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An evaluation of outcome differentiation using biologically neutral stimuli

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An Evaluation of Outcome Differentiation Using Biologically Neutral Stimuli

By

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Bachelor of Arts with Honours, York University, 1987

THESIS
Submitted to the Department of Psychology
in partial fulfillment of the requirements
for the Master of Arts degree
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In loving memory of

my father, John Tennekoon.

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Abstract

This experiment investigated the specificity of encoding the outcomes of instrumental responding with rats. The first part of the study examined the differential outcome effect (DOE) using a 0.5 second flash of light as the outcome differentiator. Acquisition of a two-choice conditional discrimination was not enhanced if Response 1 (R_1) in the presence of Stimulus 1 (S_1) produced food plus a light flash, and R_2 during S_2 produced only food. Next, 2/3 of the animals were then trained to make two new responses (R_3 and R_4), one earning light plus food and the other earning food only. There was no evidence of specific stimulus-reinforcer associations since selective enhancement of performance, by the stimulus of the newly acquired response trained with the same reinforcer, did not occur. The brief cue had no reliable effect on level of responding or rate of learning suggesting that this cue is not a successful outcome differentiator.

Introduction

Recently, there has been a substantial growth of interest in the mental processes of animals. It is well known that animals have the ability to learn about recurring sequences of events, especially when one of them is of biological importance. A simple example would be the ability of animals to learn about the taste of food and its subsequent consequences. Animals that learn about these relationships increase their chances of survival by avoiding foods that are harmful to them. Those that learn about the consequences of their action quickly are at an advantage because they can repeat behaviour that has beneficial consquences and withhold behaviour that leads to harmful outcomes. There is some debate among researchers as to the precise nature of this learning, more specifically, about how to describe the relationships among environmental events and behaviours. Recent evidence originating from two different lines of research, discussed shortly, shows that animals are able to encode the specific outcomes of their behaviour and that this representation enters into associations with other elements (ie. surrounding stimuli and responses) present in the learning situation. The present study attempts to examine the convergence of these two different experimental procedures that have provided evidence in support of specific outcome encoding.

First, Colwill and Rescorla (1988), utilizing a transfer of control design trained rats to respond on one type of response manipulandum (R_1) during the presence of one S^D (ie. tone) to receive food pellets (O_1) and respond on another manipulandum (R_2) during the presence of another S^D (ie. clicker) to receive sucrose (O_2). The animals were then trained to make two new responses, lever pressing and chain pulling (R_3 and R_4), where sucrose consistently followed one response and food pellets followed the other. The animals were then tested for responding on lever pressing and chain pulling during successive presentations of the tone and clicker. They found, for example, that training of tone (S_1) with food pellets (O_1) selectively augmented performance of lever pressing (R_3), which had also been previously and separately trained with food pellets. Similarly, training of clicker (S_2) with sucrose (O_2) selectively enhanced performance of R_4, which had also been trained with sucrose. Colwill and Rescorla interpreted these findings as evidence for the presence of stimulus-reinforcer and response-reinforcer associations.

Secondly, in another study utilizing a differential outcomes design, Fedorchak and Bolles (1986) found facilitation in learning of a two-choice conditional discrimination task when, for example, a left lever press (R_1) in the presence of a tone (S_1) produced water plus a light flash and a right lever press (R_2) during a clicker (S_2) produced only water, in comparison to conditions that did not have the light consistently correlated with a particular lever. They found that this effect occurred in the absence of any noticeable preference for either outcome suggesting that since a differential outcomes effect (DOE) may be obtained using outcomes that do not have to differ hedonically, a cognitive expectation is sufficient to explain it. Because of the perceived absence of any biologically important differences between the two outcomes, Fedorchak and Bolles (1986) have proposed that the animals developed cognitive expectations of the outcome that come to facilitate discrimination performance. Consistent with Colwill and Rescorla (1988), Fedorchak and Bolles (1986) support the notion that animals are capable of representing, in a specific way, the consequences of instrumental behaviour, but differ with . spect to how this knowledge enters into the associative structure and comes to affect behaviour. Fedorchak and Bolles (1986) suggest that a cognitive representation of the outcome, evoked by the stimulus, primarily guides the instrumental response.

The research proposed in the present paper firstly reexamines whether or not animals encode the specific consequences or outcomes of their behaviour, as the above studies suggest, and, if so, evaluates the extent to which the two outcomes are uniquely represented when a brief flash of light serves to differentiate the two outcome types. In other words, can animals discriminate between food alone versus light plus food outcomes, and does this information somehow facilitate learning a conditional discrimination task? The present study utilizes the combination of both a DO design and a transfer design, in order to assess whether instrumental learning involves both stimulus-outcome and response-outcome associations when a biologically neutral stimulus serves to differentiate each outcome. Such a finding would provide some support for an alternate explanation, that recognizes the importance of S-O and R-O associations in instrumental learning, to the cognitive account offered by Fedorchak and Bolles (1986).

Review of the Literature

Over the years, behaviourists have spent a great deal of time and effort in pursuit of scientifically attaining more knowledge about animal behaviour. Much of this experimental investigation has focused on determining the laws of learning by association. According to Weisman (1977, p.2) associative learning "seems in a large part a result of the ability of animals to extract correlations in time and space between events...". In the case of instrumental learning, the events associated by animals may include "the neural correlates of their own behaviour with the correlates of external events..." (Weisman, 1977, p.13). The development of various methods of enquiry have evolved out of researchers' endeavor to resolve differences in perspective about how associative learning processes should be characterized. For instance, consider an instrumental learning situation in which the subject is required to respond correctly to a discrete stimulus for reinforcement. It has been stated that three elements have been recognized in the instrumental learning paradigm: a response on the part of the organism, a reinforcer that is arranged to be contingent upon that response, and a stimulus in the presence of which that contingency is arranged (Rescorla, 1987). Research questions of theoretical importance examine which of these events are encoded and what the possible associative mechanisms are which underlie instrumental behaviour. Three views have historically dominated the experimental analysis of behaviour change (Rescorla, 1987). This review begins with a brief description of some of the evidence pertaining to each of these three accounts: the stimulus-response view, the response-reinforcer account, and the two-process view. The influence of stimulus-reinforcer (S-S*) contingencies on instrumental performance will also be discussed.

Stimulus-Response View

The dominant account of instrumental learning during the first half of this century, was the stimulus-response (S-R) theory. This theory, proposed by Thorndike (1898) and later supported by Guthrie (1952) and Hull (1943), asserts that an instrumental response followed by reinforcement will become associated with the stimulus event which precedes it. The role of the reinforcer (S*), according to S-R theorists, is that of a catalyst promoting a connection to be formed between the stimulus and response. According to the S-R view, the reinforcing event is not itself encoded as part of the associative structure mediating instrumental performance. However, the occurrence of S-R-S* is a necessary sequence for conditioning to take place (Trapold & Overmier, 1972). The effect of arranging such an experimental situation eventually results in an increased likelihood of responding during the discriminative stimulus. Thorndike's pioneering series of experiments with cats placed in puzzle boxes are well documented in numerous papers and elementary texts (Flaherty, 1985; Schwartz, 1984). Briefly, the cat would be placed inside a wooden box which had an escape door that could be opened by pulling on a loop hanging within the box. Thorndike recorded the time between the animal's entrance and final escape. These cats eventually learned the appropriate clawing movement of escape in two to four trials. Thorndike explained these findings as the acquisition of an association between the stimulus or the sight of the loop and the response or clawing movement. The reinforcer, food or escape in this case, simply served to stamp in S-R connections.

Adherents of S-R theory, given a scenario in which an explicit antecedent stimulus is absent, would simply argue that situational stimuli may become associated with the operant; situational stimuli may include the operant chamber environment, the area surrounding the feeder or the cue light fixtures. In other words, stimuli of some sort are always present when responses occur.

One method by which S-R associative learning may be examined is by establishing a stimulus as an S+, by reinforcing animals for correctly responding during a particular stimulus, and then manipulating a particular stimulus dimension, such as frequency of tone or wavelength of light or line orientation, in order to observe the effects upon responding during an extinction-generalization test. It is reasoned that if responding changes with changes in the nature of the stimulus, a connection between these two events may be implied. Consider the following experiment, conducted by Jenkins and Harrison (1960), which examined the effect of discrimination training on auditory generalization. In one study, a group of pigeons was initially trained on a discrimination task in which keypecks in the presence of a 1000 cps tone (S+) produced food and responses in the absence of the tone (S-) did not. After the birds reached the appropriate criterion of discrimination by learning to respond at least four times greater to the S+ than to the S-, tests for generalization were conducted without reinforcement. During this test phase, pigeons were presented with eight tones of varying frequency (e.g. 300, 450, 670, 1000/S+, 1500, 2250, 3500, no tone/S-). These researchers found the highest percentage of responses at the S+ with a sharp and systematic decrease at tones of higher or lower frequency. This development of a gradient of generalization is typical of such stimulus control investigations (Schwartz, 1984).

Similarly, investigators working in the area of classical conditioning have been able to demonstrate reliable decremental generalization gradients along a particular stimulus dimension. For instance, Moore (1972) reported auditory generalization in rabbits with the conditioned nictitating membrane response. The generalization test, in which the subject was presented with tones of differing pitch after training, revealed that animals respond most to the training stimulus (CS+) and less and less to tones that were increasingly different from it. Evidently, there appears to be a similarity between the results of studies examining the phenomenon of stimulus control observed in operant and classical conditioning procedures. Thus, because changes in a classically conditioned stimulus or instrumental discriminative stimulus influences responding, it seems entirely possible that the stimulus is associated with the response.

Response-Reinforcer View

Some more recent studies of animal behaviour suggest that the reinforcer plays a role beyond that of a simple catalyst facilitating the formation of a stimulus-response connection in the manner suggested by S-R theorists. The alternate response-reinforcer (R-S*) account (Mackintosh, 1974) acknowledges the possibility that the goal is itself encoded. Indeed, the animal recognizes and encodes the very elements in the experimental environment that has been carefully arranged by the researcher; the animal learns that reinforcement is contingent upon a correct response (Colwill & Rescorla, 1986). This view of instrumental behaviour, in which the animal associates events that reflect the "relationships that actually exist in the environment" (Mackintosh & Dickinson, 1979) parallels an interpretation that has been developed to explain Pavlovian conditioning. The subject in a Pavlovian conditioning experiment, is thought to associate the stimulus with the reinforcer or unconditioned stimulus (US); the experimenter arranges a relationship between the stimulus (CS) and the reinforcer (US). It is held that the emergence of a conditioned response is a function of the encoding of these events as associated directly with each other.

Rescorla (1987) reported a series of studies conducted by his associate Ruth Colwill which were primarily utilized to detect response-reinforcer associations. Initially rats were trained to make two different responses to either a tone or light, each earning a particular reinforcer (sucrose or pellet). After the animals had adequately learned to make one response in the presence of the tone and the other response in the presence of the light, the manipulanda were removed and one of the reinforcers was devalued with repeated pairings of LiCl until the animals refused to consume the poisoned reinforcer; during conditioning, animals were also given the opportunity to consume the nonpoisoned reinforcer. Finally, rats were measured for their willingness to emit each of the two responses during light or tone extinction test trials. It was reasoned that if the associative structure was primarily stimulus-response in nature, the tone and light would each be equally capable of evoking its respective response regardless of whether or not a particular response had previously been paired with a toxin. However, the results showed that longer latencies of the response were observed when the reinforcer associated with it had been devalued. In contrast, the stimulus provoked a relatively rapid response when the reinforcer had not been devalued. Because responding was sensitive to changes in the value of the reinforcer, it seems reasonable to assume that a R-S* relationship exists. However, Rescorla also pointed out a somewhat less prominent feature of these results; namely, there was a substantial amount of residual responding for reinforcement that the animal was no longer willing to consume. After testing and subsequently rejecting some alternative interpretations, he tentatively concluded that at least some part of instrumental performance can be explained by an S-R connection. Hence, there remains the possibility that the instrumental response, at least in this experimental situation, is associated with the stimulus as well as the outcome.

