PAVLOVIAN CONDITIONED INHIBITION

AND AVOIDANCE LEARNING

THE ROLE OF PAVLOVIAN CONDITIONED INHIBITION
IN AVOIDANCE LEARNING:
AN EXTENSION AND REVISION OF TWO-FACTOR AVOIDANCE THEORY

By

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ABSTRACT

This thesis surveys the avoidance conditioning literature of the past 30 years and discusses various theories of avoidance learning. The theory that has dominated the field has been the "two-factor avoidance theory". Two-factor theory proposes that avoidance learning is based on the interaction of Pavlovian and instrumental conditioning processes. It is shown how two-factor theory has evolved such that it can adequately handle a majority of experimental findings related to avoidance phenomena. An examination is then made of the role of Pavlovian conditioned inhibition in avoidance conditioning. Recent versions of two-factor theory do not adequately account for inhibitory processes in avoidance learning. It is hypothesized that avoidance response-contingent feedback stimuli (FSs) become Pavlovian conditioned inhibitors over the course of avoidance training and that this inhibitory property provide the FS with the capacity to reinforce avoidance behavior. If the inhibitory property accruing to the FS is responsible for its reinforcing capabilities then two converging findings are expected. First, the inhibitory and reinforcing strengths of a FS should covary in a positive manner. A more effective (reinforcing) FS should show greater inhibitory strength at the end of avoidance training than a less effective FS. The

results of Experiments 1 and 2 of this thesis confirm this prediction. Second, a pretrained Pavlovian conditioned inhibitor should function as a more powerful reinforcer of avoidance behavior than non-inhibitory stimuli. Experiments 3 and 4 provide evidence supporting this prediction. The results of Experiment 1-4 taken together support the hypothesis that the conditioned inhibitory properties accruing to a FS are of functional significance for avoidance learning. On the basis of these findings, two-factor theory is revised so that it can account for inhibitory processes. This is done by incorporating Rescorla's contingency model of Pavlovian conditioning into Anger's recent version of two-factor avoidance theory. It is then shown how this revised version of two-factor theory offers a more viable account of avoidance learning than other current theories (e.g., positive reinforcement views, expectancy theories, etc.). It is also shown how revised two-factor theory can handle extinction phenomena once thought to be anomalous to a two-factor approach. Finally, Experiment 5 is designed to test a prediction derived from an extension of the "learned-safety" formulation: that repeated nonreinforced exposure of a FS prior to avoidance training endows the FS with true inhibitory or safety signal properties thus making it an effective reinforcer of avoidance behavior. It is found, contrary to the learned-safety hypothesis, that preexposing the FS retards subsequent avoidance conditioning. This result suggests that simple preexposure in the total absence of aversive events is not a sufficient condition for establishing a safety signal.

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This thesis is dedicated with love to my wife Malerie, who has been and will remain the source of inspiration and joy in my life.

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CHAPTER I

INTRODUCTION

This thesis is an investigation of the nature of avoidance learning. The empirical validity of various theories of avoidance learning will be examined. Findings from experiments reported in this thesis and elsewhere will provide the impetus to reshape and revitalize a once-popular theory that has lately been discredited. In general, this thesis will attempt to specify the kinds of environmental events that are necessary and sufficient for the learning of avoidance responses.

1.1 Two Types of Learning

Historically, experimental investigations of animal learning phenomena have focused on two basic learning paradigms. One paradigm, called Pavlovian (also classical) conditioning, looks at a behavior change to an environmental event or stimulus which signals the occurrence of a biologically significant event. The second kind of learning situation, referred to as Thorndikian (also instrumental or operant) conditioning, examines the probability of making a response again as a function of the immediate environmental consequences of that response.

1.1.1 Pavlovian Conditioning

It was while investigating the physiology of the digestive system of the dog that I.P. Pavlov made the now famous observation that his dogs would often begin salivating when the experimenter entered the room just before food was actually placed in the animals' mouths. Pavlov (1927) reasoned that the experimenter by reliably preceding the presentation of food had in fact become a signal for food. It seemed that the dog anticipated the imminent arrival of food and salivated to a signal for food as if it was the food itself. Pavlov called this reflexive-like salivatory response to a signal for food "psychic secretions". Pavlov and other researchers found the important operation needed to produce or elicit psychic secretions, or (as he also called them) conditioned responses, is to present a neutral stimulus such as a bell, tone, light, experimenter, etc. - which does not initially elicit salivation - a few seconds before or simultaneously with the food. After a number of these temporal pairings or contiguous presentations the once neutral stimulus now referred to as the <u>conditioned stimulus</u> (CS) will acquire the capacity to elicit the <u>conditioned response</u> (CR) of salivation. This conditioned response is usually similar (but not necessarily identical) to the <u>unconditioned response</u> (UR) of salivation reflexively elicited by the <u>unconditioned stimulus</u> (US). Thus the CR was thought by Pavlov to be produced by the contiguous pairing of two stimuli - the CS and the US.[1]

Figure 1 shows the number of different ways a CS can be paired temporally with the US. Row A of the figure indicates an example of "simultaneous" conditioning. Under this arrangement, the CS and the US start at the same time. Rows B and C illustrate "delayed" conditioning procedures in which the CS starts sometime before the US and ends either with the onset of the US or the termination of the US. A "trace" conditioning procedure is represented in row D of the figure. In trace conditioning a short-duration CS is presented and goes off before the US appears. The interval between the offset of the CS and the onset of the US is called the trace interval.

