children were similar (Andrew: 118, 101; Steven: 114, 88 in the unchanged and revised conditions, respectively). Claire did not learn the final two labels because an illness prevented her from attending school.

Figure 3-2 shows, for each child, the total trials to criterion across all labels trained, thus indicating children's overall performance on the learning task. Data on the left-hand side of each panel relate to labels 1-3 for marking and value treatment conditions; data on the right-hand side relate either to labels 3-6 for the marking condition taught using value procedures or to labels 3-6 for the value condition. For Claire, the marking switched to value bar represents trials to criterion for one label only; in the value condition, however, the bar represents three labels taught.

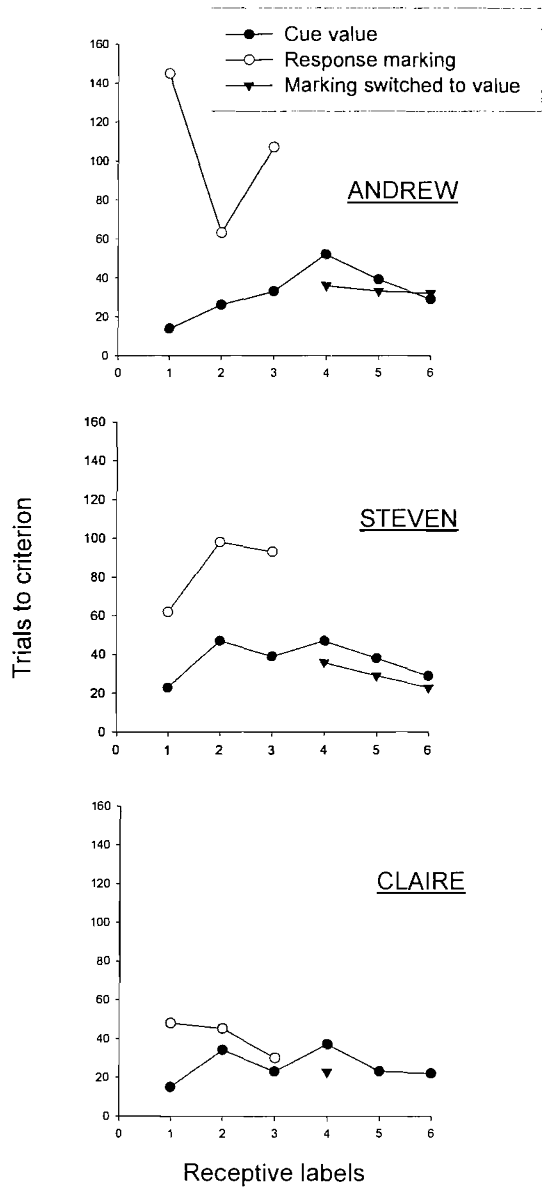

Figure 3-1. **Total number of training trials (ordinate) to learn each receptive label (abscissa) during the two conditions (lines) of the alternating treatments design (Experiment One). The last three labels assigned to the response-marking condition were taught using the value procedure.**

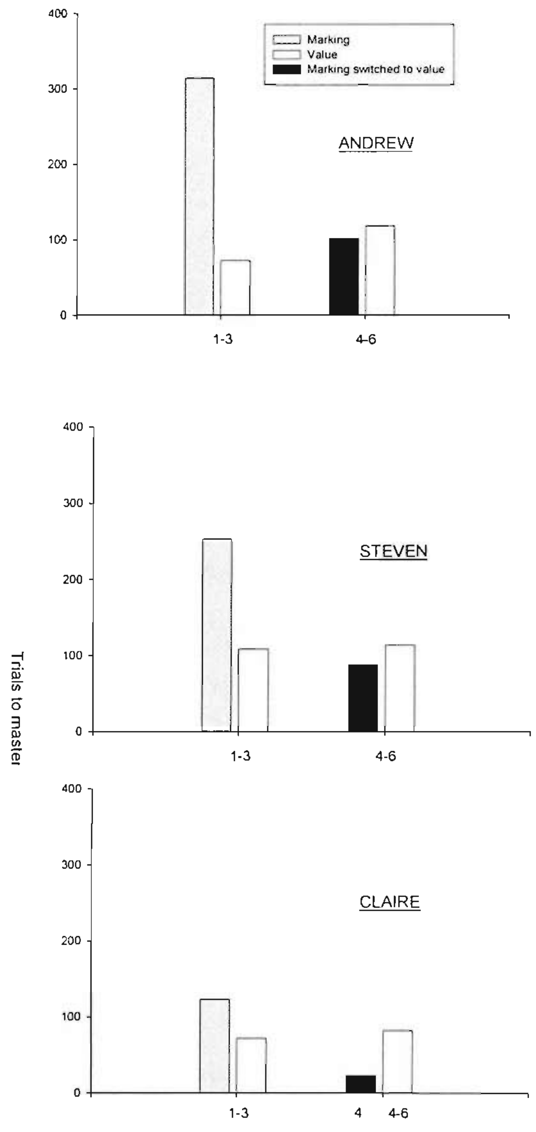

Figure 3-2. **Total number of trials to mastery for each participant (Experiment One). Data on the left hand side of each panel relate to labels 1-3 for both treatment conditions; data on the right hand side relate either to labels 3-6 for the marking condition taught using value procedures or to labels 3-6 for the value condition. For Claire, the marking switched to value bar represents trials to criterion for one label only.**

For the first three labels all children required more trials to reach criterion in the marking condition than in the value condition (Andrew: 314 vs. 72; Steven: 253 vs. 109; Claire: 123 vs. 72, respectively). When the last three labels assigned to the marking

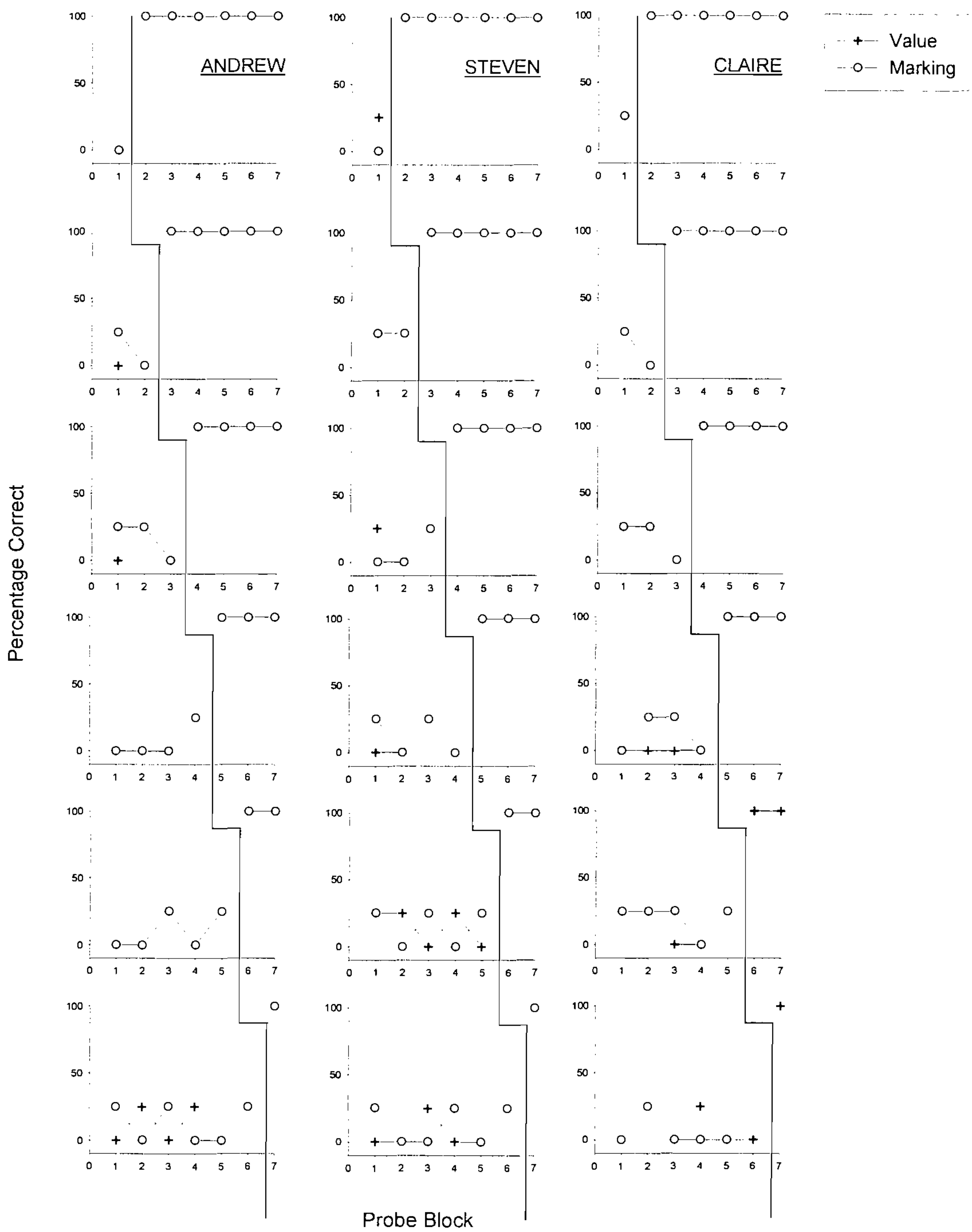

Figure 3-3. **Percentage scores for each receptive label, obtained during probe blocks (1-6) in Experiment One. In each condition (lines), percentage of correct responding (ordinate) are plotted against probe blocks (abscissa). Percentages before and after training are shown, respectively, to the left and right of the staggered line.**

condition were taught using value procedures, trials to criterion were similar to those taught in the value condition (Andrew: 101 vs. 118; Steven: 88 vs. 114; Claire: 123 vs. 72, respectively). This total score could not be calculated for Claire because of missing data.

3.4.3 MULTIPLE-PROBE DATA

Figure 3-3 shows the results of the multiple probe control procedures for each child under the two conditions. Percentages of correct responding after training are to the right of the staggered line. For all children, acquisition was as a function of the specific training procedure used in each condition rather than the result of any extraneous factors such as additional classroom experience. For every label in both conditions, correct responding was at chance level before training but 100% correct after training.

3.4.4 POST-TEST DATA

The percentage data from the maintenance test conducted 1 month after the end of training revealed a high level of retention of receptive labels for all participants. The percentage of correct responses at post-test was similar in the value and marking conditions, respectively: Andrew: 88, 83; Steven: 77, 88; Claire: 90, 83.

3.5 DISCUSSION

The aim of Experiment One was to use a discrete-trial training task with children with autism to compare the effectiveness of cue-value and response-marking procedures in bridging a 5 s delay to reinforcement. There is evidence from the animal literature that both types of procedures can effectively bridge such delays (Williams, 1994a), but no studies to date have assessed the effectiveness of response marking with human participants in an applied setting.

Taken together, the data show that learning was faster in the cue-value condition than when response marking was used, thus extending Williams' (1994a) finding from animal to human participants. Clearly, however, response marking still supported acquisition, albeit less efficiently. For Claire, in particular, the difference between conditions was modest, suggesting that refinements of the response-marking procedure might have important practical applications.

It is important to note some differences between laboratory-based marking research and this experiment. Basic research has generally used either lights or noises as markers (e.g., Lieberman et al., 1979; Thomas et al., 1983; Williams, 1994a). In the present study, however, compound audio-visual stimuli (green light/ buzzer) were used. This was considered necessary to increase the likelihood that the children with autism, who have renowned deficits in attending skills (e.g., Burack, 1994; Noterdaeme, Amorosa, Hildenberger, Sitter, & Minow, 2001; Wainwrightsharp & Bryson, 1993) would orient towards the stimuli. One drawback with using such non-verbal stimuli is that they lack social validity. Such cues would not be found in an everyday setting.

Most basic research on marking has also used a control condition in which delay-of-reinforcement occurs but no response-contingent stimulus is presented. Because there was no control condition in the present study, it was unclear whether marking had a more powerful effect on learning than delayed reinforcement alone. A delay condition was not included in the present study for two main reasons. First, the present study was designed as an exploratory study to assess the feasibility of exploring the concept of marking in an applied setting. It was not intended to be comprehensive and, in fact, the apparent effectiveness of the marking cues was somewhat surprising. Second, there are substantial practical problems associated with running an alternating treatments design with three conditions. For example, it is usually recommended that treatment conditions are separated by at least two hours (McGonigle, Rojahn, Dixon, & Strain, 1987) to reduce the degree to which one treatment condition influences behaviour under an alternating and different treatment. The three participants in this study were all taught in separate classrooms in the school so the video recorder had to be set up before each individual teaching session. Making this transition nine times a day with at least a two hour interval between each child's teaching sessions would have been difficult. A three-treatment design was, however, justifiable on the basis of these preliminary results. Thus, future procedural comparisons could be further refined by including an additional control condition in which no response-contingent cues are delivered at the start of the delay period, which terminates in primary reinforcement.

This preliminary study can be improved upon in a number of other ways. One concern is that the cues used as markers were not *socially valid* and consequently not of much applied use. They were based on the compound audiovisual markers used in the Williams (1994a) study and consequently did not lend themselves to present day child treatment protocols. Thus, a future investigation could aim to consider more socially valid forms of value ("Good!") and marking ("Look!").

A related problem is to do with the salience of the stimuli used as markers. It has been proposed that marking is most likely to occur when the marking stimulus is substantially more salient than the target response (See Section 2.4.4). It is possible that the failure to achieve strong marking effects in Experiment One was because the stimuli serving as signals were not salient enough. The experiments were carried out in the corner of a classroom, consequently other stimuli that occurred during learning trials (e.g., stimuli associated with other children in the class) may at times have been subjectively much more salient to the participants than the lights and noises presented as markers. Salience may also have been affected because the stimuli serving as markers were used for a long series of conditions. Thus, even though they may have been highly salient signals at the start of the experiment, many sessions of presentation may have produced substantial habituation to the point where they were no longer functionally salient events (cf. Williams, 1991, Section 2.5).

Another potential weakness of Experiment One was possible treatment carry over effects - "the influence of one treatment on an adjacent treatment, irrespective of overall sequencing" (Barlow & Hersen, 1984, p.257). This raises the important question of whether or not the effects observed under any one of the alternated treatments would be the same if each treatment was administered in isolation. A number of precautions were taken in Experiment One to reduce the possibility of carry-over effects. For example, the order of treatments were counterbalanced so that the interventions followed one another in an unpredictable fashion, only one treatment condition was presented in each session, the length of the intercomponent interval separating the two conditions was always at least 4 hours and finally, the experimental comparison was followed by the application of only the most effective treatment. This made it possible to assess the effects of that treatment when administered in isolation.

Despite these precautions, however, it was still possible that, because the compound stimuli in both conditions were from the same sensory modality, there was some confusion about the role of the stimuli. This could result in transfer of value and the strengthening of incorrect as well as correct responses. This interference effect due to conditioned reinforcement of incorrect responses would obscure (overshadow) the facilitation that marking might otherwise have had.

Another potential limitation of Experiment One was that no controls were in place for any variables that may have influenced the effectiveness of primary reinforcement. One of the clearest examples of a variable that may influence the effectiveness of reinforcement is the continuum from deprivation to satiation with respect to a given stimulus. These motivational variables have been termed *establishing operations* by Michael (1982, 1993) and can determine whether or not certain stimuli are effective as reinforcers.

An example of the effects of establishing operations on the behaviour of developmentally disabled adults was described by Vollmer and Iwata (1991) who examined how satiation and deprivation conditions may influence the effectiveness of edible, social and sensory (music) reinforcers. Results demonstrated that each of these classes of reinforcers functioned as reinforcers with different degrees of effectiveness during satiation versus deprivation conditions. Thus a deprivation condition period of edible reinforcers seemed to increase the reinforcing effects of food, whereas a brief period of pre-session exposure to food reduced the efficacy of food as a reinforcer.

These results have many implications for Experiment One. First, teachers only identified three reinforcers to be used with each child (out of a possible seven), so consequently the same three reinforcers were used for each child throughout the experiment and, second, the teachers in the school allowed the child to have access to these reinforcers outside of the experimental training session. The conceptual analysis of establishing operations suggests that the efficacy of the reinforcer would occasionally decrease, owing to satiation with that reinforcer. Third, even though the order of the conditions was counterbalanced the timing of the sessions was not. For example, one participant always had a training session immediately before lunch and another participant the session immediately after lunch. Presumably the edible reinforcers were more effective just before lunch, owing to naturally occurring food deprivation. Conversely the reinforcers delivered after lunch may have been less effective.

Another concern relates to the children who were used as participants. All participants in study one attended an ABA school and had already received intervention based on discrete-trial training. The cue-value condition had a number of similarities to the procedures routinely used in discrete-trial training (e.g., different outcomes being allocated for S- and S+). Thus, one explanation for the superiority of the value condition is that, because participants were already familiar with discrete-trial training using matching-to-sample, it was conceivable that the response-marking procedure may, through its unfamiliarity, have had a negative effect on learning. To ensure that children are equally unfamiliar with the two treatment conditions, only participants with no experience of a discrete-trial intervention program would need to be selected.

In conclusion, these results support a principle recommended by many authors (e.g., Epling & Pierce, 1983; Mace & Wacker, 1994; Remington, 1991, see Section 2.7), namely that there are benefits to be obtained from applying principles derived from basic research to work in applied settings. That is, one way of seeing this experiment is as a 'bridge' study, one that has examined how effectively procedures identified in basic laboratory research with animals can be used in applied settings. Applied research to date has considered that response-contingent cues occurring during a delay to reinforcement function only as conditioned reinforcers and this interpretation is routinely incorporated into accounts of discrete-trial training (Lovaas, 2003). However, this 'bridge' study supports Williams' (1994a) animal research showing that cue value is superior to response marking but that both procedures led to learning. The same effects were shown in children with autism in an applied setting. The results are promising and seem worthy of further investigation using additional controls and better procedures.

4. EXPERIMENT TWO: COMPARING CUE VALUE AND RESPONSE MARKING: A SOCIALLY VALID PROCEDURE[3]

4.1 INTRODUCTION

In Experiment One, an alternating treatments design was used to compare cue value and response marking in the context of a discrete-trial receptive labelling procedure with three children with autism. Using a methodology similar to Williams (1994a), but based on matching-to-sample training rather than a simple operant task, children with autism were taught to point to pictures of teacher-named objects. Correct responding was reinforced after a 5 s delay. In the cue-value condition, a compound audiovisual stimulus was presented after correct but *not* incorrect responses *and* again when a primary reinforcer was delivered. By contrast, in the response-marking condition, a second audiovisual stimulus was presented after both correct *and* incorrect responses, but *not* at the end of the delay. Like Williams (1994a), the results showed that although the cue-value procedure was more efficient, response marking still appeared to support acquisition. For one participant in particular, the difference between conditions was modest, suggesting that refinements of the marking procedure might have important practical implications.

Experiment One was an encouraging bridge study, which successfully applied two procedures adapted from the animal literature into discrete-trial instruction for three children diagnosed with autism. The experiment, however, was not as methodologically rigorous as it could have been, for a number of reasons. Because there was no control condition in which delay of reinforcement occurred but no response-contingent audiovisual stimulus was presented, it was unclear whether marking had a more powerful effect on learning than delayed reinforcement alone. In addition, it might be argued that the stimuli used as response-contingent cues were not socially valid. Finally, because participants were already familiar with discrete-trial training using matching-to-sample, it was conceivable that the response-marking procedure may, through its unfamiliarity, have had a negative effect on learning.

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[3] A journal article describing this experiment was published as:
Grindle, C. F., & Remington, B. (2004). Teaching children with autism using conditioned cue-value and response-marking procedures: a socially valid procedure. *Research in Developmental Disabilities*, 25, 413-429.

The purpose of Experiment Two was thus to address the above concerns and extend the previous literature using another matching-to-sample teaching task and making the following procedural modifications. First, to establish whether marking had an effect over delayed reinforcement alone, a control condition was included in which primary reinforcement was delivered after a 5 s delay period but no response-contingent cues were used. A 5 s delay-of-reinforcement was chosen to reflect the kind of delays that typically occur during discrete-trial teaching in applied settings.

Second, rate of learning in this delay condition was compared with learning when more socially valid response-contingent cues were used. Cues were chosen which were believed to be more relevant to daily teaching procedures and more similar to responses that teachers use routinely. In the response-marking condition, the social behaviour of the teacher (such as saying "look!" while pointing to the chosen item) effectively drew the child's attention to what they had just done; in the cue-value condition an expression of approval (such as "good!") drew the child's attention to what they were going to get (i.e., the cue indicated that a reward was on its way). Thus, the critical variable was the social behaviour of the teacher that occurred in the delay-to-reinforcement interval. This is a fair comparison given the role of praise in discrete-trial teaching.

To increase the salience of stimuli used as markers, training was conducted on a 1:1 basis in a distraction-free room or a quiet corridor at the children's school, rather than in a corner of a classroom. This increased the likelihood that any other stimuli occurring during learning trials were much less salient than the stimuli used as markers. In addition, there were frequent interchanges of signals in both conditions so that the possibility of habituation effects might be reduced if not eliminated.

So that participants could more easily discriminate which intervention was in effect and the possibility of treatment carry-over effects would be further reduced, response-contingent cues were chosen that could more easily be distinguished from each other. The experimenter used different verbal cues in each condition, and comparisons were indicated on every trial in the marking condition by the experimenter pointing to the chosen stimulus.

Several procedures were followed to control for any deprivation conditions that may have reduced the effectiveness of the reinforcers used in Experiment One. First, the order of sessions were further randomized so that all participants had an equal chance of being under deprivation (e.g., before lunch) or satiation (e.g., after lunch) conditions.

Second, participants did not have access to the reinforcers used in the experimental training sessions outside of these times. Finally, four different types of backup reinforcers were identified at the beginning of each experimental day to be used during that days training sessions, using a multiple stimulus preference assessment procedure (e.g., Higbee, Carr, & Harrison, 2000; see Section 4.2.5.2). Because new reinforcers were identified and used every day, deprivation effects should have been less likely.

Finally, to ensure children were equally familiar with response-marking and cue-value teaching procedures, only participants with no experience of an intervention program involving discrete-trial training were selected.

4.2 METHOD

4.2.1 DESIGN

Like Experiment One, the experiment involved three phases: pre-testing, training with interpolated probes, and post-tests. The pre-testing phase (a) ensured that the response-contingent cues to be used in the experiment did not function as reinforcers and (b) assessed whether children could match to-be-trained target words to corresponding pictures. The training phase involved teaching word-picture matching. An alternating treatments design (Barlow & Hayes, 1979) allowed the effects of training the word-to-picture task to be compared across the three teaching treatments (marking, value, and delay). As each word was trained to criterion in each condition, a block of probe trials was conducted for both trained and to-be-trained items used in that condition. Thus, the training phase of the study consisted of an alternating treatments design, with a multiple probe control procedure built into each treatment condition. Post-tests of picture-word matching performance were conducted for each child after 1 month.

4.2.2 PARTICIPANTS

Each of the five children with autism who participated in this study had generalized motor imitation and generalized identity-matching skills. All were 'table-ready' (sat willingly at a table for short periods of time) but none had previously received discrete-trial training.

Two children (Dave and Jake) attended a school for children with severe learning disabilities and three (Luke, Robby and Teddy) attended an autistic unit attached to a mainstream school. Dave (aged 9 years and 9 months) was able to understand and comply with simple one-step instructions, was capable of some self-initiated speech, mostly limited to two-to three-word utterances, and showed no comprehension of abstract concepts (e.g., colours, shapes, or prepositions). Jake (aged 10 years and 7 months) was not able to follow spoken instructions, had no intelligible speech, and also showed no understanding of abstract concepts. Luke (aged 5 years 11 months) could follow two-step instructions and typically communicated using four-to six-word utterances. Luke could also comprehend and tact about 20 actions and some colours and shapes. Robby (aged 7 years 2 months) typically communicated using seven-to eight-word sentences and was able to follow three-step directions. Robby could comprehend and tact about 40 actions and some colours and shapes. Teddy (aged 6 years 11 months) could understand a few one-step instructions but his spontaneous communication was limited to two-or three-word utterances. He could point to pictures of actions, colours, and shapes when these concepts were named but could not tact them.

The mental a ge equivalent score for all of the participants was calculated from The British Picture Vocabulary Scale (Dunn, Dunn, Whetton, & Burley, 1997). Dave, Jake, Luke and Teddy all obtained scores of 2 years and 4 months. Robby obtained a score of 4 years and 0 months.

4.2.3 SETTINGS

All sessions were conducted by the same teacher in either a small distraction-free room (Dave and Jake) or in a quiet corridor at the school (Luke, Robby and Teddy). Both teaching locations were equipped with a table and two small chairs. All participants had received one-to-one instruction in these settings prior to this study. All sessions were video-recorded for later analysis.

4.2.4 MATERIALS

Training stimuli were photographs of objects and printed words denoting the objects mounted on card (15 cm x 10 cm). Photographs were taken from the same angle and against the same background. The corresponding words were printed in 72-point lower case letters (Comic Sans MS font). Using a method based on Eikeseth and Jahr (2001), words within each condition were chosen so that there were few formal similarities between them (e.g., they neither began nor ended with the same letter).

A range of back-up reinforcers, including edible items, toys, and novelties, were selected for each child based on class teacher opinion of preferred and non-preferred items.

Pairs of toys that, apart from colour, were identical in every way were used to assess the potentially reinforcing properties of verbal stimuli to be used in the marking and value conditions.

4.2.5 PROCEDURE

4.2.5.1 Phase 1: Pre-tests

Pre-testing response-contingent cues

The response-contingent cues to be used in the marking condition were the experimenter pointing to a choice response and saying either, "*Look!*" "*See!*" or "*Here*!" In the value condition, the cues were to be the experimenter saying, "*Good!*" "*Well done!*" or "*That's right!*" contingent on a correct response. Pre-tests, conducted in the same setting as training, were used to assess whether any of these six cues functioned as reinforcers prior to the training phase of the study. In each pre-test, participants were offered a pair of toys that differed only in colour (e.g., a red and a blue car). When the child chose the toy pre-designated for reinforcement (e.g., the red car), a verbal cue was delivered. A clear preference over 10 trials for the toy associated with the cue indicated that the latter functioned as a reinforcer. None of the children showed such a preference prior to training, indicating that for them all six verbal cues initially functioned as neutral stimuli.

Pre-testing matching-to-sample performance

A matching-to-sample pre-test procedure was used to identify 15 'unknown' target words and corresponding pictures as targets for training. During pre-test trials, conducted in the same setting as training, the teacher neither modelled nor prompted the correct response. Items were rejected for subsequent training if a child produced a correct match on more than one of four trials. To maintain compliance and interest in the task, established reinforcers such as physical contact (e.g., tickles, physical games) were delivered between trials independent of correct performance using a VR3 schedule.

4.2.5.2 Phase 2: Training with interpolated probes

Identifying primary reinforcers

At the beginning of each experimental day all participants took part in a stimulus preference assessment to identify four back-up reinforcers for use during that day's training sessions. A multiple-stimulus presentation without replacement procedure (e.g., Deleon & Iwata, 1996; Higbee, Carr, & Harrison, 1999; Higbee, Carr, & Harrison, 2000) was used. An array of seven novel items per participant was chosen for presentation during each assessment. To ensure that children were familiar with them, they were given samples of each and allowed to eat the edible items and play with the toys for 20 s. Although all reinforcers were novel items, they were still based on class teacher opinion of the child's preferences. Thus, if the teacher said that the child liked playing with trains, a new toy train, which had not been seen before, was presented.

During an assessment, the experimenter verbally prompted the children to select an item from the array, recorded a selection when the participant touched one of the items within 5 s, removed the chosen item, and then rotated the positions of the remaining items prior to the next trial. This assessment continued until four of the seven original items had been selected.

Overview of training

The training procedure included an alternating treatments design to compare the effects of the three experimental conditions (value, marking and delay) on the speed of learning to match target words to corresponding pictures. A different set of five items was trained in each condition. The comparison required that each child participated in three sessions, held at the same time each day, each lasting approximately 15 min, separated by at least an hour and a half. Conditions were counterbalanced across sessions to control for order effects. Each session contained either a block of approximately 40 training trials or a block of 20 probe trials *and* a block of approximately 20 training trials.

Participants were t rained to match word card samples to corresponding comparison pictures of objects using the "reading" procedure described by Eikeseth and Jahr (2001). Up to three pictures of objects were placed on the table in front of the child. The teacher then showed a printed word card and instructed, "Read." A correct response was defined as the child selecting a picture comparison by placing the word card sample on top of or next to it within 3 s of the start of a trial. In all treatment conditions, prompted responses were always immediately reinforced with established reinforcers like physical contact. All unprompted correct responses were reinforced only after a 5 s delay with items selected semi-randomly on a trial by trial basis from the pre-identified set of four. Following incorrect responses, no reinforcement was delivered and the trial was repeated after 5 s. If the child was incorrect for two consecutive trials, he was prompted using a least-to-most hierarchy of prompts (positional, pointing, hand over hand). These prompts were withdrawn as soon as possible a mastery criterion of ten consecutive correct unprompted responses was used throughout training.

Although there was a 5 s delay to reinforcement for unprompted correct responses for *all* treatment conditions, there were marked procedural differences across conditions in terms of the cues that were *immediately* contingent on unprompted responding. In the delay condition, no cue was delivered during the delay interval. In the value condition, the teacher presented a verbal phrase of approval (e.g., "good!") immediately after each correct response and again as the primary reinforcer was delivered after the 5 s delay. In the response-marking condition, the teacher presented a mand (saying "look" while pointing to the chosen item) after both correct *and* incorrect responses, but not at the end of the 5 s delay (i.e. *not* contiguous with the primary reinforcer on correct trials).

Teaching routine

Regardless of treatment condition, the match to sample teaching procedure was based on the following routine. Each child was initially taught to match only one comparison to its corresponding sample. The teacher initiated a trial by placing the word card sample and two picture card comparisons (S+ and S-) in front of the child, saying, "Read", and prompting the child (by pointing) to select the S+ (i.e., the correct picture). Training continued until the child selected the S+ correctly for two consecutive trials when the positions of the cards remained constant. At this point, a between-trial random rotation of the position of the S+ and S-cards was initiated until the ten-trial mastery criterion was reached. Next, the second sample-comparison pair was taught using the same procedures. When this had been learned to criterion, the child was switched to a matching-to-sample procedure with the previously trained word-picture combinations. The choice of sample and the position of S+ and S-comparison cards were rotated randomly between trials. From this stage on the 10-trial mastery criterion included both new and previously trained words. Next, the child was taught to match a third word to its corresponding picture, first in isolation and then intermixed with previously trained combinations, in a ratio of two to one. The remaining two to-be-taught words were introduced in the same way, each word being intermixed with previously mastered items in a ratio of two to one.