In another study, Wilson, Sherman and Holman (1981) also found that conditioning of a taste aversion to a sucrose reinforcer after training of an instrumental response had an effect on subsequent performance of that response. In one study, rats were reinforced with sucrose during the presence of a light/white noise compound stimulus (S+) for lever pressing; presses made during the absence of the light/white noise stimulus (S-) were not reinforced. The experimental group then received pairings of LiCl with sucrose in their home cages. Next, rats were given a 30 minute extinction test in which a lever press made during the S- was followed by a 5 second presentation of the S+ while lever presses during the S+ had no consequence. Wilson et al. (1981) found no difference in rate of responding in the presence of the S+ between the two groups. However, they did find that the control group emitted significantly more responses during the S- than did the experimental group. In contrast to Rescorla (1987), these researchers concluded that there was no effect of the sucrose-LiCl pairings on the ability of the S+ to serve as a discriminative stimulus for lever pressing but that the sucrose-LiCl pairings did reduce the effectiveness of the S+ as a conditioned reinforcer. One possible explanation for the apparent discrepancy among the results reported by these researchers may be due to procedural and measurement variations. The procedure implemented by Rescorla does not allow one to address the conditioned reinforcing function of the discriminative stimuli since the stimuli did not follow responding during S- extinction trials. In addition, Wilson et al. (1981) measured the discriminative control function of the S+ by observing the rate of responding during the S+ versus S- trials, rather than the response latency as in Rescorla (1987), which may have been a less sensitive measure. Nevertheless, these findings suggest that postconditioning manipulations of the value of the reinforcer has an effect on the instrumental response supporting the response-reinforcer view.

The similarity between interpretations used to explain classical conditioning and instrumental learning, following the response-reinforcer view, certainly suggests that a single account might explain them both. Various researchers have subsequently made use of well established ideas and techniques that have been developed through the study of Pavlovian conditioning in order to further expand our knowledge about the associations formed during instrumental learning procedures. For instance, the phenomenon of overshadowing has been repeatedly and consistently demonstrated in many classical conditioning preparations. In a situation in which two stimuli (CS's) are presented in compound to signal the same US, one CS, perhaps the more salient stimulus, may overshadow the other CS (Kamin & Gaioni, 1974). Hence, only one CS is thought to develop an association with the US. It is likely that one stimulus may overshadow the other stimulus if it is a more valid predictor of reinforcement (St. Claire-Smith, 1987). The phenomenon of overshadowing differs from blocking as the latter refers to the overshadowing of control by one stimulus as a result of prior experience with a second stimulus rather than the former case which is a function of the intrinsic properties of the stimuli themselves. Several authors have attempted to apply this logic to the further examination of associative structures in instrumental learning. St. Claire-Smith (1979b), for example, has successfully demonstrated the overshadowing of instrumental conditioning by a stimulus that predicts reinforcement better than the response. Rats trained to press a lever for food on a random interval schedule (RI) reduced their rate of responding considerably relative to controls when a brief cue (eg. a 0.5 second light or tone) was presented between the operative response and the reinforcer; the uncorrelated control group experienced the brief cue following reinforced or nonreinforced responses while the no-stimulus control group did not experience the response-produced cue at all. The overshadowing interpretation for these findings suggests that the brief cue comes to predict the reinforcer better than the response, since not all responses on a RI schedule lead to reinforcement, which consequently reduces the strength of the response-reinforcer association and the signaling function of the response. Therefore, the lower response rate displayed by animals receiving a correlated stimulus is said to reflect overshadowing of the response-reinforcer association by the association between the more reliable stimulus and the reinforcer. A similar finding has been reported in an aversive instrumental conditioning situation (St. Claire-Smith, 1979a).

Two points of theoretical importance may be inferred from the above results. First, the fact that a Pavlovian CS can overshadow an instrumental response suggests that both are associated with the US in the same manner (Colwill & Rescorla, 1986). For example, an instrumental response may be thought to assume the same predictive role as a classical CS is assumed to possess in Pavlovian conditioning. Additional support for the idea that responses and stimuli are functionally equivalent may be found in a study by St. Claire-Smith and MacLaren (1983) who substituted an instrumental response for a CS in a Pavlovian response preconditioning paradigm. Secondly, the results of these studies provide direct evidence that R-S* associations may be necessary for learning to occur since inserting a stimulus between these events blocked acquisition of their association, as empirically noted by decreased response rates exhibited by the correlated group. In order to further support the notion that the overshadowing stimulus became a signal for reinforcement during RI training, a conditioned reinforcement extinction test followed RI training. Subjects were trained to make an alternate keypressing response for three extinction sessions. The brief overshadowing cue followed responses made by animals in the correlated and uncorrelated groups while no programmed event followed the responses of the no-stimulus control group. Consistent with the proposition that the stimulus became a signal for reinforcement for the correlated group, results illustrated that more keypress responses were emitted by these animals relative to controls during this test phase.

Additional evidence for the notion that animals encode R-S* relations is derived from studies that examine the effect of varying magnitude of reinforcement upon responding. The reasoning behind these studies is similar to that of reinforcer devaluation experiments in that changes in the nature of the reward should have an influence upon responding if the two events are directly related. For example, Mackintosh (1974) has cited several studies that have shown that a rat's speed of running down an alley is directly related to the size or density of reward; increases in the magnitude of reward leads to faster running speed. This same positive relationship also exists for other operants such as lever pressing. Furthermore, drastic changes in responding have been observed in reward shift studies in which the animal is first "trained with one magnitude of reward and then shifted to another" (Mackintosh, 1974, p.153). The relation between preshift and postshift rewards has a substantial impact on the nature of performance after the shift (Colwill & Rescorla, 1986). Once again, the fact that manipulating some aspect of the reward directly influences the speed or rate of responding is certainly consistent with a R-S* account of instrumental behaviour.

Studies involving the examination of reinforcement contingency effects form the last line of evidence for response-reinforcer associations discussed here. Some researchers (Colwill & Rescorla, 1986; Mackintosh, 1974) have reported the occurrence of less conditioning or learning by reducing the correlation between the US and CS in the case of appetitive classical conditioning, or between the reinforcer and response in operant procedures. In the former instance, CRs become less and less likely to be evoked as the probability of US presentations during the CS comes to equal that of USs in the absence of the CS. The simple contiguity of CS-US pairings is not sufficient for conditioning. Similar detrimental effects can be obtained in operant learning situations by concurrently presenting subjects with response-independent and response-dependent reinforcers. Evidently, the rate of responding decreases when rewards are just as likely obtained in the absence of a response as contingent upon a response. It is reasonable to assume that these results occur simply because the animal is spending more of its time engaged in eating, having less time to perform other activities. Colwill and Rescorla (1986) have utilized a strategy that is sensitive enough to evaluate the validity of such an interpretation. These investigators trained rats to make two responses (chain pulling or lever pressing) each earning a particular reward (sucrose or Noyes pellet). After the animals had learned to consistently respond equally to both manipulanda at a relatively high rate, one of the reinforcers was occasionally presented independent of its response. Results indicated that although there was a general decline in the rate of both responses, the adverse consequences of free reinforcer delivery were more severe for responses that were formerly required to earn that particular reward. Thus, although it appears that the rat's behaviour is partially affected by a general increase in time allocated to consummatory behaviour, the interesting selective depressive effect upon a particular response is consistent with the response-reinforcer view of instrumental learning.

The purpose of the above discussion was to briefly provide some evidence for the proposition that the animal essentially learns to associate a response with a reinforcer during instrumental training. However, the R-S* interpretation of instrumental learning alone may perhaps be incomplete as it does not explain stimulus control. Specifically, the R-S* view does not account for how animals come to respond more often in the presence of a particular set of stimuli as observed in the stimulus control studies discussed previously. Moreover, while there appears to be a great deal of evidence suggesting that operant conditioning depends upon the contingency between a response and reinforcer, preparing such an experimental arrangement does not always result, as will be shown, in instrumental conditioning.

S-S Relations in Operant Conditioning*

Some problems originate with the definition of classical and instrumental paradigms. In the former case, presentation of the reinforcer is independent of the animal's behaviour, whereas in the latter case, reinforcement is dependent upon the subject's behaviour. However, it is often found that in a classical conditioning procedure where an explicit response, such as key-pecking, is not required of the subject to earn reinforcement, a response may nevertheless occur with consistency. Similarly, in an instrumental procedure, sometimes a required response does not occur in spite of the experimenter's endeavor to arrange relations between the animal's behaviour and reward. In some instances it appears that classical CR's may interfere with operant performance during an operationally defined instrumental learning study, and that operants may similarly 'contaminate' an operationally defined Pavlovian conditioning experiment. The following section illustrates studies that exemplify the apparent 'impurity' of classical and operant conditioning procedures and are discussed as a problem, at least in some cases, for the R-S* account; the influence of S-S* contingencies will also be discussed.

First, some studies have shown that some responses remain relatively unaffected or can not be easily modified by their consequences (Mackintosh, 1974). For instance, the keypecking response may be considered both a Pavlovian CR influenced by S-S* contingencies and an operant response influenced by R-S* contingencies. The autoshaping experiment is an illustration of a classical conditioning procedure influenced by operant R-S* relations. In a typical autoshaping study, a lighted response key signals the presentation of food reinforcement. Although an explicit Pavlovian S-S* contingency is arranged, the animal begins to peck at the response key which is maintained, at least in part, by an implicit R-S* relation. Pigeons will actually persist in pecking a lighted response key signaling food even though pecking cancels the delivery of reinforcement scheduled for that interval (Roitblat, 1987). In fact, the birds' inability to abstain from pecking is so strong that "some animals cut themselves off from all subsequent reinforcement" (Bolles, 1972, p.397).

Still further support for the idea that keypecking may be a Pavlovian CR is inferred from an analysis of the subject's response topography when earning qualitatively different reinforcers. Several authors (Bolles, 1972; Edwards, Jagielo, Zentall & Hogan, 1982) have reviewed earlier reports in which the nature of a pigeon's key-pecking response is influenced by the type of reinforcement earned. For example, Jenkins and Moore (1973) found that the key-pecking response resulting in food reinforcement differs from the key-pecking response earning a water reward. Apparently, the topography of key-pecking responses leading to food and water highly resemble the animal's natural consummatory behaviour exhibited when eating or drinking respectively. Bolles (1972, p.397) explains that "eating is an isolated, sharp, hard peck with the beak partially opened" while the drinking response "consists of a series of brief gentle nibbling or mumbling responses." Direct observation of pigeons' behaviour reveals that the animals almost appear to be "eating" the key associated with food and "drinking" the water associated response key. This seemingly operant key-pecking response appears to look more like a classically conditioned response than an operant, leaving us to question whether the animal's behaviour has truly been influenced by instrumental, rather than Pavlovian, contingencies (Bolles, 1972; Mackintosh, 1974). On the other hand, the fact that response characteristics are affected, at least in this case, by varying the qualitative aspect of reinforcers may provide some support for R-S* view.

An example of the failure of response contingent reinforcement to control operant behaviour has been reported by Breland and Breland (1961). These researchers were unsuccessful in their attempt to condition a raccoon to pick up two coins and deposit them in the slot of a piggy bank. Apparently, the raccoon readily learned to pick up the tokens but subsequently displayed a great deal of difficulty releasing the coins into the container; instead, the raccoon persisted in rubbing the coins together and occasionally began to dip them in and out of the container. In spite of reinforcement contingency, this misbehaviour continued until, like the pigeons' autoshaping experiment described above, the raccoon cut itself off from all subsequent reinforcement. In both cases, the animal's innate consummatory or food-getting behaviour interfered with its ability to perform the target response required to obtain the reward. Thus, it appears that at least in some operant conditioning situations, stimulus-reinforcer contingencies, rather than response-reinforcer contingencies, are more likely to affect behaviour.

The evidence on the role of S-S* and R-S* associations in autoshaping cited above, has prompted some to recognize the important influence of Pavlovian contingencies on instrumental learning. In general, there appears to be two dominant models that acknowledge the importance of S-S* relations in the control of instrumental behaviour. First, according to Bolles (1972), animals are susceptible to both S-S* and R-S* conditioning during instrumental learning. It is the combination of two kinds of expectancies, S-S* and R-S*, which function to govern behaviour. His primary law of learning asserts that organisms learn that certain events, such as cues, predict biologically important events, such as reinforcement. His secondary law of learning states that organisms learn about relationships that exist between their own behaviour and the consequences of that behaviour. Bolles (1972, p.403) writes: "animals can learn R-S* expectancies that represent and correspond to the R-S* contingencies in their environment. These expectancies, together with S-S* expectancies, constitute all of what is learned in most instrumental learning experiments."