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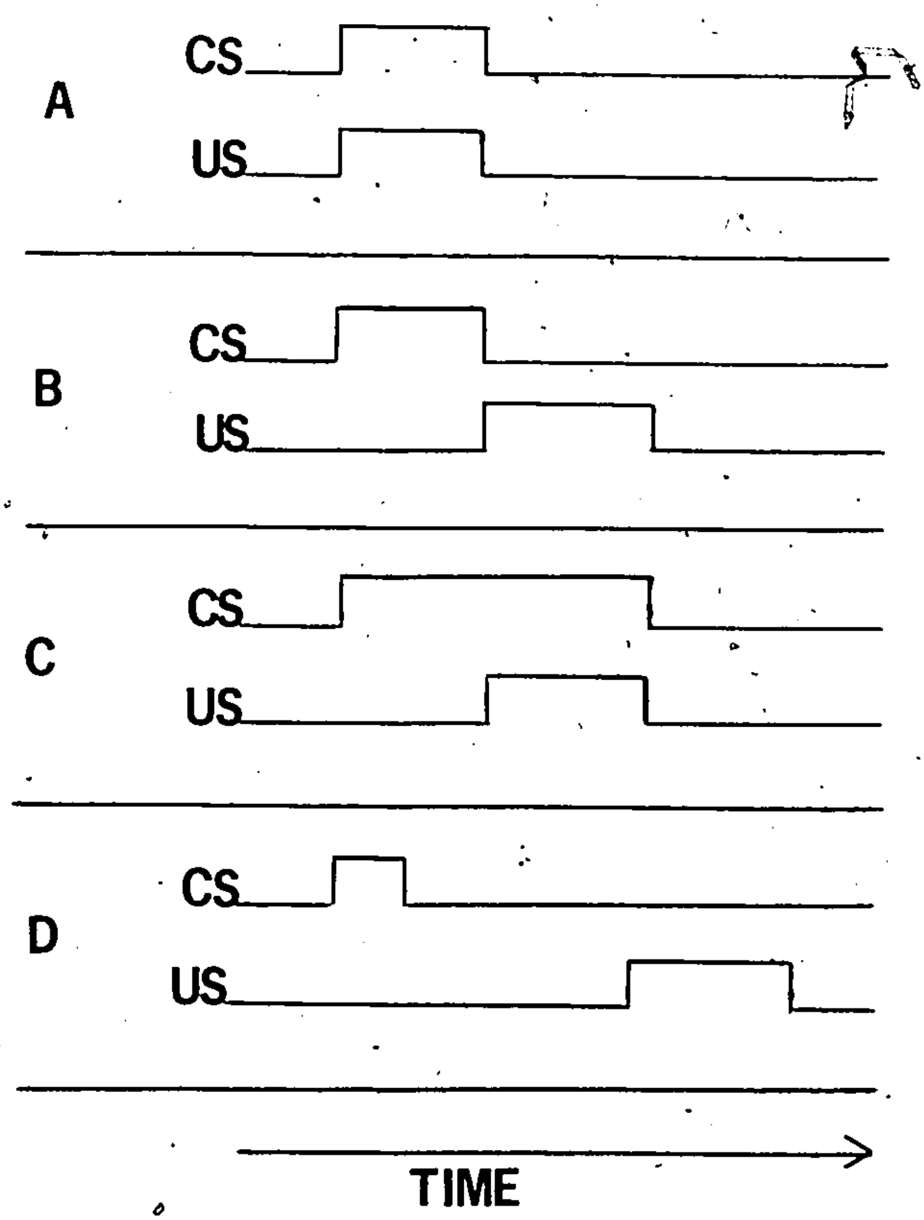
Recently, discussions of Pavlovian conditioning (particularly by Rescorla, 1967, 1968b, 1969a,c) have de-emphasized the importance of contiguity or simple temporal pairings. Instead, the focus has been on the contingency established between the CS and US. Contingency refers to the likelihood of the US occurring given either the presence or the absence of the CS. Thus, unlike the pairings notion which examines only what is paired with the CS, the contingency view looks at both what is paired and what is not paired with the CS (Rescorla, 1967). A more detailed discussion of the contingency view of Pavlovian conditioning is presented on pages 88-89 of this thesis.

Figure 1. Various temporal relationships between the CS (conditioned stimulus) and US(unconditioned stimulus) in Pavlovian conditioning.

FIGURE 1



Pavlov (1927) and others have shown that classical conditioning can occur in a variety of autonomic and skeletal response systems. For example, if an electric shock (US) is delivered to the eyelid of an animal, the animal will reflexively blink its eye (UR). If a stimulus which does not originally elicit eyelid closure reliably precedes the shock the subject will learn to close its eye in the presence of this stimulus before the shock actually occurs. This conditioned eyelid response has been demonstrated in both rabbits and humans (Gormezano, 1966; Prokasy, 1965).

Pavlovian conditioning is also thought to be responsible for the conditioning of emotional reactions such as fear and anxiety to environmental stimuli that do not normally elicit fear. In a famous human example of classically conditioned fear, Watson and Rayner (1920) clanged a loud gong while an 11-month old boy, Albert, was playing with a white rat. Watson and Rayner observed that the white rat did not elicit any type of fear response, but the loud gong immediately elicited an intense fear reaction in Albert-he started crying, shivering, etc. After a number of pairings of the white rat (the CS) and the loud gong (the US), Albert began to fear the white rat as well and would cry and try to crawl away from it. Thus Albert had apparently learned a conditioned fear response to the once nonfearful rat after it had been temporally paired with a distressing unconditioned stimulus.

Further research by Pavlov and others into the nature of classical conditioning has revealed a number of interesting phenomena. If the environment changes such that the conditioned stimulus is no longer followed by the unconditioned stimulus, a diminution or extinction of the conditioned response will occur. Furthermore, if a CR is conditioned to one stimulus, other stimuli that resemble the original CS will also acquire the capacity to elicit a CR to varying degrees. This phenomenon is called stimulus generalization. The amount of generalization increases as the stimulus becomes more similar to the CS. Another important conditioning phenomenon is referred to as stimulus discrimination. Stimulus discrimination is said to occur when an animal responds exclusively to a CS that has been paired with a US and stops responding to another stimulus that has not been paired with a US. For example, in the conditioned salivation situation, a dog would receive food following the presentation of a tone (CS+), but would not receive food following the presentation of a bell (CS-). Initially, due to stimulus generalization, the dog might make conditioned salivation responses to the bell as well as to the tone since they resemble each other to some degree. As the dog receives more and more trials, however, in which the tone is always followed by food but the bell is never presented with food, the dog should continue to respond to the tone while its responses to the bell should decline. At this point the dog is said to have learned to discriminate between the tone CS+ and the bell CS-. Thus, the phenomena of Pavlovian conditioning, extinction, generalization, and discrimination greatly enhance the capability and flexibility of the organism's reflexive response systems.