Interpolated probes

The probe trials were carried out in the same room as the training. For each condition, a baseline block of 20 trials (four probe trials for all five target words) was conducted prior to training. Similarly, and after each target word reached criterion in any of the treatment conditions, a block of 20 probe trials for that condition was conducted. During these trials a procedure similar to the pre-testing matching-to-sample phase was used (i.e., the teacher neither modelled nor prompted the correct response and physical reinforcers were delivered non-contingently between trials on a VR3 schedule). No response-contingent events followed correct or incorrect responses.

4.2.5.3 Post-test

To establish whether the words trained were retained in the absence of further specific teaching input, two follow-up test sessions were conducted approximately 1 month after the end of training. Eight trials were conducted for each word-picture combination in all of the conditions. The testing procedure used was identical to that used in the probe trial blocks.

4.2.5.4 Data collection and reliability

The numbers of correct and incorrect responses were recorded during all training, testing and probe sessions for all participants. In training sessions, the number of prompts was also recorded. To assess interobserver agreement, two observers scored 25% of the videotaped sessions for each child. Agreement was calculated for response reliability (agreement that a response was correct or incorrect) and consequence reliability (agreement that response-contingent cues were delivered accurately).

Because it was possible that the experimenter's tone of voice differed after delivering the marking cue after correct and incorrect responses, the nominally identical marking cues may have functioned differently. A test of inadvertent experimenter bias was therefore conducted. For four participants (Luke, Dave, Jake and Teddy), two 20-

item cue samples were drawn from the correct and incorrect trials (the first ten and the last ten in each case) and transferred to audiotape. Twenty pairs of cues were created by randomly sampling without replacement from these two groups of samples. Two observers were required to guess, for each pair, the verbal cue that had followed a correct response. For Robbie, the test was not conducted because he was incorrect for only three trials in total.

4.3 RESULTS

4.3.1 RELIABILITY

Inter-observer agreement was calculated by using Cohen's statistic. There was 100% agreement for responses ($K = 1, p < .005$) and a high level of agreement for consequences ($K = .94, p < .005$). 45% of verbal cues were correctly identified as following a correct response. A two-tailed binomial test was conducted to assess whether the observed proportion of .45 differed significantly from a hypothesized value of .5. The difference was not significant ($p = .37$).

4.3.2 RATE OF ACQUISITION

Figure 4-1 shows the number of training trials required for each child to meet criterion in each treatment condition. Both marking and value conditions produced more rapid acquisition than the delay condition. Overlapping data points for the marking and value conditions indicate that the total numbers of trials needed for the words in these conditions to reach criterion were very similar for all of the participants tested.

Luke and Robby acquired the first three words trained in the delay condition after 245 and 98 trials, in 6 and 3 sessions, respectively. Because Dave, Jake, and Teddy acquired these words only after 616, 502 and 454 trials, in 16, 13 and 11 sessions, respectively, their training in the delay condition was discontinued at this point.

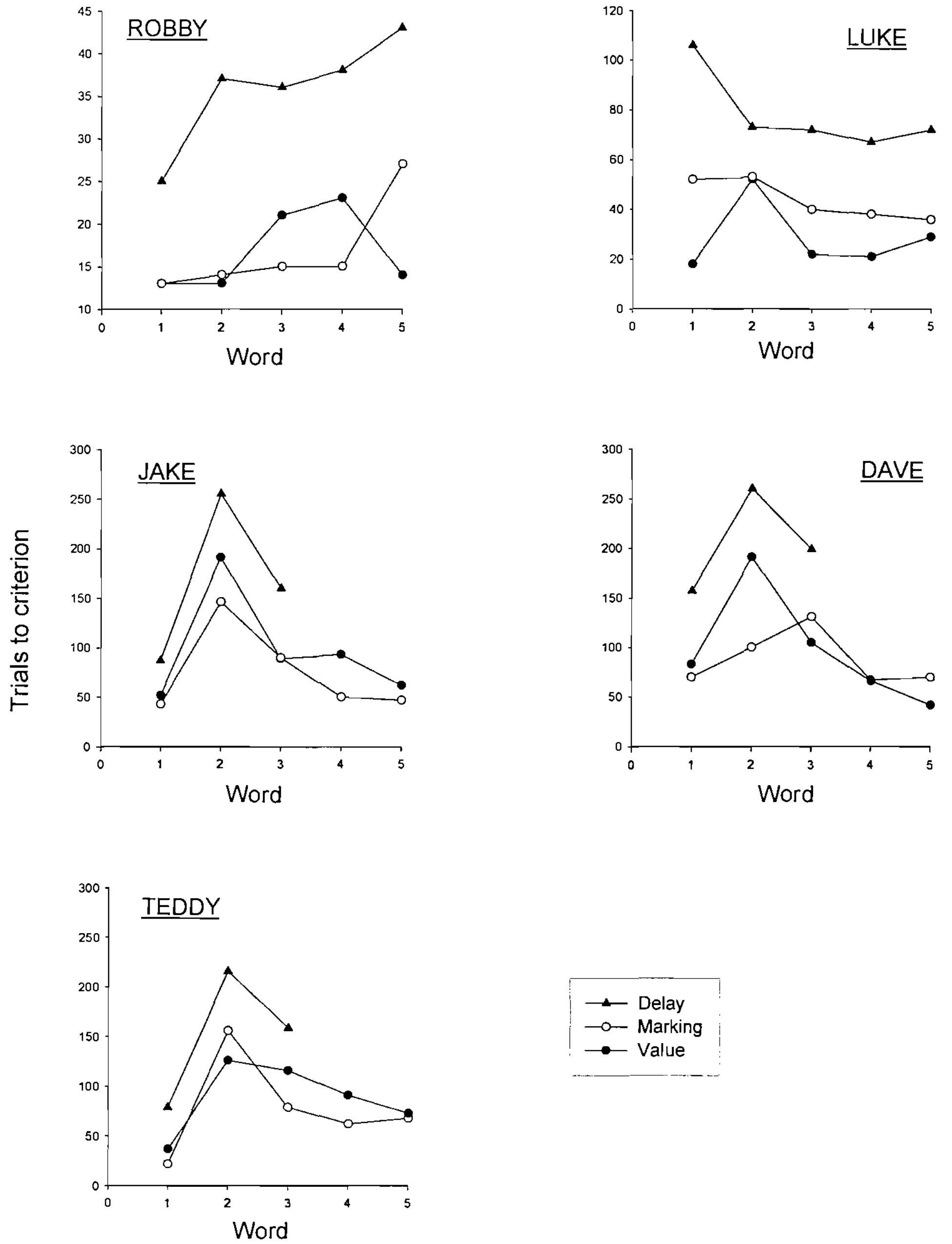

Figure 4-1. **Total number of training trials (ordinate) to learn each word 1-5 (abscissa) during the three conditions (lines) of the alternating treatments design (Experiment Two). The scale of the ordinate differs for Luke and Robby.**

Figure 4-2 shows, for each child, the total trials to criterion across all words trained, thus indicating children's overall performance on the learning task. Data on the left-hand side of each panel relate to words 1-3 for all three treatment conditions; data on the right-hand side relate to words 1-5 for the three conditions for Luke and Robby and for the value and marking conditions only for the remaining children. All children required more trials to reach criterion in the delay condition than in the other two conditions. Four children acquired the first three words taught in the marking condition faster than in the value condition (Dave: 301 vs. 379; Jake: 279 vs. 332; Robby: 42 vs. 47; Teddy: 257 vs. 279 trials, respectively). Exceptionally, Luke acquired these three words faster in the value than in the marking condition (92 vs. 145 trials). Rate of acquisition for the complete set of five words was faster for three of the children in the marking than in the value condition (Dave: 438 vs. 489; Jake: 376 vs. 487; Teddy: 387 vs. 414 trials, respectively); one child, Robby, learned at approximately the same rate (76 vs. 84 trials); and Luke again learned faster in the value than the marking condition (142 vs. 219 trials).

In sum, visual analysis revealed clear differences between the marking and delay condition and the value and delay condition, however, differences between marking and value conditions were less clear.

4.3.3 MULTIPLE-PROBE DATA

Figure 4-3 shows the results of the multiple probe control procedures for each child under the three conditions. Percentages of correct responding after training are to the right of the staggered line. For all participants, acquisition was as a function of the specific training procedure used in each condition rather than the result of any extraneous factors such as additional classroom experience. For every word in all conditions, correct responding was at chance level before training but at between 75-100% correct after training.

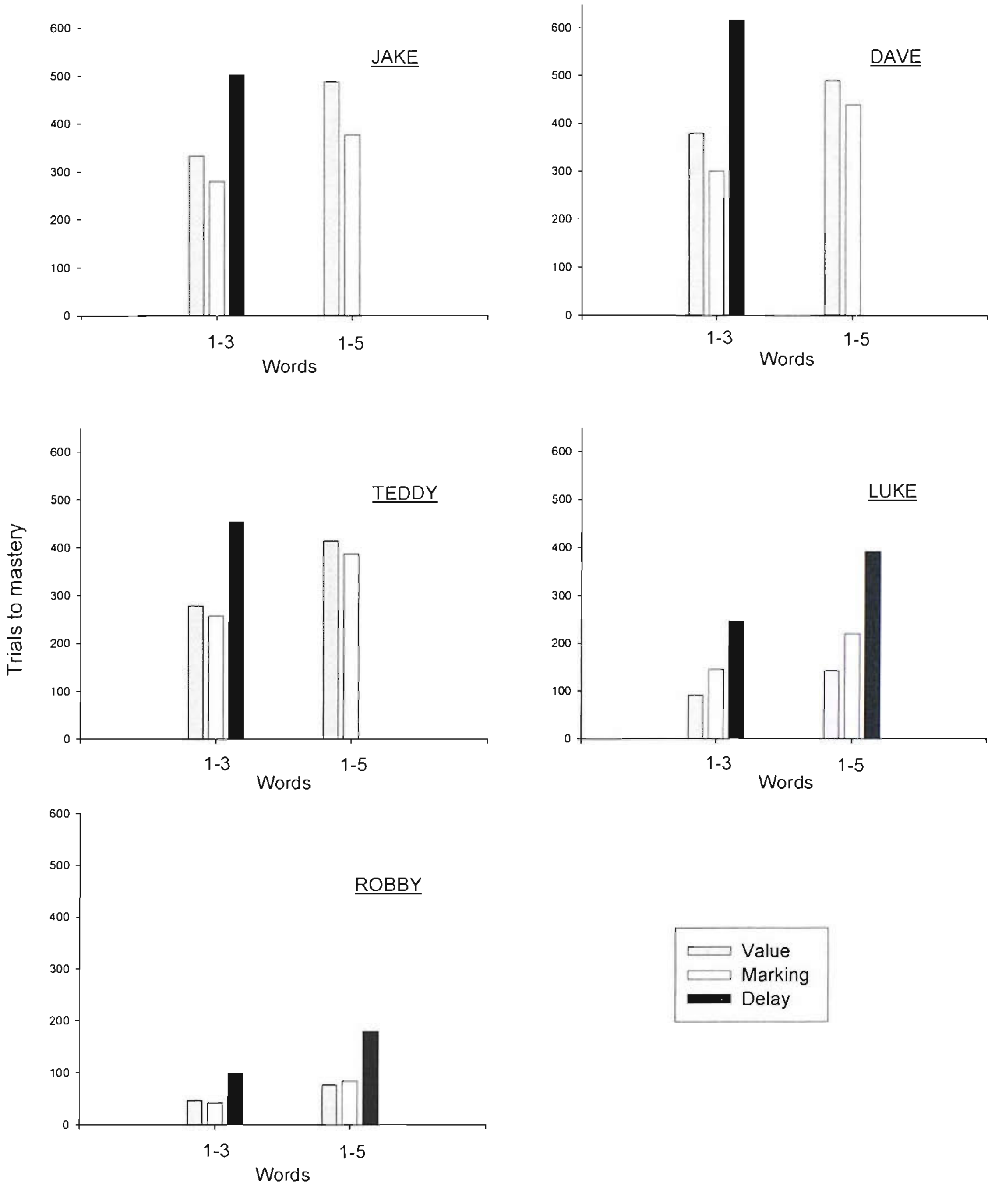

Figure 4-2. Total number of trials to mastery for each participant (Experiment Two). Data on the left-hand side of each panel relate to words 1-3 for all three treatment conditions; data on the right-hand side relate to words 1-5 for the three conditions for Luke and Robby and for the value and marking conditions only for the remaining children.

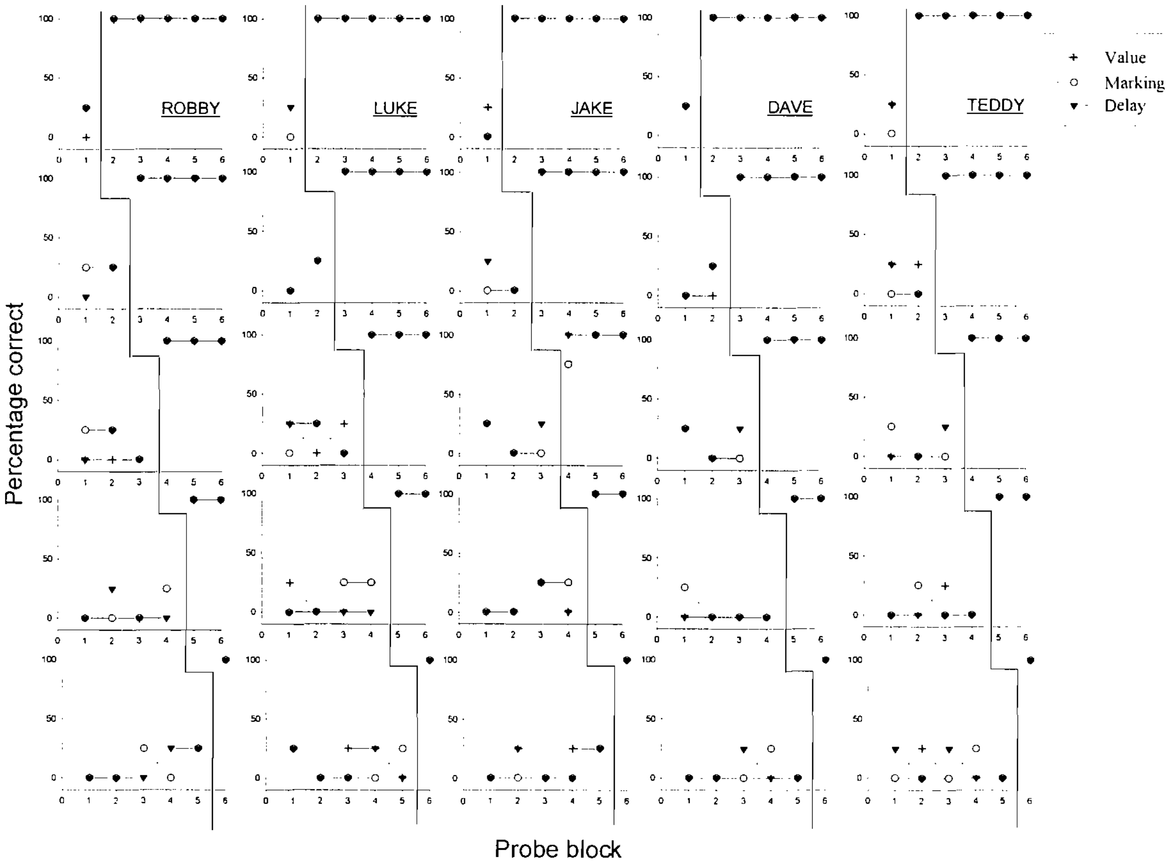

Figure 4-3. Percentage scores for each receptive label, obtained during probe blocks (1-6) in Experiment Two. In each teaching condition (lines), percentage of correct responding (ordinate) are plotted against probe blocks (abscissa). Percentages before and after training are shown, respectively, to the left and the right of the staggered vertical line.

4.3.4 POST-TEST DATA

The percentage data from the maintenance test conducted 1 month after the end of training are shown in Table 4-1. Luke and Robby showed a high level of maintenance for all words taught. For these children post-test performance showed only a slight decrement from the final probe test that had been conducted one month previously. Conversely, Dave, Jake and Teddy showed greater decrements in performance. Between treatment differences indicate that only Luke showed better retention for words taught in the value condition. Dave and Teddy recalled more words in the marking condition and Jake and Robby recalled more in the delay condition.

	Value	Marking	Delay
Dave	33	55	50
Jake	40	43	54
Luke	88	73	80
Robby	68	65	78
Teddy	50	83	38

Table 4-1. Percentage of correct words at 1-month post-test (Experiment Two).

4.4 DISCUSSION

The aim of the present study was to use a discrete-trial training task with children with autism to compare the effectiveness of cue-value and response-marking procedures in bridging a 5 s delay to reinforcement. There is evidence from the animal literature that both types of procedures can effectively bridge such delays but only one study to date (Experiment One) has assessed the effectiveness of response marking with human participants in an applied setting. This study attempted to improve on Experiment One by employing a delay only control, using more socially valid forms of marking, and selecting as participants children who had no previous experience of discrete-trial training.

Our results demonstrated that, for all five children, response-marking and cue-value procedures were both more effective in establishing conditional discrimination performance with a 5 s delay to reinforcement than a no-cue control. Experiment One failed to use a no-cue control but its inclusion in the present study indicates that, despite the fact that a marking procedure requires the same stimuli to be delivered following both correct and incorrect responses; its use improves the acquisition of a conditional discrimination rather than retarding it.

Of the five children in the present study, Jake learned substantially faster in the marking condition and Dave, Robby, and Teddy learned at essentially the same rate in both the cue-value and response-marking conditions. Only one child, Luke, learnt markedly faster in the value condition. Such a result would not be expected based on conventional accounts of the conditioned reinforcement function of response-contingent cues.

It could be argued that the lack of differentiation between the marking and value conditions for most of the participants resulted from their failure to discriminate which intervention was in effect. Although no unique exteroceptive stimulus was paired with each condition, a number of signals were available. For example, a different set of photographs was trained in each condition, the experimenter used different verbal cues in each condition, and comparison stimuli were indicated on every trial in the marking condition.

Moreover, the presence of signals functioning as discriminative stimuli are not, in any case, always essential to a valid comparison. For example, using an alternating treatments design to compare two pharmacological treatments would be perfectly acceptable, even when each drug is not paired with a signal. The drugs would have their effects regardless of any signals (Barlow & Hersen, 1984). Similarly, in my learning-based design, the different programmed consequences of responding will get the children to mastery at different rates, bearing in mind that these consequences will have their selective effect on behaviour regardless of any antecedent cues. The only issue is whether the immediate consequences of choice behaviour (value or marking cues) select correct choices more effectively.

It is useful to consider why the results of the current study differ from the finding in Experiment One that the cue-value procedure was more effective than the marking procedure for three children. A plausible explanation is that the children who participated in the earlier study were engaged in intensive early intervention programs and were thus already familiar with a discrete-trial training procedure that used a procedure similar to the cue-value condition, although without the 5 s delay. For them, the response-marking procedure was truly novel, whereas participants in the present study were equally unfamiliar with all three treatment conditions. Because children with autism are known to prefer consistency in teaching situations (Lord & Schopler, 1994; Pennington & Ozonoff, 1996) marking was potentially disruptive of their learning routines.

Additionally, the participants in Experiment One were observed during training to be adept at orienting to the stimuli. The effectiveness of marking stimuli may have thus been reduced because observing was already at a high level. In the present study, however, three of the four children whose performance in the marking condition was the same as or superior to that in the cue-value condition (Dave, Jake and Teddy) often found it difficult to concentrate on the learning task, and their attention was easily disrupted by external environmental stimuli. Luke and Robby, whose attentional skills were better, gained less benefit from the marking procedure. Thus, across both studies, marking procedures appeared to be more effective for those participants who had a greater deficit in attending skills. Thomas and Lieberman (1990) have similarly speculated marking effects would not be expected to occur with animal preparations in those situations where, through extended training, participants' attention is already fully focused on the task in hand. Future applied research would benefit from obtaining a pre-test measure of attending skills to establish whether such skills can be used to predict which children with autism would benefit most from teaching methods incorporating response marking.

An additional goal of the present study was to use more socially valid forms of value and marking that would be more relevant to everyday teaching practices. These were verbal cues uttered by the teacher (e.g., "Good!"; "Look!") rather than the automated procedures used in Experiment One. This approach raises the possibility that the effectiveness of the response-marking procedure was the result of inadvertent differential reinforcement by the teacher. Such an interpretation is, however, hard to sustain in view of the fact that blind judges were unable to discriminate between verbal cues following correct and incorrect responses. Moreover, given that autism is in part characterized by social impairments (Wing & Gould, 1979), we would not, on a priori grounds, expect children with autism to show the kind of sensitivity that would be required for them to detect subtle verbal cues. Finally, from an applied perspective, evidence of inadvertent reinforcement in the response-marking procedure would not undermine its utility, but merely suggest another mechanism by which its effectiveness could be explained.

Further research might address the question of whether a combination of the value and the marking procedures would be superior to either used separately. The present findings raise the possibility that a procedure in which correct responses were followed with "Good!" and incorrect responses with a marking stimulus such as "Look!", might be more effective than the more usual procedure in which errors are followed by an "informational 'No' " (e.g., Dunlap & Johnson, 1985; Rincover & Newsom, 1985, Schreibman, 1975).

One potential shortcoming of the present study is that the effectiveness of the procedure has been demonstrated only with a 5 s delay to reinforcement. Further research is required to establish whether the relative effectiveness of marking and value procedures remain the same when the delay is extended. Although the present data show that even small delays can disrupt discrete-trial training, procedures capable of bridging longer delays would be more functional to the learner.

Future research could also conduct a series of post-tests to identify any acquired functions of the response-contingent cues. Such tests would be similar to the pre-tests used to establish that the to-be-used cues were functionally neutral. If the value cues had actually acquired conditioned reinforcing properties, participants should respond differentially to these comments. Likewise the marking cues should have acquired attention-eliciting properties.

In conclusion, this experiment makes a significant contribution by demonstrating that a response-marking procedure, in which both correct and incorrect choices are followed by identical social cues, can be as effective as the traditional conditioned reinforcement procedure. Thus, response marking may provide teachers with an alternative or supplement to conditioned reinforcement that can also be used to improve their tutees' performance on a range of learning tasks, especially when primary reinforcement cannot be delivered immediately. Further research is needed to extend our understanding of response marking. By applying marking procedures to new populations and learning tasks, future studies may identify the conditions under which it is able to facilitate learning in applied settings and illuminate the mechanism of its action.

5. EXPERIMENT THREE: THE EFFECTS OF MARKING BEFORE AND AFTER[4]

5.1 INTRODUCTION

Experiments One and Two demonstrated the efficacy of using response-marking procedures during discrete-trial training with children with autism. In Experiment Two for example, five children with autism who had no previous experience of discrete-trial training were taught to match printed words to pictures using a 5 s delay to reinforcement. Children's speed of learning was compared across three training conditions using an alternating treatments design. In the *cue-value condition*, a verbal phrase of approval (e.g., "Good!") was delivered only on correct trials, first immediately after the correct response and again at the time when the primary reinforcer was delivered. In the *response-marking* condition, an attention-eliciting verbal cue (e.g., "Look!") was delivered after both correct and incorrect responses, but not at the end of the delay period. In the *delay* condition, there were no cues during a 5 s delay. Results showed that the cue-value and response-marking conditions did not differ in terms of speed of acquisition, but both produced much more rapid learning than the delay condition. Thus, while Lovaas' (2003) suggestion that even small delays can disrupt discrete-trial training (see Section 3.1) was confirmed, the study also demonstrated that a marking procedure—in which both correct and incorrect choices are followed by identical cues—was at least as effective as a conditioned reinforcement procedure in four out of five children tested. Such a result would not be expected based on conventional accounts of the conditioned reinforcement function of response-contingent cues.

Given that most children with autism have deficits in attending skills (Burack, 1994; Noterdaeme et al, 2001; Wainwrightsharp & Bryson, 1993), the results of these two studies led to the conclusion that response-marking procedures may be a valuable ABA teaching method for those children with autism who have attentional deficits or are prone to distractibility. The children who benefited most from the marking

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4 A journal article describing this experiment is currently in press as:
Grindle, C. F., & Remington, B. (in press). Teaching children with autism when reward is delayed. The effects of two kinds of marking stimuli. *Journal of Autism and Developmental Disorders.*

procedure often found it difficult to concentrate on a learning task, frequently orienting to external environmental stimuli. Children whose attentional skills were better benefited less, possibly because their attention was already focused on the task.

If response marking does facilitate orientation to the learning task, we might also expect a similar procedure that directed attention to task-relevant stimuli *before* a response occurred would also be effective. Thomas Lieberman, McIntosh, and Ronaldson (1983) acknowledged that this possibility is closely linked to a common experience in human memory: When people experience an event of special importance they often have vivid memories for what they did *after* that event as well as memories of what happened *before* (e.g., Brown & Kulik, 1977; Pillemer, 1984; McCloskey, Wible, & Cohen, 1988). Evidence for pre-response marking is, moreover, already available from the animal discrimination learning literature.

Thomas et al. (1983, Experiments Two and Three), using a maze similar to that employed by Lieberman et al. (1979, Experiment Four, see Figure 3-2), compared rate of learning of a simple two-choice discrimination task with a 2 min delay to reinforcement, when rats received a marker either before making a choice response, immediately afterwards, or not at all. In the *marked-before* condition, subjects received a 2 s burst of noise, presented immediately *before* the doors to the side arms were raised to allow subjects to make their choice responses; in the *marked-after* condition, subjects received a similar 2 s burst of noise immediately after their choice response; subjects in the *no-marker* condition experienced no noise.

Compared to the no-marker control condition both marked-before and marked-after procedures facilitated learning, confirming that marking stimuli may enhance memory for subsequent events as well as preceding ones. Potentially these results create problems for the backward-scan hypothesis (Section 2.2.1). If the noise in the marked-before group initiated a backward scan through memory, it would mark behaviour irrelevant to solving the discrimination (e.g., whatever the rat was doing just before the marker was presented). This interference from responses irrelevant to solving the discrimination would probably reduce learning of the correct choice.

To explain learning in this group, Thomas et al. (1983, Experiment Two) proposed that the rats may have been more likely to focus their 'attention' on the black and white cues facing them in the two alleys of the maze, so they could better recall which alley they chose when they later received reinforcement. If this is correct, the backward-scan interpretation of the marked-after group could be discredited. Presenting a marker after a choice response might also focus the rat's attention on the colour of the chosen alley, irrespective of any memory search.

To control for this possibility, Thomas et al. (1983, Experiment Three) altered the maze so that discriminative cues were present only on the doors leading to the alleys. Thus, once the rats entered an alley and received a marker, there were no cues to attend to. If the attention hypothesis was correct for marked-after subjects, learning should not have occurred because there were no discriminative cues for the subject to attend to. Nevertheless, a strong effect was still obtained indicating that markers do not simply focus attention on subsequent events but also, as is the general case (e.g., Lieberman et al., 1979); focus attention on preceding events as well. Thomas et al. (1983) concluded that a marker can facilitate learning either by drawing attention to the response just emitted, thereby enhancing acquisition of the relation between the correct response and reinforcement, or by focusing attention on subsequent discriminative stimuli, enabling better recall of the chosen stimulus at the time of reinforcement (but for criticisms of this hypothesis see Section 8.5).

Although Thomas et al's (1983) cognitively flavoured explanation of the learning process does not sit comfortably with conventional descriptive ABA accounts, the empirical findings are sufficiently strong to merit further exploration in the context of discrete trial learning for children with autism. Thus, the purpose of the current study was to compare children's learning using marked-before and marked-after procedures in the context of a discrete-trial receptive labelling procedure with delayed reinforcement.

Because children with autism have profound difficulties in understanding others' mental states (Baron-Cohen, 1997) participants were taught receptive names for emotional expressions pictured in photo-cards. In my *marked-after* condition, the social behaviour of the teacher (saying "Look!" while pointing to the chosen item) effectively drew the child's attention to (or oriented the child towards) the response they had just made (thereby replicating the marking condition in Experiment Two). Although a number of possibilities were considered for marked-before cues, not all were socially valid (e.g., experimenter clapping their hands just before the child makes their choice response). The procedure finally identified is both common clinical practice in discrete-trial training and also corresponds to a marking procedure. Thus, in my *marked-before* condition, the instructions to turn over face-down picture cards oriented children to the stimuli from which they were required to choose. This procedure somewhat resembles the observing response paradigm (Wyckoff, 1952) in which a response of some kind leads to the appearance of discriminative stimuli. A *delay* control condition was also included, against which the impact of the marking conditions could be assessed.

5.2 METHOD

5.2.1 DESIGN

The experiment involved four phases: pre-testing, pretraining, training with interpolated probes, and post-tests. The pre-testing phase identified 15 photo-cards of emotions as teaching targets for receptive labelling. In addition, children were tested on their ability to follow the teacher's instructions to "look" and to "turn over" photo-cards. The pretraining phase taught children to respond to turn over the cards in response to instruction. The training phase involved using discrete-trial procedures to teach receptive labels for the emotions pictured on the cards. An alternating treatments design (Barlow & Hayes, 1979) allowed the effects of teaching to be compared across the three conditions (marked-before, marked-after, and delay), in each of which correct responses were reinforced after a 5 s delay. On each weekday, children participated in three 15 min sessions, separated by at least 2 hours and spread across mornings and afternoons, with conditions counterbalanced to control for order effects.

A multiple-probe control procedure was also built into each treatment condition. A block of probe trials (i.e., 4 trials each of both trained and to-be-trained emotion names) was conducted before teaching began and after each label had reached criterion. Post-tests of performance were conducted for each child after 1 month.

5.2.2 PARTICIPANTS

The three children with autism who participated (Lenny, aged 6 years and 5 months; Ross, aged 7 years and 8 months; and Andrew, aged 5 years 3 months) attended an autistic unit attached to a mainstream school. Mental age equivalent scores, calculated from The British Picture Vocabulary Scale (Dunn, Dunn, Whetton, & Burley, 1997) were: Lenny: 3 years and 8 months; Ross: 4 years and 6 months; and Andrew: 3 years and 10 months. All had generalized motor imitation and generalized identity-matching skills and could understand and comply with simple requests, including pointing to some familiar objects when they were named (receptive labelling). In addition, all were capable of self-initiated speech and typically communicated using at least four word sentences. Although none had previously received discrete-trial training, all sat willingly at a table for short periods of time.

5.2.3 SETTING

The teaching location comprised of a table and two small chairs in a quiet corridor outside the children's regular classroom. All children had received one-to-one instruction in this setting prior to this study. All sessions were conducted by the same teacher and video-recorded for later analysis.

5.2.4 MATERIALS

Training stimuli were ColorCards®, large photographic illustrations (15 cm x 20 cm) portraying people showing a variety of emotions through facial expression and body language. Emotion cards were chosen by the children's regular class teacher because she wanted to expand their understanding in this area.

A range of potential back-up reinforcers, including edible items, toys, and novelties, were identified for each child based on the class teacher's report.