Jenkins (1977), on the other hand, has extended Skinner's (1938) assertion that a discriminative stimulus sets the occasion for the reinforcement of a response. It is thought that the three-termed stimulus-response-reinforcer relation represents an irreducible structure (St. Claire-Smith & Imhoff, 1985) unlike Bolles' (1972) two-termed proposition. In the language of expectancy, Jenkins (1977, p.51) explains that the organism "learns to expect a certain outcome of responding (R-S*) conditional upon a prior stimulus. The expectancy might be represented as S(R-S*). This conditional expectancy cannot be synthesized from two separate expectancies of the form (S-S*) and (R-S*) because it has a different structure." Jenkins reports a study which systematically evaluates the effects of S-S*, R-S*, and S(R-S*) relations on different responses. For the first response, pigeons were reinforced on a VI 30 second schedule for waving their heads during an eight second noise. The interruption of two carefully placed infrared beams by an operable head waving movement produced a sharp clicking sound and reinforcement. It should be noted that this particular response is not part of the pigeon's natural food-getting behaviour nor can it be established by S-S* contingencies alone (Jenkins, 1977, p.52). The second requirement was that the pigeon peck a lighted response key for reinforcement. Unlike the autoshaping studies discussed earlier, the delivery of food, on a VI 30 second schedule, was contingent upon the response. However, this keypecking response, unlike head-waving, could be initiated and maintained by S-S* contingencies. A number of manipulations were implemented in order to further assess the adequacy of the three-termed (S(R-S*)) and two-termed ((S-S*) and (R-S*)) models. Jenkins (1977) subsequently compared performance when: (1) The reinforcer was jointly contingent on the stimulus and response, as in the first phase; (2) The reinforcer was contingent upon only the stimulus, by virtue of the fact that the response contingency was removed during the stimulus presentation; (3) The reinforcer was only contingent upon the response, whereby food could be earned equally either in the presence or absence of the stimulus; (4) The reinforcer was neither contingent upon the stimulus nor the response. These manipulations were also used to specifically test, what he refers to as, the "origin hypothesis"; this hypothesis states that "if the response resembles the one elicited by the reinforcer, then control of the response is dominated by the S-S* relation... Conversely, the control of a response that requires for its establishment an R-S* contingency, and the form of which is arbitrarily related to the response elicited by the reinforcer, is largely controlled by R-S* relations..." (Jenkins, 1977, p.54). Jenkins found that keypecking was maintained at a higher proportion of its baseline level than was head-waving, by either an S-S* contingency alone or by an R-S* contingency alone. Therefore, he asserts that the origin hypothesis may be inadequate since the keypecking response is affected by R-S* contingencies. Jenkins reasoned that for the keypecking response, when the S-S* contingency was removed, these responses continued because the discriminative stimulus functioned to set the occasion for responding by virtue of the R-S* contingency. Jenkins concludes that each response was sensitive to an S-S* contingency, an R-S* contingency and an S(R-S*) contingency. Overall, it is clear that at times innate behaviour patterns controlled by Pavlovian contingencies appear to interfere with instrumental learning.

Two-Process Theories

One implication of the finding that responses are sometimes modified by Pavlovian reinforcement during operationally defined instrumental learning experiments is that classical contingencies implicitly exist in, and interact with, such instrumental preparations; this remains the main proposition of two-process theories which gained popularity approximately 25 years ago. Specifically, researchers (Mackintosh, 1974; Rescorla, 1987) note that when a response is reinforced in the presence of a tone, the tone is also paired with the reinforcer. Thus, it is thought that the subject learns about the reinforcer through a Pavlovian process. While the reinforcer (US) forms a Pavlovian association with the stimulus (CS), it presumably also functions as a catalyst forging a connection between the stimulus and response. The stimulus-response association, or the first learning process, is assumed to develop concurrently with the second learning, or Pavlovian associated S-S*, process (Trapold & Overmier, 1972). Although the first S-R process is actually embedded within the structure of the second S-R-S* process, the sequence S-R-S* may be considered irreducible.

According to two process theory, the CR elicited by the stimulus plays an important role in the production of the operant response. However, over the years, there has been some differences in opinion as to the precise role, and nature of, the CR. Some researchers have proposed that this Pavlovian CR initiates the operant response while others have argued that the CR itself actually reinforces the operant (Rescorla & Solomon, 1967). Presumably, if the former case is an accurate account, stronger CR's would be more likely to occur before the operant response, whereas if the latter is true, more robust CR's would be observed following the operant. For example, Pavlovian CR's, such as salivation may be thought to reinforce the operant by perhaps increasing the palatability of food. On the other hand, the CR may be rich in sensory feedback functioning to elicit the instrumental act. Unfortunately, results of studies that have attempted to concurrently measure both Pavlovian and operant responses have been inconclusive. For example, salivation or heart rate changes have been observed to occur before the operant in some appetitive studies and after the operant in other similar experiments (Rescorla & Solomon, 1967). Meanwhile, other research strategies, which will be discussed in further detail shortly, have been employed to examine the related issue concerning the specific identity of this mediating state. Earlier suggestions proposed that the mediating state may have emotional (Amsel, 1972) or motivational (Rescorla & Solomon, 1967) properties that can affect the instrumental response. The 'peripheral response mediation hypothesis', which has typically been examined via concurrent measurement experiments, asserts that changes in the subject's "muscles, or glands, or peripheral nervous system" (Trapold & Overmier, 1972) is an index of the conditioned mediating state. Since attempts to find and measure overt peripheral responses that directly correspond with instrumental behaviour have been unsuccessful, researchers have more recently turned toward a more cognitive model assuming that a central classically conditioned mediator exists (Edwards, Jagielo, Zentall & Hogan, 1982).

Having provided a structural analysis and discussed some of the general assumptions of two-process theories, it would be helpful at this point to review the evidence obtained, and examine the research strategies used, by those engaged in studying this area. A technique that is said to provide substantial support for two-process theories has been termed the 'transfer of control' experiment. Directly following the structure of two-process theory, the design of these experiments employs three distinct phases in order to examine the interaction of both processes while having the opportunity to study the first process relatively unconfounded by the second process. First, during the instrumental training phase, subjects learn to correctly respond to a discriminative stimulus (S^D) for a reward. Secondly, during the pairing phase, some other stimulus (S_2) is temporally paired with the same reinforcer as was earned in phase one; a specific instrumental response is not a requirement. Lastly, the transfer of control phase assesses the ability of S_2 to evoke the response that was learned during the first phase. The typical finding of such an experiment is that S_2 acquires the capacity to evoke the instrumental response which has never previously been paired with it on the test (Trapold & Overmier, 1972). According to two-process theory, the ability of S_2 to acquire control over the instrumental response is due "directly to the second response-independent learning process established during the pairing phase" (Trapold & Overmier, 1972, p.429). By partitioning out, in a sense, the second process, which is assumed to be embedded in the first process, one may interpret the observed transfer of control as support for the notion that instrumental learning involves more than just learning the association between the stimulus and response. Similar findings have been reported for variations of transfer of control experiments of this sort. For instance, some researchers have reversed the order of the pairing phase and instrumental training phase or have carried out some or all of these phases concurrently (Trapold & Overmier, 1972).

Although Trapold and Overmier (1972) have reviewed two-process theories, as applied to the transfer of control paradigm, in considerable detail, it is worthwhile briefly noting a few of the main points of their discussion here; many of these ideas will reappear in the next section of this paper which looks at dual process theories as applied to another paradigm. Early operant mediation theories speculated that perhaps the type of learning which takes place during the pairing stage is not truly response-independent in form. According to such theories, the animal, perhaps superstitiously, learns to perform some operant during the pairing phase which in turn apparently influences the target response during the test phase. Trapold and Overmier (1972) have listed a number of research strategies that have been conducted to test this operant mediation hypothesis, some of which include the following: (1) training subjects, during the pairing phase, to make an operant response which is mechanically incompatible with the target response; (2) training subjects to perform a variety of responses, during the pairing phase, which may include those that are thought to be facilitative, interfering or neutral with respect to the target response; (3) administering paralysis inducing drugs in order to minimize operant behaviour during the pairing phase; (4) running the pairing phase before the instrumental training phase so that operants that may be established during this phase are done so without having previous knowledge about the target response; (5) physically restraining subjects during the pairing stage and; (6) conducting the first two phases in different experimental environments thereby minimizing the subject's chance of generalizing the mediating response between stages. In spite of using all of these variations, transfer of control effects are nevertheless reported. The suggestion that arises from these numerous operant mediation studies is that the formation of stimulus-response connections during the pairing phase apparently can not adequately account for the transfer effects obtained in these studies.

Consequently, the results that have been found by examining operant mediation theories strengthen the argument of the dual-process position; namely, the formation of a Pavlovian stimulus-outcome association during the pairing phase influences or facilitates instrumental responding during the test phase. The assumed important role of Pavlovian CR's has already been mentioned and the status of the peripheral response mediation hypothesis as applied to the concurrent measurement literature reported by Rescorla and Solomon (1967) has already been revealed. These two-process theories also assume that reinforcement is not only a reward for correct instrumental responding but also acts as a classical US. The stimulus is also thought to have a dual role. For example, when a rat is reinforced for pressing a response lever during a tone, the tone is both a discriminative stimulus that controls instrumental responding as well as a classical CS which evokes the presumed mediating CR; this particular assumption, as we will see later, may be questioned in light of recent studies of Pavlovian conditioning.

Since it does not appear that the mediating CR is located in the peripheral nervous system, as suggested by concurrent measurement studies, it is thought that the CR may perhaps be centrally located. Perhaps the theoretical mediating state observed and measured in some of these experiments is simply a manifestation of a central state (Peterson, 1984). Because the mediator is assumed to be a Pavlovian CR, a reasonable research strategy would be to determine whether or not it truly functions as a CR should (Rescorla & Solomon, 1967) and follows the established laws of classical conditioning. Rescorla and Solomon (1967) have provided a complete review of the literature employing these research methods. However, although this idea may appear to be quite a simple matter, there is still much ambiguity surrounding the categorization of classical versus instrumental responses. Trapold and Overmier (1972) note the danger of trying to compare the mediator with Pavlovian CR's which are events that have not yet been completely defined. The pigeon's autoshaped key-pecking response, discussed earlier, is a good example of this sort of problem. These researchers also raise another issue of concern within the two-process model; namely, the problem involves identifying the mechanism by which the mediating CR influences the instrumental response. Although a motivational explanation has been offered (Rescorla & Solomon, 1967), there is still some confusion as to the precise meaning of the term 'motivation'. Hence, one may question the usefulness or explanatory power of using a term that is not yet completely understood.

Recently, investigators have increasingly placed less emphasis on motivation and more emphasis on the associative role of the mediator's stimulus feedback properties (Trapold & Overmier, 1972). According to the stimulus feedback view, the stimulus properties of the mediator become associated with whatever operant is reinforced in their presence. This conditioned state, which is apparently elicited by the onset of the preceding external cue, functions as part of the stimulus compound to which the operant response is learned. The conditioned state has become familiarly known as an 'expectancy' (Peterson, 1984). Although the term "expectancy" may be quite a cognitive sounding term, it should be noted that no specific assumption has been made concerning the location of this expectancy thus far.