1.1.2 Instrumental Conditioning

The development of the conditioned response in Pavlovian conditioning results from exposure to a stimulus-stimulus relationship-- the presentation of the US is dependent on the occurrence of the CS. These stimuli are presented independently of the animal's behavior. Thus, the presentation of the food US or the pairing of a CS with food does not depend on the dog salivating or making any kind of response. Much learned behavior, however, seems to be acquired and maintained because what the animal does has important effects on the animal's immediate environment. For example, a hungry raccoon which finds a bountiful supply of food in a garbage can is quite likely to return to the garbage can again in search of food. On the other hand, a child who puts his hand on a hot stove and is burnt is less likely to put his hands on the stove again. This kind of learning is often referred to as instrumental or operant conditioning. Instrumental and operant responses are called such because they are "instrumental" in leading to rewards (Hilgard & Marquis, 1940) or "operate" on the environment to produce beneficial outcomes or escape from distressing situations (Skinner, 1938).

E.L. Thorndike (1905) in his statement of the "Law of Effect" formally recognized the importance of immediate consequences of behavior in promoting learning. Thus he stated:

> "Any act which in a given situation produces satisfaction becomes associated with that situation, so that when the situation recurs, the act is more likely then ever before to recur also. Conversely, any act which in a given situation produces discomfort becomes disassociated from the situation, so that when the situation recurs, the act is less likely than before to occur (1905, p.202)".

Basically, Thorndike was saying that any response that is rewarded will be strengthened and any response that is punished will be weakened.

While Thorndike's Law of Effect has become the cornerstone of instrumental conditioning, his use of unobservable mediating constructs such as "satisfaction","discomfort", etc. to describe conditioning situations has been dropped in favor of more objective directly observable events and operations. What were satisfying consequences to Thorndike are now referred to as "reinforcers". Discomforting events are now called "punishers". Furthermore, reinforcers and punishers are defined according to their observed effects on behavior. Thus, an empirical definition of a reinforcer is any stimulus whose presentation or removal immediately following a response increases the probability of that response occurring again. Conversely, a punisher is also empirically defined as any stimulus immediately following the response that decreases the probability of that response occurring again. Thus, in one type of operant conditioning situation a food-deprived rat is placed in a enclosed chamber commonly called a "Skinner box". The Skinner box has a lever sticking out from one wall. If the rat presses the lever a pellet of food will drop down into the tray located underneath the lever. Food is not presented unless the rat presses the lever. If food is reinforcing to a food-deprived rat, the rate of lever-pressing should increase; this is in fact the typical finding. When the presentation of a stimulus (e.g., food) is shown to increase the probability of the response it follows as in the above example, the stimulus is called a positive reinforcer. Often, however, the removal of a stimulus will also result in an increase in the immediately preceding behavior. For example, a rat is placed in a shuttlebox which consists of two identical compartments separated by a barrier. A continuous painful electric shock from a shocking device is delivered to the rat's feet via metal grid bars that make up the floor of the shuttlebox. The rat can turn off the shock only by jumping over the barrier into the adjacent compartment. This conditioning situation is called "escape learning" and rats quickly learn to jump over the barrier as soon as the shock is turned on. In this situation the shock would be considered a negative reinforcer since its removal led to an increase in the escape response. Finally, a stimulus which decreases the probability of the immediately preceding response is called a punisher. Thus, if everytime the rat pressed the lever in the Skinner box it received a shock and the rat's rate of lever-pressing decreased then the shock would be considered to be a punisher.

Many of the same phenomena that occur in the Pavlovian conditioning situation (e.g., extinction, generalization, discrimination) also happen in an analogous manner in operant conditioning. Thus, extinction, or a gradual reduction in the rate of responding often results in operant conditioning when the reinforcer maintaining the response is removed. Stimulus generalization and discrimination also occur. If a response is only reinforced in the presence of a particular stimulus, then this response will tend to occur much more frequently when the stimulus is present than when it is absent. At this point the stimulus (referred to as the "discriminative stimulus" or "S^D") is said to "control" the response. Stimulus generalization occurs when other stimuli that resemble the S^D also gain some control over responding although these other stimuli have never been presented with reinforcement. The probability of the response being emitted to an untrained stimulus is greater the closer the resemblance between the untrained stimulus and the original S^D. Thus, if a pigeon is trained to peck at a red light (S^D) for food reinforcement, it may also peck, with gradually reducing rates of responding, at an orange, yellow, and green light. In this example the pigeon's pecking response to the red light has generalized to the other colored lights. Stimulus discrimination can occur in the instrumental conditioning paradigm when a response is reinforced in the presence of one stimulus and is never reinforced in the presence of another stimulus. The probability of responding increases to the former stimulus and decreases to the latter stimulus. Thus, if a pigeon is reinforced for pecking when a red light is on, but is never reinforced when a green light is on, then the pigeon will usually peck at a high rate to the red light and peck at a much lower rate or stop altogether when the green light is presented.