5.2.5 PROCEDURE

5.2.5.1 Phase 1: Pre-tests

Pre-testing receptive labelling performance

Children were tested on their receptive labelling skills by requiring them to select from an array of three photo-cards of familiar everyday objects as they were named by the teacher. Performance on this test was satisfactory, allowing identical tests to be carried out on photo-cards of emotions believed to be unknown to the children. For each child, this pre-test identified 15 photo-cards as targets for teaching on the basis that the child could not match a card to a spoken name correctly on more than one of four test trials. Five of the 15 photo-cards so identified were then randomly assigned to each of the three training conditions. During pre-test trials, the teacher neither modelled nor prompted correct responses. To maintain the children's interest in the task, established reinforcers like physical contact (e.g., tickles, physical games) or praise were delivered intermittently between trials on a VR3 schedule, independent of performance accuracy.

Pre-testing for generalized instruction-following

Children were tested on their ability to follow instructions by carrying out the requested actions (e.g., "clap hands"). At least 10 'understood' instructions were identified for all children.

Pre-testing for following the experimental instructions

Three photo-cards depicting objects were placed on the table in front of the child. Over four trials, the teacher pointed to randomly selected photo-cards and said “Look!” All children followed the instruction to look at the marked photo-card. On a similar pre-test, this time with three photo-cards placed face down on the table, only Ross consistently followed the instruction to, *“Turn over the cards.”*

5.2.5.2 Phase 2: Pretraining

Pretraining to follow the instructions

Lenny and Andrew were taught to turn over the cards when instructed to do so. Trials were initiated by the teacher placing the cards face down on the table, pointing to the cards, issuing the instruction, and manually prompting a child turn them photo-side up. Over successive trials, prompts were gradually faded until both children followed the instruction without assistance. At this point, Lenny and Andrew were taught to discriminate between them when they were presented in a random rotation to a mastery criterion of 10 consecutive correct responses. An additional pre-test established Ross could discriminate between these instructions.

5.2.5.3 Phase 3: Training with interpolated probes

Identifying primary reinforcers

A multiple-stimulus presentation without replacement procedure (e.g., Deleon & Iwata, 1996; Higbee, Carr, & Harrison, 1999; Higbee, Carr, & Harrison, 2000) was conducted for all children at the start of each experimental day) to identify four back-up reinforcers for use in teaching. Seven potential reinforcers were chosen daily for each child and, prior to the assessment itself, they were allowed to eat small samples of the edible items, and play briefly with the toys to ensure familiarity. The teacher then verbally prompted the children to select from an array of the seven items, recorded a selection when the child touched one within 5 s, removed it, and the rotated the positions of the remaining items prior to the next trial. This assessment continued until four of the seven original items had been selected.

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Overview of training

Using a teaching procedure similar to that described in Experiment Two, children's speed of learning was compared across three experimental conditions (marked-before, marked-after and delay) using an alternating treatments design. Children were taught the labels they did not know in the pre-test assessment. Each child was taught a different set of five items in each condition.

Children were taught to identify pictures of emotions using the following procedure. Three pictures were placed on the table in front of the child. Training trials for each receptive label were initiated by the teacher saying, "Touch [pictured emotion]." A correct response was defined as the child touching the correct card within 3 s of the start of the trial. All unprompted correct responses were reinforced only after a 5 s delay using items selected semi-randomly from the pre-identified set of four. In the case of incorrect responses, no reinforcer was delivered after 5 s, and the trial was repeated. If a child was incorrect for two consecutive trials, he was prompted using a least-to-most hierarchy of prompts (positional, pointing, hand over hand). In all treatment conditions, prompted responses were always immediately reinforced with praise and prompts were faded as soon as possible. A mastery criterion of ten consecutive correct unprompted responses was used throughout.

Although there was a 5 s delay to reinforcement for unprompted correct responses for *all* treatment conditions, there were important procedural differences across conditions in terms of the cues that were presented either immediately before or after a choice response. In the *marked-before* condition, the teacher placed three photo-cards face down on the table, and then presented the marker cue by instructing the child to "Turn over the cards." If he did not respond, the instruction was repeated while the teacher prompted the response by pointing to the cards. When the cards were picture-side up, the teacher instructed the child to "Touch [pictured emotion]" and, following each correct choice, reinforcement was delivered after the delay. In the *marked-after* condition the teacher placed three photo-cards face up on the table and initiated each training trial with the instruction to "Touch [pictured emotion]." Regardless of whether the child chose correctly or incorrectly, the teacher immediately said "Look!" and pointed to the chosen card, but reinforcement was delivered at the end of the delay after correct choices. In the *delay* condition, children did not receive a marking cue at any point during their training trials.

To remove any possible confounds, the overall time to reinforcement was equated across all conditions by including an inter-trial-interval (ITI). During the marked-before condition, children were instructed to turn over the cards during the ITI; in the marked-after and delay conditions, they were required to follow one of ten pre-identified instructions (e.g., "clap hands") during the ITI. The time required to follow these pre-identified instruction did not differ from that required to fulfil the marked-before instructions. Figure 5-1 shows each of the procedures incorporated into alternating treatments design.

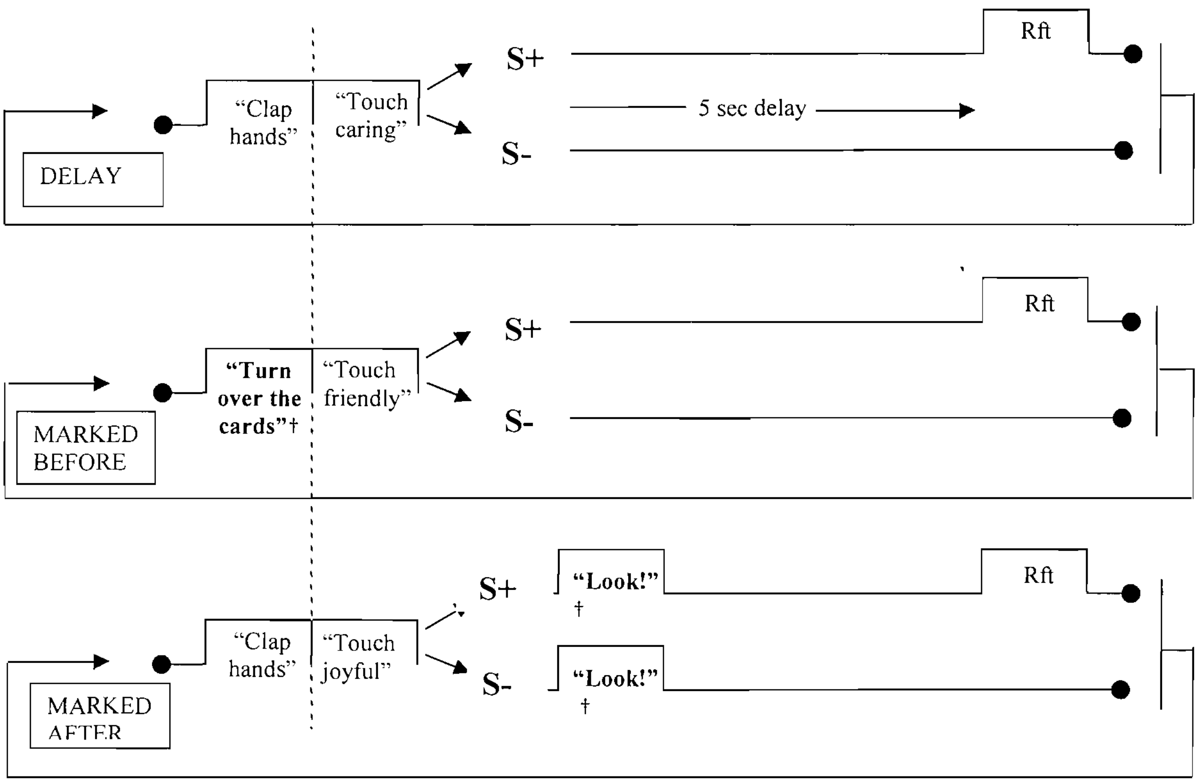


Figure 5-1. Procedural differences between the experimental conditions. Different receptive labels were trained in each condition but each featured a 5 s delay to reinforcement for unprompted correct responses. All conditions involved a short inter-trial interval during which, in the delay and marked-after conditions, children were asked to perform a gross motor response (e.g., "clap hands"); in the marked-before condition, they were asked to turn over the cards. In the marked-after condition, a marking cue was delivered in the first second of the delay. The † symbol indicates a marking cue.

Teaching routine

Regardless of treatment condition, the receptive labelling procedure used the teaching routine previously described in Experiment Two (section 4.2.5.2). In brief, each child was first taught to identify only one picture card. The teaching trials for each receptive label were initiated by the teacher saying, "Touch [pictured emotion]" and prompting the child (by pointing) to select the correct card (i.e., the S+) from an array of three. These prompts were withdrawn as soon as possible. Teaching continued with the positions of the cards remaining constant until the child selected the correct card (S+) on two consecutive trials. Finally, positions of S+ and incorrect comparison cards (S-) were randomized between trials until the ten-trial mastery criterion was reached.

Next, the second target label was taught using the same procedures. When this had been learned to criterion, the first trained target S+ was reintroduced. This allowed receptive labelling trials for both previously taught emotion names to be intermixed, the choice of the sample emotion name and the position of S+ card and the two S- comparison cards varying randomly between trials. From this stage on, the 10-trial mastery criterion included both new and previously trained emotion names. Thus, the child was taught to identify a third label, first in isolation and then intermixed with previously trained combinations, in a ratio of two to one. The remaining two to-be-taught labels were introduced in the same way, each being interspersed with previously mastered items in a ratio of two to one.

Interpolated probes

Probe trials, carried out in the same setting as the teaching, were used to establish internal validity by assessing whether each emotion name had been acquired as a consequence of the teaching procedure. For each treatment condition independently, a 20 trial probe block (four probe trials for all five labels) was conducted prior to training and after each target label reached criterion in that condition (i.e. six probe blocks for each condition). During probe trials, a procedure similar to the receptive label pre-test was used (i.e., the teacher neither modelled nor prompted the correct response and praise was delivered non-contingently and intermittently between trials). No response-contingent events followed correct or incorrect responses.

5.2.5.4 Post-test

Two follow-up test sessions were conducted approximately 1 month after the end of training to assess whether the different teaching conditions produced a differential effect on the recall of emotion names. Eight trials were conducted for each label combination in each condition. The testing procedure used was identical to that used in the probe blocks.

5.2.5.5 Data collection and reliability assessment

The numbers of correct and incorrect responses were recorded during all training, testing and probe sessions for all children. In teaching sessions, the number of prompts was also recorded. To assess interobserver agreement, two observers scored 25% of videotaped sessions for each child. Agreement was calculated for response reliability (agreement that a response was correct or incorrect) and instruction reliability (agreement that the teacher delivered all instructions in each condition accurately).

5.3 RESULTS

5.3.1 RELIABILITY

Inter-observer agreement was calculated by using Cohen's statistic. There was 100% agreement for responses ($K = 1, p < .005$) and a high level of agreement for consequences ($K = .96, p < .005$).

5.3.2 RATE OF ACQUISITION

Figure 5-2 shows, for each child, the total trials to criterion across the five labels trained, thus indicating children's overall performance on the learning task. All children required more trials to reach criterion in the delay condition than in the marked-after condition which, in turn, required more trials than the marked-before condition (respective mean scores: Lenny: 132 vs. 91 vs. 82; Ross: 158 vs. 97 vs. 90; Andrew: 200 vs. 152 vs. 121).

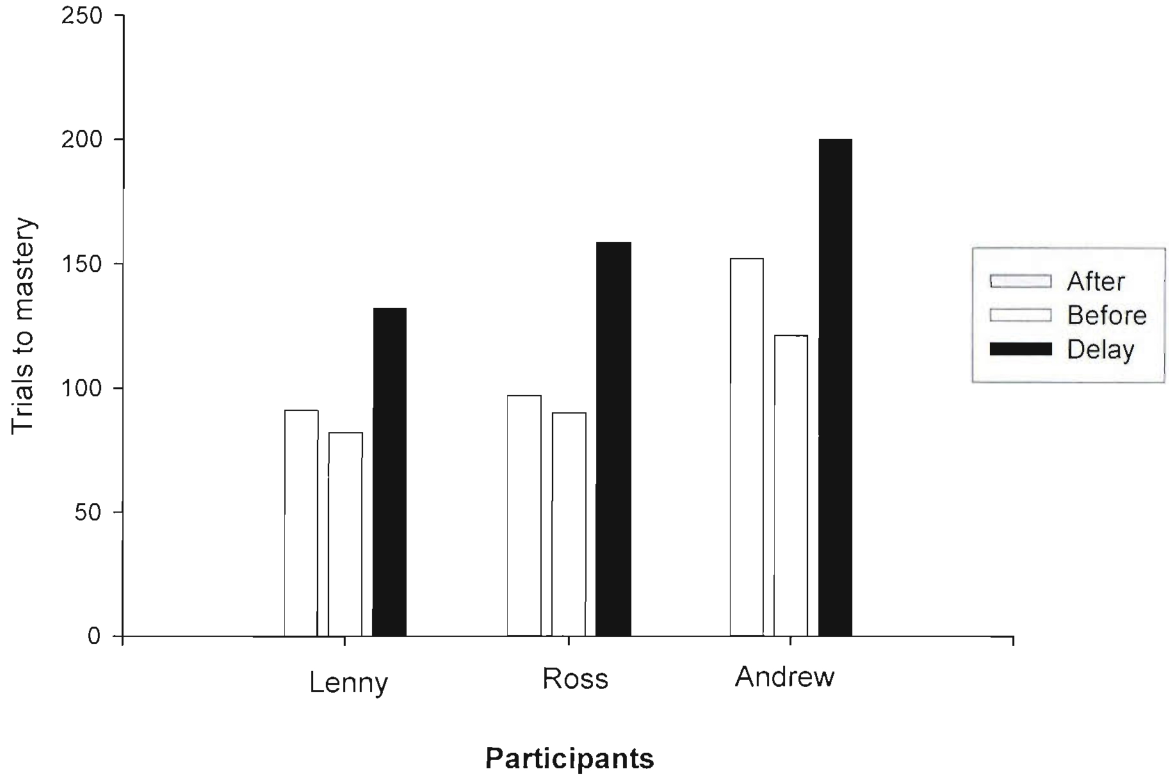


Figure 5-2. Total number of training trials to reach mastery for the five trained receptive labels (Experiment Three).

Figure 5-3 shows this pattern in more detail for each child. The number of training trials required (ordinate) to meet criterion on each receptive label (abscissa) is shown for each treatment condition (lines). Overlapping data points for the marked-before and marked-after conditions indicate that the total numbers of trials needed for the words in these conditions to reach criterion were very similar for all of the children tested.

In sum, visual analysis revealed clear differences between the marked-before and delay condition and the marked-after and delay condition, but only slight differences between marked-before and marked-after conditions.

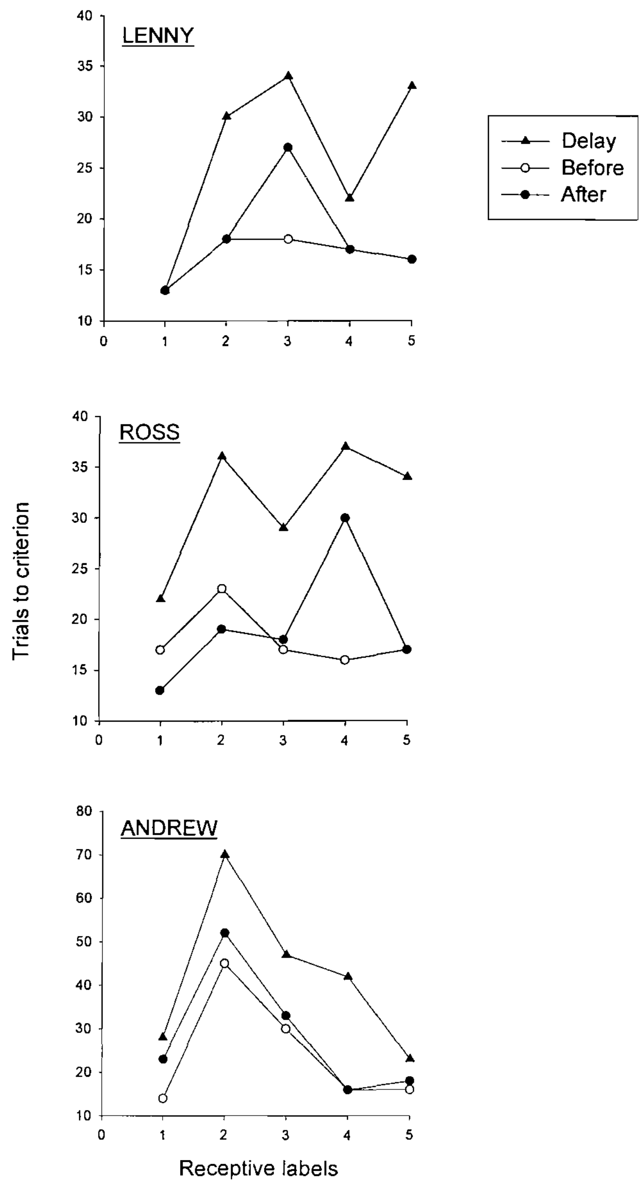


Figure 5-3. **Total number of training trials (ordinate) to learn receptive labels 1-5 (abscissa) during the three conditions (lines) of the alternating treatments design (Experiment Three). The scale of the ordinate differs for Andrew.**

marked-before and marked-after conditions, however, were not statistically significant (Lenny: $\chi^2 = .47$, $.5 > p > .3$; Andrew: $\chi^2 = 3.52$, $> .1 > p > .5$; Ross: $\chi^2 = .26$, $.7 > p > .5$). Andrew's analysis though did show that differences between marked-before and marked-after conditions were just outside the conventional significance level ($p < .1$; marked-before was more effective).

5.3.3 MULTIPLE PROBE DATA

The multiple probe data for each child are shown in Figure 5-4. Each of the three alternating treatment conditions had its own independent set of probes but the data from all three sets are shown on each graph, with the treatment conditions indicated by the line markers. For each child, the probe scores for the first emotion word trained in each condition are shown in the topmost graph, initially at baseline (to the left of the vertical line) and then in the probe sessions subsequent to teaching using reinforcement (to the right of the vertical line). The vertical line is staggered because a probe test was carried

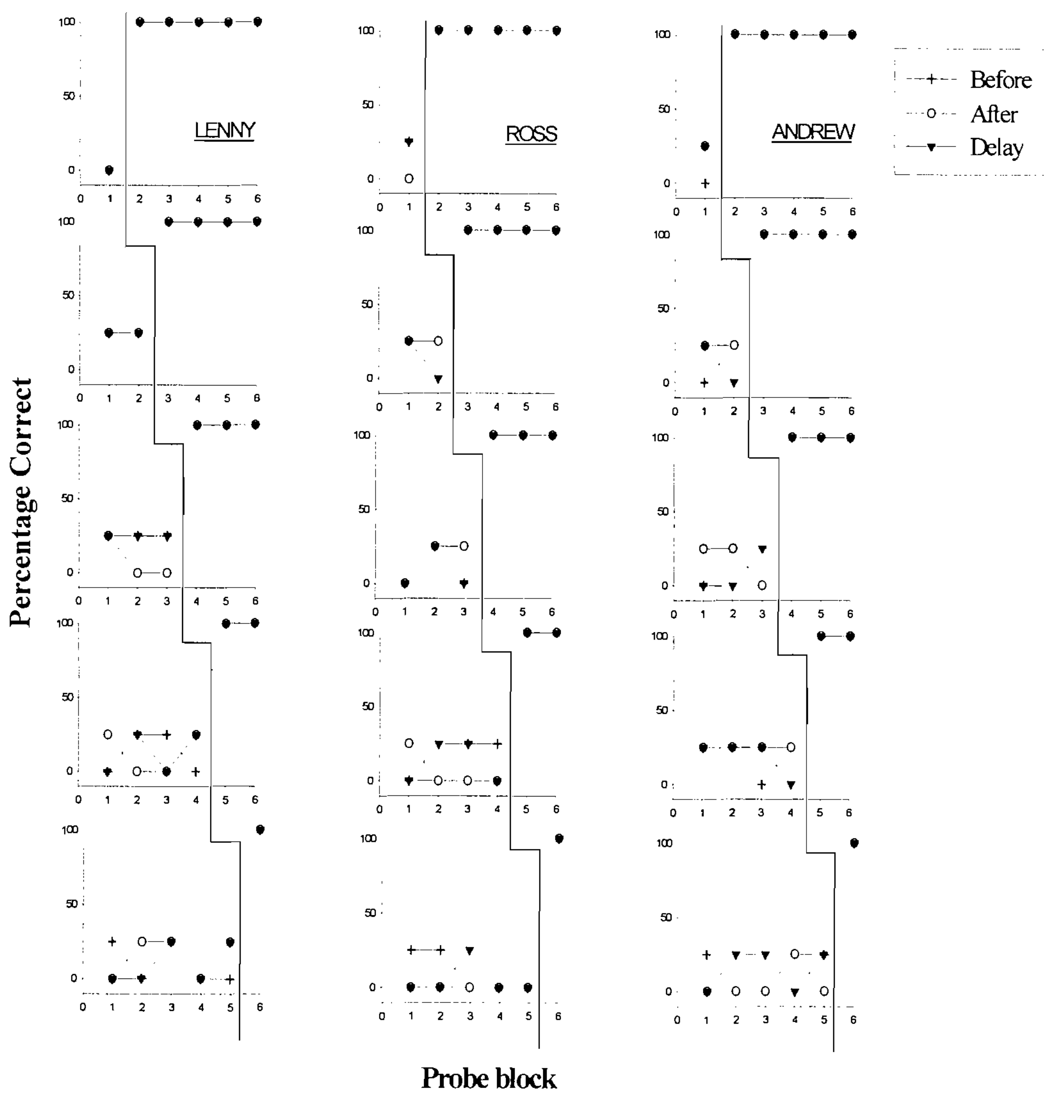


Figure 6-4. Percentage scores for each receptive label, obtained during probe blocks (1-6) in Experiment Three. In each teaching condition (lines), percentage of correct responding (ordinate) are plotted against probe blocks (abscissa). Percentages before and after training are shown, respectively, to the left and the right of the staggered vertical line.

out only when the next to-be-taught emotion word met criterion. Thus, the remaining graphs indicate—for each child in each condition—the changes that occurred in performance following teaching of each of the remaining emotion words. These results clearly show that in each condition responding was at chance before training but at 100% following teaching. Thus, acquisition was a function of the specific teaching procedure used rather than the result of any extraneous factors such as additional classroom experience.

5.3.4 POST-TEST DATA

The percentage data from the maintenance test conducted 1 month after the end of training are shown in Table 5-1. Results were varied. Andrew showed the greatest decrement in performance, with recall only at chance level in all conditions. Ross scored at chance level in the marked-before condition, but above chance in the marked-after and delay condition, respectively. Lenny showed a high level of maintenance for all words taught.

	Marked-before	Marked-after	Delay
Lenny	70	100	70
Ross	40	60	95
Andrew	45	35	45

Table 5-1. Percentage of correct words at 1-month post-test (Experiment Three).

5.4 DISCUSSION

The purpose of this study was to investigate whether marking procedures, derived from a cognitive account of associative learning, would be effective in facilitating learning in children with autism taught using a behavioural discrete-trial training procedure. More specifically, I sought to compare the effectiveness of marked-before and marked-after procedures in bridging a delay to reinforcement in a receptive labelling task. There is evidence from the animal learning literature that both types of procedure can effectively bridge such delays (Thomas, et al., 1983) but, although the effectiveness of a marked-after procedure using children with autism has previously been demonstrated

(Experiment Two), no studies to date have evaluated the impact of marked-before procedures with human participants in an applied setting.

The most significant finding was that marked-before and marked-after procedures produced very similar acquisition rates for the receptive use of emotion names taught by discrete-trial training with a 5 s delay to reinforcement, both facilitating learning by comparison with a delay control. Thus, Experiments One and Two were constructively replicated by showing that, by comparison with the delay condition; marked-after procedures continued to be effective with a new learning task and a sample of older and more able children over delays of the sort typically found in table-top teaching tasks. Additionally, Thomas et al's (1983) research was replicated by showing that a marker presented prior to choice can enhance learning. Thus, marking stimuli can facilitate the acquisition of subsequent choices responses as well as preceding ones. The teaching procedures used did not systematically affect how well learning was retained over a 1 month period.

One plausible explanation for the effects of marking, developed by Lieberman et al. (1979) and Thomas et al. (1983) relies on a cognitive account of associative learning. In their view, different marking conditions focus a participant's attention on the stimuli involved in the learning task either by drawing attention to the response just emitted, or by focussing attention on subsequent discriminative stimuli (see Section 5.1). Considering the marked-after condition from this perspective, we might expect the teacher's instruction (saying "Look!" while pointing to the chosen item) to orient children to the card they had just selected. This could facilitate rehearsal of the relation between the representations of the emotion name heard and the photo-card chosen. Correct associations would be strengthened by subsequent—albeit delayed—reinforcement. In the marked-before condition, the action of turning over the cards may have induced children to attend more effectively to the photo-cards at the time they responded. Such an effect might similarly facilitate rehearsal, again allowing for subsequent strengthening of the association between emotion name and photo-card later, at the time reinforcement was delivered. Thus, the common feature of marked-before and marked-after conditions is that both may have increased the overall amount of time spent attending to the photo-cards and rehearsing the association between cards and emotion names.

It is, however, important to note that there are some differences between laboratory-based marking research and the present applied experiment. For example, in both the marked-after and marked-before conditions, the marker was not simply a salient stimulus but rather a verbal stimulus, an instruction specifically designed to orient children to one or all of the photo-cards. Although it was previously shown that a non-verbal (audio-visual) marker presented after both correct and incorrect responses can facilitate discrete-trial training (Experiment One), the effects obtained in that study were not as strong as those obtained here or in Experiment Two.

In addition to issues relating to the translation from laboratory to applied settings, there are some inherent problems with the cognitive account of marking. For example, Thomas et al. (1990) claimed that a marking stimulus has to be relatively more intense or salient than other stimuli associated with the learning task to produce the rehearsal necessary to facilitate acquisition of the associations (see Section 2.4.4). Unfortunately, it is hard to establish the relative salience of the diverse stimuli involved in studies such as this. It might thus be argued that in the delay condition the inter-trial interval motor instructions (e.g., "Clap hands!") could have functioned as markers, in which case the observed difference between this condition and marked-before condition would not have been expected. Thus, it may be more sensible to attribute the outcomes obtained to the very specific orienting functions of the markers than to a difficult-to-specify quality such as stimulus salience.

Some issues have been highlighted that arise both in translating experimental procedures between laboratory and applied settings and in operationalizing some of the concepts on which cognitive account depends. Nevertheless, consideration of a cognitive theoretical perspective in relation to simple teaching procedures for children with autism has substantial heuristic value. Conventional ABA models of teaching, based exclusively on an operant perspective, have rarely considered approaches other than the use of conditioned reinforcement to counter the impact of delay. There are, however, some good reasons why unconventional procedures that are nevertheless demonstrably effective in promoting learning in discrete-trial training should be further explored by behaviour-analytically oriented practitioners. All that is required is an openness to the use of novel teaching methods, combined with some consideration how they might best be described and analysed within the preferred conceptual framework.

In the case of the marked-before procedure, a framework is potentially available in Skinner's account of precurrent behaviour (Skinner, 1953) and the experimental literature on the observing response (Wyckoff, 1952), indicating that discriminative stimuli can function as reinforcers for such behaviour by virtue of the information they provide on the availability or non-availability of reinforcement (e.g., Badia, Culbertson, & Harsh, 1973; Lieberman, 1972; Schrier, Thompson, & Spector, 1980). Regarding the marked-after procedure, a number of recent studies have demonstrated that spoken or written self-instructions produced during a delay can facilitate learning (e.g., Jay, Grote, & Baer, 1999; Stromer, Mackay, McVay, & Fowler, 1998; Taylor & O' Reilly, 1997). Clearly, these procedures can be used only with children with effective expressive language or writing skills and—unlike response marking—are choice-specific and self-initiated. Nevertheless, my data indicating the effectiveness of experimenter-supplied markers suggest a line of future research exploring whether self-marking might be effective with both verbal and non-verbal stimuli (such as pointing to a just-chosen item).

5.5 THEORETICAL CONCLUSIONS FROM APPLIED STUDIES

Taken together, the three applied studies demonstrate how effectively procedures identified in basic laboratory research with animals can be used in applied settings. Experiments Two and Three showed that delaying reinforcement for 5 s during discrete-trial training for children with autism impeded learning, thus supporting Lovaas' (2003) suggestion that even small delays disrupt discrete-trial training.

To explain delay-of-reinforcement effects in instrumental conditioning experiments with animals, some theorists (e.g., Revusky, 1971, Williams, 1978) have suggested that a delayed reinforcement contingency impedes learning, not because of the length of the delay per se, but because of interference from competing responses that also occur during this interval. In the applied experiments, therefore, delayed reinforcement might have impeded learning because a behaviour other than the "correct" response was strengthened. For example, the child with autism might have performed an ongoing succession of behaviours during the delay (e.g., self-stimulatory behaviours, orienting towards irrelevant stimuli in the teaching situation), so that when reinforcement was delivered at the end of the delay, it was contiguous with a behaviour other than that defined "correct" by the experimenter.

If this is the case, the effectiveness of delayed reinforcement could be increased in one of two ways. First, reducing the number of competing responses should increase the likelihood that the correct response will be associated with the reinforcer. For example, Erickson and Lipsitt (1960) showed that when children were instructed to

orient to the place of reinforcement throughout the delay ("watch out for the red light"), discrimination learning was not reduced. They concluded that attending to the place of reinforcement may have prevented the occurrence of competing responses during the delay interval (which might have retarded acquisition), thus minimizing the usual effects of delay (see also Raymond, 1954 for similar results with rats).
Finally, if the number of competing responses cannot be reduced, some way of isolating the effective instrumental response from other behaviours is required. The focus of this thesis is to use a response-contingent cue (i.e., a marker) to fulfil this role.

Verbal behaviour might also be an important variable in determining delayed reinforcement effects. For example, in the 1950s and 1960s several studies were published that were concerned with the effects of reinforcement delay on children's learning of a discrimination problem and verbal behaviour was shown to be a crucial factor (e.g., Brackbill & Kappy, 1962; Erickson & Lipsitt, 1960; Hockman & Lipsitt, 1961; Lipsitt & Castaneda, 1958; Lipsitt, Castaneda, & Kemble, 1959). One of the most influential of these was Brackbill and Kappy's (1962) study which compared the effects of 0, 5, and 10 s reinforcement delay on children's learning of 18 simple two-choice discriminations. Surprisingly they found that differences in rate of acquisition between these groups were not significant. To explain their results they proposed that if participants are able to produce and make use of response-produced cues, the potential negative effects of delay will be reduced by virtue of a bridging effect from response to reinforcement (e.g., Spence, 1947). In their study, the distinctive response-produced cues were verbal: participants were required to call out the name of the picture they thought correct on each trial. They suggested that participants may have covertly repeated the name of the chosen stimulus over and over until reinforcement was delivered. They concluded that the potential negative effects of delay were reduced by virtue of this bridging effect from response to reinforcement, brought about by the child's capacity to self-instruct.