In addition to transfer of control tasks, the differential outcomes procedure (DO) is yet another experimental approach used to investigate the influence of conditioned mediators on choice responding. During a DO procedure, typically two different reinforcers are used in a conditional discrimination task, one of which follows a correct response R_1 to one stimulus S_1, while the other consistently follows a correct choice R_2 to the other stimulus S_2. The differential outcome effect (DOE) was initially illustrated by Trapold (1970), and later extensively examined, by Peterson and his colleagues, who questioned whether or not expectancies based on different reinforcers are discriminably different. Trapold showed that in a two-choice discrimination task, the use of qualitatively different reinforcers, such as sucrose solution and solid food, for each of two correct choice responses produces faster discrimination learning than either of the reinforcers used alone. Trapold explained the better performance of the "differential outcomes group" in terms of conditioned expectancies: each cue came to elicit distinct expectancies that were specific to each outcome and these expectancies, in turn, helped cue the appropriate response in rats. In a follow up study presented in the same paper, Trapold attempted to see whether or not discrimination learning would be faster for rats whose preestablished expectancies to S_1 and S_2 are consistent, rather than inconsistent, with those encountered during the choice task. In the first phase of the study rats were trained on a classical conditioning procedure in which one group was trained with pairings of tone-food and clicker-sucrose while the other group was trained with the clicker as the CS for food and the tone as the CS for sucrose. Next, rats were trained on a conditional discrimination problem in which they earned food reinforcement for correct responses on one lever in the presence of the tone and sucrose for pressing another lever in the presence of the clicker. As predicted by expectancy mediation theory, the task was acquired faster when the relationship between the CS and US was the same as the relationship formed between the discriminative cue and the outcome. This demonstration is consistent with the dual process assumption that Pavlovian S-S* connections are an implicit part of instrumental learning and that a discriminative stimulus, which is presumably also a CS, elicits a conditioned state that affects instrumental responding.

Others have also reported that Pavlovian CS effects upon instrumental choice performance are reinforcer specific (Kruse, Overmier, Konz & Rokke, 1983). For example, in a transfer of training study, Kruse et al. (1983) were able to demonstrate that Pavlovian conditioned stimuli evoke response cuing expectancies that are specific to the particular reinforcer (US) signaled. First, animals were administered successive conditional discrimination training. Rats were required to press the left lever ten times during a clicker to receive food, and press the right lever ten times during a tone to receive a sugar solution. Four groups of animals received the appropriate reinforcer for each correct choice (CRF: continuous reinforcement) while two groups experienced the appropriate reinforcer on only half of their correct response choices (PRF: partial reinforcement). Next, half of the subjects in each condition experienced a Pavlovian conditioned excitation (CS+) procedure while the others experienced conditioned inhibition (CS-). During the CS+ procedure, animals were occasionally presented with three seconds of white noise which was immediately followed by delivery of either a sucrose or pellet reinforcer. To establish a CS-, sucrose or pellet reinforcers were presented at least sixty seconds after the termination of the noise so that there was a negative correlation between the US and the noise. Following retraining of the original conditional discrimination task, animals were given the opportunity to respond on either lever during the presence of the S^D alone, the CS alone, and the S^D/CS compounds (e.g. tone/noise and clicker/noise). The results indicate that CS+'s evoked choices of the lever which had been reinforced with the event identical to the Pavlovian US, while the CS-'s displayed only a slight tendency to evoke the other choice responses. Also, the CS+/S^D compound had little effect upon rate of responding while the CS-/S^D compound reduced the vigor of responding for the reinforcer that was identical to the US employed during the CS- procedure. These data offer support for a specific-expectancy mediational model.

A number of subsequent experiments have replicated the DOE in pigeons, rats and dogs. Various outcomes have been used, some of which include food versus water (Honig, Matheson & Dodd, 1984), food versus no food (Peterson, Linwick & Overmier, 1987), food versus tone (Peterson & Trapold, 1980), small versus a large reward (Carlson & Wielkiewicz, 1976), food versus sugar water (Kruse et al., 1983), 5-second delay versus no-delay (Carlson & Wielkiewicz, 1972), differential foods (Edwards et al., 1982), differential probabilities of reinforcement (Santi & Roberts, 1985), and differential shocks in an avoidance paradigm (Overmier, Bull & Trapold, 1971).

There seems to be a great deal of uncertainty as to the nature and role of these mediating states and this ambiguity is apparent by the varying interpretations offered by a few of the above studies. For example, Overmier, Bull and Trapold (1971) illustrated the DOE in a two-choice successive discrimination avoidance task in dogs using different kinds of aversive events. Discrimination learning was faster when, after incorrect responses, two distinctively different US's, such as pulsating shock to the right leg or constant shock to the left leg, was paired consistently with each stimulus. Overmier et al. (1971) concluded that these different aversive events condition distinctively different states or fears, which together with the preceding stimulus, function to cue correct instrumental responses. Therefore, in this case, it appears that different emotional states mediate discriminative responding via the stimulus feedback mechanism.

In fact, with one exception, all of the experiments listed thus far may appeal to peripheral conditioned states or emotional factors acting as mediators. In most of the studies mentioned above, there appeared differences in responding during each of the conditional stimulus cues which is apparently related to differences in some aspect of reinforcement. Edwards et al. (1982) specifically note two possible differences in response behaviours. First, there were different patterns of responding which "correspond to differences in the incentive value of the two reinforcing events" (Edwards et al., 1982, p.245). For instance, in a study by Carlson and Wielkiewicz (1972) in which a 5 second delay of reinforcement delivery was correlated with one lever and no delay of reinforcement delivery on the other lever, found that during initial testing rats had a "marked preference" for pressing the no-delay lever. These initial preferences have been observed elsewhere using differential magnitudes of the same reward (Carlson & Wielkiewicz, 1976). Secondly, Edwards et al. (1982) note that in addition to different response patterns, there are differences in "response topographies". For example, in a delayed symbolic matching-to-sample task with pigeons where food or water are the differential reinforcers following each of two correct responses, the topography of key-pecks to each sample reflected the reinforcer associated with it (Brodigan & Peterson, 1976). These observations concerning different response patterns or topographies are in accordance with a peripheral response mediation hypothesis or an emotional mediation account (Edwards et al., 1982; Trapold & Overmier, 1972). Once again, the idea is that these different conditioned states may be indexed by reinforcer-specific responses to enhance discrimination performance through either a motivational or stimulus feedback mechanism.

Problems for a motivational/peripheral response account arise when a procedure, using two distinctively different but equally preferred rewards yielding similar response topographies is implemented. Edwards et al. (1982) were able to illustrate the DOE in such a situation. Edwards et al., in their second transfer experiment, presented pigeons with a matching-to-sample (MTS) procedure using wheat and peas as reinforcers. During the first phase, pigeons were initially presented during each trial with one of two shape samples (plus or circle). Ten pecks to this centre sample key turned on the two side comparison keys (plus or circle shape). A response to the comparison key which matched the sample key constituted a correct choice response leading to reward. For the Correlated group, correct responses to circle samples were reinforced with wheat while correct responses to plus samples were reinforced with peas. The Uncorrelated control group received peas for correct responses to half of the trials of each type (plus or circle) and wheat for the remaining trials. The Common Outcome control group was reinforced with an equal mixture of peas and wheat for correctly responding during either trial type. Phase

2 introduced colour (red and green) MTS trials. The Correlated group was reinforced with peas for matching red and were reinforced with wheat for matching green. The Uncorrelated control group received random presentations of peas or wheat for each trial type while the Common Outcome control group received a mixture of peas and wheat for correct matches during each type of trial. An equivalent number of shape trials were also presented during this phase of training. Following Phase 2 training, the birds were introduced to the symbolic MTS transfer phase. The birds were reinforced with peas for responding to the red comparison during plus sample trials and to the plus comparison on red sample trials. On green and circle sample trials, responses to the circle comparison and green comparison, respectively, were reinforced with wheat. Following this transfer phase, the pigeons were reintroduced to some additional sessions that were identical to those of Phase 2. The birds were then exposed, in Phase 4, to symbolic delayed-matching-to-sample (DMTS) training. Various delay intervals (0, 2, 4 seconds and 0, 1, 2 seconds) were inserted between the offset of the sample key and onset of the side comparison keys. The insertion of these delay intervals remained the only difference between Phase 2 and Phase 4. Analysis of the birds' rate of responding to stimuli associated with peas and to stimuli associated with wheat reveal no significant differences across the three groups. This finding was taken as evidence for the proposition that the birds displayed no apparent food preferences. However, perhaps it should be noted that one can not definitively prove that these two rewards are indeed equally preferred by the animals; instead, we may only infer that this is so by the fact that there appears to be no evidence of differential preferences. Perhaps more important is the finding that the animals in the Correlated group remained the least affected by the insertion of the delay intervals while these delays impeded performance of both control groups equally. This enhanced memory performance demonstrated by the Correlated group was confined to the shape task. Apparently, pigeons are known to have more difficulty with tasks which use shapes, as opposed to

colours, as the initial sample in DMTS. Therefore, these researchers reasoned that pigeons will use memory for reinforcers associated with two stimuli only when the values of the initial sample stimuli are difficult to remember. Finally, these researchers concluded that mediational effects can be obtained in the absence of peripheral response factors and subsequently suggest a "cognitive model of outcome expectancy" (Edwards et al., 1982, p.258). Most important, the model assumes that reinforcers are represented centrally and that expectancies are acquired because of the biological significance of the reinforcer or outcome.

However, results of a fairly recent study by Fedorchak and Bolles (1986) seems to yield problems for this particular account. These authors discovered that they were able to obtain the DOE for correct responses using a biologically neutral outcome event. These researchers presented rats with a discrete trial conditional discrimination task in which the animals were required to press one response lever in the presence of one cue, either a tone or clicker, and the other lever during the presence of the other cue to receive reinforcement. Specifically, each trial began with the presentation of one of two auditory stimuli (either a tone or clicker) with both response manipulanda (left lever or right lever) available within the chamber. After the occurrence of a single correct response, the appropriate scheduled outcome was presented (either water alone or light plus water) followed by the 30 second intertrial interval (ITI). However, an incorrect response was simply followed by the ITI. They found that water deprived rats learned the discrimination task faster when water and light were consistently paired with S_1 following correct responses on one lever, and water alone was paired with S_2 following correct responses on the other lever than either of the control groups; the nondifferential outcome control group was presented with water alone following correct responses to both stimuli, while in the random control group, light accompanied water only after half the correct responses to each bar.

The results of the Fedorchak and Bolles (1986) study do not conform to the notion that Pavlovian conditioned informational/emotional states interact with instrumental learning. As they point out, one would have to describe how the unconditioned response to light and water differs from an unconditioned response to water alone. Moreover, they apparently found no preference or aversion to the bar associated with light outcomes; however, perhaps a stronger argument for the neutrality of the light flash could have been made if, for example, they had conducted an extinction test. Thus, during this extinction phase, the procedure could be identical to that experienced during discrimination training except that animals would not be reinforced. For the experimental and random groups, response contingent cue lights would still flash after the correct appropriate response while the nondifferential control group would receive nothing. No between group differences in responding would be expected if the light flash remained biologically neutral.

Instead of explaining their data in terms of peripheral conditioned mediational states, which they can not do given neutral outcome events, Fedorchak and Bolles refer to a study by Meck (1985) which examined postreinforcement signal processing in a discrimination learning procedure. Meck illustrated that postreinforcement stimuli, such as a 8 or 2 second noise which have no current value in terms of predicting correct response choices, can serve as discriminative stimuli and control responding when they subsequently precede the opportunity for choice responding. Specifically, rats that had acquired backward associations between specific responses (e.g., R_1=left lever; R_2=right lever) and different tone durations (e.g., R_1-->2-s tone; R_2-->8-s tone) later emitted the corresponding response in the presence of the tone durations that had previously followed those responses. The simple temporal contiguity of unique tone duration and specific response subsequently came to evoke that response. Fedorchak and Bolles suggest that perhaps a cognitive representation of the signal would have the same effect. They propose that the reason that they obtained the DOE in their experiment was that "the auditory cue that elicited a representation of the light flash evoked responses toward the bar that produced it (the flash), whereas the cue for the nonoccurrence of the light flash evoked responses toward the bar that did not" (Fedorchak & Bolles, 1986, p.129). Unlike other models of outcome expectancy (Edwards et al., 1982; Trapold & Overmier, 1972), the biological significance of different outcomes is not a necessity here. These researchers conclude by suggesting that their account could explain the DOE's obtained in previous studies providing the differential outcomes are salient enough to produce distinct corresponding cognitive representations.

Therefore according to Fedorchak and Bolles (1986), a two-process model of instrumental learning that appeals to mediating states affected by hedonically different reinforcers is not required to explain the DOE. In fact, after regarding the literature generated by two-process theory, one may notice a trend which has developed over the years; assumptions regarding the mediator have evolved from emotional/peripheral to central conditioned states, and finally to cognitive representations of hedonically neutral events. Similarly, focus on the mechanism has changed from motivational to stimulus feedback accounts.