1.2 Avoidance Conditioning

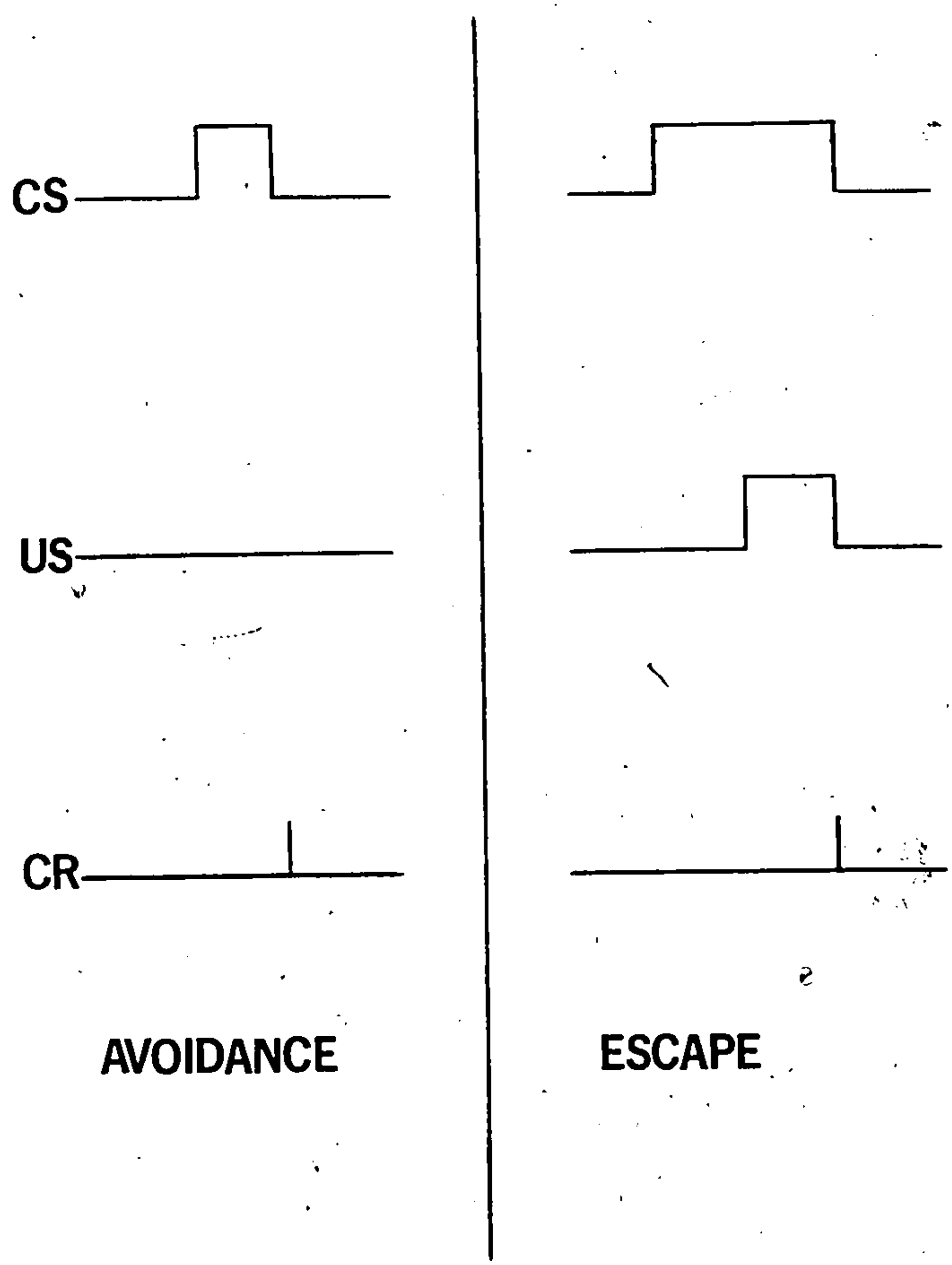
Avoidance conditioning is generally defined as the acquisition of a response which prevents or postpones the occurrence of an aversive or punishing stimulus. The experimental operation that has been used most often to study avoidance learning in animals is called the discrete-trial signalled avoidance learning paradigm. Figure 2 presents a schematic representation of this paradigm. As can be seen on the left side of the figure, each trial begins when a warning stimulus (e.g., a tone, buzzer, light, etc.) is presented to the animal for a period of time (e.g., 5, 10 sec.) prior to the onset of shock. If the animal makes the designated avoidance response (hurdle-jump in a shuttlebox, lever-press in a Skinner box, etc.), the warning stimulus immediately terminates and the shock is omitted on that trial. Borrowing the terminology from classical conditioning, the first stimulus signalling the upcoming shock is referred to as the CS, the shock is called the US, the time between the onset of the CS and the onset of the US is called the CS-US interval, and the avoidance response occurring during the CS before the US is presented is sometimes called the CR. Oftentimes, a discrete-trial signalled avoidance paradigm will incorporate escape training on those trials in which the subject fails to respond during the CS-US interval. On such occasions, as can be seen on the right side of Figure 2, the shock comes on at the end of the CS-US interval and remains on until the animal makes the designated escape response which is usually but not always the same as the avoidance response. On escape trials the CS typically remains on during the US and terminates with it.

1.2.1 Is Avoidance Learning an Example of Pavlovian or Instrumental Conditioning-- Or Both?

Avoidance learning has been well-documented and extensively researched. Factors which affect avoidance learning such as species, strains within species, type of CS, US intensity, type of response required, prior escape training, etc. have been thoroughly investigated (see reviews by Fantino, 1974; Mackintosh, 1974; Olton, 1972; Solomon & Brush, 1956; Tarpy, 1975). Despite the abundance of empirical demonstrations, a controversy still surrounds the true nature of avoidance learning. Some investigators (e.g., Hull, 1929) have argued that it is an example of Pavlovian

Figure 2. A schematic representation of a typical discrete-trial signalled avoidance learning paradigm (CS = conditioned stimulus; US = unconditioned stimulus;CR = response).

FIGURE 2



conditioning. Other researchers (e.g., Herrnstein, 1969) have maintained that avoidance learning can be considered most simply as an instance of instrumental conditioning. Still other authors (e.g., Bolles, 1971) have stated that the avoidance response is innate and thus no actual learning may be involved. The one theory, however, which has dominated the area of avoidance learning is the "two-process" or "two-factor" theory. Two-factor theory of avoidance (Anger, 1963, in press; Dinsmoor, 1954; Mowrer, 1947; Schoenfeld, 1950) proposes that appeals to either Pavlovian or instrumental conditioning alone will not provide an adequate account of avoidance learning. Rather, according to two-factor theory, an attempt must be made to examine the <u>interaction</u> between Pavlovian and instrumental processes. Only by doing this does a clear picture of the nature of avoidance learning emerge.