There has also been a considerable amount of research which has examined the effects of delay on free-operant responding with preverbal infants (e.g., Ramey & Ourth, 1971; Millar, 1990; Reeve, Reeve, Brown, Brown, & Poulson 1992; Reeve, Reeve, & Poulson, 1993). The main purpose of using this population has been to control for verbal factors that could help bridge the delay. Ramey & Ourth (1971) measured the effects of immediate and delayed social reinforcement (e.g., saying, "good baby") on increasing the rate of vocal responding in 3, 6, and 9 month old infants, and found that immediate reinforcement substantially increased vocalizations, whereas a 3 or 6 s delay between responding and reinforcement produced no significant increase in responding above baseline.

In a more recent study, Millar (1990) measured the effects of reinforcement (a 1 s episode of auditory and visual feedback) on a hand-pulling operant response in 6 to 8 month old infants and also found that a 3 s delay between the response and reinforcement was sufficient to decrease responding relative to immediate response contingent reinforcement. Possibly these results were obtained because nontarget responses were adventitiously reinforced during the delay, and thus may have interfered with reinforcement of the target response (cf. Revusky, 1971).

Although the children with autism in these studies had some language (unlike the preverbal infants), it is still probable that they lacked the capacity to self-instruct. This may have reduced the likelihood of a delay-bridging effect from response to reinforcement (e.g., through verbal rehearsal, see Section 7.4.1, for a more detailed discussion).

Applied research has typically considered that the detrimental effects of delay can be counteracted only when response-contingent cues—functioning as conditioned reinforcers—are presented during a delay-to-reinforcement interval. This interpretation is routinely incorporated into discrete-trial training (Lovaas, 2003). My research, however, demonstrated that response-marking and cue-value procedures were both more effective in establishing conditional discrimination performance with a 5 s delay than a no-cue control (Experiments Two and Three) and that marking was as effective or more effective than conditioned reinforcement for some children (Experiment Two).

Although further research will undoubtedly lead to a better understanding of how marking achieves its effects, some tentative explanations can be proposed on the basis of this set of experiments. One explanation previously offered is that marking is particularly useful for children who have significant deficits in 'attending' skills (see Section 4.4). Thus, the children who have difficulty in sitting still or orienting towards relevant discriminative stimuli in a teaching situation may be more severely affected by delayed reinforcement than children who have learnt these prerequisite behaviours. As mentioned previously, for the former, any number of responses that occur during the delay interval may be strengthened rather than the "correct" response. Marking cues may thus serve a facilitatory function because they isolate effective instrumental responses from the other competing behaviours (e.g., self-stimulatory behaviour) that also occur during the delay. If, however, the child consistently attends to the relevant stimuli in a learning task, marking cues would not be expected to increase orienting towards the task to any significant degree (cf. Thomas and Lieberman, 1990, Section 7.4.4).

In Experiment One, for example, the children who were familiar with discrete-trial teaching had already been taught most basic 'attending' skills. They were observed during the experiment to be able to sit quietly at the table for several minutes at a time, keep their hands still in their lap during teaching and to orient visually towards the discriminative stimuli during training trials. Thus, because the prerequisite skills were already at a high level marking may not have produced a powerful effect. In Experiment Two, however, where marking effects were more pronounced, orienting behaviours were less established for most of the children. Unfortunately, no objective measures of attending or orienting were obtained in these experiments. Future applied research would benefit from obtaining either a concurrent measure of attending throughout the experiment or a pre-test measure to establish whether attending skills are indeed predictive of marking effects (e.g., from the Revised Conners' Parent Rating Scales-CPSR-R, 1997).

In addition an important prerequisite skill for the children in Experiments Two and Three was that they were able to respond to 'joint attention' acts (i.e., the marking cue). These behaviours included looking at where another person is pointing, a skill with which many children with autism have difficulty (Baron-Cohen, 1989). Thus, they were able to respond to the marking cue by orienting themselves towards the response they had just made. It may be that younger or developmentally less advanced children would have more difficulty responding to joint attention bids than the children used in this study, making the cues less effective for these children.

In sum, the applied studies showed that marking procedures could facilitate learning with children with autism when reinforcement is delayed. A delayed reinforcement effect may have been found in Experiments Two and Three because children with autism were unable to bridge the delay with verbal response-produced cues. Marking may have facilitated learning by isolating the correct response from other irrelevant responses that also occurred in the delay interval. Furthermore, marking may have worked best for those children with greater deficits in attending skills by bringing about an increase in perceptual processing.

These conclusions raise some interesting questions. First, would the delayed reinforcement or marking effect still be found with a non-autistic population who could bridge the delay with self-instruction? This seems a valid question as other researchers (e.g., Reed, 1999) have also anticipated that marking effects might be found despite self-instruction (see Section 7.6). Moreover, if learning is not facilitated it might be useful to remove self-instruction to determine if this is the critical variable. Second, if participants did not have attention deficits, would a marking effect still be found? Thus, the aim of the next set of experiments was to examine whether marking effects would be found with adult non autistic participants who could both self-instruct during the delay and also remain fully focussed throughout the duration of a conditional discrimination task.

6. MARKING WITH ADULT HUMAN PARTICIPANTS

Chapter Two showed that the delay bridging properties of marking has received considerable empirical support in the animal learning literature (e.g., Lieberman, Davidson & Thomas, 1985; Lieberman, McIntosh & Thomas, 1979). Moreover, Chapters Three to Five showed that marking procedures facilitated learning during discrete-trial training with autistic children when primary reinforcers were delayed

Marking has been explored in experiments using adult humans as participants but reliable marking effects have not generally been found. For example, Reed (1998) assessed whether recall of items presented in a serial list could be facilitated by a salient stimulus presented *after* an item and, if so, whether this facilitation could be attributed to marking (see Section 2.6). In fact, salient stimuli were not able to improve recall of the preceding word, and even attenuated it. Reed concluded that the backward-scan mechanism may be restricted to associative learning procedures and has no generality in paradigms typically used to investigate human memory processes.

In experiments on human causality judgments, any facilitatory effect of a stimulus inserted during the delay interval is also usually attributed to conditioned reinforcement and not to marking effects (e.g., Reed, 1999, Section 2.6). Equally, however, there have been no attempts to separate out the effects of conditioned value and marking in these experiments.

Although research on adult humans has so far reported no consistent evidence for the marking phenomenon, "one of the main obstacles to progress may lie in identifying a suitable paradigm" (D. Lieberman, personal communication, October, 2002). Because research has so far explored whether the marking hypothesis can extend to account for effects in human causality judgments (Reed, 1999) or human working-memory tasks (Reed, 1998), it has inevitably moved away from the associative learning paradigms used in the majority of previous studies on marking with animals.

The present series of experiments was designed to investigate whether a marking effect can be demonstrated in humans acquiring conditional discriminations in an arbitrary matching task. In doing so, the experiments have relied on a paradigm more analogous to previous successful demonstrations of marking effects.

6.1 EXPERIMENT FOUR

6.1.1 INTRODUCTION

In Experiment Four a between-participants design was used to assess marking effects on a computerised visual-visual matching-to-sample task. Although a 5 s reinforcement delay was used for all conditions, the response-contingent stimulus procedure differed between conditions. In the marking condition an audiovisual cue occurred after both correct and incorrect choice responses; in the cue-value condition, the same audiovisual cue was presented only after a correct response and again at the end of the 5 s delay, immediately before reinforcement delivery. To establish whether marking or value had an effect over delayed reinforcement alone a control condition, in which primary reinforcement was delivered after a 5 s delay period but no response-contingent cues occurred, was included.

Basing expectations on previous successful demonstrations of marking, it was predicted that rate of learning in value and marking conditions would be roughly comparable and that both conditions would be more effective than a delay only condition. Written post-experimental tests were also conducted to measure any strategies used to learn the task.

6.1.2 METHOD

6.1.2.1 Participants

The participants were 30 students (2 males and 28 females) recruited from the departmental participant pool, whose ages ranged from 18 to 33. Participants were randomly assigned, but in equal number, to one of three experimental groups (marking, value, delay), prior to their arrival in the laboratory. Participants were unfamiliar with Kanji script. Participants were given course credits for their participation but no monetary payment. A prize was also offered for the participant who learnt the task in the quickest time.

6.1.2.2 Apparatus and Stimuli

Participants were tested individually in a small cubicle (1.5m by 3m) containing a desk, on which was mounted on a Power Macintosh® computer, a monitor and a mouse. Using software designed specifically for matching-to-sample research (Dube & Hiris, 1996), the computer presented all stimuli and automatically recorded participants' response choices and latencies. During matching-to-sample trials, a sample stimulus was presented in the centre of the screen and four comparisons at each of its 4 corners (see Figure 6-1). Choice responses were made with the mouse.

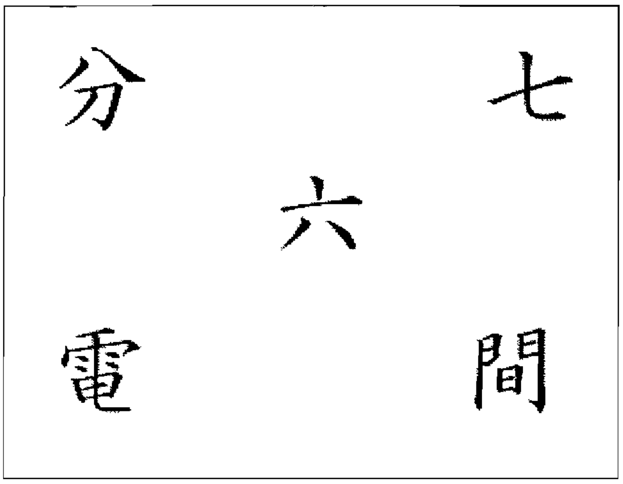


Figure 6-1. Typical matching-to-sample screen display, where 六 is the sample stimulus and 七 is the correct comparison (i.e., the S+).

Written instructions (see Section 6.1.2.3) were also placed on the table, alongside an envelope containing a pen and post-test booklet for completion after the matching-to-sample experiment. All experimental stimuli were presented in the booklet, each followed by a blank space.

Stimuli were 20 pairs of Kanji letters. Two blocks of matching trials were run (block AB and block CD) with ten pairs of letters in each (see Table 6-1). Regardless of their experimental condition, all participants were exposed to the same training stimuli throughout the experiment.

6.1.2.3 Procedure

Instructions

At the beginning of each experimental session participants were asked to familiarise themselves with written instructions which were placed on the table. The instructions, closely modelled on those of Randell and Remington (1999), read as follows:

Block AB		Block CD	
Sample	Correct Comparison	Sample	Correct Comparison
A1 六	B1 七	C1 三	D1 子
A2 上	B2 分	C2 長	D2 高
A3 出	B3 電	C3 円	D3 外
A4 月	B4 十	C4 後	D4 東
A5 本	B5 百	C5 北	D5 時
A6 女	B6 間	C6 見	D6 気
A7 国	B7 小	C7 行	D7 校
A8 下	B8 万	C8 白	D8 雨
A9 入	B9 毎	C9 父	D9 半
A10 火	B10 中	C10 毎	D10 右

Table 6-1. Sample and correct comparison stimuli used during training for all conditions. On each trial three incorrect comparison stimuli were chosen at random from the remaining stimuli in the same stimulus block.

> When the experiment begins, and at the start of each subsequent trial, you will see a symbol in the middle of the screen in front of you. Use the mouse to click on it. More symbols will now appear in the corners of the screen. Use the mouse to click on one of these. After a slight delay, you will receive feedback for your choice. If you are correct you will hear a beep and the word "CORRECT" will appear on the screen. If you are incorrect then you will hear a buzz and the word "WRONG" will appear on the screen. Your task is to try to get ten correct responses in a row. The computer will tell you when you have achieved this. Have a short rest if you want and then press 'continue' when you are ready to resume the experiment.
>
> In the second part of the experiment you will be shown different symbols. Your task is again to try to get ten correct responses in a row. The computer will record your performance throughout and a message on the screen will tell you when the experiment is over. Please aim to complete the experiment as quickly and accurately as possible. Remember that there is a prize for the person who learns the task in the quickest time. When you are ready to start, please click on "Continue". Thank you for participating in this experiment. You are free to leave at any point.

After they had read the instructions the experimenter asked if there were any questions. If there were none, the participant was left to complete the experiment.

Overview of training

Each matching-to-sample trial began with the presentation of a sample stimulus in the centre of the screen. An observing response made with the mouse (i.e., clicking on the sample stimulus) caused four comparison stimuli (i.e., one correct and three incorrect stimuli) to be displayed at the four corners of the screen. All remained there until selection of a comparison caused them immediately to disappear. After a 5 s interval, an auditory trill and the word "CORRECT" was displayed on the screen for a correct response (i.e., the R+), or a buzz and the word "WRONG" displayed on the screen followed an incorrect response (i.e., the R-). Comparison selections made within 0.5 s of presentation had no consequence, and all stimuli remained in view. There was no limit to trial duration and the inter-trial interval was set at 1 s.

For one condition (delay), these were the only contingencies in operation. For the value group, a 1 s audiovisual stimulus (a beep and a red square presented in the centre of the screen), was presented twice following each R+, once immediately after the S+ had disappeared from the screen and again at the end of the 5 s delay (i.e., immediately before the word "correct"). In the marking group, the same audiovisual stimulus (i.e., beep and red square) was presented immediately after both R+ and R-, but not at the end of the delay. Figure 6-2 shows each of these procedures for the different conditions.

Positions of S+ and S-varied pseudo-randomly from trial to trial and, throughout training. Comparisons were always the S+ and pseudorandomly sampled members of a stimulus block sharing the same alphabetic designation (e.g., for A1, comparisons were B1 B5, B8, B9). The target stimulus was thus paired with different incorrect comparisons on different trials. At no point did the location of S+ remain the same for more than two consecutive trials, nor did the sample stimulus appear for more than two trials consecutively. Table 6-2 illustrates the trial configurations for the first ten trials during training of the AB pairs.

When a criterion of 10 consecutive correct responses had been achieved, a message appeared on the screen telling participants that they had been successful and could take a short break if needed. Next, CD pairs were trained in an identical fashion. When the same criterion had been attained for these pairs, a message appeared on the screen asking the participants to complete the written post-test provided in the envelope. The session was terminated for participants who had not reached either the AB or the AB and CD criterion after 45 minutes, but they were nevertheless asked to complete the post-test.

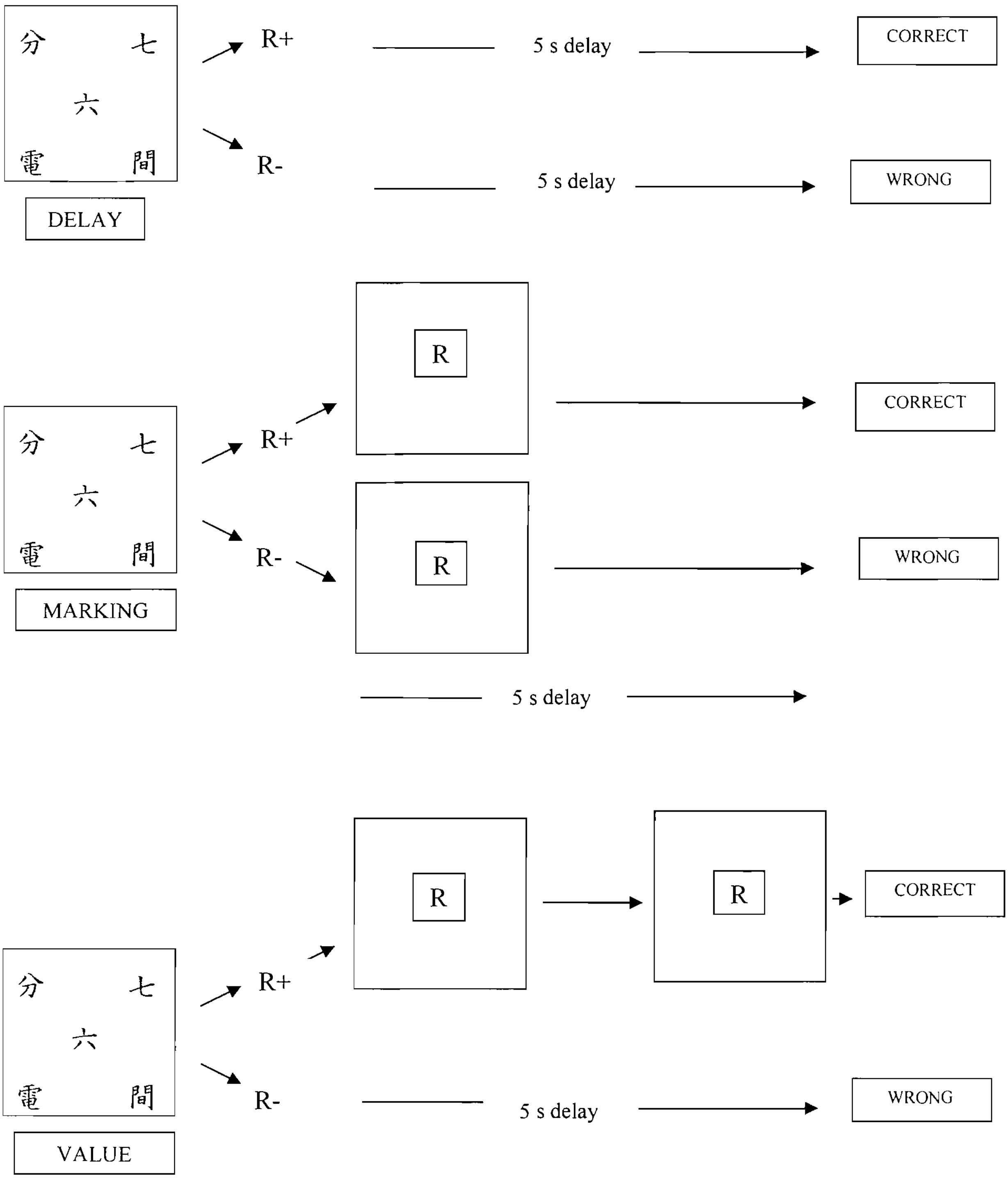


Figure 6-2. **Procedural differences between the experimental conditions. The same stimulus pairs were trained in each condition, and all featured a 5 s delay to reinforcement for correct responses. In the marking condition an audiovisual red square and beep was presented after both the R+ and R-. In the value condition this was presented twice following each R+, once immediately after the R+ and again immediately before reinforcement.**

Sample	Comparison			
C	TL	TR	BR	BL
A1	B4	B3	B2	**B1**
A7	**B7**	B2	B8	B6
A5	B8	**B5**	B6	B1
A9	B10	B7	**B9**	B1
A2	**B2**	B3	B4	B9
A3	B8	**B3**	B2	B10
A4	B9	B7	B5	**B4**
A6	**B6**	B5	B9	B3
A10	B6	B4	**B10**	B5
A8	B5	**B8**	B3	B4

Table 6-2. Trial configurations for the first ten trials during AB training. The sample stimulus always appeared in the centre (C) of the screen, the comparison in the four corners of the screen; TL-top left, TR-top right, BR-bottom right, BL-bottom left. The comparison stimuli in bold are the correct comparisons.

Post-test

The post-test booklet was headed by the following instructions:

> Printed below are the symbols that you have seen during the experiment. Please write down next to the symbols any words used to help you remember them. If you did not refer to a symbol in any way, please leave the box next to it blank.

The post-test also gave participants an opportunity to describe any other factors that they considered determined their responding or any other strategies they used to help them learn the task. Questions also aimed to investigate the possibility of position bias in response allocation. Finally participants were asked if they had any other information that could have had a bearing on their performance.

6.1.3 RESULTS

Three groups of ten participants took part in this experiment. Table 6-3 shows that of these ten (for example, in the value condition), two could not master either block AB or CD, eight could master block AB and, of those eight, seven could master both blocks AB and CD. Participant mastery will be depicted in this way for the remainder of the adult human experiments.

	Training Blocks		
Condition	Neither AB or CD	AB	AB and CD
Value (n = 10)	2	8	7
Marking (n = 10)	4	6	5
Delay (n =10)	1	9	5
Total	**7**	**23**	**17**

Table 6-3. The number of participants from each condition who could not master either block, who could master block AB, or who could master both blocks AB and CD (Experiment Four).

6.1.3.1 Total trials and errors to termination of training for all participants on block AB

Seven out of 30 participants (23%) were not able to reach criterion on block AB. The best estimate of how many trials it would have taken them to reach criterion on this block is the number of trials they had reached on that block when training was terminated after 45 min. Although this is a conservative measure of what their performance might have been if they had been allowed to continue, their data is still important for analysis because many participants failed to reach criterion. Thus, for all participants the means and standard deviations for trials and errors to termination of training on block AB (mastery or non- acquisition after 45 minutes) were calculated and this data is presented in Table 6-4.

		Trials to termination of training		Errors made until termination of training	
Condition		Mean	SD	Mean	SD
Value	(n = 10)	130.8	32.1	79.7	28.1
Marking	(n = 10)	144.4	71.8	90.2	57.6
Delay	(n = 10)	127.6	54.6	74.5	31.6

Table 6-4 Means and standard deviations of trials and errors to termination of training and errors for all participants on block AB (Experiment Four).

A one-way analysis of variance was performed on these data. There were no differences on either number of trials to termination of training (F (2, 27) = .26, p = .8) or on errors made during training (F (2, 27) = .4, p = .7). Figure 6-3 shows the mean total trials and errors until termination of training for all participants on block AB.

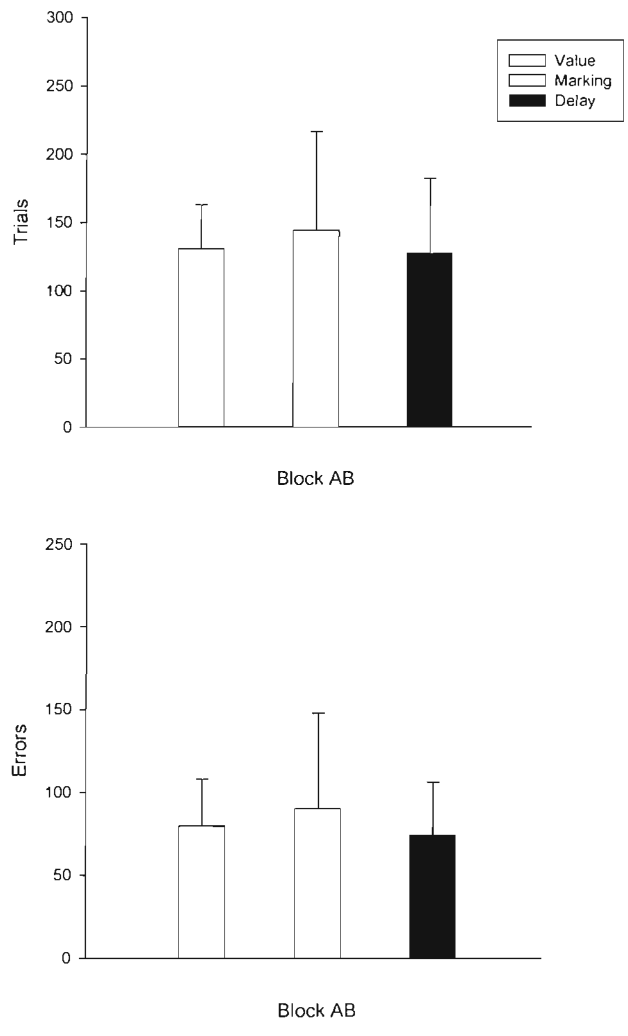


Figure 6-3. Mean total trials and errors (+*SE*) until termination of training for all participants on block AB (Experiment Four).

6.1.3.2 Trials to criterion and errors for learners on block AB

The preceding section examined differences between conditions when the data from unsuccessful participants were taken into consideration (n = 30). Because of the conservative nature of this data, the means and standard deviations were also calculated for only those participants who reached criterion on block AB (n = 23). Table 6-5 presents the means and standard deviations of the trials to criterion and number of errors for the different conditions.

	Trials to criterion		Errors	
Condition	Mean	SD	Mean	SD
Value (n = 8)	123.9	30.9	68.7	17.4
Marking (n = 6)	96.2	40.2	49.3	24.7
Delay (n = 9)	122.8	55.6	72.1	17.4

Table 6-5. Means and standard deviations for trials to criterion and errors across the different conditions for block AB (Experiment Four).

A one-way analysis of variance was performed on these data. There were no differences on either number of trials to reach criterion (F (2, 20) < 1) or on errors made during learning (F (2, 20) = 1.49, p = .25). Figure 6-4 shows the mean number of trials required and errors made by participants who mastered block AB.

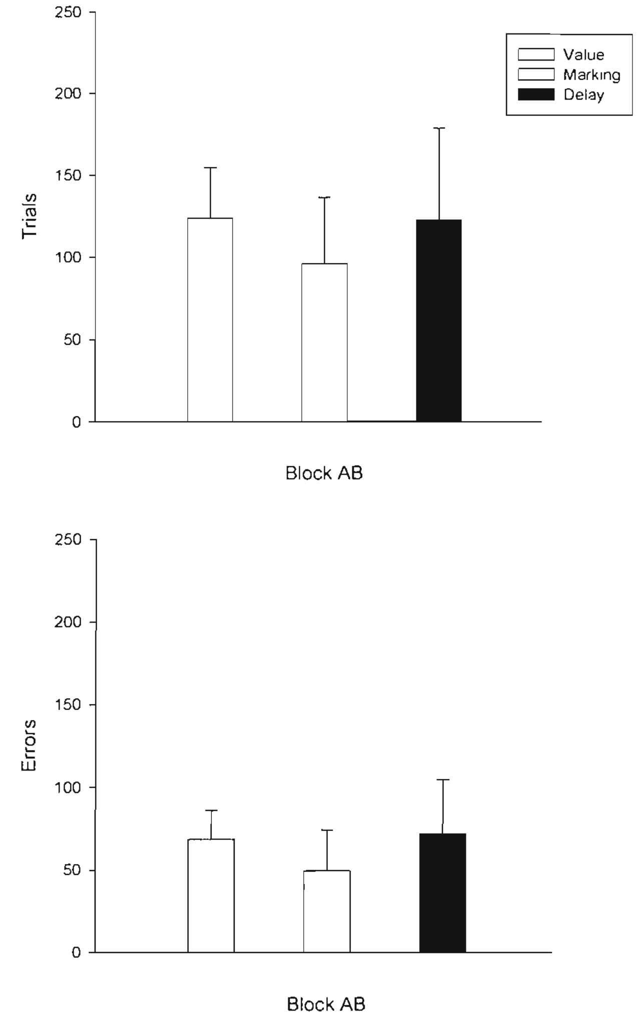


Figure 6-4. Mean trials and errors (+*SE*) in all conditions for participants who mastered block AB (Experiment Four).

6.1.3.3 Total trials and errors to termination of training for all participants on blocks AB and CD

Thirteen out of 30 participants (43%) were unable to reach criterion on both blocks AB and CD. Table 6-6 presents the means and standard deviations for trials and errors to termination of training (mastery or non acquisition after 45 minutes) for all participants, including non learners.

Condition		Trials to termination of training		Errors made until termination of training	
		Mean	SD	Mean	SD
Value	(n = 10)	171	29.6	96.9	22.26
Marking	(n = 10)	164.8	53.6	98.6	50.18
Delay	(n = 10)	177.2	39.2	81.1	24.19

Table 6-6. Means and standard deviations of trials to termination of training and errors for all participants on blocks AB and CD (Experiment Four)

A one-way analysis of variance was performed on these data. There were no differences on either number of trials to termination of training, F (2, 27) =.22, p = .8, or on errors made during training, F (2, 27) = .78, p = .47. Figure 6-5 shows the mean total trials and errors to termination of training for all participants on blocks AB and CD.

6.1.3.4 Trials to criterion and errors for blocks AB and CD

Seventeen out of 30 participants (57%) reached criterion for both blocks AB and CD. Table 6-7 presents the means and standard deviations of the trials to criterion and errors for the different conditions for both blocks AB and CD.

Condition		Trials to criterion		Errors	
		Mean	SD	Mean	SD
Value	(n = 7)	175.6	33.3	85.8	19.8
Marking	(n = 5)	122.6	26.1	57.4	17.2
Delay	(n = 5)	157.2	19.7	75.8	11.5

Table 6-7. Means and standard deviations for trials to criterion and errors across the different conditions for blocks AB and CD (Experiment Four).

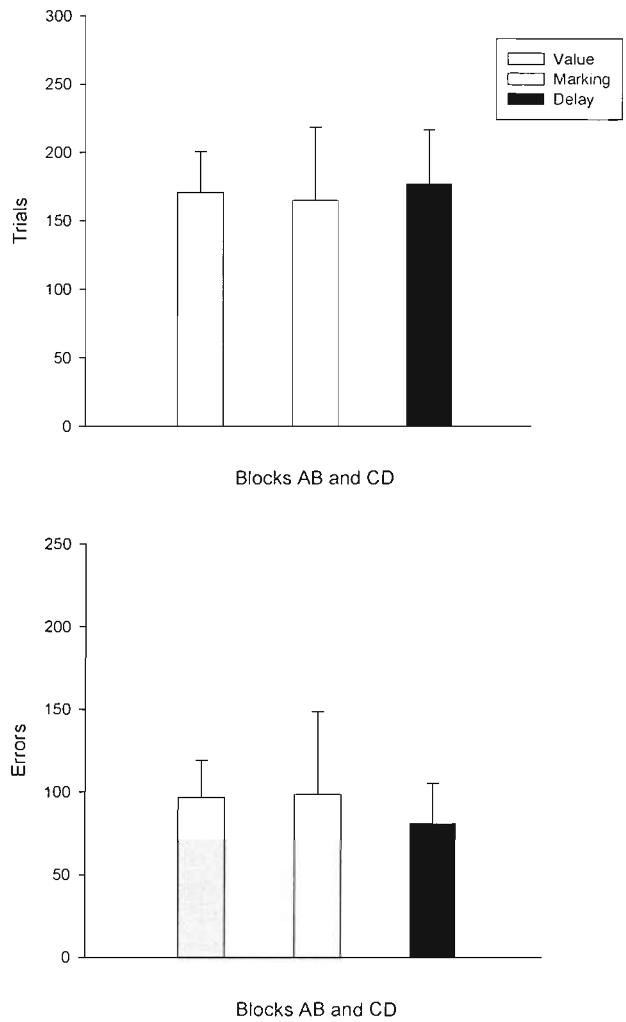


Figure 6-5. Mean total trials and errors (+*SE*) until termination of training for all participants on blocks AB and CD (Experiment Four).