The assertion that the two-process model appears unnecessary may be quite reasonable in light of recent studies of Pavlovian conditioning. An important finding of these studies is that a stimulus becomes associated with the reinforcer only when it reliably predicts, or provides new information about, the reinforcer thereby weakening the argument that contiguity is a sufficient condition for the occurrence of learning (Rescorla, 1987). Colwill and Rescorla (1986, p.92) explain that "if an AX compound is followed by a reinforcer but A is nonreinforced when presented separately, animals typically show little association between A and the reinforcer". The stimulus and response in an operant learning situation parallels the "A" and "X" of the Pavlovian preparation. For instance, the animal is not reinforced when the stimulus (A) occurs in the absence of a response (X) but is reinforced when both events occur together. Following this logic, the subject should not form a simple Pavlovian association between the stimulus and outcome. Note that these findings provide a problem for accounts, such as the one suggested by Fedorchak and Bolles (1986), that focus on the importance of temporal contiguity. Recent additional research within the area of Pavlovian conditioning has also suggested that CS+'s and discriminative stimuli (S^Ds) are functionally independent (Ross & LoLordo, 1987).

A recent study conducted by Colwill and Rescorla (1988), using a variation of the transfer of control prototype design described earlier, also suggests that a dual process model need not be a necessary account for the explanation of transfer effects. The design of their first experiment was as follows: (1) during S^D training, subjects were given food for making R_1 in the presence of a light (S_1) and earned sucrose for making R_2 in the presence of a noise (S_2); (2) during the response training stage, subjects were placed on a free-operant schedule in which R_3 earned food reinforcement and R_4 earned sucrose; (3) next, during the extinction test phase, subjects were occasionally presented with S_1 and S_2 separately and both manipulanda were available. Note that the "pairing phase", which presumably partitions out the embedded Pavlovian second learning process, has been changed into a response training phase. The transfer tests indicate "that the S^D selectively increased the likelihood of the response with which it shared a reinforcer" (Colwill & Rescorla, 1988, p.157). Therefore, this particular transfer of control experiment was able to demonstrate that a reinforcer in instrumental learning establishes two kinds of associations: during the course of instrumental training, the reinforcer becomes associated with the discriminative stimulus, as well as the operant response which precedes it. Moreover, the results of the third experiment, in which during the first stage, subjects experienced both

S^D-R_1-Outcome 1 training and CS+-Outcome 2 pairings, also suggest a functional difference between S^Ds and CS+'s. While S^Ds increased the likelihood of the response trained with the same reinforcer, the effect of the CS+ was to depress the likelihood of responses trained with a different reinforcer. Thus, in opposition to the two-process position, it appears that CS+'s and S^Ds are associated with the reinforcer in somewhat different ways. The most reasonable suggestion provided by Colwill and Rescorla, in light of their results, is that the S^D "sets the occasion" upon which a response will be reinforced,as originally proposed by Skinner (1938), while the CS+ reliably predicts reinforcement delivery.

Thus, even though the transfer effects obtained by these researchers suggests that an association is formed between the S^D and reinforcer, there appears to be little evidence that this association develops through a Pavlovian process as suggested by previous transfer of control studies and DOE experiments. Once again, transfer effects were evident in spite of replacing the 'pairing phase' of traditional transfer studies with a target response training stage. Moreover, Colwill and Rescorla's final experiment illustrates that the relationship between the CS+ and reinforcer is different from that of the S^D and reinforcer, a finding that directly contradicts one of the major assumptions of two-process theories. Evidence for the concurrent development of a response-reinforcer association is yet another departure from the two-process view which instead proposes a stimulus-response connection; numerous studies examining the presence of response-reinforcer associations in instrumental learning have already been reported in this paper as well as elsewhere. Without reference to the various mediational or motivational mechanisms of two-process theories, Colwill and Rescorla (1988, p.163) attribute the transfer effects to "the shared terms of the S^D-outcome and response-outcome associations". In addition, they assert that this particular explanation may be applied to the results of previous traditional transfer of control and DOE studies. For example, these researchers note that enhanced acquisition of the two-choice conditional discrimination task in DO studies for animals receiving two different outcomes for each unique stimulus/response combination may be due to consistent response-reinforcer relations which are implicitly embedded in the design. Similarly, it is possible that the first phase of the prototype transfer of control experiment discussed earlier may actually promote the establishment of response-reinforcer associations rather than the presumed 'first process' stimulus-response relation.

In an attempt to provide further support for the notion that response-reinforcer associations play a primary role in governing instrumental behaviour, Rescorla and Colwill (1989) recently conducted a study in which they directly compared two different theoretical views that describe how this association forms and functions. They contrasted the view that knowledge about the response and the reinforcer is represented as an R-O association with the alternative two-process position which asserts that the reinforcer expectancy preceding the instrumental response forms a connection with that response in the form O-R. During the first phase of their study, the animals received instrumental discrimination training during which time specific reinforcer expectancies were presumed to be established given a particular stimulus environment. All animals received either sucrose or pellets for nose-poking in the presence of one stimulus (a light or a noise) and received the other reinforcer for nose-poking in the presence of the other stimulus. Next, two new instrumental responses (lever pressing and chain pulling) were reinforced in the presence of each of the stimuli. For Group Same, the stimulus-reinforcer configurations were consistent across both phases. For Group Switched, the reinforcer that had previously followed S_1 now followed S_2 while the reinforcer that had followed S_2 now followed S_1. Accordingly, these researchers were able to arrange for the anticipation of one reinforcer to precede a response but for the other reinforcer to follow that same response in the case of Group Switched. Following this training stage, either O_1 or O_2 was devalued with pairings of a lithium chloride (LiCl) toxin. Finally, animals had the opportunity to pull the chain or press the lever during the extinction test. Although the two theories make similar predictions for Group Same, they differ in their predictions for Group Switched. The two-process theory predicts that the response will be most affected by devaluing the anticipated outcome, whereas the response-reinforcer view expects the response to be most affected by devaluing the outcome that followed it (consequent outcome). The results of Group Switched were congruent with the latter position; devaluation of the consequent, rather than anticipated reinforcer, had a more profound effect on instrumental performance. Subsequently, animals were given the opportunity to nose poke in the presence of the stimuli in order to verify that the anticipations developed during discrimination training with the nose poke response had persisted throughout training of the lever press and chain pull response. Results of this extinction test revealed that in each group, the level of responding was lower during the stimulus associated with the devalued reinforcer. Thus, it appears that the short length of target response training did not interfere with the original S-O associations. However, due to the absence of any explicit external stimuli during previous extinction testing, one could argue that the expectation of the reinforcer was not evoked and therefore learning of O-R could not have an influence on instrumental choice performance. Rescorla and Colwill (1989) addressed this argument in a subsequent study by presenting S_1 and S_2 in compound during testing with the target responses. Similar results to those of experiment one were obtained for responding during the ITI. Moreover, generally animals maintained a higher level of responding during the presentation of the stimulus compound compared to the ITI but once again poisoning of the consequent reinforcer depressed instrumental responding more than did poisoning of the anticipated reinforcer. In their final experiment, Rescorla and Colwill (1989) evaluated the importance of R-O and O-R associations in instrumental performance by using a transfer design instead of a devaluation procedure. This experiment demonstrated that a S^D associated with a reinforcer will selectively augment a response that has the same reinforcer as a consequence rather than as an antecedent. These findings are congruent with their earlier data (Colwill and Rescorla, 1988) which showed that discriminative stimuli transfer preferentially to responses trained with the same outcome. In light of these recent findings (Rescorla and Colwill, 1989) it appears that the transfer effects observed in both studies were primarily governed by the combination of S-O and R-O associations.

While it is thought that the interpretation provided by Colwill and Rescorla (1988) may also explain the findings of past transfer of control and DO studies, it remains unclear as to whether or not this interpretation can also suitably address the results found by Fedorchak and Bolles (1986). These researchers, like Colwill and Rescorla, have attempted to provide an alternative to the traditional two-process account by suggesting that the cognitive anticipated outcome is centrally located serving as part of the stimulus complex controlling the instrumental response. Their explanation appears to be rather weak especially since their results have not yet been replicated. Perhaps the interpretation suggested by Colwill and Rescorla (1988) can more convincingly explain the DOE obtained by Fedorchak and Bolles (1986). That is, their animals may have concurrently developed response-reinforcer and stimulus-reinforcer associations during the course of instrumental learning. As Colwill and Rescorla point out, it could be the consistency between the response and reinforcer, rather than the assumed second-process S^D-outcome, that is responsible for the enhanced performance of the conditional discrimination task for the experimental animals. Use of the DO design does not permit us to separate these explanations of the DOE.

In summary, the preceding review of the literature has attempted to evaluate the various theories of associative learning. First, although an S-R associationist view can adequately explain the stimulus control data, this account is incorrect in postulating that reinforcement does not enter into part of the associative structure controlling instrumental performance. S-R associations may play some role in instrumental learning (Mackintosh, 1983) but there appears to be numerous studies which support the notion that instrumental learning involves R-S* associations and that these associations may be necessary; however, appeal to a R-S* account alone can not explain the control of instrumental behaviour by an S^D. Other evidence suggests that S-S* associations are learned during the course of instrumental learning but investigators remain uncertain as to the necessity and mechanism of this connection. According to two-process theories, the S-S* association, formed through a Pavlovian process, concurrently develops with an S-R instrumental association (Trapold & Overmier, 1972). However, recent evidence suggests that S^Ds are not simple CS's (Colwill & Rescorla, 1988; Ross & LoLordo, 1987) and that CR's may not play the motivational or mediating role as suggested by two factor theorists (Fedorchak & Bolles, 1986; Rescorla & Colwill, 1989).

The present study is based on the following rationale. Colwill and Rescorla (1988) conclude their discussion by suggesting that motivational/mediating conditioned responses are unlikely factors involved in their observed transfer effects. Similarly, Fedorchak and Bolles (1986) were able to obtain a DOE using biologically neutral outcome differences, suggesting again that perhaps a classically conditioned response is not a necessary component involved in the explanation of the DOE. If it is the case that motivational CR's do not play an important role in the production of the operant, then it should be possible to demonstrate the selective transfer of control of an S^D from one instrumental response to another, by way of a Colwill and Rescorla (1988) transfer design, on the basis of a shared outcome event where a biologically neutral stimulus serves to differentiate each outcome (e.g. Fedorchak & Bolles, 1986). It also follows that a DOE should be obtained during the first phase of the experiment if the animals have the ability to represent O_1 as different from O_2.

The basic design is outlined in Table 1. During the first phase, rats in the experimental group were given a light flash/food outcome combination (O_1) contingent upon a correct response (R_1) in the presence of one S^D (S_1), and food alone (O_2) contingent upon a different response (R_2) in the presence of another S^D (S_2). Animals in the control group also received discrimination training but the flash of light occurred after a random half of each of the two operable responses while food alone followed the other half of the responses. Next, the animals in the experimental group were trained to make two new instrumental responses (R_3 and R_4), each followed by either O_1 or O_2. Finally, the occurrence of these additional responses (R_3 and R_4) were tested in the presence of the S^Ds; both response manipulanda were continuously available and animals were not reinforced at this time.

A decision was made to employ a conditional two-choice discrimination task, unlike Colwill and Rescorla (1988), during the first phase so that the results and discussion to follow may be applied to the DOE literature. Thus, this study has a possible advantage over other studies that have explored two-process theory since its design combines a DO procedure with a transfer of control technique; the former may illustrate how using differential outcomes effect learning, while the latter may reveal information about the associative structure of this instrumental behaviour. Finding a facilitation in performance for the animals in the experimental group during the conditional discrimination would provide support for the idea that the animals differentially represented the two outcomes and that this information improved choice performance. Subsequent selective transfer effects for the experimental animals would be expected during the transfer of control test. To be more specific, if the animal's representation of O_1 is distinctly different from O_2, then it is expected that an S^D initially trained with one response will selectively transfer its control to another instrumental response trained with the same outcome. Such a finding would be congruent with studies which manipulate some aspect, either quality or quantity, of the reward itself (Colwill and Rescorla, 1988). Also of interest to the present paper is the question of whether or not the brief stimulus remains a biologically neutral outcome differentiator as suggested by Fedorchak and Bolles (1986). Once again, the neutrality of the light flash is of importance to the cognitive/nonmotivational account proposed by these researchers. This particular question can be reevaluated here by simply noting the number and persistence of responses on the response manipulandum associated with the light flash.