In the next chapter of this thesis, the development of two-factor avoidance theory is traced. Findings from studies of avoidance conditioning and related areas will be presented to illustrate both the strengths and past and present weaknesses of two-factor and alternative theories of avoidance learning. It will be shown how two-factor theory has changed over the years so that it, and it alone, can continue to handle the majority of empirical findings from avoidance studies. Then experimental data will be described in subsequent chapters of the thesis and these results will be employed to further increase the predictive and explanatory strengths of two-factor theory so that it remains the most complete theoretical account of avoidance learning available.

CHAPTER II

THE EVOLUTION OF TWO-FACTOR AVOIDANCE THEORY

2.1 Early Avoidance Conditioning Studies

In the classical or Pavlovian conditioning situation a temporal relationship is established between two stimuli, the CS and the US. The usually initially neutral CS is followed closely in time by the biologically significant appetitive or aversive US. In signalled avoidance conditioning paradigms the conditioned stimulus is also temporally paired with an aversive unconditioned stimulus, usually electric shock. Unlike the classical conditioning procedure in which USs are presented whether the subject responds or not, the avoidance procedure also includes an instrumental contingency. Responses made during the US will terminate the US (escape) while responses made during the CS will prevent the occurrence of the US on that trial (avoidance). While the introduction of a response-shock relationship seem to be a significant departure from the typical Pavlovian conditioning paradigm, early investigators of avoidance conditioning (e.g., Bekhterev, 1913; Hamel, 1919; Warner, 1932) failed to recognize the important distinction between avoidance conditioning and classical conditioning. These researchers thought that their paradigms were still basically Pavlovian even though their subjects could avoid the aversive US.

Schlosberg (1934) was one of the first experimenters to appreciate the potential difference between an avoidance response and a purely classical conditioned response. For a reason he does not make clear, Schlosberg implied that avoidance learning should proceed faster than simple classical conditioning. Measuring tail-withdrawal in the white rat as the conditioned response, Schlosberg did not find any differences in response acquisition rates between a classically conditioned group and an avoidance group. Subsequently, however, both Hunter (1935) using rats in a circular runway, and Brogden, Lipman, and Culler (1938) using guinea pigs in a wheel-turn apparatus, found superior acquisition of a running response made during the CS in avoidance groups as compared to classically conditioned groups. The findings of these two studies were important because they provided data which proved to be difficult to interpret solely within the Hullian classical conditioning model which was popular at that time. Hull (1929) had attempted to show how the avoidance response could be thought of as an example of a classically conditioned response. According to Hull, avoidance responses were nothing more than the conditioned replicas of the unconditioned escape responses to the shock US that moved forward in time to be elicited by the CS that has been paired with shock. The transition from unconditioned escape responses to conditioned avoidance responses was thought to occur in much the same manner as a conditioned response resembling the unconditioned salivation response to food comes to be elicited by a CS that signals food. It should be remembered, however, that in the avoidance paradigm, if the CR occurs the US is omitted. This is equivalent to the extinction operation in classical conditioning. Under these circumstances the CR should decrease in magnitude until a CR would not occur during the CS. At this time the US would again be paired with the CS. This pairing should function to re-strengthen the response. Thus, a prediction based on Hull's simple contiguity model would be that an avoidance contingency with its inherent extinction operation should result in slower conditioning than a pure classical conditioning group which always has the CS paired with the US. The opposite results, however, were found in the Hunter (1935) and Brogden et al.(1938) studies. Their results, then, raised a serious dilemma because they seemed to indicate that the absence or nonoccurrence of the US could also serve as the US. It became apparent that an explanation based solely on classical conditioning was not sufficient. Any analysis of avoidance learning would have to consider the role played by the consequences of the subject's response (i.e., Thorndike's 1905, Law of Effect).

2.2 Mowrer's Two-Factor Theory of Avoidance

In his 1947 paper, Mowrer attempted to provide a complete explanation of avoidance behavior. He postulated a theory of learning based on the interplay of "two basic learning processes": Pavlovian or classical conditioning of "emotional" responses and Thorndikian or instrumental "problem-solving" (p.14). Mowrer argued that fear could be thought of as a response. If a neutral stimulus is paired with shock the unconditioned fear response to the shock moves forward in time and becomes a conditioned fear response elicited by the CS. Such classical fear conditioning had already been demonstrated in a human infant (Watson & Rayner, 1920). This conditioned fear aroused by the CS motivates or energizes the animal to make responses in an attempt to escape from the fear-arousing situation. That response which is successful in terminating the feared CS is immediately reinforced by the consequential reduction in fear brought about by the removal of the CS. Thus, the two "factors" or "learning processes" in Mowrer's two-factor avoidance theory as stated in 1947 are:

1) classical conditioning of fear to an originally neutral stimulus which has been paired with shock
2) instrumental learning of a response which removes the subject from the fear-eliciting CS with consequential fear reduction serving as the reinforcing event.

Mowrer maintained that these two basic learning processes represent the dichotomy that exists in the mammalian physiological and neurological systems. That is, the two nervous systems - central and autonomic - and the two general response systems - voluntary actions of the skeletal muscles and involuntary actions of the smooth muscle and glands (visceral-vascular responses) - were thought to serve as a basis for a division between classical conditioned responses and instrumental responses. Thus, according to Mowrer, the CS acquires fear-provoking properties as a result of the classical conditioning of visceral-vascular responses. Their concommittant emotions mediate the learning of a skeletal response that leads to drive (fear) reduction. Mowrer believed, as did some of his contemporaries (Miller, 1948, Miller & Dollard, 1941), that drive reduction serves as the mechanism of reinforcement for instrumental learning. According to this view, the avoidance response is not reinforced by the omission of shock per se, but rather by the turning off of the feared CS which produces immediate fear reduction. Thus, extrapolating to a more natural setting than the one provided in the shuttlebox, this view maintains that a rat would be reinforced for running away from a cat not because this prevents the cat from biting the rat but rather because the cat is no longer in view.