A one-way analysis of variance showed significant differences between groups in the number of trials to reach criterion (F (2, 14) = 5.28, p = .02) and on errors made during learning (F (2, 14) = 3.94, p = .05). Tukey tests (α = .05) indicated faster acquisition in marking than in value and less errors in marking than in value. Figure 6-6 shows the mean number of trials required and errors made by participants who mastered both block AB and block CD.

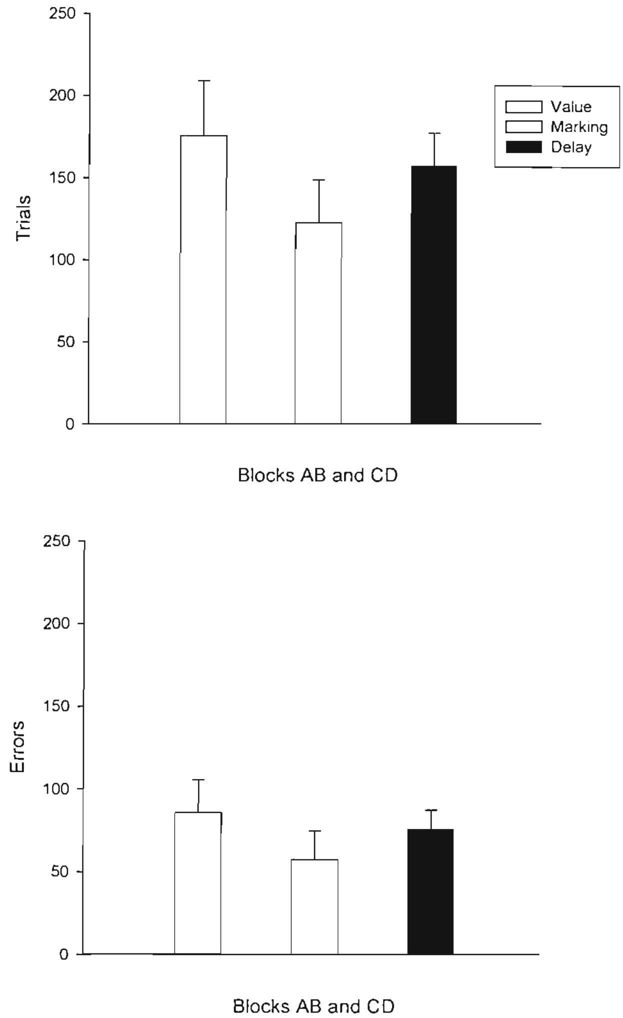


Figure 6-6. Mean trials and errors (+*SE*) in all conditions for participants who mastered blocks AB and CD (Experiment Four).

6.1.3.5 Post-Test

Most participants who reached criterion for both phases of training indicated in the post-test that they had used a high degree of stimulus naming to help them remember which pairs went together. Four of the symbols were given the same names by almost all of the participants that used a naming strategy (i.e., participants used normative naming for these symbols). Thus,

六 was usually referred to as 'man', 七 as 't', 三 as '(three) lines' and 十 as 'cross'. The majority of symbols, however, were given a wide variety of names by participants (i.e., participants used more idiosyncratic names). Thus, 入 was called 'lambda', 'hill', 'skirt', 'legs', 'slope' and 'upside down 'v''. Furthermore, participants who were able to complete the task often reported using intraverbal phrases during training to remember which pairs went together, for example, one participant reported thinking: "A 'man'(六) having a cup of 'tea' (七)" to remember A1B1, and "A 'person' (女) looking out of a 'window' (間)" to remember A6B6.

The second main finding of the post test was that participants who were unable to reach criterion, or who reached criterion after an above-average number of trials, often reported trying out positional strategies irrelevant to the task requirements. For example, some participants reported trying to match the number of right angles on shapes, or the number of lines, or indicated that they had thought that the correct comparisons followed a certain positional sequence. Table 6-8 presents the means and standard deviations for the number of names applied to the 40 symbols and the number of positional strategies used by all participants.

	Names		Strategies	
Condition	Mean	SD	Mean	SD
Value (n = 10)	15.6	14.06	3.4	1.4
Marking (n = 10)	20.1	18.5	1.6	2.3
Delay (n = 10)	24.6	12.2	2	2.1
Total	20.1	15.12	2.33	2.07

Table 6-8. Means and standard deviations for number of names applied to stimuli and number of positional strategies used (Experiment Four).

A one-way analysis was performed on this data. There were no differences between conditions on number of names used (F (2, 27) = < 1) or the number of positional strategies implemented (F (2, 27) = 2.26, p = .12). There was, however, a significant negative correlation between the mean number of trials to termination of training (mastery or non acquisition after 45 min) and the number of names used (r (28) = -.6, p < .005) and between the mean number of trials to reach criterion and the number of names used (r (15) = -.68, p < .003). A positive correlation between mean number of trials to termination of training and number of positional strategies used was also significant (r (28) = .276, p < .005) as was the positive correlation between the mean number of trials to criterion and number of positional strategies used (r (15) = .723, p < .001).

6.1.4 DISCUSSION

The clearest finding from this experiment was that there were no differences between marking and delay, and between value and delay for both trials to criterion and trials to termination of training data. This finding would not be expected based on the traditional conditioned value interpretation of response-contingent cues, where value at least would be expected substantially to increase learning over a delay (see Chapter One). For participants who did learn both blocks of symbols there was faster acquisition in marking than in value.

One possible explanation for these results is that the participants' behaviour was not under the control of the experimental variables, but instead, was controlled by self-produced cues which varied from participant to participant. This explanation is supported by consideration of the post-test data. These show that participants named over half of the experimental stimuli without instruction. This naming was correlated with more rapid learning of the matching-to-sample task. It seems plausible therefore that matching-to-sample learning was a product of verbal control through naming and that this powerful influence overwhelmed any potential function of the response-contingent cues.

Although participants simply had to remember which pairs went together, the written post-tests also identified that some participants overinterpreteted positional locations of comparison cues as a basis for the construction of complex rules to govern their selection of stimuli. Thus, a variety of positional strategies, irrelevant to learning the task, were employed by many participants (cf. Bruner & Revusky, 1961).

Participants who learned only block AB, or who learned block AB and CD after an above average number of trials, usually indicated that they had eliminated several positional strategies before realising that stimulus 'naming' was the more beneficial.

Participants, who were unable to learn either block of symbols, usually indicated that they had not realised that they needed only to remember which pairs went together and that naming could help them to do so. Thus, these two strategies were usually absent from their pool of potential solutions. It seems plausible therefore that the failure to learn the task was, for some participants, a product of verbal control through the formation of irrelevant non-associative strategies, again irrespective of any effects of the response-contingent cues.

The last section of the post-test asked participants to report any more relevant information that might have a bearing on how well they did in the task. Several participants who could not learn either AB or CD indicated that they thought that the task was impossible and had subsequently 'given up trying'. Participants also reported feeling "anxious" when they had a high frequency of errors, commenting particularly on the aversive characteristics of the buzzer noise that was paired with the word "WRONG" on incorrect trials.

In summary, therefore, the findings of Experiment Four strongly suggested that acquisition was substantially affected by participants' verbal behaviour during experimentation. Participants who learnt the matching-to-sample task usually used naming, whereas those who could not learn usually did not use naming or used ineffective positional strategies instead. Thus, learning may have occurred irrespective of any effects of the response-contingent cues.

6.2 EXPERIMENT FIVE

6.2.1 INTRODUCTION

The results of Experiment Four indicated that 43% of participants did not fully acquire the conditional matching-to-sample task within 45 min. For the remaining participants, marking was significantly more effective than value, but there were no other differences between the conditions. Participants who reached mastery used a high degree of stimulus naming; those that did not used ineffective positional strategies or failed to name the stimuli. Thus, naming and positional strategies may have overshadowed any effects of the response-contingent cues.

The results of Experiment Four, however, did not allow a decision to be made about which factor was crucial. Did forming positional strategies determine the speed of learning or was it the number of names attributed to stimuli? The next two experiments aimed to separate out these alternatives by controlling participants' use of positional strategies (Experiment Five) and naming (Experiment Six). To facilitate comparison, the procedural characteristics of Experiment Four, including stimuli used, were retained as far as possible. In Experiment Five, training blocks were also identical to those presented in Experiment Four. To discourage the use of positional strategies, however, participants received instructions which indicated more clearly that these strategies would not benefit them. Because the buzz presented following errors was reportedly aversive, auditory stimuli were removed leaving only visual cues to indicate the correctness of the response.

In Experiment Four, the prediction that learning would be slower in the delay condition was not supported, possibly because many participants learned at a low rate regardless of the condition they were in (i.e., the task was too difficult). To establish that delay alone had an impact on acquisition, an immediate reinforcement condition was included in Experiment Five.

6.2.2 METHOD

6.2.2.1 Participants

The participants were 44 students (5 males and 39 females), whose ages ranged from 18 to 37, with a mean age of 19.4 years. Participants were recruited and assigned to conditions as described in Experiment Four.

6.2.2.2 Apparatus and stimuli

Except for a slight change in written instructions (see below), the experimental setting, apparatus and stimuli were the same as Experiment Four.

6.2.2.3 Procedure

Instructions

For participants in the marking, value and delay conditions, the changes in instructions from Experiment Four are indicated in italics. Instructions for participants in the immediate condition excluded the text shown in parentheses.

> When the experiment begins, and at the start of each subsequent trial, you will see a symbol in the middle of the screen in front of you. Use the mouse to click on it. More symbols will now appear in the corners of the screen. Use the mouse to click on one of these. *Your task is to try to remember the symbols that always go together.* To help you, you will receive feedback for your choice (after a slight delay). If you are correct the word "CORRECT" will appear on the screen. If you are incorrect the word "WRONG" will appear on the screen. The first task ends when you get ten correct responses in a row. The computer will tell you when you have achieved this. Have a short rest if you like and then press 'continue' when you are ready to resume the experiment.
>
> In the second part of the experiment you will be shown different symbols but your task is again to try to get ten correct responses in a row. *Don't forget, you will learn the task most easily if you simply remember which symbols go together.* The computer will record your performance throughout and a message on the screen will tell you when the experiment is over. Please aim to complete the experiment as quickly and accurately as possible. There is a prize for the person who learns the task in the quickest time. When you are ready to start, please click on "Continue". Thank you for participating in this experiment. You are free to leave at any point."

Overview of training

The training procedure was identical to Experiment Four, except when the word "CORRECT" or "WRONG" appeared on the screen it was not accompanied by an auditory trill or a buzzing sound (for correct and incorrect responses respectively).

There were four conditions in this experiment, the value, marking and delay conditions, were as described for Experiment Four. In the *immediate* condition, the word "CORRECT" or "WRONG" was presented immediately after a choice response; that is, there was no 5 s delay in this condition. As in the other conditions, there was a 1 s interval between receiving reinforcement and the start of the next trial.

Post-test

Participants were also asked to complete the same post-test questionnaire as in Experiment Four.

6.2.3 RESULTS

Four groups of 11 participants took part in this experiment. The numbers of participants who could not master either block, who could master block AB, or who could master both blocks AB and CD are shown in Table 6-9.

	Training Blocks		
Condition	Neither AB or CD	AB	AB and CD
Value (n = 11)	6	5	3
Marking (n = 11)	1	10	9
Delay (n = 11)	1	10	7
Immediate (n = 11)	0	11	8
Total	**8**	**36**	**27**

Table 6-9. The number of participants from each condition who could not master either block, who could master block AB, or who could master both blocks AB and CD (Experiment Five).

6.2.3.1 Total trials and errors to termination of training for all participants on block AB

Eight out of 44 participants (18%) were unable to reach criterion on block AB.

Table 6-10 presents the means and standard deviations for trials to termination of training (mastery or non acquisition after 45 minutes) for all participants, including non learners.

	Trials to termination of training		Errors made until termination of training	
Condition	Mean	SD	Mean	SD
Value (n = 11)	137	45.6	72.5	39.2
Marking (n = 11)	106.1	43.1	69.1	31.8
Delay (n = 11)	103.1	46.3	57.8	33.5
Immediate (n =11)	147.7	43.8	82.1	28.1

Table 6-10. Means and standard deviations for total trials to termination of training and errors for all participants on block AB (Experiment Five).

A one-way analysis of variance was performed on these data. There were no differences on either number of trials to termination of training, F (3, 40) = 2.7, p = .06 (although this was just outside conventional significance), or on errors made during training, F (3, 40) = .41, p = .47. Figure 6-7 shows, for all participants, the mean number of trials and errors to termination of training for block AB.

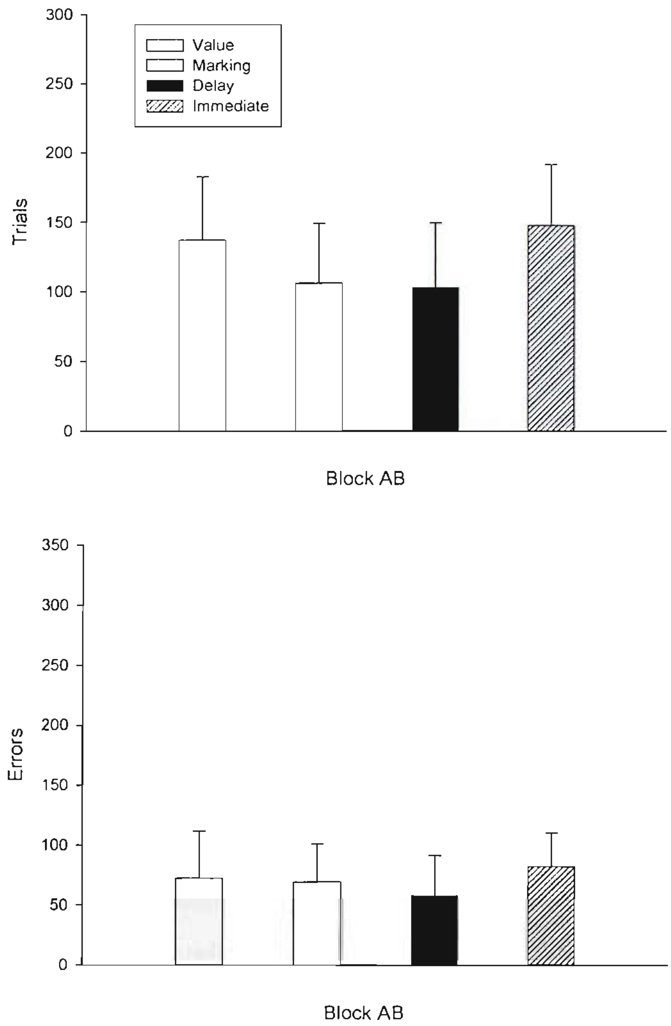


Figure 6-7. Mean total trials and errors (+*SE*) until termination of training for all participants on block AB (Experiment Five).

6.2.3.2 Trials to criterion for learners on block AB

As Experiment Four, few participants were able to learn both blocks AB and CD, particularly in the value condition, so trials to criterion for block AB only was compared across conditions. Thirty six out of 44 participants (82%) reached criterion on this block. Table 6-11 presents the means and standard deviations of the trials to criterion and errors for the different conditions.

		Trials to criterion		Errors	
Condition		Mean	SD	Mean	SD
Value	(n = 5)	96.2	19.4	33.2	7.1
Marking	(n = 10)	98.5	36.8	68.3	33.4
Delay	(n = 10)	99.3	46.9	52.7	30.4
Immediate	(n = 11)	147.7	43.8	82.1	28.1

Table 6-11. Means and standard deviations for trials to criterion and errors across the different conditions for block AB (Experiment Five).

The mean number of trials required and errors made by participants who mastered block AB are shown in Figure 6-8.

A one-way analysis of variance showed significant differences between groups in the number of trials to reach criterion (F (3, 32) = 3.78, p = .02) and on errors made during learning (F (3, 32) = 3.94, p = .02). Tukey tests (α = .05) showed slower acquisition in the immediate condition than in the value, marking and delay conditions. Owing to the large difference in variance in the error data, non-parametric post-hoc tests were performed. The Dunnet's C test (α = .05) showed more errors in the immediate than in the value condition, but there were no differences between the other conditions.

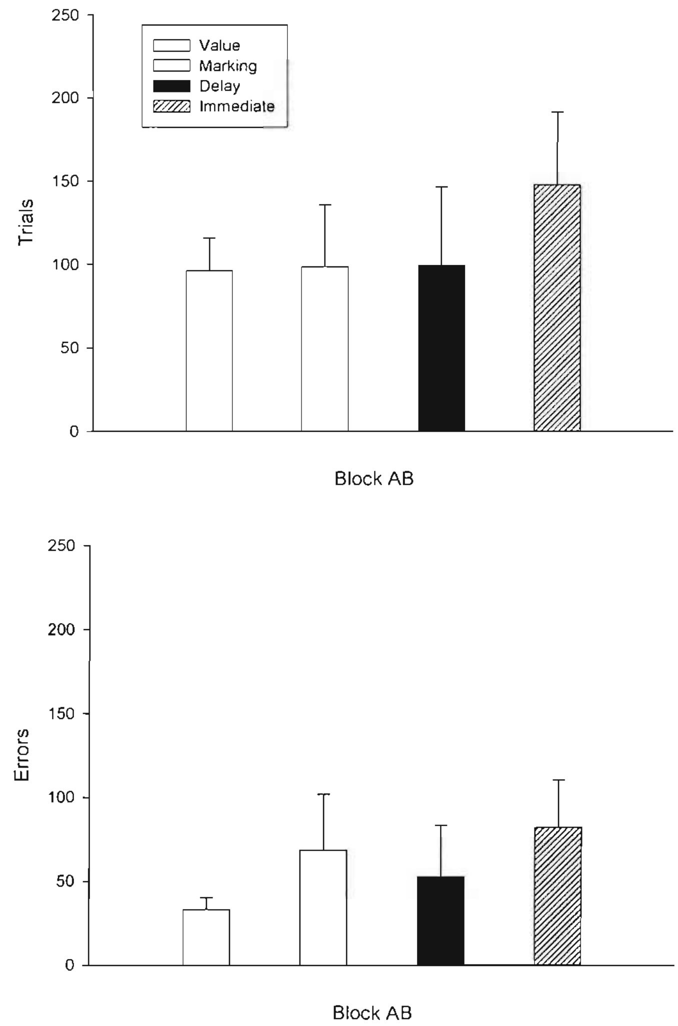


Figure 6-8. Mean trials and errors (+*SE*) in all conditions for participants who mastered block AB (Experiment Five).

6.2.3.3 Total trials and errors to termination of training for all participants on blocks AB and CD

Fourteen out of 44 participants (32%) were unable to reach criterion on both blocks AB and CD. Table 6-12 presents the means and standard deviations for trials and errors to termination of training (mastery or non acquisition after 45 minutes) for all participants, including non learners.

	Trials to termination of training		Errors made until termination of training	
Condition	Mean	SD	Mean	SD
Value (n = 11)	160.1	29.8	89.8	23.2
Marking (n = 11)	143.7	38.4	66.4	21.2
Delay (n = 11)	139.8	34.2	70.4	27.1
Immediate (n =11)	231	67.7	108.1	29.9

Table 6-12. Means and standard deviations for total trials and errors to termination of training for all participants on blocks AB and CD (Experiment Five).

A one-way analysis of variance was performed on these data. Regarding the total number of trials to reach criterion, the ANOVA was significant, $F(3, 40) = 9.78$, $p < .005$. There was no homogeneity of variance so a Dunnet's C post-hoc test was performed. This test ($a = .05$) revealed significant differences between the immediate and value condition, the immediate and marking condition, and the immediate and delay condition.

Regarding errors, the ANOVA was also significant, $F(3, 40) = 6.7, p < .002$. Scheffé tests showed significant differences between the immediate and the marking condition, and the immediate and the delay condition, but not between the immediate and value condition. Figure 6-9 shows, for all participants, the mean number of trials and errors to termination of training for blocks AB and CD

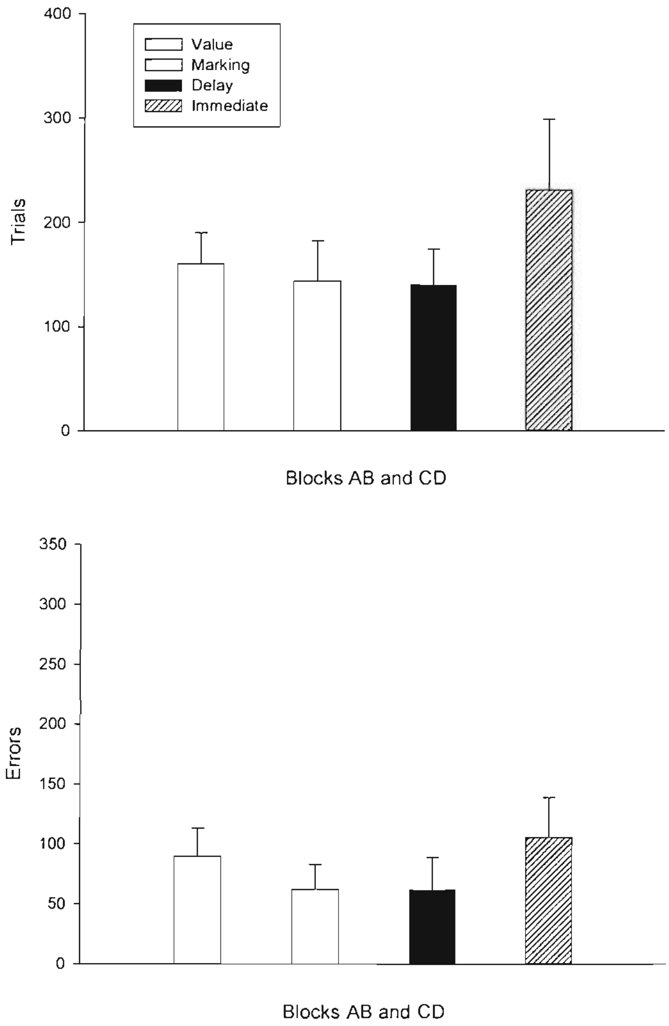


Figure 6-9. **Mean total trials and errors (+*SE*) until termination of training for all participants on blocks AB and CD (Experiment Five).**

6.2.3.4 Trials to criterion for learners on blocks AB and CD

Twenty seven out of 44 participants (61%) reached criterion for both blocks AB and CD. Table 6-13 presents the means and standard deviations for the trials to criterion and errors for these blocks.

	Trials to criterion		Errors	
Condition	Mean	SD	Mean	SD
Value ($n = 3$)	158	32.4	72	20.8
Marking ($n = 9$)	134.9	36.9	62.2	20.5
Delay ($n = 7$)	125.6	33.8	61.5	27
Immediate ($n = 8$)	212.4	64.2	105.4	33.1

Table 6-13. Means and standard deviations for trials to criterion and errors across the different conditions for block s AB and CD (Experiment Five).

Figure 6-10 shows the mean number of trials required and errors made by participants who mastered both block AB and block CD.

A one-way analysis of variance showed significant differences between conditions in the number of trials to reach criterion (F (3, 23) = 5.64, p = .005) and on errors made during learning (F (3, 23) = 4.84, p = .01). Tukey tests (α = .05) indicated faster acquisition in marking and delay than in the immediate condition. Participants in the marking, value and delay condition learnt at the same rate. Tukey tests (α = .05) also indicated more errors in the immediate than in the marking and delay conditions.

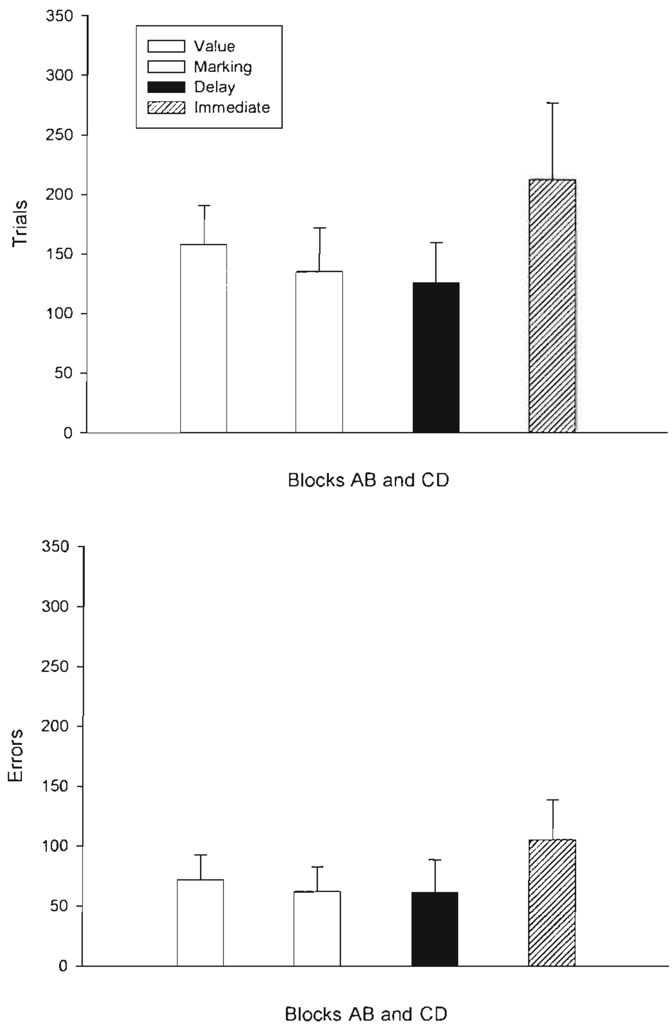


Figure 6-10. Mean trials and errors (+*SE*) in all conditions for participants who mastered blocks AB and CD (Experiment Five).

6.2.3.5 Post-test

The means and standard deviations for the number of names applied to symbols and number of positional strategies used are presented in Table 6-14. Naming continued to be beneficial for many participants, although most did not use positional strategies.

	Names		Strategies	
Condition	Mean	SD	Mean	SD
Value (n = 11)	10.6	8.6	0.2	0.6
Marking (n = 11)	21.9	13.7	0.1	0.3
Delay (n = 11)	21.9	11	0.1	0.3
Immediate (n =11)	16.9	11.7	0.4	0.7
Total (n = 44)	17.8	11.25	0.19	0.4

Table 6-14. Means and standard deviations for number of names applied to stimuli and number of positional strategies used (Experiment Five).

An ANOVA showed no differences between conditions on the number of names (F (3, 40) = 2.44, p = .08) or the number of positional strategies used (F (3, 40) < 1). For this experiment, the number of strategies did not correlate with the number of trials to termination of training (r (42) = .224, p = .144), or with the number of trials to reach criterion (r (25) = .05, p = .83). However, as Experiment Four, there was a significant negative correlation between number of names used and number of trials to termination of training (r (42) = -.36, p = .02) and between names and trials to criterion (r (25) = -.4, p = .04).

Independent-sample t tests were conducted to see if the use of strategies or names differed between Experiments Four and Five. Participants in Experiment Four (N = 30, M = 2.33, SD = 2.07) used more strategies than those in Experiment Five (N = 44, M = 0.19, SD = 0.4), t (30.4) = 5.62, p < .0001. Participants in Experiment Four (N = 30, M = 20.1, SD = 15.12) used about the same number of names as participants in Experiment Five (N = 44, M =17.84, SD = 11.93), t (52.5) = .67, p = .5.

6.2.4 DISCUSSION

In Experiment Five, four experimental conditions (marking, value, delay and immediate) were compared by using the same computerised matching-to-sample task as Experiment Four. Results showed that participants who met criterion for both blocks AB and CD, took significantly more trials to do so in the immediate condition than in the delay condition. This significant difference was also found when the trials to criterion measure included scores from non-learners. It is difficult to explain this finding in terms of traditional reinforcement theory, which would predict the opposite result (see Chapter One). Additionally, the superiority of marking over delay, reported in Experiment Four, was not replicated.

One explanation for the unexpected results is that either naming or the use of positional strategies again contributed to the results. The post-test data, however, revealed a considerable reduction in the use of positional strategies compared to Experiment Four, presumably because of the change in instructions. Task performance cannot therefore be interpreted as being a product of verbal control through using positional strategies.

Post-test data also revealed, however, that naming of stimuli continued to be associated with better matching-to-sample performance. When participants named the stimuli, learning again occurred more quickly and reliably than when participants did not name, making it possible that Experiment Five performance was a product of verbal control through naming. These results are in some ways consistent with the literature suggesting that a delay may have no effect when the interval is mediated by a verbalization (Brackbill & Kappy, 1962, Section 5.5). According to Brackbill and Kappy (1962), if participants covertly repeat or rehearse the names of stimuli during the delay interval, the classic effects of delay should not be expected. Brackbill and Kappy's findings do not, however, explain why participants in the immediate condition, who on average assigned 17 names to the experimental stimuli, performed less effectively than those who experienced a delay.

A limitation of this experiment was the absence in the immediate reinforcement condition of a control for the 5 s delay inherent in the other conditions. Thus, participants in the immediate condition were able to complete more trials in an experimental session than was possible in the other conditions. This could have contributed to the higher average score in that condition. To equate delay intervals across conditions, and thus to control for this factor, it was decided that for Experiment Six, a 5 s inter-trial interval would be added in the immediate condition.

Recall that the main aim of Experiment Four was to explore whether marking could facilitate learning with adult humans under conditions of delay. Experiments Four and Five, however, lacked an important prerequisite for studying marking: delay alone did not produce lower rates of acquisition than value (Experiments Four and Five) or immediate reinforcement (Experiment Five)-in fact the reverse was the case. Because learning may have been affected by participants' naming of stimuli, regardless of the condition they were in, Experiment Six aimed to reduce or eliminate naming altogether.

6.3 EXPERIMENT SIX

6.3.1 INTRODUCTION

The results of Experiment Four and Five showed that naming was strongly associated with matching-to-sample performance. If participants did not name stimuli, acquisition was usually delayed. These data contribute to the growing body of literature on how self-directed verbal behaviour can affect other forms of human operant behaviour so that it differs in fundamental respects from that of other animal species (e.g., Horne & Lowe, 1996; Lowe, 1983; Lowe, 1979). For example, animal performance on a FI schedule is typically characterised by a pause after reinforcement followed by an accelerated rate of responding which terminates at the next reinforcement (Ferster & Skinner, 1957). In humans, however, two main patterns of responding occur, neither of which resembles this pause-respond pattern. One is a *high-rate* pattern, which consists of a steady high response rate throughout each interval (e.g., De Casper & Zeiler, 1972) the other is a *low-rate* pattern, consisting of just one or two responses at the end of the inter-reinforcement interval (e.g., Lippman & Meyer, 1967).

Animals and adult humans also show dissimilarity, not only in their pattern of responding, but also in their sensitivity to changing schedule conditions. For example, Lowe (1983) reported that if human participants perform first on FR schedules, they typically produce high rates of responding which persist unaltered for many sessions even when the schedule is changed to FI. Animal performance, on the other hand, is usually not characterised by this behavioural 'rigidity' and is generally much more sensitive to changing schedule conditions.