Table 1.

Design of Experiment

Conditional discrimination training	Target response training	Test
	Control Group	
$S_1{:}R_1 \rightarrow O_c$		
$S_2{:}R_2 \rightarrow O_c$		
	Experimental Group	
$S_1{:}R_1 \rightarrow O_1$	$R_3 \rightarrow O_1$	$S_1{:}R_3$ vs R_4
$S_2{:}R_2 \rightarrow O_2$	$R_4 \rightarrow O_2$	$S_2{:}R_3$ vs R_4

Note: R_1, R_2, R_3 and R_4 are instrumental responses (nose poking, left lever pressing, right lever pressing, and rod pushing); S_1 and S_2 are discriminative stimuli (noise and tone); O_1 and O_2 are the different outcomes (light + food and food only); O_c refers to the common outcomes, O_1 and O_2, that equally follow both responses.

Method

Subjects

The subjects were 24 experimentally naive male Sprague-Dawley rats. They were about 100 days old at the start of the experiment. During the course of the experiment the animals were maintained in individual wire mesh cages at 85% of their free-feeding weight. Water was available on an ad libitum schedule throughout.

Apparatus

The apparatus consisted of four modular conditioning chambers of identical physical dimensions manufactured by Colbourn Instruments. Each measured 30 cm long by 25.5 cm wide by 29 cm high and was enclosed in a sound-attenuating and light-resistant shell equipped with a ventilating fan. The two side walls were acrylic plastic; the end walls were aluminum. The floors consisted of 0.5-cm stainless-steel rods spaced 1.7 cm apart. A Colbourn pellet trough, the opening 3 cm wide and 4 cm high, was recessed in the centre of the front wall of each chamber 2 cm above the floor. The left lever was located 2.5 cm above the floor midway between the food magazine and the left side wall. The right lever was located 2.5 cm above the floor midway between the food magazine and right side wall. After the first phase of the study, this retractable lever was removed and replaced by the nose-poke manipulandum. The nose poke manipulandum, which was a standard Colbourn pigeon key recessed 0.9 cm behind a round opening 2.5 cm in diameter, was located to the left of the magazine 3 cm above the floor for half of the animals in each of the four counterbalanced conditions described later; for the remaining animals, the nose poke manipulandum was located to the right of the magazine. A stainless-steel rod, 0.8 cm in diameter and 11 cm in length, was suspended from the ceiling 13 cm from the front panel and midway between the side walls. To prevent access to the manipulanda, they could be either retracted, as in the case of the left lever, right lever and rod, or removed and replaced entirely, in the case of the left lever, right lever and nose-key. Ambient illumination in each chamber was provided by a 7.5-W, 125-V house light installed in the ceiling between the rod and rear wall of the chamber. The house light remained present throughout. The response-produced cue was a 0.5 second visual stimulus provided by 3 7.5-W opaque white jewel lamps. These lamps were positioned on the front panel 4 cm from the ceiling above the left lever, the food magazine and right lever respectively. Mounted beneath the house light was a 4-ohm speaker that permitted presentation of white noise measuring approximately 76 dB that served as one S^D. An 1800-Hz tone measuring approximately 74 dB served as the other S^D. Experimental events were controlled and recorded by a microcomputer located in an adjacent room.

Procedure

Magazine training was established during the first day of the experiment. During this 30 minute session, reinforcers were delivered on a random-time 60 second schedule (RT 60-s). This schedule was produced by sampling the computer's random probability generator once every six seconds wherein reinforcement was delivered with a probability of 1/10. The reinforcers were 45-mg Bioserv sucrose pellets. The response manipulanda were not present during this stage of training.

Continuous reinforcement training (CRF) of the left lever-press response was begun following magazine training while training on the right lever occurred subsequently. Subjects were placed in the chambers, with the magazines preloaded with five food pellets and each response programmed to deliver a reinforcer. These sessions terminated after 50 reinforcers had been earned. Individualized handshaping was necessary in a few instances in which subjects failed to make a response. The pellet dispenser's clicking sound provided a salient signal for food for all rats throughout the experiment. Next, each response was reinforced for 20 minutes on a random interval (RI) 30-s schedule. This RI schedule was produced by sampling the computer's random probability generator once every three seconds and setting up the contingency that the next response would be reinforced with a probablity of 1/10. For half the experimental animals, pressing the left lever earned light and food while pressing the right lever earned food alone; for the remaining animals, the opposite arrangements were in effect. For the control animals, a random half of the operable responses on each lever was followed by O_1 while the remainder was followed by O_2. Hardware and programming difficulties resulted in a four week delay in the experiment. Therefore, the animals were given an additional 20 minutes of RI 30 second lever press training on each lever preceding discrimination training.

Following lever-press training, rats were introduced to the conditional discrimination task. Each session of discrimination training contained 20 random presentations each of the 30 second noise and the tone S^Ds. Responding during either S^D was reinforced with the same reinforcer as that initially used to train the response on a RI schedule. Therefore, for the control animals, O_1 or O_2 had an equal probability of following either of the two lever press responses. For half the experimental animals, the tone S^D was followed by O_1 and the noise S^D was followed by O_2 contingent upon a correct response; for the remaining animals, the opposite arrangements were in effect. Therefore, for the 8 animals given the former arrangement, the cue lights flashed for 0.5 seconds following all correct responses on the left lever; for the 8 animals given the latter sequence, the 0.5 second light flash followed all correct presses on the right lever. All animals experienced a 0.5 second delay between the operable response and reinforcement. Depending upon which of the above arrangements were in effect for a particular animal, the 0.5 second light flash was inserted in this delay period.

The beginning of each trial was marked by the presentation of the scheduled discriminative stimulus and the insertion of both response manipulanda. One response on either response manipulandum caused the alternate one to be retracted for the remainder of the trial. During this 30 second stimulus presentation, animals, who had made the correct choice, immediately earned reinforcement (FR-1) and then were given the opportunity to earn additional reinforcement according to an RI 30-s schedule for the remainder of the trial (FR-1/RI-30s schedule). Therefore, depending upon the number of programmed reinforcement opportunities, animals were given the chance to collect more than one reinforcer per trial. When animals chose the incorrect manipulandum, once again the alternate manipulandum retracted and the stimulus remained present for 30 seconds but with no reinforcement scheduled. Both trial types terminated with a 30 second intertrial interval (30-s ITI) during which both manipulanda were retracted. A daily performance measure was computed by dividing the number of correct response choices by the combined number of correct and incorrect response choices (discrimination ratio).

The following description of training refers to only the experimental animals. Following discrimination training, experimental rats were separately trained to make two additional target responses. CRF training of the nose-poke and rod-push responses terminated after 50 reinforcers had been earned. Animals were once again counterbalanced according to target response identity and outcome type. The eight animals receiving the sequences S_1-R_1-O_1 and S_2-R_2-O_2 were split into two groups of four where O_1 followed R_3 and O_2 followed R_4 for half of the animals while O_2 followed R_3 and O_1 followed R_4 for the rest. The same counterbalancing arrangements were applied to the other eight rats receiving the sequences S_1-R_1-O_2 and S_2-R_2-O_1. For a complete description of counterbalancing for the experimental group see Appendix A. Following the target response training procedure outlined by Colwill and Rescorla (1988), each response was then reinforced on a RI 30-s schedule for one 20-min session. The animals received food for rod-pushing and the light/food combination for nose-poking. Finally, both response manipulanda were made simultaneously available for four 20-min sessions. The two responses were reinforced on an RI 60-s schedule. During the second day of target response training, one animal from Experimental Group A became notably ill. The data for this animal was not included in the target response training or test phase analyses.

On the day before testing, the nose-key and rod were concurrently available for one

8-min session during which responding was never reinforced. The purpose of this extinction session was to obtain a depressed level of responding that would be sensitive to the potential augmenting and depressing effects of the S^Ds.

The transfer test session contained eight presentations each of the 30-s tone and noise S^Ds in a counterbalanced order with an ITI of 30 seconds. Both the nose-key and rod were available during the test, but responding was never reinforced.

Results

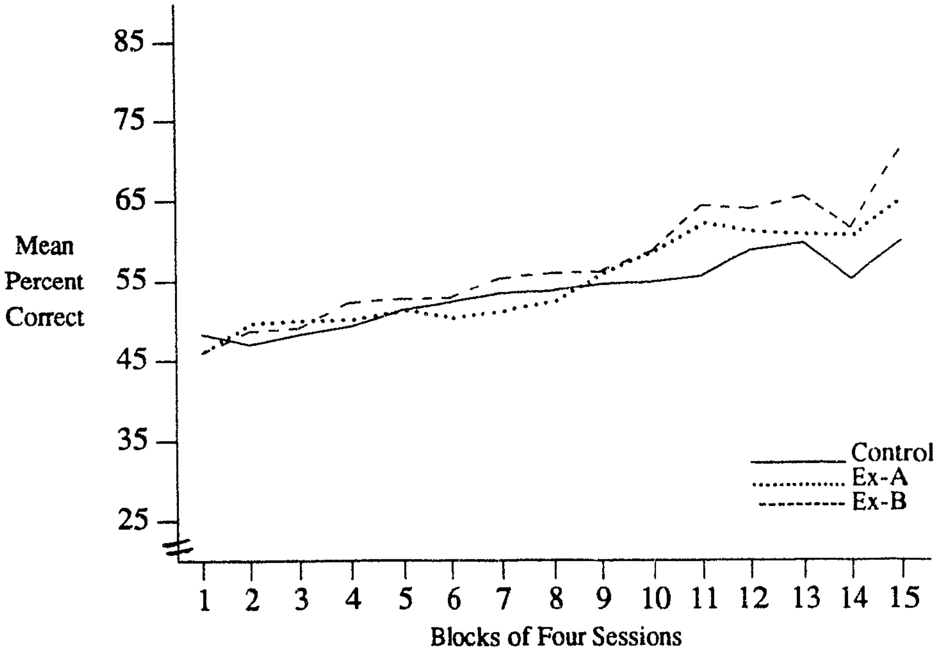
Figure 1 illustrates the discrimination performance for the three groups across the fifteen blocks of four sessions. Once again, discrimination ratios for each session were calculated by dividing the number of correct response choices by the total number of trials (forty). Appendix B displays the mean discrimination ratios for the three groups over fifteen blocks. As illustrated, discrimination training continued for sixty days and, despite this lengthy training phase, the groups were not able to achieve the .80 discrimination ratio criterion within this time period as originally anticipated. It should also be noted that during Sessions 53 and 54, the food dispenser in box #3 failed to deliver reinforcement. Consequently, two animals from each group may exhibit lower performance measures on these two days.

A split-plot analysis of variance, with Groups (3) as the between-subject factor and Blocks (15) as the within-subject factor, revealed no reliable differences between the Groups [$F(2, 21)=0.68$, $p>.05$], a significant effect due to Blocks [$F(14, 294)=15.53$, $p<.001$], and no significant Group X Block interaction [$F(28, 294)=0.68$, $p>.05$]. Thus, it appears that discrimination performance of all animals improved equally over training sessions with no difference between control and experimental animals. The mean discrimination ratios for the three groups collapsed across Blocks are .534, .548, and .569 for the Control, Experimental A, and Experimental B groups respectively.

A separate Blocks X Trial Type Repeated Measures analysis of variance within the experimental animals indicated that there were no differences in accuracy on light-flash

Figure 1.

Discrimination Performance across fifteen blocks for the three groups



Note: Discrimination performance across the fifteen blocks of four days. All animals received reinforcement for pressing the right lever during the tone and the left lever during the noise. The control animals received the light flash following a random half of their correct response choices on each lever. For experimental group A, the flash of light was perfectly correlated with correct left lever presses while for group B, the flash of light followed all correct right lever presses.

versus non-light-flash trials, [*F*(1, 15)=1.35, *p*>.05], and no significant two-way interaction [*F*(14, 210)=0.53, *p*>.05]. However, as expected, the effect of Blocks was significant [*F*(14, 210)=16.39, *p*<.001). The mean discrimination ratios across the fifteen blocks were .502 and .616 for light-flash and non-light-flash trials respectively. These findings concur with those of Fedorchak and Bolles (1986) who demonstrated that their rats showed no preference for either outcome.