2.2.1 Early Evidence in Support of Two-Factor Theory

Evidence began to accumulate which appeared to provide strong support for Mowrer's propositions that reduction in fear via CS termination and not the avoidance of shock per se reinforced, avoidance behavior and that fear classically conditioned to a stimulus paired with shock could motivate responding to escape from the CS. Mowrer and Lamoreaux (1942) and Kamin (1957 b,c) demonstrated quite clearly that keeping the CS turned on for an additional 2.5, 5, or 10 sec. following avoidance responses rather than terminating the CS immediately, seriously disrupted avoidance conditioning. This result obtained even though avoidance responses were still effective in preventing the shock. Moreover, the effect could be demonstrated after one trial (Kamin, 1957c, Expt. 2), attesting to the strong reinforcing power of immediate CS termination.

The so-called "acquired drive" studies (Brown & Jacobs, 1949; May, 1948; Miller, 1948) also provided support for Mowrer's two-factor theory. These studies showed that the learning of a response to escape from a stimulus is due to the pairing of that stimulus with shock. The acquired-drive paradigm procedurely separates the initial classical conditioning of fear to a CS paired with shock and the subsequent instrumental conditioning of a response which terminates the CS. Basically, in the first stage of an acquired drive experiment a CS is paired a number of times with an inescapable shock US. Supposedly, during this phase, fear is being conditioned to the CS. In the second stage of the experiment the CS is turned on and the animal is allowed to make a response which turns off the now feared CS. Shock is never again presented to the animal in the second phase. In the Brown and Jacobs (1949, Expt. 1) experiment, for example, one group of rats was given 40 pairings of a buzzer and an inescapable and unavoidable shock in a shuttlebox. During this phase fear was supposedly being classically conditioned to the buzzer. In the next phase the buzzer was present alone, and the rats were given the opportunity to turn off the buzzer by jumping a hurdle separating the two identical compartments of the shuttlebox. Shock was never presented in this phase of the experiment. Compared to a group of rats which simply received the buzzer alone during the first phase of the experiment but identical treatment during phase 2, the group that had received CS-US pairings quickly learned to jump the hurdle to terminate the buzzer CS (as measured by a significant decrease in latency). Similarly, Miller (1948) had found that if a response (turning a wheel) which had allowed the rat to escape from the feared CS was made ineffective, the wheel-turn response would soon extinguish and a new response (e.g., pressing a lever) which terminated the CS could be learned instead. As in the Brown and Jacobs (1949) experiment, no shocks were scheduled in this phase. This result clearly demonstrated the reinforcing power of CS termination since a response which no longer produced this consequence dropped out and was replaced by a response which did terminate the CS. This phenomenon is particularly impressive considering the fact that both responses were equally effective in "preventing" shock. The findings of the acquired drive studies led Miller (1948) to conclude, much in agreement with Mowrer's two-factor approach, that fear is an acquired drive which can motivate or energize responding; responses which are effective in reducing fear by terminating the CS will be reinforced via the mechanism of drive reduction.

The delayed CS termination studies (Kamin, 1957 b,c; Mowrer & Lamoreaux, 1942) demonstrated the reinforcing power of CS termination for avoidance responses. The acquired drive studies also showed that CS termination is a reinforcer. Furthermore, the acquired drive experiments provided evidence pointing to the important role played by prior classical conditioning of fear which endows a CS paired with shock with motivating properties. It appeared, therefore, that the two basic premises of two-factor theory - classical conditioning of fear and the instrumental learning of a response which turns off the feared CS thereby reducing fear - provided a valid explanation of avoidance learning.

2.2.2 The Nature of Fear in Mowrer's Two-Factor Theory

Mowrer, in his 1947 formulation of two-factor avoidance theory, made certain committments to the role of physiological and mentalistic phenomena. That is, he argued that an emotional state called "fear" or "anxiety" mediates avoidance learning and that this emotional state results from the conditioning of visceral and vascular responses controlled by the autonomic nervous system (ANS).[2] Wynne and Solomon (1955) tested Mowrer's assumption that emotional conditioning mediates avoidance learning. They reasoned that if emotional conditioning was necessary for avoidance learning and if emotions are produced by the workings of the ANS then a procedure which blocks ANS activity should seriously disrupt avoidance acquisition and maintenance. Using various surgical and chemical techniques, Wynne and Solomon were able to minimize ANS activity in dogs. Certain dogs which had never had avoidance training before the assault on their ANS showed retardation of acquisition of the avoidance response but all eventually managed to meet a strict response criterion. The avoidance responses of other dogs which had received prior avoidance training were not affected by ANS blockage. These results led Solomon and Brush (1956) to conclude that while emotional reactions may be important (but not completely necessary) for the acquisition of avoidance responses,

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2 Mowrer's view of emotion was similar to an earlier position elucidated by James (1884). According to James our feelings and emotional reactions are the product of underlying physiological responses to certain stimuli, rather than the other way around. To use his example, we don't first feel fear perceiving a bear and then have a heightened physiological reaction; instead our body's physiological system is first triggered by the sight of the bear and this arousal produces a conscious state called fear. This theory of emotion is now often referred to as the James-Lange theory.

they are probably not necessary for the maintenance of a well-learned response. Further support for this view came from observations made by Solomon and Wynne (1954). They reported that dogs which had become successful avoiders appeared to show no obvious fear reactions such as shivering, defecating, whining, etc., to the CS. In fact these animals avoided so quickly when the CS came on that the CS terminated before the ANS responses could be fully initiated. Yet, the dogs continued to successfully avoid shock for hundreds and hundreds of trials. The problem these findings created for Mowrer's theory is obvious: if fear of the CS motivates avoidance responding, why do these animals continue to respond when they no longer appear fearful of the CS? Thus, the findings from Solomon's lab in the 1950's strongly questioned Mowrer's assumptions that fear results from the conditioning of ANS activity and that the concommittant emotional reactions serve to motivate avoidance responding.