Lowe (1979, 1983) has argued that it is adult humans' verbal capacity for describing and analyzing the experimental situation and reinforcement contingencies, to "self-tact" (Skinner, 1957, p.139), and to formulate rules for responding, that results in their schedule performance being so different from that of other animals. Thus, participants who respond only at a low rate on FI schedules of reinforcement typically state on post-experimental questionnaires that they counted out the interval before responding. Participants who respond at a high and steady rate, however, typically state that they thought more responses would earn them more reinforcement (Leander, Lippman, & Meyer, 1968; Lippman & Meyer, 1967).

The study of choice in concurrent schedules, however, is one area, where some similarities have been reported between animal and human performance (cf. Herrnstein, 1961, 1970). For example, Herrnstein (1970) proposed that when two programmed sources of reinforcement, A and B, are available independently and concurrently, pigeons will approximately match their relative rates of responding to the relative rates of reinforcement. Some studies have claimed that human performance on concurrent VI schedules is also characterised by this relation between rate of responding and rate of reinforcement (e.g., Bradshaw, Ruddle, & Szabadi, 1981).

In contrast with these results, however, a number of studies have failed to find animal-type matching behaviour in humans (e.g., Horne & Lowe, 1982; 1993; Silsberg, Thomas, & Berensden, 1991). For example, Horne and Lowe (1993) showed that not only did human participants fail to conform to the matching law but that they showed patterns of responding not previously encountered in animal studies of performance on concurrent schedules. These patterns of responding varied both between and within participants and were closely related to the different rules reported by the participants in their post-experimental questionnaires. Thus, these results seem to be in agreement with those studies of human performance on simple schedules, suggesting that rule-governed behaviour may be an important determinant of human choice.

According to the studies described thus far, reducing human participants' covert verbal behaviour, might lead to their responding to be governed more by experimental contingencies and hence more closely to resemble patterns characteristic of animal behaviour. There are, however, some experiments (e.g., Bradshaw, Ruddle, & Szabadi, 1981) which report that humans do respond in a similar way to animals on certain operant conditioning tasks.

One of the main purposes of Experiment Six therefore was to try to reduce or eliminate verbal behaviour, specifically the use of stimulus naming strategies. To this end, a class of stimuli with few easily nameable discriminative features was identified. These were photographs from a database of police cadets. All faces had similar hair length, hair colour, shape of face, skin colour, and so on, and all were photographed in a standard pose. It was hoped that these stimuli would be more difficult to name because of the absence of distinctive features such as moustaches, spectacles, unusual hair shape and so on. This procedural modification was based in part on a study by Courtois and Mueller (1981) who demonstrated that face recognition was poorer when either the target or distractor faces were similar with respect to the other faces encountered.

Because it was also expected that, without naming, participants would find each pair more difficult to learn than in the previous experiments they were required to learn only 2 sets of 6 pairs of faces compared to 2 sets of 10 pairs of kanji stimuli in

Experiment Four and Five. Experiment Six also added a 5 s inter-trial interval (ITI) to the immediate reinforcement condition. A delay of 5 s was therefore equated across all conditions, occurring either between each response and reinforcement (marking, value and delay) or between reinforcement and the start of the next trial (immediate). The procedural characteristics of the immediate condition compared to the delay condition are shown in Figure 6-11.

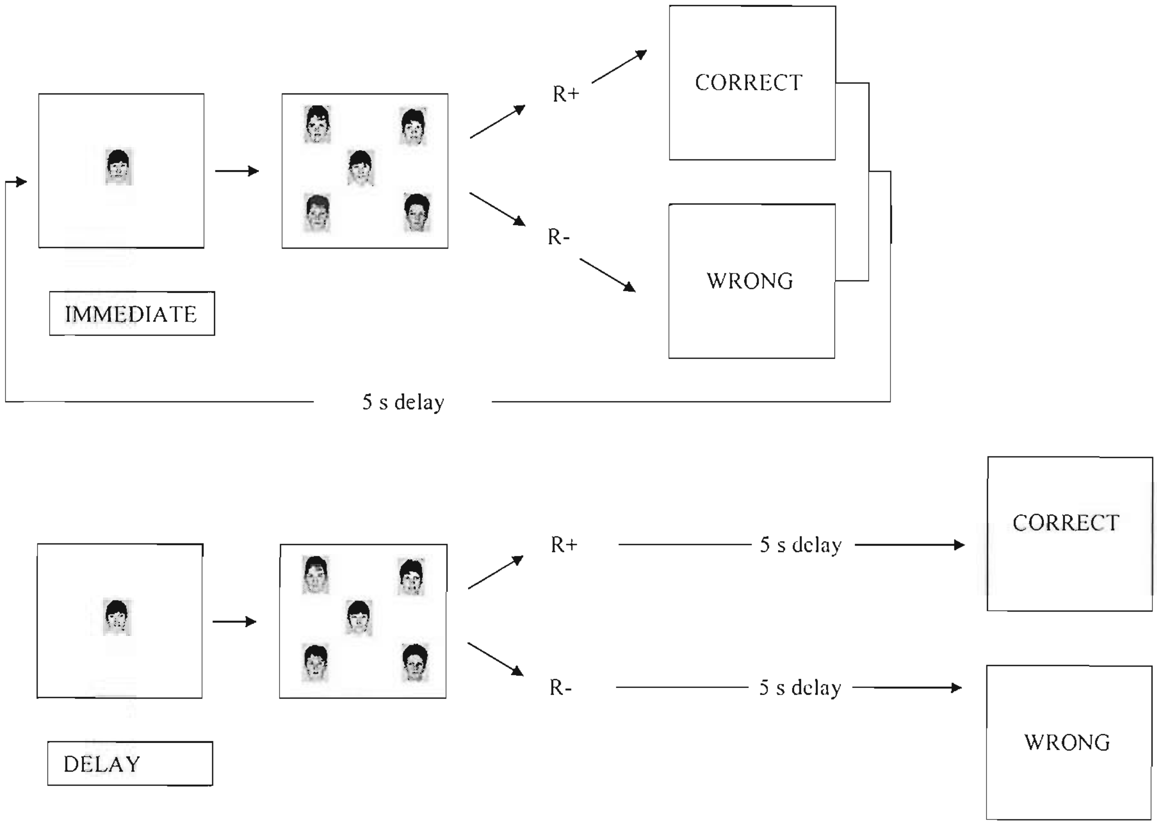


Figure 6-11. Procedural characteristics of the immediate and delay condition in Experiments Five and Six. In the immediate condition a 5 s inter-trial interval occurred between reinforcement and the start of the next trial. Thus, a delay of 5 s was equated across all conditions (see Figure 6-2).

In summary, the aim of Experiment Six was, through the removal of naming as a strategy, to gain access to more basic associative processes.

6.3.2 METHOD

6.3.2.1 Participants

The participants were 42 students (10 males and 32 females). Their ages ranged from 18 to 33, with a mean age of 21.2 years. Participants were recruited and assigned to conditions as Experiment Four and Five.

6.3.2.2 Apparatus and stimuli

The experimental setting and apparatus were as described previously. Stimuli were 12 pairs of photographs of faces, selected on the basis of their similarity to each other. They were taught in two blocks with six pairs in each (see Table 6-15). In the first block, the photographs were faces of policewomen. In the second block the photographs were faces of policemen. All participants were exposed to the same training stimuli throughout the experiment, regardless of their experimental condition.

6.3.2.3 Procedure

Instructions

Except that participants were told they would they be matching faces instead of symbols, instructions identical to those in Experiment Five were given.

Overview of training

In the immediate condition there was a 5 s ITI between the reinforcing stimulus and the start of the next trial but, to facilitate comparison with the findings of Experiment Five, all remaining procedural characteristics were retained.

Post-test

Participants were given a similar post-test questionnaire to the previous experiments, this time containing pictures of faces rather than kanji symbols.

Block AB		Block CD	
Sample	Correct Comparison	Sample	Correct Comparison
A1 	B1 	C1 	D1 
A2 	B2 	C2 	D2 
A3 	B3 	C3 	D3 
A4 	B4 	C4 	D4 
A5 	B5 	C5 	D5 
A6 	B6 	C6 	D6 

Table 6-15. Sample and correct comparison stimuli used during training for all conditions in Experiments Six and Seven.

6.3.3 RESULTS

Two groups of 10 participants and two groups of 11 took part in this experiment. The numbers of participants who could not master either block, who could master block AB, or who could master both blocks AB and CD are shown in Table 6-16.

Condition	Training Blocks		
	Neither AB or CD	AB	AB and CD
Value (*n* = 10)	1	9	8
Marking (*n* = 10)	1	9	9
Delay (*n* = 11)	0	11	11
Immediate (*n* = 11)	0	11	11
Total	**2**	**40**	**39**

Table 6-16. The number of participants from each condition, who could not master either block, who could master block AB, or who could master both blocks AB and CD (Experiment Six).

6.3.3.1 Total trials and errors to termination of training for all participants on blocks AB and CD

Because most participants learnt both sets of faces (*n* = 39, 89%) it was not considered necessary to compare total trials to termination of training for participants on block AB only. Table 6-17 presents the means and standard deviations for trials to termination of training (mastery or non acquisition after 45 minutes) for all participants, including non learners, on blocks AB and CD.

	Trials to termination of training		Errors made until termination of training	
Condition	Mean	SD	Mean	SD
Value (*n* = 10)	103.9	14.6	30.3	14.6
Marking (*n* = 10)	104	33.8	41.4	22.6
Delay (*n* = 11)	87.4	38.2	36.6	12
Immediate (*n* =11)	129	17	50.5	20.8

Table 6-17. Means and standard deviations for total trials and errors to termination of training for all participants on blocks AB and CD (Experiment Six).

A one-way analysis of variance was performed on these data. Regarding the mean number of trials to termination of training, the ANOVA was significant, $F\,(3, 38) = 2.91, p = .05$. Tukey tests ($a = .05$) showed that there were more trials in the immediate condition than in the delay condition. Regarding errors, the ANOVA was not significant, $F\,(3, 38) = 2.2, p = .11$. Figure 6-12 shows, for all participants, the mean number of trials and errors to termination of training for blocks AB and CD

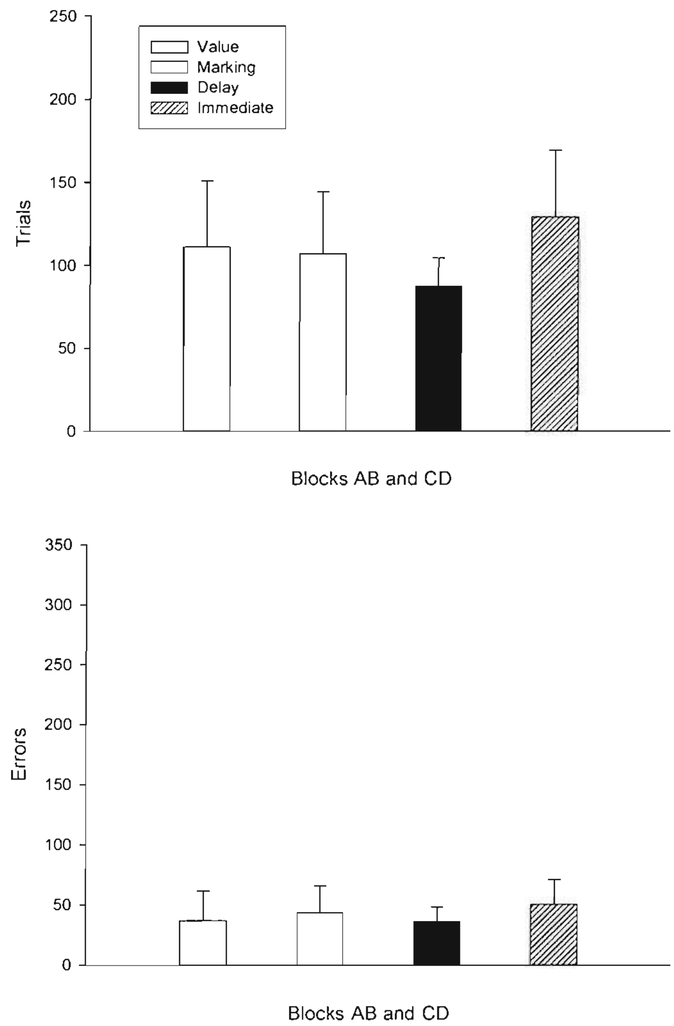


Figure 6-12. **Mean total trials and errors (+*SE*) until termination of training for all participants on blocks AB and CD (Experiment Six).**

6.3.3.2 Trials to criterion for learners on blocks AB and CD

Thirty nine out of 42 participants (89%) reached criterion on both blocks AB and CD. Table 6-18 presents the means and standard deviations for the trials to criterion and errors for these blocks.

		Trials to criterion		Errors	
Condition		Mean	SD	Mean	SD
Value	(n = 8)	95	30	30.25	14.6
Marking	(n = 9)	105.1	40.4	41.4	22.5
Delay	(n = 11)	87.4	17	36.6	11.9
Immediate	(n = 11)	129	40.1	50.5	20.8

Table 6-18. Means and standard deviations for trials to criterion and errors across the different conditions for block s AB and CD (Experiment Six).

Figure 6-13 shows the mean number of trials required and errors made by participants who mastered both block AB and block CD.

A one-way analysis of variance showed significant differences between conditions in the number of trials to reach criterion (F (3, 35) = 3.22, p = .034) but not on number of errors made during learning (F (3, 35) = 2.17, p = .12). Owing to the large differences in variance in the trials to criterion data, nonparametric post-hoc tests were performed. Dunnet's C tests (α = .05) indicated faster acquisition in the delay than in the immediate condition.

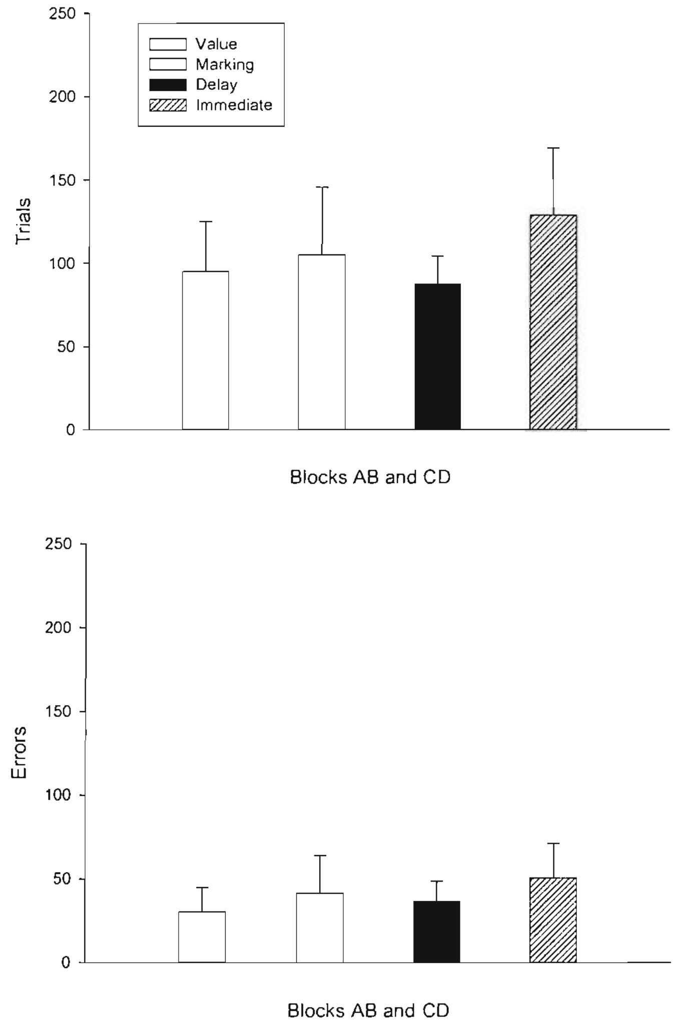


Figure 6-13. Mean trials and errors (+*SE)* in all conditions for participants who mastered blocks AB and CD (Experiment Six).

6.3.3.3 Post-test

None of the participants reported using strategies other than naming to learn the task. Table 6-19 shows the means and standard deviations for the number of names used.

Condition	Mean	SD
Value (n = 11)	18.3	6.9
Marking (n =11)	16.8	10.3
Delay (n = 11)	20.8	3.1
Immediate (n = 11)	19.1	6.8
Total	18.8	7.07

Table 6-19. Means and standard deviations for number of names applied to stimuli (Experiment Six).

A one-way analysis was performed on these data. There were no differences between conditions on number of names used (F (3, 38) < 1). However, as Experiment Four and Five, there was a negative correlation between number of names used and number of trials to criterion (r (37) = -.47, p = .002).

Independent-sample t tests were conducted to see if the use of names differed between Experiment Five and Six. Participants in Experiment Five (N = 44, M = 17.84, SD = 11.93) used on average about the same number of names as participants in Experiment Six (N = 42, M = 18.81, SD = 7.07), t (84) = -.46, p = .7.

6.3.4 DISCUSSION

As in Experiment Five, participants took fewer trials to learn the matching-to-sample task in the delay condition than in the immediate condition (for both trials to criterion and trials to termination of training data). This occurred despite the fact that delay intervals had been equated across conditions. The failure of delayed reinforcement to produce a significant decrease in acquisition rate compared to immediate reinforcement is inconsistent with much previous research (Chapter One).

Information from the post-test revealed that the change in stimuli had not achieved its purpose: participants still used naming strategies to help them remember which faces went together. In fact, overall, participants named 78% of the available stimuli, compared to only 45% in Experiment Five (although they only needed to name 24, not 40 as previously). Some participants assigned names corresponding to someone they knew who looked like the face in the photograph. Others used labels to describe the most distinctive features of the photographs (e.g., 'big ears'). Attaching verbal labels to faces in this way probably made the faces more distinctive, in that it served to direct attention to specific facial features during viewing (e.g., Groeger, 1997). Naming, therefore, appeared to continue to overshadow the effects of the response-contingent cues.

The aim of Experiment Six was to reduce naming by using stimuli which would be difficult to name. Unfortunately, this change in procedure did not attenuate the persistence of naming so the classic effects of delay were still not found. To achieve this, another way to reduce naming would be to use a secondary interference task. Laties and Weiss (1963) used a concurrent subtraction task to reduce counting out the intervals on a FI schedule of reinforcement, and this produced a pattern of responding very similar to that observed with animals. This use of a secondary interference task, designed to interfere with covert naming during the delay interval, was the method chosen for Experiment Seven. This final procedural variation might reveal more fundamental associative processes by removing the interfering effects of higher order verbal strategies.

6.4 EXPERIMENT SEVEN

6.4.1 INTRODUCTION

The results of Experiment Six showed that, as in Experiment Five, participants took more trials to meet criterion on the matching task in the immediate condition than in the delay condition. Furthermore, participants' naming of the visual stimuli continued to facilitate learning. The main purpose of Experiment Seven was therefore to try once again to reduce naming. To this end, the same experimental stimuli were used as Experiment Six but participants were now asked to perform a secondary verbal interference task (counting backwards in threes), during the delay interval.

It was hypothesised that the effect would be similar to that of articulatory suppression (Baddeley, 1996) which typically requires the participant to generate repetitive speech, thus preventing rehearsal of previously attended material. It was intended that the verbal interference task in this experiment would prevent the participants' from rehearsing the names, and that, by reducing rule-governed behaviour, human sensitivity to the effects of the nonverbal operant contingency would be improved. A similar effect was found by Svartdal (1992) who showed that contingency governed behaviour in humans was increased when verbal and attentional control were diverted from the critical contingency (i.e., participants thought that outcomes depended on accuracy on a discrimination task when in fact they depended on the force of pressing response keys).

It was hypothesised that because naming would be reduced in this experiment compared to previous experiments, that fewer trials would be required to meet criterion in the immediate condition than in the other conditions. It was further predicted that the secondary task would reduce participants' overall performance in comparison with those in Experiment Six.

6.4.2 METHOD

6.4.2.1 Participants

The participants were 60 students (5 males and 55 females), who received no payment for their participation. Their ages ranged from 18 to 23, with a mean age of 19.4 years.

6.4.2.2 Apparatus and stimuli

Except for a change in instructions (see below), the experimental setting, apparatus, photographs of faces and post-test booklet were that as described in Experiment Six.

6.4.2.3 Procedure

Instructions

Apart from the inclusion of a paragraph to explain the secondary interference task, the instructions were the same as Experiment Six. The instructions read as follows and differences between conditions are indicated in italics:

In the delay and marking condition:

> At the start of each delay the experimenter will call out a random number. Your task is to count backwards in threes from that number *until the word "CORRECT" or "WRONG" appears on the screen.* Keep looking at the computer screen while you are counting.

In the immediate condition:

> At the start of each delay the experimenter will call out a random number. Your task is to count backwards in threes from that number *until the picture of the face for the next trial appears on the screen.* Keep looking at the computer screen while you are counting.

In the value condition:

> At the start of each delay the experimenter will call out a random number. Your task is to count backwards in threes from that number *until either a red square or the word "WRONG" appears on the screen.* Keep looking at the computer screen while you are counting.

Overview of training

The procedure for the four conditions was identical in most respects to that in Experiment Six except that the experimenter called out a random number during the delay and participants were required to count backwards in threes from that number, announcing their numbers aloud. The random numbers, ranging from 12-100, were chosen before the experiment began and used, in the same order, for all relevant conditions.

In the marking condition, the experimenter called out a random number immediately after each marking stimulus appeared on the screen, in the value condition immediately after the R- choice response, or after the first value stimulus (red square) for R+; in the delay condition immediately after both R+ and R-, and in the immediate reinforcement condition immediately after the word "CORRECT" or "WRONG".

Participants counted backwards from the random number until either the S^R (i.e., the reinforcing stimulus) appeared (for marking, delay and value R-), the second value stimulus (for value R+), or the beginning of the next trial (for immediate). Thus participants were required to count backwards in threes for 3 s in the value condition for R+ and 4 s in the value condition for R-, 4 s in the marking condition and 5 s in the delay and immediate reinforcement condition. Participants in all conditions were asked to stay looking at the screen while they were counting to increase the likelihood that they would be looking at the screen when relevant stimuli (e.g., reinforcement, response-contingent cues) appeared (e.g., Erickson & Lipsitt, 1960).

Post-test

Participants were given the same post-test questionnaire as Experiment Six.

6.4.3 RESULTS

Four groups of 15 participants took part in this experiment. The numbers of participants who could not master either block, who could master block AB, or who could master both blocks AB and CD are shown in Table 6-20.

	Training Blocks		
Condition	Neither AB or CD	AB	AB and CD
Value (*n* = 15)	1	14	9
Marking (*n* = 15)	5	10	9
Delay (*n* = 15)	4	11	7
Immediate (*n* = 15)	4	11	7
Total	**14**	**46**	**32**

Table 6-20. The number of participants from each condition who could not master either block, who could master block AB, or who could master both blocks AB and CD (Experiment Seven).

6.4.3.1 Total trials and errors to termination of training for all participants on block AB

Fourteen out of 60 participants (23%) were unable to reach criterion on block AB. Table 6-21 presents the means and standard deviations for trials and errors to termination of training (mastery or non acquisition after 45 minutes) for all participants, including non learners.

	Trials to termination of training		Errors made until termination of training	
Condition	Mean	SD	Mean	SD
Value (n = 15)	79.7	26.3	37.1	17.3
Marking (n = 15)	84.9	34.2	45.7	28.4
Delay (n = 15)	119.9	39.2	58.9	24.8
Immediate (n = 15)	101.5	47.3	50.9	33.6

Table 6-21. Means and standard deviations for total trials to termination of training and errors for all participants on block AB (Experiment Seven)

Because this data did not meet the requirements for parametric testing, non-parametric tests were performed. The Kruskal-Wallis test showed significant differences between conditions in the total number of trials to termination of training, χ^2 (3, N = 60) = 8.9, p = .03, but not on errors made during training, χ^2 (3, N = 60) = 4.8, p = .19. Mann Whitney U tests showed more trials in delay than in value (U = 42.5, p = .005), and more in delay than in marking (U = 63, p = .04), but not more in delay than in immediate (U= 85.5, p = .27). There were no differences in total trials to termination of training between the other conditions. Figure 6-14 shows, for all participants, the mean number of trials and errors to termination of training for block AB.

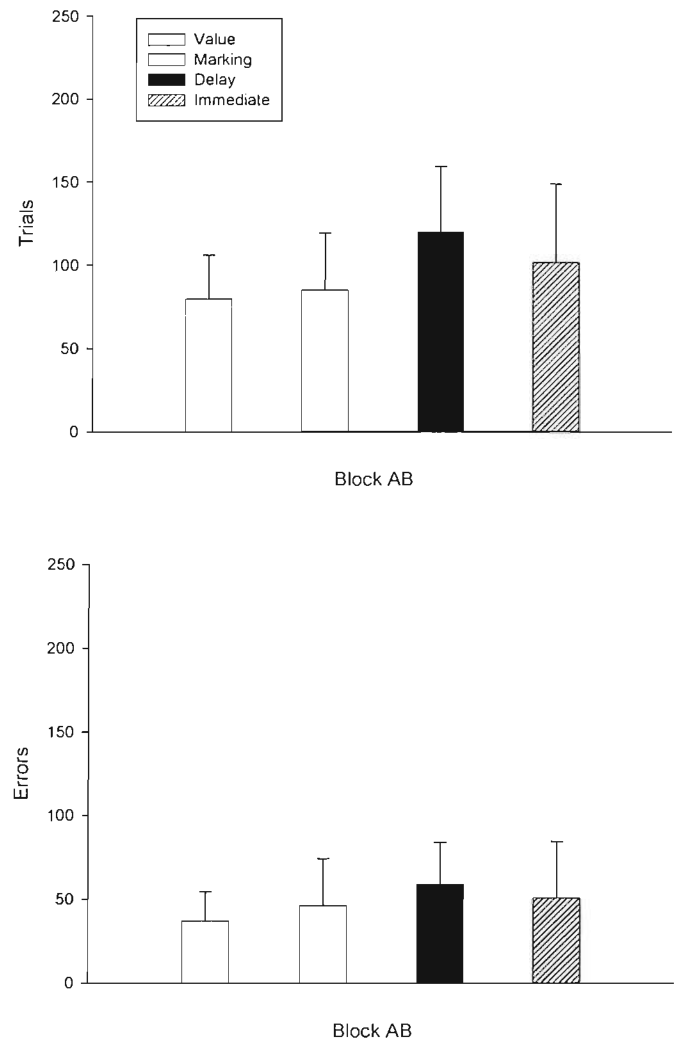


Figure 6-14. **Mean total trials and errors (*+SE)* until termination of training for all participants on block AB (Experiment Seven)**

6.4.3.2 Trials to criterion for learners on block AB

Forty six out of 60 participants (77%) reached criterion on block AB. Table 6-22 presents the means and standard deviations of the trials to criterion and errors for this block.

	Trials to criterion		Errors	
Condition	Mean	SD	Mean	SD
Value (n = 14)	76	23	35.4	16.1
Marking (n = 10)	65.6	23.2	28.2	12.5
Delay (n = 11)	107.9	32.4	47.7	16.3
Immediate (n = 11)	88.7	47.8	40	29.5

Table 6-22. Means and standard deviations for trials to criterion and errors across the different conditions for block AB (Experiment Seven).

A one-way analysis of variance showed significant differences between conditions in the number of trials to reach criterion (F (3, 42) = 3.56, p = .03) but not on errors made during learning (F (3, 42) = 1.88, p = .15). Tukey tests (α = .05) showed faster acquisition in marking than in delay. There were no differences in rate of acquisition between the other conditions.

The mean number of trials required and errors made by participants who mastered block AB are shown in Figure 6-15.

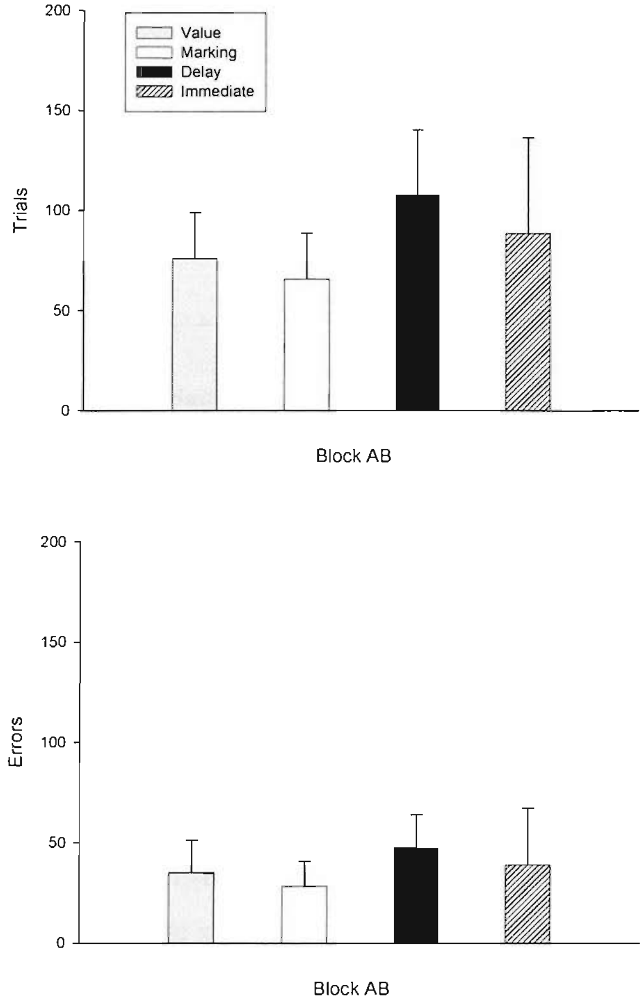


Figure 6-15 **Mean trials and errors (+*SE*) in all conditions for participants who mastered block AB (Experiment Seven).**

6.4.3.3 Total trials and errors to termination of training for all participants on blocks AB and CD

Twenty eight out of 60 participants (47%) were unable to reach criterion on both blocks AB and CD. Table 6-23 presents the means and standard deviations for trials and errors to termination of training (mastery or non acquisition after 45 minutes) for all participants, including non learners.

	Trials to termination of training		Errors made until termination of training	
Condition	Mean	SD	Mean	SD
Value (n =15)	126.4	30.2	54.7	17.1
Marking (n =15)	123.4	32.7	61.5	22.4
Delay (n =15)	161.9	40.3	77.9	28.2
Immediate (n =15)	126.3	28.5	57.3	28.9

Table 6-23. Means and standard deviations for total trials to termination of training and errors for all participants on blocks AB and CD (Experiment Seven).