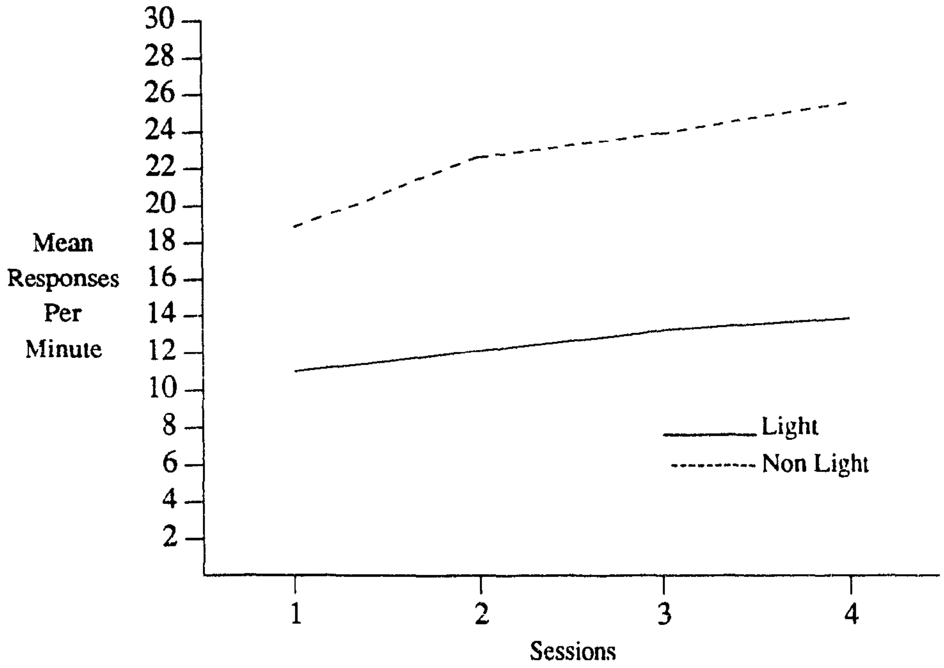
An additional Blocks X Trial Type Repeated Measures analysis of variance, using mean number of responses per minute as the dependent variable, within the experimental animals indicated that there were no differences in response rate for light-flash versus non-light-flash trials, [*F*(1, 15)=2.35, *p*>.05], and no significant Block X Trial Type interaction, [*F*(14, 210)=1.35, *p*>.05]. However, the analysis revealed a significant main effect of Blocks [*F*(14, 210)=10.14, *p*<.001]. The mean number of responses per minute across the fifteen blocks were 24.36 and 34.65 for light-flash and non-light-flash trials respectively. Hence, it appears that the rate of responding during each of the two trial types increased equally across sessions. The mean number of responses per minute over fifteen blocks for each outcome type are displayed in Appendix C.

All of the results to follow refer to the data generated by fifteen of the experimental animals. Figure 2 shows the mean number of responses per minute as a function of sessions for both trial types during target response training. The mean rate of responses per minute over the four sessions of target response training for each outcome type are illustrated in Appendix D.

Over the final four target response training sessions, differences in the mean number of responses per minute for each of the two trial types was assessed using a Repeated Measures analysis of variance procedure. The analysis did not reveal a significant main effect of Trial Type, [*F*(1, 14)=2.78, *p*>.05], a significant effect due to Sessions [*F*(3, 42)=1.07, *p*>.05], or a significant two-way interaction between Trial Type and Session

Figure 2.

Mean responses per minute as a function of four sessions



Note: Mean responses per minute as a function of 4 sessions of target response training for light-flash and non-light-flash outcomes.

[$F(3, 42)=0.12, p>.05$]. According to these results it appears that the rats maintained a stable level of responding over the four training sessions with no significant difference between light-flash and non-light-flash trials. The mean rate of responding was 12.54 for light-flash trials and 22.74 for non-light-flash trials.

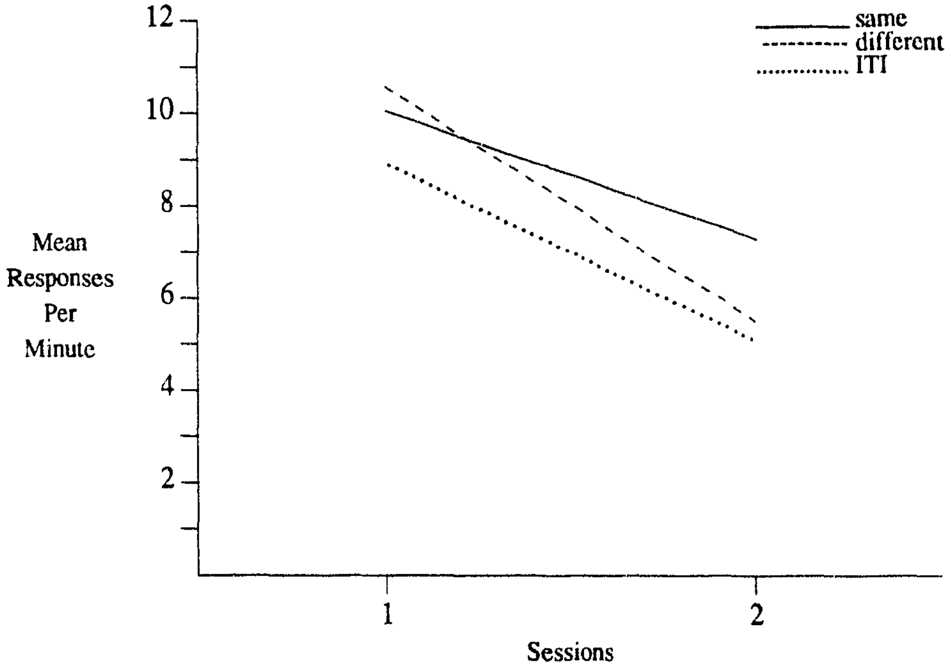
There was, however, a difference in performance of the two responses during target response training. A Repeated Measures analysis of variance with Sessions and Manipulandum Type as within-subject factors revealed no significant effect of Session [*F*(3, 42)=1.07, *p*>.05], and no significant interaction between Session and Manipulandum [*F*(3, 42)=0.31, *p*>.05]. However, there was a main effect of Manipulandum [*F*(1, 14)=14.26, *p*<.01]. The mean rate of rod pulling was reliably lower (8.74 responses per minute) than the mean rate of nose poking (26.54 responses per minute) over target response training. The mean rate of responding according to manipulandum identity over the four target response training sessions are shown in Appendix E.

Figure 3 illustrates the results of the two test sessions with the target responses and the two discriminative stimuli. The rate of responding during the S^D is displayed separately for the response that had earned the SAME reinforcing outcome as had been previously available during that S^D and the response that had earned a DIFFERENT reinforcing outcome from the one available during that S^D. Performance during the ITI is also shown as a baseline measure. The mean response rates for the Same, Different, and ITI conditions during testing are displayed in Appendix F.

A repeated measures analysis of variance with Sessions and Condition as the within-subject factors revealed a significant effect of Sessions [*F*(1, 14)=18.66, *p*<.001], a significant effect due to Condition [*F*(2, 28)=5.18, *p*<.05], but did not reveal a significant interaction between Session and Condition [*F*(2, 28)=1.29, *p*>.05]. Not surpisingly, the mean number of responses per minute decreased from Session 1 (9.82 responses per minute) to Session 2 (5.92 responses per minute) during this extinction test phase. A priori tests, using orthogonal contrasts, indicated that the mean overall rate of responding in the

Figure 3.

Mean responses per minute as a function of two test sessions



Note: Mean responses per minute as a function of 2 sessions of testing. Responding during the stimulus is shown separately when the reinforcer was the same for both the response and the discriminative stimulus and when the reinforcing outcome was different; in addition, responding during the ITI is also shown when neither stimulus was present.

the SAME condition and DIFFERENT condition was significantly higher than the rate of responding during the ITI [$F(1, 14)=13.44$, $p<.001$], but there was no reliable difference in level of responding between the SAME condition and DIFFERENT condition [$F(1, 14)=1.00$, $p>.05$]. The results reported here are not congruent with those of Colwill and Rescorla (1988); these researchers found that the S^D augmented the same-reinforcer response compared to its ITI rate but did not significantly elevate the level of different-reinforcer responding relative to the ITI rate. In addition, Colwill and Rescorla (1988) demonstrated that the S^D produced significantly more same-reinforcer responses than different-reinforcer responses. In contrast, the results reported in the present study illustrate nonselective transfer since each S^D had the effect of augmenting both same-reinforcer and different-reinforcer responses relative to the ITI level of responding with no reliable differences between the SAME and DIFFERENT conditions.

Discussion

Contrary to Fedorchak and Bolles (1986), the present results of discrimination training do not suggest that consistently correlating a neutral stimulus (flash of light) with all of the correct responses to one of two stimuli in a two-choice conditional discrimination enhances the rate of discrimination learning. One possible explanation for the absence of a DOE may be that the animals were not able to discern a difference between the two outcomes. Apart from Fedorchak and Bolles (1986) all other investigators examining the DOE phenomenon have used reinforcers that differed with respect to quality or quantity (Carlson & Wielkiewicz, 1976; Trapold, 1970). Perhaps it is the case that there was potentially greater generalization between the light flash/food and food outcomes, whose differentiating features were less salient, in comparison to these other studies. In other words, the animal's representation of the light/food outcome was not distinctly different from that of the food outcome. These other DOE studies used outcomes that may have differed along many stimulus dimensions making it less difficult for animals to distinguish between the two outcomes. Recently, Rescorla (1990) used a devaluation technique in one study to further explore the specificity of outcome encoding. The outcomes differed along a single stimulus dimension which was said to be irrelevant to the motivational state of the animal. Each animal received response training on the lever and chain where each response was either followed by slightly sour water or slightly bitter water. One of these two outcomes was subsequently devalued by pairing it with LiCl. To the extent that the bitter and sour features of the outcomes were differentially associated with the different responses, a bias against the response that had previously produced the now-devalued outcome would be expected. The results confirmed this hypothesis. Perhaps more important to the present paper is the finding that the magnitude of the difference between the responses to the devalued and nondevalued manipulanda were smaller in this study in comparison to a previous experiment (Colwill & Rescorla, 1985) that used food pellets and liquid sucrose as outcomes. Thus, the size of the devaluation effect is in part related to the discriminability of the outcomes being employed. Also, the idea that animals were unable to discriminate between O_1 and O_2 in the present study is also suggested by the absence of any significant difference in the level of responding for each of these two outcomes. However, the strength of this argument appears rather weak given the fact that Rescorla (1990) observed no reliable differences in the rates of the responses that earned bitter and sour water. Nevertheless, there is no evidence in the present study which suggests that one outcome was more or less preferred than the other. Therefore, in light of the fact that a DOE using biologically neutral outcome differences was neither observed in the present case nor reported by another laboratory suggests that this novel finding reported by Fedorchak and Bolles (1986) may not be replicable.

On the other hand, procedural variations between the two studies may account for the discrepancy in results. First, in order to maximize the saliance of the brief flash of light, Fedorchak and Bolles (1986) ran their animals in almost complete darkness with the only illumination provided by a small television screen located near the chamber. Therefore, it could be argued that the difference between the three brief cues, with the house light present, and no cues in the present study was not as great as the difference between the single house light flash and near darkness in the other study. If this alternative is correct, then it should be possible to demonstrate the DOE using the present procedure but with preparations that would increase the salience of the brief cue. Although this explanation seems quite reasonable, it is worth noting that other studies that examine the effects of brief visual stimuli on free-operant responding do not necessarily practice running their animals in near dark conditions (Tarpy, St. Claire-Smith & Roberts, 1986). In some of these studies, the brief stimulus appears to affect behaviour even when a house light is concurrently present during training. In any event, the use of a relatively less salient stimulus to differentiate one outcome from the other may account for the lack of an effect seen here.