2.3 Schoenfeld's Version of Two-Factor Theory

Mowrer's reliance on the use of such mentalistic terms as "fear", "anxiety", and "fear-reduction", was soon challenged by Schoenfeld (1950). He presented cogent arguments why those terms should be dropped from a scientific analysis of avoidance behavior. Schoenfeld argued that these terms were so widely used in a variety of situations that they had become vague and poorly defined, thus making them of no use in scientific analysis. Rather than try to specify an exact operational definition of anxiety or fear, Schoenfeld decided that since these terms had taken on so many different connotations it was best to replace them with a new term - "aversion" - which he believed would eliminate problems of misinterpretation generated by the terms anxiety and fear. What is important in avoidance learning, Schoenfeld (1950) argued, are the operations of CS-US pairings and CS termination following the appropriate response. An investigation of avoidance behavior should not be concerned with "verbal constructs" (anxiety, anxiety-reduction) whose "purely nominal status puts the matter beyond proof or disproof (Schoenfeld, 1950, p.87)". Schoenfeld preferred to call a stimulus that had been paired with shock a "conditioned aversive stimulus".

Schoenfeld also contended that certain stimuli, not necessarily programmed by the experimenter, become conditioned aversive stimuli and play a role in avoidance learning. The source of these stimuli, Schoenfeld argued, are the subjects' responses themselves. That is, since a variety of responses other than the avoidance response will eventually be paired with shock, the proprioceptive and tactile stimuli associated with non-avoidance responses will also develop conditioned aversive properties. These stimuli form a compound with the experimenter-programmed exteroceptive CS and it is this compound stimulus which is then followed by shock. The avoidance response, however, terminates these aversive stimuli and is thereby reinforced. Moreover, since the proprioceptive and tactile feedback associated with the avoidance response is consistently paired with the termination of aversive stimulation, these avoidance response-dependent stimuli "become secondary positive reinforcers and hence strengthen the tendency to make the response which generate them (p. 88)". Thus, according to Schoenfeld, avoidance responses are not only reinforced by the removal of conditioned aversive stimuli but also by the presentation of conditioned positive reinforcers. Schoenfeld reiterated Mowrer's contention that the omission of shock itself is not the actual reinforcer of the avoidance response but is simply a by-product of making a response which allows the subject to escape from conditioned aversive stimulation.[3]

2.3.1 Experimental Tests of Schoenfeld's Two-Factor Formulation

Schoenfeld's two-factor formulation had an advantage over Mowrer's theory in that vague terms such as fear and anxiety

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[3] In effect, then, Mowrer's two-factor avoidance theory and Schoenfeld's refinement of it, as some authors (e.g., Bolles, 1972a;Herrnstein, 1969) point out, rejects the existence of true avoidance learning per se. Rather two-factor theory describes avoidance learning as a double-escape situation in which the subject first learns to escape from the primary aversive stimulus and then learns to escape from conditioned aversive stimuli.

were substituted by well-defined stimulus and response properties established through clearly specified operations. "It makes no new assumptions about intervening variables" and thus "makes possible an experimental check upon the validity of this formulation (Schoenfeld, 1950, p.88-89)". Experimental tests of his theory focused on the role of tactile and proprioceptive feedback from avoidance and nonavoidance responses.

According to Schoenfeld, during the interval between trials (intertrial interval - ITI) the animal is exposed to a compound of conditioned aversive stimuli made up of stimuli associated with nonavoidance responses and conditioned aversive apparatus cues. Both kinds of stimuli are aversive because they have, on escape trials, been paired with shock. ITI responses which mimic the avoidance response should receive some immediate reinforcement since they replace aversive proprioceptive and tactile stimuli associated with nonavoidance responses with nonaversive stimuli associated with the avoidance response. Thus, Schoenfeld's analysis predicts that many subjects should make numerous ITI responses. Indeed, when intertrial interval responding has been recorded, it does appear to occur at a high rate (Mowrer & Lamoreaux, 1942; Zeaman, 1947, cited in Schoenfeld, 1950).

Recently, Taub and his associates (Taub, 1968; Taub, Bacon, & Berman, 1965, Taub & Berman, 1963) have directly tested Schoenfeld's proposition that avoidance learning is dependent on the termination of conditioned aversive proprioceptive and tactile stimuli by studying avoidance behavior in deafferentated monkeys. Through spinal deafferentation, in which the afferent nerve fibers sending information from the skin and muscles to the brain are severed, Taub attempted to prevent any proprioceptive, tactile, and kinesthetic stimulation from reaching the monkey's brain. If avoidance responding still occurred then this would indicate that this peripheral information is not necessary to control avoidance behavior. Indeed, Taub and his associates have found that the acquisition and maintenance of avoidance behavior is not seriously affected by the surgical removal of proprioceptive, tactile, and kinesthetic feedback. Thus the role of response-produced peripheral stimulation does not appear to be as important to avoidance behavior as Schoenfeld claimed it to be.

Schoenfeld's (1950) version of a two-factor theory was a partial improvement of Mowrer's (1947) formulation in that it dropped a committment to mentalistic and poorly-defined mediating variables. In addition, Schoenfeld expanded the concept of the conditioned aversive stimulus to include stimuli not directly programmed or under the control of the experimenter (e.g., proprioceptive and tactile feedback). At the same time, however, Schoenfeld's version continued to maintain allegiance to the operation of CS termination as the necessary reinforcing event for avoidance behavior. In addition, Schoenfeld, like Mowrer, also proposed a functional role for a specific physiological system. Subsequent research by Taub and his associates, however, failed to confirm the importance of proprioceptive and tactile feedback for avoidance learning.