Again this data did not meet the requirements for parametric testing, so non-parametric tests were performed. The Kruskal-Wallis test showed significant differences between conditions in the total number of trials to termination of training, χ^2 (3, N = 60) = 9.2, p = .03, but not on errors made during training, χ^2 (3, N = 60) = 6.8, p = .07. This was, however, just outside the conventional level of significance. Mann Whitney U tests showed more trials in delay than in value (U= 55.5, p = .02), more in delay than in marking (U= 56, p = .02), and more in delay than in immediate (U= 50, p = .009). There were no differences in total trials to termination of training between the other conditions. Figure 6-16 shows, for all participants, the mean number of trials and errors to termination of training for blocks AB and CD.

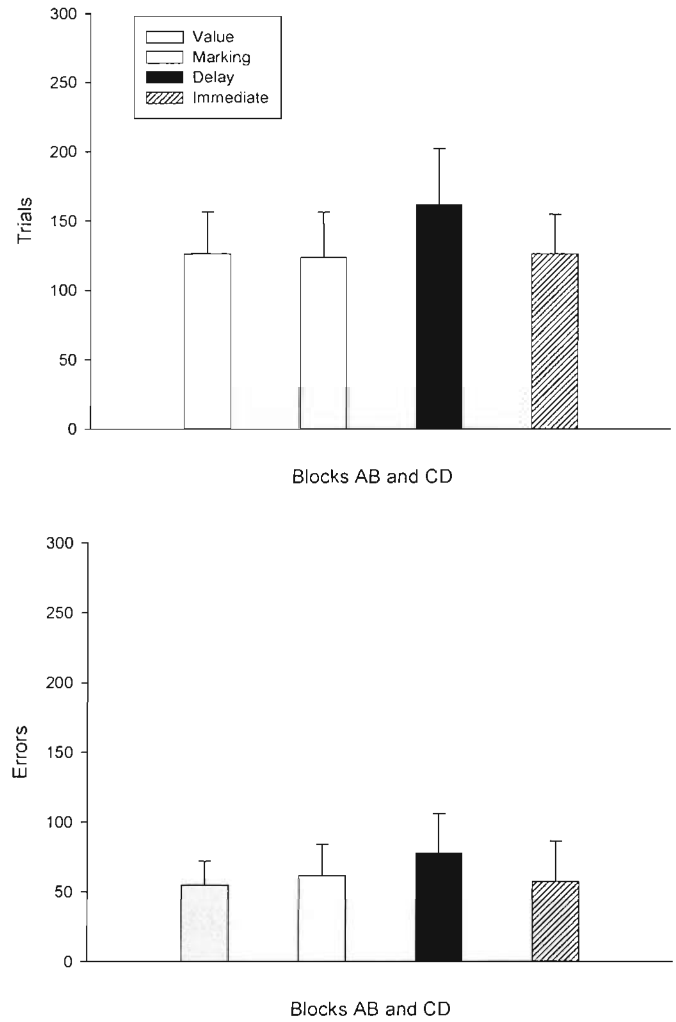


Figure 6-16 **Mean total trials and errors (+*SE*) until termination of training for all participants on blocks AB and CD (Experiment Seven)**

6.4.3.4 Trials to criterion for learners on blocks AB and CD

Thirty two out of 60 participants (53%) reached criterion on both blocks. Table 6-24 presents the means and standard deviations for the trials to criterion and errors for these participants.

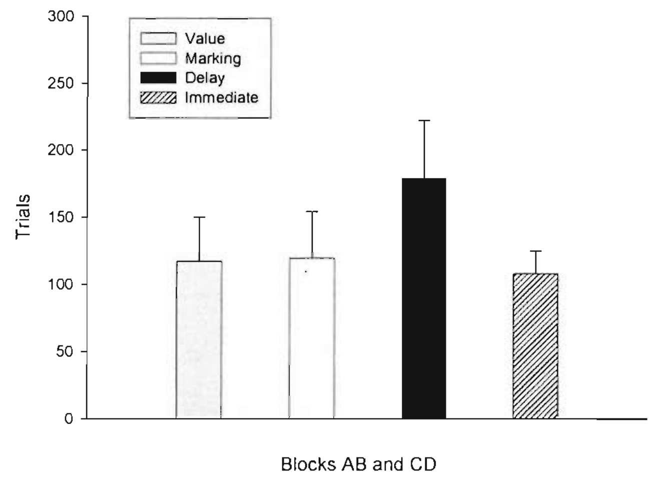
	Trials to criterion		Errors	
Condition	Mean	SD	Mean	SD
Value ($n = 9$)	117	32	47.4	17.5
Marking ($n = 9$)	119.2	34.8	50.2	20.2
Delay ($n = 7$)	179	43.1	81.4	34.2
Immediate ($n = 7$)	108	16.8	41.4	18.4

Table 6-24. Means and standard deviations for trials to criterion and errors across the different conditions for block s AB and CD (Experiment Seven).

The mean number of trials required and errors made by participants who mastered both block AB and block CD are shown in Figure 6-17.

A one-way analysis of variance showed significant differences between conditions in the number of trials to reach criterion (F (3, 28) = 6.8, p = .001) and on errors made during learning (F (3, 28) = 4.32, p = .013). Tukey tests (α = .05) showed slower acquisition in the delay condition than in the other conditions. Regarding errors, Tukey tests showed more errors in the delay condition than in the immediate and value conditions.

The trials to criterion data were also subjected to mixed design analyses of variance, where the between-participant factor was condition (marking, value, delay and immediate) and the within-participant factor was training block (AB, CD). Regarding the number of trials required to meet criterion, there was a significant main effect of condition, F (3, 29) = 7.35, p = .001, but not a significant main effect of training block, F (1, 29) = 2.3, p > .05. The Condition x Training block interaction was also not significant, F (3, 23) = .23, p > .05.



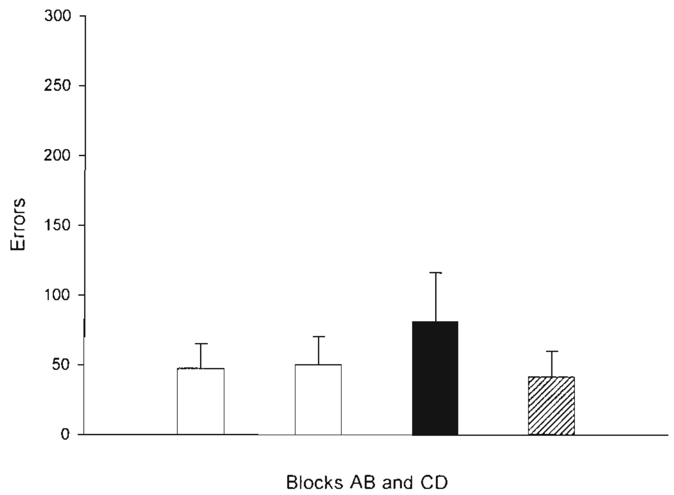


Figure 6-17. Mean trials and errors (+*SE*) in all conditions for participants who mastered both block AB and block CD (Experiment Seven).

6.4.3.5 Response latencies

It is possible that some participants may have paused longer before choosing, and that this extra exposure to the discriminative stimuli may have contributed to differences in rate of learning between the conditions (see Section 2.2.2). Participants' response latencies are shown in Table 6-25.

Condition	Mean	SD
Value (n = 15)	5.1	1.1
Marking (n = 15)	4.8	1.4
Delay (n = 15)	4.7	1.4
Immediate (n = 15)	5.1	1.9

Table 6-25. Means and standard deviations for response latencies (seconds).

Participants' mean response latencies did not allow differentiation between the conditions, F (3, 56) < 1. A negative correlation between mean number of trials to termination of training and mean response latencies, however, was significant (r (58) = -.34, p = .008) as was the negative correlation between the mean number of trials to reach criterion (for those participants who did so) and mean response latencies (r (30) = -.421, p = .02).

An independent-samples t test was conducted to see if participants who mastered blocks AB and CD had longer response latencies than those who did not. The t test for equal variances was not significant, t (58) = 1.2, p = .25.

Independent-sample t tests were conducted to see if mean response latencies differed between Experiments Six and Seven. Participants in Experiment Six (N = 42, M = 3.8, SD = .76) had on average shorter response latencies than participants in Experiment Seven (N = 60, M = 4.94, SD = 1.45), t (100) = 4.66, p = .003.

6.4.3.6 Post-test

None of the participants reported using strategies other than naming to learn the task. The means and standard deviations for the number of names used for the 24 faces are shown in Table 6-26.

Condition	Mean	SD
Value (*n* = 15)	13.3	8.3
Marking (*n* = 15)	12.9	8.2
Delay (*n* = 15)	8.7	7.5
Immediate (*n* = 15)	9.2	9.4
Total	11.04	8.43

Table 6-26. Means and standard deviations for number of names applied to stimuli (Experiment Seven).

There were no differences between conditions on the number of names used, F (3, 56) = 1.22, p = .31. In addition, participants indicated that they named the stimuli when they were on the computer screen, but not during the delay when they were distracted by the verbal interference task.

As previous experiments, there was a negative correlation between number of names used and number of trials to termination of training (r (58) = -.26, p = .05). However, a correlation between the mean number of trials to criterion for those who reached it in 45 minutes or less and the number of names used was not significant, r (30) = -.12, p = .46.

An independent-sample t test was conducted to see if the use of names differed between Experiments Six and Seven. Participants in Experiment Six (N = 42, M =18.81, SD = 7.06) used more names than those in Experiment Seven (N = 60, M = 11.03, SD = 8.43), t (100) = 4.9, p < .005.

6.4.4 DISCUSSION

The most important finding of Experiment Seven was that participants in the delay condition took significantly more trials to learn the matching-to-sample task than those in the other three conditions (for both trials to criterion and trials to termination of training data). Furthermore, the trials to criterion in the marking and value conditions did not differ from those in the immediate reinforcement condition. Thus, this study appears to show a beneficial effect of marking stimuli in adult human participants.

One explanation for these findings is that the incidence of stimulus naming was substantially reduced from the previous experiment (46% of stimuli were named in

Experiment Seven compared to 78% in Experiment Six) and that this suppression of covert verbal behaviour allowed more basic associative learning processes to act. That naming occurred at all was initially surprising. Possibly the secondary interference task was not enough to prevent all participants from rehearsing names during the delay: perhaps some participants were able to rehearse the names and count backwards simultaneously. One way of exploring this hypothesis further would be to assess how accurately participants counted backwards. If participants shifted between rehearsal and counting activities, their accuracy on the secondary interference task might be reduced compared to those who simply counted. Unfortunately, no such data were collected in this study.

A second possibility is that participants were unable to rehearse names during the delay, but instead developed an alternative way to make use of naming. Research by Lowe (1979) is relevant here. He investigated the effects on FI performance when subjects were required to perform a concurrent task which interfered with covert counting behaviour. Participants were asked to repeat a series of random numbers presented, at varying speeds, through participants' head phones. Most reported that the concurrent task prevented counting behaviour, but some developed alternative behaviours, such as counting on fingers, to help estimate the interval.

The post-test data indicated that participants had developed an alternative strategy to that used in previous experiments. Many reported that they had assigned and rehearsed names when the faces were on the computer screen before selecting a comparison stimulus because the counting task prevented them from rehearsing the names throughout the delay. The increased response latencies in Experiment Seven compared to Experiment Six also seems to support this conclusion. Interestingly, participants who acquired the matching-to-sample in the shortest number of trials generally had higher response latencies than those who took more trials.

It is also worth considering whether response latency could account for the differences between conditions in Experiment Seven. For example, participants in the immediate, value and marking conditions might have taken fewer trials to reach criterion than in the delay condition, because they had longer latencies. Perhaps, they spent more time looking at the photographs on the screen than in the delay condition. An ANOVA, however, was unable to differentiate between the conditions.

It is also possible that the shadowing task had a more detrimental effect on learning during block AB than during CD. Participants may have performed better on block CD than AB because by then they had had more practice on the subtraction task and had realised that they could name stimuli when the faces were on the screen. The results from the mixed design do not, however, support this hypothesis because there were no significant differences in trials to criterion for the different training blocks.

A possible limitation of this experiment was that there was no control in the value and marking conditions for the 5 s of counting backwards inherent in the immediate and delay conditions. Instead, participants in the value and marking conditions counted backwards for 3 or 4 s. This was considered necessary so that participants could attend fully to the response-contingent stimuli on the screen rather than counting. It could therefore be argued that participants might have taken more trials to reach criterion in the marking and value conditions than in the immediate condition because rehearsal was blocked for 5 s in the immediate condition compared to only 3 and 4 s in the value and marking conditions, respectively. According to this hypothesis, however, there should also have been *less* interference (and hence faster learning) in the value condition than in the marking condition because rehearsal was blocked for longer in the latter. There were, however, no significant differences in trials to criterion between the marking and value conditions.

The results from Experiment Seven show that a verbal interference task inserted during a delay interval can significantly affect acquisition of conditional discrimination matching-to-sample performance with delayed reinforcement. It seems likely that the effect of the shadowing task relies on its interfering with the ability to use naming strategies during the delay. The present experiment also indicates, however, that to eliminate covert naming effectively, it is not enough to prevent rehearsal during the delay: If participants can control their exposure to the to-be-named stimuli as in matching-to-sample studies, naming and rehearsal can still occur at other points during the trial.

In sum, Experiment Seven supported traditional understanding that inserting a delay between a response and a reinforcer can substantially reduce learning compared to when reinforcement is immediate. This detrimental effect can, however, be alleviated by inserting response-contingent cues, functioning as either conditioned reinforcers or as marking stimuli, during the delay.

6.5 MAIN DISCUSSION

A dominant theme of the present set of experiments has been that adult participants' verbal behaviour can influence their acquisition of a matching-to-sample conditional discrimination task with delayed reinforcement. As such, a systematic attempt was made in this series of experiments to establish 'pure' contingency control which was not influenced by any verbal factors. Taking the four experiments together, the results show that the effects of delay and response-contingent cues has no discernible effect when adult participants can mediate the temporal interval by using verbal strategies (cf. Brackbill & Kappy, 1962, Section 5.5): both naming and positional strategies affected performance, the former improving it and the latter undermining it. When these verbal cues were absent, adult humans learned in a manner more reminiscent of that seen with non-human animals (e.g., Williams, 1994a) or with children with autism (Experiment One).

One source of participants' verbal behaviour was shown to be the instructions provided by the experimenter (cf. Catania, 1981; Shimoff, Catania, & Matthews, 1981). Experiments Four and Five demonstrated that the experimental instructions determined whether participants used naming or positional strategies. When the best way to learn the task was not made explicit (Experiment Four), participants typically developed complicated positional strategies to try to account for the relationship between the sample and comparison stimuli. When the instructions proscribed them (Experiment Five), however, more participants adopted other approaches (i.e., naming).

The evidence in support of these sources of verbal behaviour comes from the participants' retrospective reports, in response to a post-experimental questionnaire. It has frequently been pointed out, however, that this type of evidence may be problematic, particularly because the rules articulated in post-experimental reports might not have been operative during the experiment and might be a *post-hoc* rationalization rather than an accurate description of what actually happened in the experimental situation (e.g., Perone, 1988). In addition, it has been suggested that participants might not be able or willing to describe the determinants of their behaviour (cf., Nisbett & Wilson, 1977). Thus, one limitation of using post-experimental verbal reports may be the ambiguity of the interpretations that can be attributed to the participants' responses.

It is important to note, however, that the self-report data were the only feasible means of monitoring participants' covert verbal behaviour. Furthermore, the validity of their accounts was generally consistent with other data in that acquisition performance was in accord with participants' use of naming. The introduction of the verbal interference task in Experiment Seven further supported the proposition that naming affected participants' learning. The use of a shadowing task throughout the delay disrupted naming for many, and this seemed to be responsible for producing more purely associative effects. Future research, however, is needed to compare, within the same experiment, the effects of using a shadowing task during a delay with a delay only condition.

7. DISCUSSION

7.1 INTRODUCTION

There is a considerable research literature detailing how delays in the delivery of reinforcement can undermine learning and performance. Researchers have also identified that response-contingent cues inserted during the delay interval can usually attenuate such detrimental effects (see Chapter One). The knowledge accumulated over several decades of experimentation and discussion has led most researchers and practitioners to conclude that such response-contingent cues function as conditioned reinforcers. More recently, however, another body of evidence has emerged suggesting that a response-contingent cue presented after both correct and incorrect responses in discrimination learning procedures can facilitate learning and that the effect cannot be explained in terms of conditioned reinforcement. This idea, response marking, has been shown to establish accurate discrimination performance in rats and pigeons when primary reinforcement is delayed (see Chapter Two). Relatively few studies, however, have explored this phenomenon with human participants.

The aim of this thesis was to explore how marking procedures would affect human learning when reinforcement is delayed. To this end, the two streams of experimentation reported here examined the effects of marking on conditional discrimination learning with delayed reinforcement using children with autism in an applied setting (see Experiments One to Three) and adult humans in a laboratory setting (see Experiments Four to Seven). The reasons for choosing the conditional discrimination paradigm were straightforward. First, many previous successful demonstrations of marking in animals had used a discrimination learning paradigm. Second, the nature of the paradigm appeared to offer ample opportunities through which to further explore the effects of marking in humans.

The results showed that marking can facilitate learning by children with autism but that a similar effect is difficult to obtain with adult humans. It was hoped that the marking effect could be investigated more thoroughly in adult humans once a satisfactory procedure had been identified but unfortunately many difficulties were encountered in creating such a paradigm.

The next section of this chapter will summarise the conclusions that can be derived from the current research. The rest of the chapter will defend these conclusions and explain why marking may have enhanced learning with children with autism in an applied setting but not adult humans in the laboratory. The applied and theoretical implications of the findings will also be discussed and suggestions for future research offered. Finally, the relevance of studying marking procedures with these two populations will be considered.

7.2 SUMMARY OF CONCLUSIONS

The main conclusions relating to conditional discrimination learning under conditions of delay that can be drawn from this research are summarised below. The experiments that provide support for each conclusion are cited in parentheses.

1. Delay impedes learning for children with autism (Experiments Two and Three) but does not always have an effect with adult humans (Experiments Four to Six).
2. Marking facilitates learning with children with autism in an applied setting (Experiments One to Three) but does not always have a facilitatory effect with adult humans (Experiments Four to Six)
3. Children with autism show individual differences in their susceptibility to marking (Experiments One and Two).
4. Marking may be as effective, or more effective, than conditioned reinforcement for some children (Experiment Two)
5. Both marked-before and marked-after procedures facilitate learning with children with autism (Experiment Three).
6. Marked-before and marked-after procedures appear to work for different reasons (Experiment Three)
7. Marking effects generalise to children with autism of various abilities, to different settings, and to different learning tasks (Experiments One to Three).
8. Marking effects with adults depend on suppression of verbal behaviour (Experiment Seven).

This research, therefore, demonstrates the generality of the marking phenomenon in applied settings but also suggests limits to the circumstances in which an effect will be found with adult humans in the laboratory. Several issues are raised by the conclusions presented here, and will be discussed below.

7.3 INTERNAL VALIDITY

The marked-after condition facilitated learning for children with autism and adult humans in Experiments One to Three and Experiment Seven, respectively. Experiment

Three also showed that marked-before procedures could facilitate learning for children with autism. The following discussion will determine if marking theory can provide a full and comprehensive explanation of increased learning in these experiments or whether the facilitation effect could be explained equally well in terms of other well-established principles of learning.

One explanation is that the marking cue functioned as a source of immediate *conditioned reinforcement.* This argument, however, is difficult to sustain because marking was effective even though the same cue was presented after both correct *and* incorrect responses in the discrimination learning task. Under the conditioned reinforcement hypothesis, both correct and incorrect responses should have been strengthened equally which would have impeded differentiation of the correct response. The effectiveness of a conditioned reinforcer should depend on its appearing only on trials that terminated in primary reinforcement (i.e., correct trials).

Another explanation is that the children found the marking cues more reinforcing than those in the value condition. This *stimulus preference hypothesis* is also not supported because any potential reinforcing properties of the response-contingent cues were assessed before the experiment began (Experiments One and Two). Children who found one type of cue more reinforcing than the other were not used as participants.

Another possibility is that *experimenter bias* through accidental cueing influenced the way in which the marking cue was delivered. In Experiment One and Experiments Four to Seven this possibility was reduced by using automated procedures. Such procedures were intended to eliminate any possibility of inadvertent cueing. Continued use of such automated response-contingent cues in the applied studies would have been in tension with the need to develop socially valid procedures, so in Experiment Two and Three more normative forms of marking (e.g., "Look!") were used. This raised the possibility that the experimenter's tone of voice may have differed when delivering marking cues after correct and incorrect choices. Care was taken from the outset of the experiment, however, to reduce variations in tone of voice. In addition a reliability assessment was conducted in Experiment Two and this was not able to detect differences between the two types of cues (see Section 4.2.5.4). Experimenter influence was therefore minimized as an issue in these experiments.

An alternative explanation raised in Experiment Seven was that *response latency times* affected rate of learning (see Section 6.4.4). Although response latency time did not differ between conditions in this experiment, this may have contributed to marking effects in the child studies. For example, if participants paused longer before making their choice response in the marking than in the other conditions, they would have had extra exposure to the discriminative stimuli and this may have been responsible for the improvement in learning. Although no data were obtained on choice latency times in the child studies, participants in all conditions were, after 3 s without a response, always consequated with redelivery of the instruction for that training trial. Thus, participants were not able to pause before responding for longer than 3 s in any of the training conditions.

The main problem encountered in the conditional discrimination paradigm with adults was the repeated failure in Experiments Four to Six to demonstrate a delayed reinforcement effect. Thus, in these experiments, the absence of such an effect rendered any analysis of the effects of a marking cue redundant. A key question explored in the adult experiments was whether the lack of a marking effect could be attributed to verbal control over performance. The implication of Experiment Seven was that it could; when the opportunity to self-instruct during the delay was reduced (by a verbal shadowing task), delay produced the expected detrimental effect on behaviour and a marking effect was found. It is unlikely that other explanations are responsible for this effect because only one independent variable at a time was manipulated across the experiments.

This section has reviewed alternative explanations for the effects found and suggests that in Experiments Two and Seven, the effects can only be attributed to the marked-after procedure; in Experiment Three to the marked-before procedure. Further, the marking effect in Experiments Seven can probably be attributed to the suppression of verbal control over performance. Although facilitatory effects can probably be attributed to marking effects and not to other possible causes, questions still remain concerning the obvious differences in the magnitudes of the marking effects found in children and adults. Possible explanations for these differences will be reviewed in the next section.

7.4 EXPLANATIONS FOR DIFFERENCES BETWEEN CHILDREN AND ADULTS

One of the most striking findings of this thesis was that the behaviour of adult humans when reinforcement is delayed differed in fundamental respects from that of other animal species and from children with autism. The aim of the following discussion is to try to identify why marking was effective with children with autism but not with adult humans.

7.4.1 VERBAL BEHAVIOUR

The evidence from Experiments Four to Seven and also from previous research literature (e.g., Lowe, 1983, Section, 6.3.1; Ramey & Ourth, 1971, Section 5.5) suggests that verbal behaviour may be a critical variable in determining the differences in the operant behaviour of children with autism and adult humans. For example, in Experiments Four to Six adults used self-instruction to bridge delays and subsequently delayed reinforcement had little impact on the acquisition of discriminative performance. When the opportunity to self-instruct, however, was reduced in Experiment Seven, delay produced the expected detrimental effect on behaviour and a marking effect was found.

As mentioned previously, however, the children with autism probably lacked the capacity to self-instruct (Section 5.5). For example, a related series of studies demonstrated that the operant behaviour of preverbal infants performing on FI schedules was indistinguishable from that of animals, but had few similarities with adult human performance (e.g., Bentall, Lowe, & Beasty, 1985; Lowe, Beasty, & Bentall, 1983). By the time the children reached the age of 2½ to 4 years, however, they had some functional verbal behaviour, but their responding resembled neither that of adults or non-human animals (Bentall, Lowe, & Beasty, 1985). According to Lowe (1983) this pattern of responding indicates a transituational stage between animal and adult-like behaviour. By 5 or 6 years of age, however, when they had more extensive verbal skills, children showed similar self-directed verbal behaviour (i.e., self-instruction) to that of adults and their differences on FI schedules were affected accordingly.

Thus, one possibility is that the children with autism, like the typically developing children of 2½ to 4 years in Bentall et al's (1985) study, at best had some verbal behaviour (the 5 most vocal children typically communicated using between 4 and 8 word sentences) but they could not self-instruct during the delay. Thus, because they had not yet acquired functional verbal behaviour, they would have learned in a more animal-like way on the operant conditioning tasks.

Despite this, however, another source of influential verbal behaviour, in the form of the instructions provided by the experimenter, was evident. In Experiments Two and

Three one of the elements of the marker was a vocal stimulus, an experimenter-given instruction specifically designed to orient children to one or all of the photo-cards (e.g., "Look!"). Thus, the children usually responded to the markers as instructions by immediately orienting towards their chosen response card. It is possible that participants did not orient towards their chosen card so readily in Experiment One and to the stimuli in the adult-human experiments (see Table 7-1), because the marking cue in these experiments did not have this social instructional property.

It is also important to note that although the pre-test in Experiment Three identified that children could turn their head or move their eyes towards the correct photo card when the teacher randomly pointed to a card and said "Look," they did not identify whether they were responding to the meaning of the word "Look!" or were simply following the teacher's pointing response. Future studies could identify whether it is the vocal cue "Look!" or the nonverbal pointing behaviour that is the critical variable.

In sum, adults used-self instructions to bridge delays and marking effects were seen only when the opportunity to self-instruct was reduced. Children responded to markers as instructions (in Experiments Two and Three) but they probably lacked the capacity to self-instruct. Therefore functional verbal behaviour did not interfere with more primary associative learning effects in these experiments.

7.4.2 SALIENCE OF MARKERS

Lieberman et al. (1979) proposed that only salient (and unexpected) stimuli would function effectively as markers (see Section 2.4.4). One explanation for the differences between the adult and child studies, therefore, is that the markers differed in salience between the two sets of studies.

The types of stimuli used as markers in Experiments One to Seven are depicted in Table 7-1. To enhance the salience of the marker, compound audio-visual stimuli were used across all studies. It was hoped that in the child studies, children would pay attention to at least one element in the stimulus compound (see literature on *stimulus overselectivity,* e.g., Lovaas, Koegel, & Schreibman, 1979; Mundy, 1995).

Experiment	Audio-visual Marker
Experiment One	Buzzer/ green light
Experiment Two	Verbal cue ("look/ here/ there it is") and point
Experiment Three	Marked After- as Experiment 2
	Marked Before- Verbal cue ("Turn over the cards")
Experiments Four to Seven	Beep/ red square on screen

Table 7-1. Properties of the markers used in this thesis.

Despite this precaution, however, several factors may have modified the salience of the marking cues. It has already been suggested that vocal cues may have been more salient to participants than nonvocal audiovisual markers (see Section 7.4.1). Salience may have been reduced though by *habituation.* That is, when the same stimulus was used for a long series of discrete trials (e.g., as in Experiment One and Experiments Four to Seven), its repeated presentation reduces its capacity to elicit orienting (cf. Williams, 1991, Section 2.5). Habituation could thus have reduced marking effects in these experiments. In Experiment Two, however, different marking stimuli were delivered from trial to trial (e.g., "Look!" "Here!" "There it is") with the intention that this would reduce habituation effects. Future research might consider whether such a procedure could facilitate marking effects with adult humans.

7.4.3 SPATIAL CONTIGUITY

Another factor that may also help to explain the differences between the child and adult results is the location of the marking cue. Research with pigeons has demonstrated that closer spatial contiguity between a CS and a US can greatly facilitate classical conditioning (Christie, 1996), so perhaps spatial contiguity between a marking cue and a chosen comparison stimulus is important too (cf. Thomas & Lieberman, 1990). In Experiment One, where value was more effective than marking, the marking cue (audiovisual green light/ buzzer) cue was generated by a table-mounted box, placed in the top right hand corner of the table away from the cue S^D cards. In Experiments Four to Seven, limitations of the software design meant that the visual marking cue (red square) could only appear in the centre of the screen after the chosen S+ or S- had disappeared (for the same reasons, the value cue was also not spatially contiguous with either the S+ or the S^R). Thus, in both of these cases, the visual marking cue was not spatially contiguous with the chosen stimulus (and the auditory cue was ambient). As a result these cues may not have adequately oriented participants towards the response they had just emitted.

In Experiments Two and Three, however, the teacher said "Look!" while pointing to the chosen picture. Thus, the marking stimulus was spatially contiguous with the chosen picture it immediately followed, and may consequently have been more effective at orienting participants towards their chosen response than the non-vocal audiovisual marker described previously. The issue of *causal relevance* is also important here (see Section 2.6). Adult participants observing the marking stimulus presented on the screen may not have attributed its presentation to their preceding choice response. It is possible that the children found it easier to attribute their teacher pointing and saying "Look!" to their chosen comparison stimulus because the marking cue was spatially contiguous with that stimulus.

Future research, examining the importance of the topography of response-contingent cues in determining effectiveness would help to clarify the conditions under which marking effects can be obtained with human participants. This idea suggests the importance of comparing auditory cues with visual cues or visual cues located contiguously with non-contiguous cues.

7.4.4 ATTENDING BEHAVIOUR

According to Thomas and Lieberman (1990), marking seems to work best for those individuals whose "attention is not already fully committed [to the task in hand]" (p.123). To support this argument they cite several experiments which aimed to see if marking cues could facilitate learning of delayed matching-to-sample in pigeons (Davidson, 1986). Results were generally inconclusive; some pigeons performed reliably better on marked trials, others showed no improvement. To explain these results, Thomas and Lieberman suggested that "after extended training on the delayed matching-to-sample task most subjects were already devoting all their attention to the sample, anyway, so there was no possibility of the marker bringing about an increase in processing" (p.122). They further supposed that all of the previous successful demonstrations of marking had involved situations in which subjects were "uncertain about which cues or responses to attend to in order to solve the problem" (p, 122, but for criticisms of this account, see Section 7.5).

Taking the three applied experiments together, the marking procedure clearly helped some participants more than others. One explanation previously offered is that marking may be particularly useful for children who have significant deficits in 'attending' skills (see Section 6.5). Children who found it difficult to concentrate on the learning task, and whose attention was easily disrupted by external stimuli, seemed to benefit most from the marking procedure. Such attending skills may account for differences between individual participants but also between child and adult participants.

In the adult human studies ceiling effects may have influenced attending behaviours. It was observed, for example, that participants in Experiments Four to Six appeared to study the computer screen and experimental stimuli closely throughout each trial. If visual orientation is equated with "attention", Thomas and Lieberman (1990) might argue that marking would not bring about an increase in processing for these participants because they were already fully focussed on the conditional discrimination task. In Experiment Seven, however, the verbal shadowing task appeared to interfere with participants' orienting to the task during the delay interval. Participants were often observed to look up at the ceiling or look down at the floor when they were counting backwards. As a result, marking may have bought about an increase in processing for these participants. Unfortunately, however, no measures of orienting were made so this explanation remains post hoc. Future studies with adults might consider whether lower levels of orienting contribute to marking effects.