In addition, it should be noted that the overall level of discrimination performance for the animals in the present study was lower in comparison to Fedorchak and Bolles (1986); in the former case, the mean percentage of correct responses for the experimental animals was approximately 68, while in the latter case, performance reached approximately 80 percent by the final block of training. Moreover, the number of trials required to achieve final performance levels obtained in the present study were substantially greater. The main reason for these discrepancies is that a correction procedure was employed in the other experiment wherein following an incorrect response, the same discriminative stimulus was repeated on the next trial. The significance of the low discrimination performance observed in this phase of the experiment will be further discussed later.

Also, the present study appears to be different from other DOE studies, at least those using rats, as it was the first known attempt at exploring this effect through the use of something other than a fixed ratio schedule of reinforcement. Most researchers (Carlson & Wielkiewicz, 1972, 1978) have not attempted to deviate from the methodology of Trapold's original experiment (1970), which employed a fixed-ratio 10 (FR-10) schedule, with the exception of Fedorchak and Bolles (1986) who used an FR-1 schedule of reinforcement. The difference between the random interval (RI) schedule of reinforcement used here and the FR schedule is that in the former case, reinforcement is delivered after a single response occurs after the passage of a variable amount of time whereas in the latter case, reinforcement depends on the completion of a certain number of responses; time is irrelevant in FR schedules. Thus, on a ratio schedule, the faster the animal responds, the faster it gets reinforced. The likelihood of reinforcement delivery depends solely on the performance of the animal, excluding other factors such as time, which may be perceived as resulting in the development of stronger R-O associations. It may be more beneficial to employ a somewhat more simple schedule of reinforcement, such as a FR schedule, given the apparent difficulty of the two-choice conditional discrimination task. However, the procedure used here was a modification of the RI schedule since the first correct response earned reinforcement followed by the concurrent RI schedule. It was hoped that this added feature would enhance discrimination learning since the reward always immediately followed a correct response choice similar to Fedorchak and Bolles' FR-1 schedule.

Unfortunately, it is difficult to determine conclusively whether or not these procedural deviations during conditional discrimination training were responsible for the lack of effects seen here. Rerunning the present experiment with an additional experimental group using outcomes that differ along many stimulus dimensions may shed some light on this problem.

The results of target response training appear to indicate that there was no reliable difference between the level of responding for O_1 and the level of responding for O_2. This appears to be a rather peculiar finding especially since the depressing effect of signaling a brief delay of reinforcement on a VI schedule has been well documented (Schachtman & Reed, 1990; St. Claire-Smith, 1979; Tarpy, St. Claire-Smith & Roberts, 1986). A number of factors may have played a part in diminishing this typically robust effect. First, individual variation among subjects, including differences between high scorers and low scorers, is removed and do not constitute a source of either systematic or error variation when using a repeated measures design (Collyer & Enns, 1986). However, error variation is estimated from individual differences in the effect of Trial Type. Observation of the raw data reveals a fair amount of variability along this dimension. One reasonable explanation for this variability stems from the subjects' individual response manipulandum preferences. The analysis on the response manipulandum indicate a preference for nose-poking over rod-pulling. Since all conditions were counterbalanced with respect to manipulandum and trial type, the strong differences attributed to the manipulanda flooded the scores, broken down by trial type, with much variability. Moreover, an error in programming the schedule of reinforcement for this stage of training undoubtedly compounded this manipulandum effect. Instead of training each of the two responses with independent RI schedules, as in Colwill and Rescorla (1988), the two responses were inadvertently reinforced on a single RI schedule. A single RI schedule would reduce the probability of being reinforced for infrequent rod pulls following consistent nose poking, since nose poking would most likely be reinforced, which would subsequently decrease the strength of an already weaker response. Thus, it is suggested that the absence of attenuation effects on levels of responding leading to the signaled reward may have been influenced by the factors above.

The test phase assessed the degree to which an S^D trained in conjunction with one response would selectively transfer its control to other instrumental responses trained with the same outcome. The results of testing the newly acquired target responses in the presence of S_1 and S_2 indicate nonselective transfer effects. Presentation of either the tone or noise had the effect of elevating the same-reinforcer and different-reinforcer responses relative to the ITI rate of responding. More importantly, the rate of the response for the response that earned the same reinforcer as had been previously available during that S^D was not significantly higher than the rate of the response that earned a different reinforcer from the one available during that S^D. A number of factors may have contributed to the failure to attain selective transfer effects. First, as mentioned earlier, it may be that the flash of light was not a salient feature capable of distinguishing O_1 from O_2. Hence, nonselective transfer would occur since each S^D had been previously trained with, what was perceived to be, a common event equally capable of augmenting either of the two target responses. This possibility seems reasonable especially since transfer of control studies of this sort have been replicated a number of times using qualitatively different reinforcers (Colwill & Rescorla, 1988; Rescorla, 1990; Rescorla & Colwill, 1989). Furthermore, there is evidence which shows that decreasing the discriminability of the two outcomes affects performance during subsequent transfer. For instance, Rescorla (1990) repeated an earlier transfer of control study (Colwill & Rescorla, 1988) using bitter versus sour water instead of liquid sucrose versus food pellets. Rats were trained to make a common response during the presence of two different stimuli each consistently signaling which one of the two possible outcomes would follow the response. They were then trained to make two new responses, one with each of the two outcomes. Finally, the stimuli were presented separately and the animals were given the opportunity to respond on either of the two newly acquired responses. Once again, selective transfer effects were uncovered. That is, overall responding was elevated relative to the ITI by both stimuli, similar to results of the present study. However, only the final two blocks of testing revealed that same-outcome responses were elevated relative to different-outcome responses. The earlier study (Colwill & Rescorla, 1988) which used sucrose and pellets as reinforcers found stronger transfer effects. First, the level of responding during the different outcome condition did not differ from that of the ITI. Second, the S^D significantly augmented responding associated with the same reinforcer relative to the different reinforcer throughout testing. Thus, it appears that the magnitude of the selective transfer effects were lowered in Rescorla (1990) by using outcomes that were not as obviously different. The results of the present study appear to be consistent with the idea that there was potentially greater generalization between the outcomes utilized here.

Another possibility is that overall low level of discriminative performance during the last block of discrimination training may be an index of weak associations developed between the stimulus, response and outcome which may, in turn, have an effect on subsequent transfer performance. Colwill and Rescorla (1988) utilized a less difficult initial S^D training procedure which exposed the animals to only one of two possible S^D, response, outcome combinations in a single session. On the other hand, two-choice conditional discriminations, like the one introduced in the present study, can be seen as inherently more complex since the animals are exposed to two stimuli, two responses, and two reinforcers in a single session. Hence, these animals may have failed to fully discriminate between the stimuli, or may have had difficulty keeping the responses separate, or may not have identified the outcomes as different. Some evidence for this possibility is offered by Colwill and Rescorla (1990) who once again utilize the transfer of control design to explore the hierarchical S-(R-O) structure of instrumental learning. Generally, the animals in this particular experiment were exposed to a more complex S^D training procedure during the initial stage of training in comparison to previous experiments (Colwill & Rescorla, 1988). As a result, the transfer effects were much smaller possibly because discriminative control by the stimuli during training was not as strong as was typically observed in previous experiments. Therefore, it seems plausible that the nonselective transfer effects observed here may be, in part, a result of the complexity of the initial discrimination.

In summary, one major finding of this experiment is that correlating a light flash with one of two correct responses does not enhance learning of a two-choice conditional discrimination task. Also, there is no evidence to suggest that the animals acquired either an aversion or preference to the response manipulandum associated with the flash of light. Finally, this study does not demonstrate the transfer of control of a stimulus from one response to another, based on their shared outcomes. Although the present data does not encourage the view that a flash of light may serve as a suitable outcome differentiator, many other studies reviewed here strongly suggest that animals are capable of developing detailed representations of the outcome event. Further research is needed to explore the specificity of outcome encoding and to determine how these representations interact with other elements to guide behaviour.

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APPENDIX A

Counterbalancing Arrangement for
the Animals in the Experimental Groups

Table 2.

Counterbalancing arrangement for the experimental groups

	Experimental Group A		Experimental Group B	
	(n=4)	(n=4)	(n=4)	(n=4)
RI training	$R_1 \rightarrow O_1$ $R_2 \rightarrow O_2$	$R_1 \rightarrow O_1$ $R_2 \rightarrow O_2$	$R_1 \rightarrow O_2$ $R_2 \rightarrow O_1$	$R_1 \rightarrow O_2$ $R_2 \rightarrow O_1$
Conditional discrimination training	$S_1{:}R_1 \rightarrow O_1$ $S_2{:}R_2 \rightarrow O_2$	$S_1{:}R_1 \rightarrow O_1$ $S_2{:}R_2 \rightarrow O_2$	$S_1{:}R_1 \rightarrow O_2$ $S_2{:}R_2 \rightarrow O_1$	$S_1{:}R_1 \rightarrow O_2$ $S_2{:}R_2 \rightarrow O_1$
Target response training	$R_3 \rightarrow O_1$ $R_4 \rightarrow O_2$	$R_3 \rightarrow O_2$ $R_4 \rightarrow O_1$	$R_3 \rightarrow O_2$ $R_4 \rightarrow O_1$	$R_3 \rightarrow O_1$ $R_4 \rightarrow O_2$

APPENDIX B

Mean Discrimination Ratios for the Three Groups
During 15 Blocks of Discrimination Training

Table 3.

Discrimination ratios during discrimination training for all animals

Control		Ex- A		Ex- B	
Block	MEAN	Block	MEAN	Block	MEAN
B1	0.4828	B1	0.4609	B1	0.4594
B2	0.4703	B2	0.4953	B2	0.4867
B3	0.4820	B3	0.4977	B3	0.4906
B4	0.4922	B4	0.4992	B4	0.5219
B5	0.5125	B5	0.5102	B5	0.5266
B6	0.5227	B6	0.5008	B6	0.5281
B7	0.5336	B7	0.5094	B7	0.5531
B8	0.5367	B8	0.5219	B8	0.5594
B9	0.5453	B9	0.5578	B9	0.5609
B10	0.5484	B10	0.5852	B10	0.5867
B11	0.5555	B11	0.6188	B11	0.6430
B12	0.5867	B12	0.6086	B12	0.6383
B13	0.5953	B13	0.6047	B13	0.6539
B14	0.5508	B14	0.6039	B14	0.6148
B15	0.5984	B15	0.6508	B15	0.7109

APPENDIX C

Mean rate of responding per minute for the light-flash
and non-light-flash outcomes over 15 blocks
of discrimination training

Table 4.

Mean response rates collapsed by outcome type over blocks in phase 1

Blocks	Light	No Light
1	14.90	17.22
2	14.17	23.57
3	16.88	30.92
4	17.50	33.09
5	21.82	37.33
6	22.33	36.27
7	23.01	37.55
8	26.33	37.21
9	27.31	38.52
10	26.99	36.34
11	29.85	38.96
12	33.42	40.34
13	27.88	36.78
14	29.59	38.48
15	33.36	37.19

APPENDIX D

Mean rate of responding per minute for the light-flash

and non-light-flash outcomes over 4 sessions

of target response training

Table 5.

Mean response rates collapsed by outcome type over sessions in phase 2

Session	Light	No Light
1	10.97	18.83
2	12.13	22.63
3	13.21	23.93
4	13.85	25.58

APPENDIX E

Mean rate of responding per minute for the
nose-poke versus rod manipulanda over 4 sessions
of target response training

Table 6.

Mean response rates collapsed by response type over sessions in phase 2

Session	Rod	Nose
1	7.96	21.84
2	7.67	27.09
3	9.40	27.74
4	9.94	29.49

APPENDIX F

Mean responses per minute during

the two transfer extintion tests

Table 7.

Mean response rates during the two transfer test sessions

Session	Same	Diff	ITI	Mean
1	10.05	10.57	8.85	9.82
2	7.27	5.49	5.00	5.92
Mean	8.66	8.03	6.93	

APPENDIX G

Source table for the Split-Plot

Analysis of Variance:

Discrimination training phase

Table 8.

Source table for the split-plot ANOVA: Discrimination training

Source of variability	Sum of squares	Degrees of freedom	Mean squares	F statistic	Probability
Mean	109.099	1	109.099		
Group	0.073	2	0.037	0.68	0.517
Error	1.130	21	0.054		
Session	1.050	14	0.075	15.53	0.000*
Group X Session	0.092	28	0.003	0.68	0.888
Error	1.419	294	0.005		

* Significant