7.4.5 SUMMARY AND CONCLUSIONS

This thesis demonstrates that marking procedures can be effective in facilitating learning for children with autism when reinforcement is delayed but does not always have an effect with adult humans. A number of factors have been identified which may account for these differences, including adult humans' capacity for self-instruction, marking-stimulus salience variability, spatial contiguity of the marker to the preceding choice response and, finally, participants overall level of attention to the conditional discrimination task.

Even though evidence was obtained to show that marking cues could improve response acquisition, this does not in itself support the memory process proposed (by

Lieberman's and Thomas' cognitive theory, see Sections 2.2.1 and 5.1) to underlie marking effects. It is possible, for example, that any or all of the aforementioned factors may have modulated (or otherwise interfered with) these processes. Lieberman and Thomas' cognitive account is probably not, however, undermined by these factors alone. In the next section I will revisit the theory to identify continuing problems and consider alternatives.

7.5 THEORETICAL ACCOUNTS OF MARKING IN LIGHT OF THE PRESENT RESEARCH

Lieberman's and Thomas' cognitive theory is based on a backward scan process to explain marked-after procedures and a forward scan process to explain marked-before procedures. Recall that Lieberman et al. (1979) proposed that during marked-after procedures the marker causes a backward scan through memory to identify the cause of the 'surprise' and that during this search the choice response would be identified as the most reliable predictor (see Section 2.2.1). As a result, organisms should be more likely to remember that 'marked' choice response when they are later rewarded. In marked-before procedures, on the other hand, Thomas et al. (1983) proposed that the marker focuses attention on subsequent discriminative stimuli, enabling better recall of the chosen stimulus at the time of reinforcement (see Section 5.1). There are, however, a number of problems with this account as it stands, and in relation to explaining the present data.

First, explanations are somewhat post-hoc in terms of the processes posited to account for the effects. That a marker can have two functions, either triggering a backward or forward scan, is probably not an adequate explanation for marking effects. The direction of the scan is conveniently matched to the phenomena that need to be explained- but there are apparently no principles allowing us to state in advance which direction scanning will proceed in.

Second, there are a range of undefined terms in relation to the process. For example, Thomas and Lieberman (1990) stated, "Marking effects...are most readily observed in circumstances where the [organisms] attention is not already fully committed" (p. 123). There are, however, no criteria for establishing whether this is the case in advance. Marking is also said to be more effective under conditions of uncertainty but again, what makes for uncertainty between one experiment and the next? Additionally, because terms such as these are undefined their account is potentially circular: marking will work if an organism's attention is not fully engaged but the only way to know if the organism's attention is not fully engaged is if marking works.

Third, there appear to be some contradictions between the backward scan account and well-established models of information-processing in animal conditioning. One model that has been highly influential is Wagner's (1979, 1981) priming theory of short-term memory (STM) (see Section 2.2.3). The most relevant assumptions of his model for marking theory are that: (1) STM has a limited capacity; (2) Surprising events are more likely to be "rehearsed" than events that have already been represented or "primed" in STM and (3) during rehearsal, surprising events occupy the limited capacity STM and displace other events.

The backward-scan hypothesis corresponds to the framework provided by Wagner in several important ways. First, Wagner's model was intended as a theoretical extension of Kamin's (1968, 1969) 'surprise' analysis of classical conditioning and, as such, was structured in terms of the process by which CSs and USs become associated. That responses also fit into STM in the same way as stimuli, is a distinct possibility. Wagner's definition of a surprising event, "one that is not well predicted on the basis of the entire aggregation of cues which precede it" (Wagner, Rudy, & Whitlow, 1973, p. 409), also seems to encompass markers. Indeed, Lieberman et al. (1979) suggested that only "salient and unexpected stimuli" would initiate a backward scan through memory (see Section 2.2.1).

If it is accepted that markers are surprising events, would they have a facilitatory function according to Wagner's model? Wagner's model predicts that a stimulus interpolated between a CS and a US *weakens* the connection by displacing the CS representation in STM. Lieberman's backward scan account, however, predicts that a stimulus interpolated between a response and a reinforcer *facilitates* the connection between them. According to Wagner's model, the marker should actually reduce learning by interfering with rehearsal of the preceding response. This interference effect would occur because rehearsal capacity is assumed to be limited, so any processing given to a surprising event such as a marker would reduce the processing capacity available for the preceding response, and thereby lower the probability of the response being remembered.

Another potential limitation to the backward scan account is that it does not explain why marking is not merely a transient effect. We might expect the marking stimulus to habituate after several presentations and thus lose its effectiveness (Section 7.4.2). After several trials, for example, the marking cue should be expected at the choice point, and this would make a backward scan through memory superfluous. If this were true, marking would be most effective only in the early trials of training. The results show, however, that marking cues can continue to be effective over extended periods of training. One explanation is that the response-contingent cue functions as a marking stimulus only initially, but then begins to function as a conditioned reinforcer as it becomes more frequently associated with correct than incorrect responses (i.e., as the organism learns). This interesting dynamic change in stimulus functions is not considered in the backward-scan hypothesis.

Applying the backward/forward scan account to the data obtained in the present set of studies has all of the above problems. Additionally, however, the backward scan account needs to be extended still further to account for conditional discrimination learning. The backward-scan hypothesis was intended as an explanation for learning of *simultaneous discriminations*, in which two stimuli are present at the same time each of which is correlated with a different response (e.g., as in choosing an arm in the maze experiments or pecking one of two response keys). Using such discrimination tasks, marking effects were found to be a reliable and robust phenomenon (Chapter Two). According to the backward scan hypothesis, learning occurs because individual responses are marked in memory so that they are more likely to be associated with the subsequent occurrence or non-occurrence of reinforcement.

The studies reported here, however, used conditional discrimination tasks in which participants had to choose between one of three or four comparison stimuli depending on the presence of the sample stimulus. The backward-scan hypothesis cannot explain learning of a conditional discrimination task if only 'individual' responses are marked in memory because each comparison stimulus is correct on some trials but incorrect on others, depending on the sample stimulus presented.

Conditional discrimination learning can, however, be explained if additional assumptions are made of the backward scan hypothesis. If the marker acts to fix together both the conditional stimulus and the discriminative stimulus as one unit (or pair) on any trial in memory, this *combination* of events might be associated with the subsequent occurrence or non-occurrence of reinforcement, in the same way that a single response is fixed in the original backward scan account. Similarly, the marked-before procedure may require a forward scan that fixes together the relevant comparison stimulus and the (not yet present) sample stimulus together as a pair in memory, so that this pair would more likely be identified at a later time when reinforcement is delivered. Again, however, this explanation seems rather post hoc.

One final criticism of the backward-scan account is that it cannot alone explain the considerable differences in the magnitude of marking effects between the children with autism and adults. On the basis of scanning alone these differences would not be expected. Thus, a more adequate explanation for marking effects is needed, one which can explain why such differences occurred.

An alternative conceptualization of marking effects, which accounts for such differences, can be made on the basis of the data obtained. Perhaps marking stimuli simply encourage sensory orientation towards stimuli that are important in learning. In the child experiments, for example, the matching-to-sample tasks all required participants to identify a comparison card from an array of three. To do this successfully participants would have to orient towards the cards and their positions on the table to be able to successfully discriminate between them in relation to the sample. Thus, the marked-after procedures in Experiments Two and Three may have facilitated learning by re-orienting children towards the comparison stimulus they had just chosen. This effect was probably further facilitated because the marking cue was spatially contiguous with the critical comparison stimulus and because it was verbal.

It is also possible that, because the comparison cards remained on the table throughout the delay, participants remained oriented towards the marked comparison stimulus up until the occurrence or non-occurrence of reinforcement (cf. Erickson & Lipsitt, 1960, Section 5.5). This would of course make it easier for them to associate the sample-comparison pair with later reinforcement. Similarly, marked-before procedures might also have facilitated orientation towards the comparison stimuli, but this time before they made their choice response rather than after.

If this behavioural orientation account is accepted, it has some implications for understanding the usual process of discrete-trial training. Teachers who use this method are normally instructed to bridge the delay between response and reinforcement delivery by using praise (e.g., saying "Good!") because it is assumed that this will acquire reinforcing properties through pairing with the delayed primary reinforcer (e.g., Lovaas, 2003). The applied demonstrations of a facilitative effect for the marked-after procedure, however, suggest that some or all of the effects of response-contingent praise could result from the orientation (marking) process: When praise occurs, its orientation-focusing function may be more significant than its acquired value. In other words, rather than directly strengthening a response, praise may serve to mark that response in memory until such time as primary reinforcement is delivered (cf. Thomas et al., 1983). Recall that the effects of marking cannot be explained in terms of conditioned reinforcement because the same marking stimuli follow both correct and incorrect choices.

The present data lead the suggestion that, in some applied settings at least, marking (leading to orienting) can be as important as value (conditioned reinforcement) in facilitating learning and that orienting and conditioned reinforcement functions may be difficult to separate. Participants may not benefit from conditioned reinforcement unless they are orienting to the stimulus (cf. Lovaas et al., 1966, see Section 3.1). The present data provide evidence that marking can play as important a role as conditioned reinforcement in bridging temporal delays to reinforcement. In doing so, the research makes a contribution to the ongoing debate about whether conditioned reinforcement is an adequate explanation for sustained responding when reinforcement is delayed (e.g., Williams, 1994a, and 1994b).

If it is accepted that marking stimuli produce sensory orientation towards stimuli that are important for learning, we would expect weak marking effects in the adult human experiments for a number of reasons. First, the marker would not be able to produce orientation towards the chosen comparison stimulus because limits of the software design meant that the comparison stimuli were always removed from the screen *prior* to the marker being presented (see Figure 6-2). Second, the comparison stimuli were also not present throughout the delay so sustained orienting towards the chosen stimulus until the time of reinforcement or non reinforcement would not be possible. Third, if close spatial contiguity between a marking cue and a comparison stimulus is necessary to facilitate orienting to any degree, weak marking effects would be expected in the adult experiments because the location of the marker differed from that of the comparison stimuli (see Section 7.4.3). Finally, until it was suppressed in Experiment Seven, verbal self-instruction might have been sufficient to control orienting in the absence of a marking cue, reducing the possibility of the marker bringing about an increase in orienting. When verbal instruction was suppressed in Experiment Seven, however, the marking cue may have increased orienting over and above when no marking cue was present during the delay (see Section 7.4.4).

7.6 RELEVANCE OF MARKING EFFECTS

One of the main aims of this thesis was to determine whether a marking effect could be obtained with adult humans in a laboratory setting. Unfortunately, obtaining marking effects with this population proved methodologically difficult. In particular, it took several attempts to find an appropriate design that could reduce participant self-instruction to the point that the basic requirements for marking effects (i.e., a delay-of-reinforcement effect) were observed.

Lieberman has also commented on difficulties that he and his students have found in identifying a suitable paradigm to study marking in adult humans (D. Lieberman, personal communication, March, 2004). He suggested that it may be difficult to find marking effects with this population because participants can sometimes solve the problems by using self-instruction rather than relying on the more-automatic contingency-governed process found in animals. In a series of eight studies he tried to draw on a more automatic process by using the following paradigm. Participants were required to watch a video on a TV set which, midway through, appeared to "explode"- there was a loud bang and the picture disappeared. They were later tested on their memories for the video, to see if material preceding the explosion was better remembered than participants in a control group who watched the video without such an explosion. Lieberman felt that this paradigm relied on more automatic processes because participants had no reason to suppose that the explosion had anything to do with anything they had done or anything they had seen in the video. Unfortunately, however, a marking effect was still not found.

Some parallels can be drawn between the difficulty in finding marking effects in adult humans and findings from human research on blocking[5]. Like marking, blocking has also been investigated primarily with rats and other nonhuman animals as experimental subjects and the effect has been well documented with animals during many years of research (e.g., Kamin, 1968; Miller & Matute, 1996). Generally, however, this blocking effect has proven to be quite elusive with humans (e.g., Davey & Singh, 1988; Lovibond, Siddle, & Bond, 1988).

[5] In a traditional blocking procedure, there are two acquisition phases. In the first phase, the experimental group is exposed to a conditioned stimulus (CS), A, paired with an unconditioned stimulus (US), whereas the control group is not exposed to these pairings; in the second phase, both groups are exposed to a compound of CS A and CS X, that is paired with the US; finally, subjects are tested with CS X. The outcome is that the target CS, X, which was paired with the US the same number of times for both the experimental and the control groups, produces weaker responding at test in the experimental group than in the control group.

One explanation for the discrepancy between the animal and human research is that conditioned suppression of an ongoing behaviour (Annau & Kamin, 1961) is used to study blocking in animals (i.e., the dependent variable is a nonverbal measure). In contrast, human experiments use a verbal assessment of causal judgment as the dependent variable; participants have to indicate verbally the probability with which they believe that an event (the CS) will be followed by its outcome (the US). The use of verbal responses (e.g., causality judgments) as a dependent variable has some problems. For example, Matute, Arcediano, and Miller (1996) reported that the manner in which the test question was worded strongly influenced the results that were obtained.

For this reason, a great deal of research on blocking in humans has attempted to suppress verbal control over performance to obtain an effect in humans that is more similar to that found in animals (e.g., Davey & Singh, 1988; Martin & Levey, 1991). This has proven difficult to achieve and has generally provided inconclusive results. Thus, the literature of both marking and blocking supports the interpretation that there may be a fundamental difference in the way humans and animals process information and respond to it, and that it may be language which accounts for the hiatus between animal and human performance.

In the human marking experiments attempts were also made to suppress verbal cues by using a verbal shadowing task during the delay interval. Although this did not suppress verbalization entirely, the procedure may nevertheless provide the starting point for researchers to explore further the concept of marking in adult human learning. The effectiveness of a marker may be related to a great number of variables such as its salience, the time to reinforcement, and so on. The usefulness of carrying out more detailed manipulations in the laboratory, however, will largely depend on whether or not verbal cues (i.e., from instructions provided by the experimenter or from participants' self-instructions) can be controlled. This is likely to be problematic for researchers, however, because of the durability of verbal behaviour in adult humans.

An important question therefore is whether researchers should continue to focus their efforts on a more detailed laboratory analysis of marking in adult humans, as has been the case with the blocking experiments. If we are to believe that humans share fundamental associate processes with other animals which, for some reason, are very difficult to demonstrate experimentally, this would be an important way forward. What differentiates the blocking phenomena from marking, however, is that blocking effects may exist outside of the laboratory in situations when verbal control is not so important.

For example, continued research on blocking in humans may help to explain peoples' failure to acquire fear (Delprato, 1980).

It is more difficult to see, however, where response marking fits in terms of interpreting everyday adult learning. If the main purpose of using marking procedures is to facilitate learning when reinforcement is delayed but, because self-instruction in adult humans is so much more effective at reducing negative effects of delay than marking, this calls into question the value of experimentation. What is the practical benefit of demonstrating findings with humans in the laboratory that would not be relevant outside of this setting?

Although response marking appears to have little to say about learning in adult humans, it clearly is important as a new teaching device for those individuals, such as children or adults with autism or Attention-Deficit/ Hyperactivity Disorder, who have poor attending skills. As discussed previously, marked-after procedures appear to work by orienting children towards the response just emitted; marked-before procedures induce children to orient to the discriminative stimuli before a response is emitted (see Section 5.4). Thus, both procedures may increase the overall amount of time participants spend looking at discriminative stimuli. Unfortunately, however, no objective data were recorded to establish whether this occurred.

The question of how relevant marking is for teaching in applied settings should also be considered from the perspective of the generality of its procedures to different participants, across settings and with different learning tasks. Experiments Two and Three showed that marking effects can facilitate learning with children with autism of various ages and abilities. Across the two studies participants with chronological ages ranging from 5 years and 3 months to 10 years and 7 months, and mental ages ranging from 2 years and 4 months to 4 years all benefited from marking procedures. In Experiment Three, marking procedures continued to be effective with a new learning task and a sample of more able children than those used in Experiment Two.

Future studies, however, could usefully examine whether marking effects would generalise to children with autism who fall outside of the age range and ability levels studied here. Marking procedures may not benefit children with autism who are developmentally more advanced than those who participated in these studies because they have more highly developed verbal skills and may be capable of self-instruction (see Section 7.4.2). In addition, marking effects may also not generalise to participants who are already proficient at attending throughout the learning task (see Section 7.4.4).

Comparison studies though would also show if there is something about the marking procedure which is specific to autism. Comparative studies would be required to assess whether many find it difficult to orient towards relevant stimuli in their environment (e.g., Noterdaeme et al., 2001) and whether marking cues help to orient them more effectively.

Another potential limit to the generality of marking to children with autism is that the demonstration of marking effects is specific to children who are not familiar with discrete-trial teaching (DTT). Recall that in Experiment One, marking may have had a negative effect on learning because of its unfamiliarity compared to the value condition (which used a procedure similar to that used in DTT). Subsequently, participants were chosen in Experiment Two (and in Experiment Three, to ensure continuity between the two studies) who were not familiar with DTT. It would be interesting to see whether marking procedures could also enhance learning for children who have a prior history of DTT.

The generality of marking effects across a range of contexts should also be considered. Marking procedures have only been shown to be effective in conditional discrimination learning. Within this situation, moreover, it is important to note the distinction between acquisition and maintenance. The critical feature of the marking procedure is that the cue follows both correct and incorrect responses. As the discrimination is acquired, marking cues seem more and more closely tied to correct responses. As performance reaches asymptote, the marking cue is functionally equivalent to a conditioned reinforcer. Thus, the distinction between marking and conditioned reinforcement cannot be sustained beyond acquisition.

In sum, although marking procedures are important as a new teaching device in applied settings, there are some potential limitations to the generality of the marking phenomenon to children with autism. Marking may not be useful for those children who have advanced verbal behaviour skills (Section 7.4.1), who are already adept at staying oriented towards a learning task (Section 7.4.4), or who have not yet acquired joint attention skills (Section 5.4). Furthermore, marking procedures may only be useful for table-top conditional discrimination tasks (this section). It might therefore be profitable for research in future to explore possible limits to the generality of marking in applied settings.

7.7 CONCLUSIONS

Although there is much interest in how to alleviate the negative effects of delay-of-reinforcement in humans, the majority of research has focussed on the way in which response-contingent cues may acquire conditioned reinforcement functions. The ubiquity of this account may have subtly discouraged further investigation into the efficacy of using other procedures. This thesis has presented a programme of research that aimed to investigate the role of response-marking procedures in human conditional discrimination tasks when reinforcement is delayed. Overall, the results indicated that response-marking procedures may be effective with human participants but that their effects are more reliable in applied settings with children with autism than in laboratory settings with adults.

The research has indicated that verbal behaviour may be one of the main factors to underlie this difference in experimental outcome. Participant self-instruction was probably not present in the child data but the adult participants in Experiments Four to Six used self-instruction which interfered with direct control by the delayed reinforcement contingency. The absence of any effect of delay rendered any analysis of the effects of a marking cue redundant. In Experiment Seven, however, when the confounding effects of verbal behaviour were adequately controlled, a marking effect was found.

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9. APPENDICIES

APPENDIX A: SIMPLE OPERANT SCHEDULES

To study the effects of delay on performance of the operant, researchers have often used simple operant schedules where a delay-of-reinforcement arrangement is initiated on completion of the response requirements (e.g., Sizemore & Lattal, 1977; 1978; Williams, 1976). Such experiments have typically exposed animals (e.g., rats and pigeons) to variable interval (VI) schedules[6]. After the VI schedule is completed a delay is inserted between the occurrence of the to-be-reinforced response and the delivery of primary reinforcement. This procedure is illustrated in Figure 9-1.

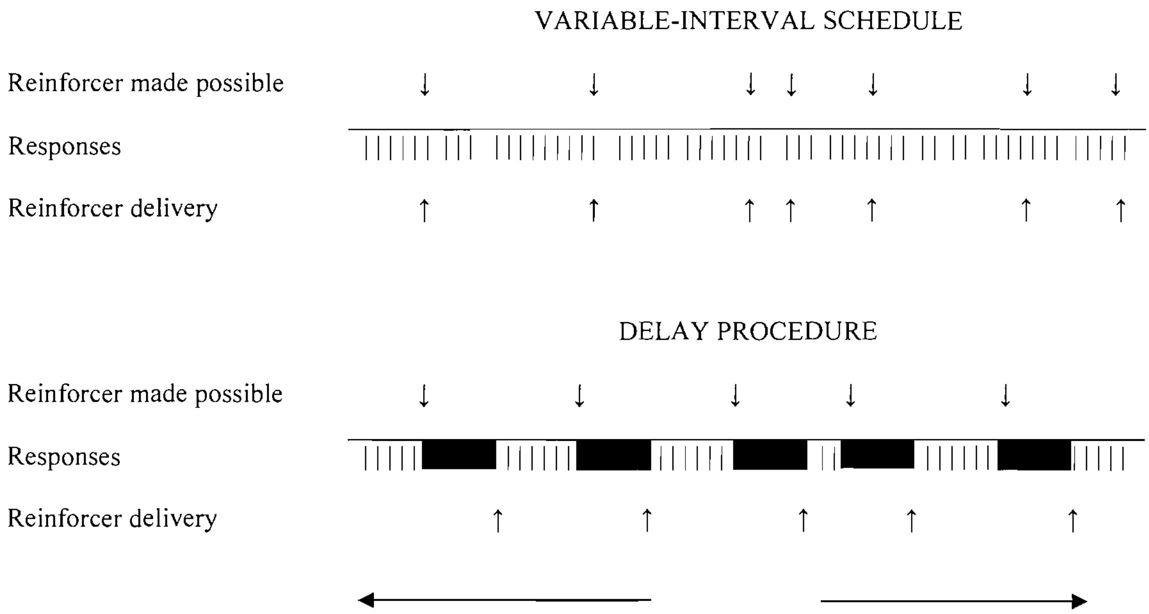

Figure 9-1. A schematic representation of a delay-of-reinforcement arrangement in a VI schedule, as depicted by Ferster (1953). The top part of the figure illustrates a VI schedule of reinforcement. The bottom part of the figure illustrates the delay procedure. The darkened portions represent the delay interval.

[6] In an interval schedule, a minimum amount of time must elapse before a response can be reinforced and in a VI schedule, the time that must elapse before a response is reinforced is averaged around a particular interval.

In signalled delay-of-reinforcement procedures, a response-dependent cue is presented during the delay and the opportunity to respond may or may not be withdrawn. Stimulus arrangements have included a key light colour change (e.g., Kelleher & Gollub, 1962, Rachlin & Green, 1972), an illuminated pilot light (e.g., Morgan, 1972), an auditory stimulus change (e.g., Richards & Hittesdorf, 1978) and lever retraction (e.g., Pierce, Hanford, & Zimmerman, 1972). Although the present thesis has been restricted to a discussion of signalled or unsignalled nonresetting delays (i.e., a delay during which responses are non-functional), several researchers have also investigated the effects of a DRO contingency, during which responding during the delay is punished by resetting the delay interval (e.g., Azzi et al., 1964; Gonzales & Newlin, 1976).

APPENDIX B: CHAIN SCHEDULES

Chain schedules are also frequently used by researchers to study the impact of response-contingent cues on delay. In a chain schedule, a sequence of reinforcement schedules, each with a separate response requirement, must be completed sequentially such that fulfilling the requirements of one link leads to the following link. Each link is associated with a different discriminative stimulus (e.g., a coloured light), but only the final link results in reinforcement. Usually, the first and last links in any chain sequence are called the *initial link* and the *terminal link* respectively.

Consider a chain VI 2 min FI 2 min two-component schedule (see Figure 9-2). In this schedule, in (say) the presence of the green light, a pigeon would have to emit a key peck after an average of 2 min has elapsed (VI 2 min). When this peck occurs the light changes from green to blue. In the presence of the blue light, a single peck after 2 minutes (FI 2 min) produces food and the light changes back to green (i.e., the chain starts over). Thus when the pigeon pecks during the green component, the only consequence would be a response-contingent stimulus change, namely that the key light colour changes to blue. The pigeon would only receive food reinforcement for pecks in the presence of the blue light.

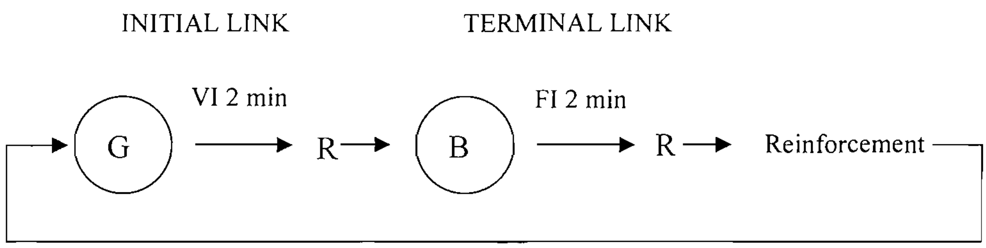

Figure 9-2. A schematic diagram of a two-component chain schedule of reinforcement, VI 2 min FI 2 min. The circles represent response keys and the letters within show they are associated with different colour lights: (G)reen and (B)lue. The arrow followed by the letter R tell us that the first response after the schedule has been completed will change the key colour from green to blue (in the initial link) or produce reinforcement (in the terminal link).

APPENDIX C: CONCURRENT CHAIN SCHEDULES

One of the most popular methods for studying the effects of response-contingent cues is the *concurrent chains schedule*. Figure 9-3 depicts such a schedule in a characteristic pigeon study. During the initial link of the chain, two response keys are lit, each associated with separate but equally valued VI schedules. Pecks that complete the VI schedule on either key result in a change in colour on the pecked key while at the same time the other key becomes dark and inoperative. Different schedules of primary reinforcement (e.g., Schedules A and B in the diagram) are correlated with each colour in the terminal link of the schedule. Once the terminal link schedule has been completed and the primary reinforcer has been delivered, the entire procedure recycles so that the initial link is presented again.

The relative rates of pecking in the two initial link keys are assumed to reflect the relative preferences for the schedules in the respective terminal links. For example, if a pigeon pecked the right key more often than the left it could be said that the pigeon preferred schedule B to schedule A. Because responding in the initial link is never followed by primary reinforcement, the terminal-link stimuli associated with each schedule are believed to determine preference; possibly because they have acquired reinforcing value in relation to the terminal-link reinforcer (see Section 1.3.1). Other conceptualizations, however, may also be possible (see Section 1.4.2).

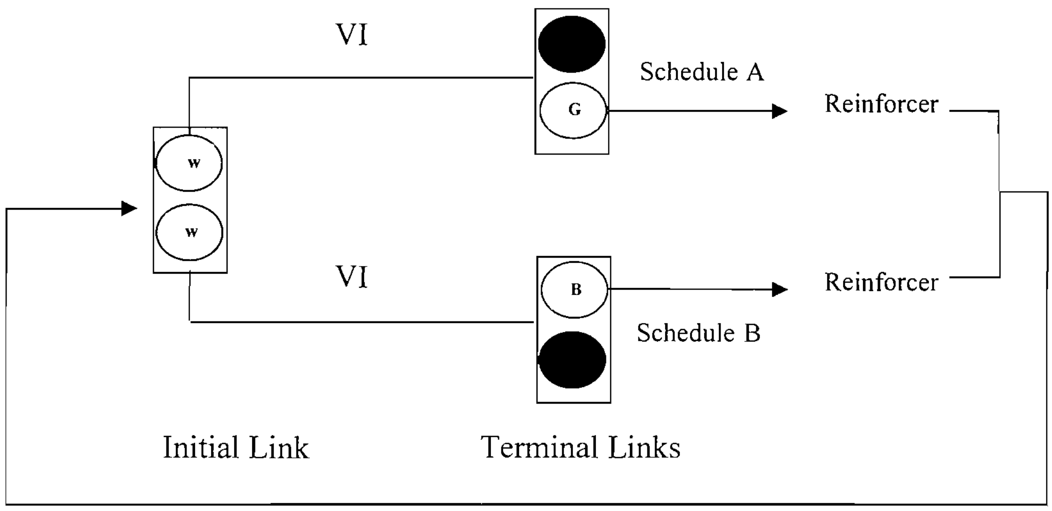

Figure 9-3. **Schematic diagram of a typical concurrent-chain schedule consisting of an initial link and two alternative terminal links. The circles represent manipulanda, often response keys or levers, and the letters within show that they are associated with different discriminative stimuli. Commonly, manipulanda are differentiated by colour lights: (W)hite, (B)lue and (G)reen in the example.**

APPENDIX D: SECOND-ORDER SCHEDULES

Second-order schedules with brief stimuli have also been used to study the effect of response-contingent cues. In such a schedule, the completion of one schedule is a response unit that is reinforced according to another schedule. For example, Kelleher (1958) arranged a fixed ratio[7] second-order schedule of the form FR 50 (FR 125: token), where 125 lever pulling responses were required for one token and 50 tokens were required before the tokens could be exchanged for food; thus, FR 125 was the first-order schedule and FR 50 the second-order schedule.

Second-order schedules with brief stimuli usually increase responding compared to when no brief stimuli are presented during a schedule. For example, Findley and Brady (1965) reinforced a chimpanzee's key pressing on a FR 4000 schedule and postreinforcement pauses varied from many minutes to hours. But when the schedule was converted to FR 10 (FR400: light), so that a light was presented after every 400 responses and food was delivered upon the 10th repetition of the FR 400 schedule, responding increased dramatically and post-reinforcement pauses decreased to 5 minutes or less.

That brief stimuli can produce major enhancements of response rates when they are presented according to second-order schedules has been replicated several times (e.g., Kelleher & Gollub, 1962; Lee & Gollub, 1971). What is disputed, however, is how the brief stimuli acquire their facilitatory effect (see Sections 1.3.1 and 1.4.4).

[7] In a ratio schedule, a specified number of responses must be completed before reinforcement is given and in a fixed-ratio (FR) schedule, the number of responses that must be completed remains constant from one reinforcer to the next.

APPENDIX E: OBSERVING RESPONSES

In any discrimination, the discriminative stimuli are effective only if the organism observes them (Catania, 1992). In an observing response procedure (e.g., Wyckoff, 1952), an animal will look at discriminative stimuli provided it has to perform a response to produce them. Wyckoff (1952), for example, alternated the consequences of key pecking between a FI 30 s and an extinction schedule. In this mixed schedule (mix FI 30 s EXT) pigeons pecked through both components. When a pedal press (i.e., the observing response) turned the key green when the FI 30 s schedule was in operation or red when the extinction period was in effect (i.e., a multiple FI 30 s EXT schedule), pigeons pecked at near zero rates during red (EXT) and high rates during green (FI 30 s). Thus, in an observing response procedure, an operant response produces a switch from an unsignalled to a signalled condition (e.g., from a mixed to multiple schedule). Without an observing response, a single stimulus is presented regardless of whether or not reinforcement is available. With the observing response a stimulus (S+) is presented if reinforcement is available, and another stimulus (S-) if it is not.