2.4 Sidman Avoidance Learning

The strength of early versions of two-factor theory (Mowrer, 1947; Schoenfeld, 1950) rested in part on the demonstration that if an originally neutral exteroceptive stimulus is paired with shock a number of times a response which terminates this new aversive stimulus will be acquired and maintained. The CS appeared to develop aversive characteristics either when the CS was paired with inescapable shock in a prior classical conditioning phase (e.g., Brown & Jacobs, 1949), or when the CS was paired with shock during ongoing instrumental escape training (e.g., Kamin, 1957a; Mowrer & Lamoreaux, 1942). Sidman (1953) reported an avoidance procedure, however, in which the subject could learn to delay the presentation of shock if it made a response during the appropriate time interval. The significant aspect of the Sidman avoidance paradigm is that no exteroceptive stimuli are presented which could function as explicit conditioned aversive stimuli. Short inescapable shocks are simply programmed to be delivered to the animal at regular time intervals [shock - shock (S-S) interval]. If the animal makes the correct response (e.g., lever-press), hurdle-jump, etc.) the next shock is postponed for a specified period of time [response-shock (R-S) interval]. If, after making a response, the subject fails to respond again during the R-S interval, a shock is then delivered at the end of the R-S interval and the S-S interval is reinstated until another response occurs. The animal could effectively avoid all shocks if it makes a response during the first S-S interval and then continues to make at least one response during all succeeding R-S intervals. Indeed, Sidman has found that many of the rats trained on this schedule could eventually learn to avoid a majority, if not all, shocks (see Sidman, 1966, for a complete review of studies using the Sidman or free-operant avoidance paradigm).

The finding that rats could learn to reliably avoid shocks on a Sidman schedule seemed to pose serious problems for two-factor theory. Since no explicit stimuli such as tones, buzzers, lights, etc. are ever presented, let alone paired with shock, where was the conditioned aversive stimulus that motivates avoidance behavior? How is the response selectively reinforced in the absence of CS termination?

2.4.1 Dinsmoor's Version of Two-Factor Theory - An Attempt to Reconcile Sidman Avoidance and Two-Factor Theory

From the rat's point of view, a Sidman avoidance schedule consists of a series of short inescapable shocks occurring every few seconds. No explicit stimuli are presented before, during, or after the shock. The rat is simply receiving shocks every so often in a small enclosure which has a lever protruding from one wall. If the rat happens to press this lever it finds that the train of shocks every few seconds is interrupted; the next shock following the lever-press response comes only after a much longer time interval has elapsed. Sidman (1953) and Dinsmoor (1954) were both impressed by the apparent fact that, of the various stimuli present in the Skinner box (apparatus cues, shocks, nonavoidance response-dependent stimuli), only the lever-press response and its associated stimuli remained consistently unpaired with shock. Emphasizing the role played by response-dependent stimuli both Sidman (1953) and Dinsmoor (1954) attempted to apply Schoenfeld's (1950) two-factor formulation to Sidman avoidance. The position taken by Sidman (1953) and Dinsmoor (1954) was summarized by Dinsmoor in his 1954 paper:

> "Any form of behavior other than pressing the bar will eventually be followed by shock. The dependent stimuli that accompany such behavior thereby acquire an aversive character, through their pairing with the primary stimulus. But pressing the bar is never immediately followed by shock if a reasonably long response-shock interval is used, and the stimulation which accompanies this form of response does not become aversive. Hence,

> whenever a bar press follows some response that has previously been shocked, it will be reinforced by the change from an aversive to a nonaversive pattern of stimulation (p.38)".

Thus, the conditioned aversive stimuli can be identified in the Sidman paradigm as stimuli associated with nonavoidance responses. These "response-dependent stimuli" (Anger, 1963) are, unlike experimenter-programmed exteroceptive stimuli, not directly observable or controllable. The reinforcement is the substitution of highly aversive nonavoidance response-dependent stimuli by nonaversive avoidance response-dependent stimuli. One major shortcoming of this analysis, as Sidman (1962), himself, later pointed out, is that rats usually learn the lever-press avoidance response much sooner than might be expected if a larger proportion of other responses must first be paired with shock.

Dinsmoor's (1954) formulation of two-factor theory was quite similar to that of Schoenfeld (1950). Both authors eliminated reference to mediating and mentalistic concepts such as fear and fear-reduction. Rather they concentrated on the experimental operations such as the stimulus-shock pairings which presumably endowed stimuli with conditioned aversive and negative reinforcing properties. In addition, both Schoenfeld and Dinsmoor maintained that stimuli produced by responses themselves could become conditioned aversive stimuli and "play a role which is similar to that of the "warning signal" [CS] in the conventional study of avoidance training (Dinsmoor, 1954, p.43)". Dinsmoor, however, unlike Schoenfeld, was unwilling to commit himself to the workings of any one response system (e.g., proprioceptive and tactile feedback). Instead, he preferred to use the global term "dependent" meaning "those stimuli produced by the subject without the intervention of the experimenter (p.38)", but which nevertheless can come to influence behavior depending on their relationship with shock. Although Dinsmoor (1954, p.38) suggests that physiological manipulations could be used to identify and gain control over dependent stimuli, the fact that he refused to specify the nature of these stimuli other than to say that they are produced by the animal's responses, makes his proposal more difficult to test than was Schoenfeld's proposition that these dependent stimuli were proprioceptive and tactile in nature.

2.5 Changes in Two-Factor Theory in the 1950's

During the 1950's certain revisions were made in Mowrer's (1947) original formulation of two-factor theory. Both Schoenfeld (1950) and Dinsmoor (1954) attempted to remove Mowrer's reliance on vague and poorly defined concepts such as fear. Instead, Schoenfeld and Dinsmoor emphasize the functional properties (e.g., discriminative, reinforcing) a stimulus acquires as a result of certain well-specified operations such as CS-US pairings.

As part of this trend the term "conditioned aversive stimulus" replaced "conditioned fear stimulus" in referring to a stimulus that has been paired with shock. Furthermore, the use of the term "conditioned aversion" was preferred to "conditioned fear" when describing the properties acquired by a stimulus paired with shock.[4] Schoenfeld and Dinsmoor, as well as Sidman (1953), also attempted to expand the concept of the conditioned aversive stimulus by allowing for the conditioning of aversive properties not only to experimenter-programmed exteroceptive stimuli, but also to stimuli (e.g., visual, tactile, proprioceptive, olfactory, etc.) produced by nonavoidance responses. These response-dependent stimuli are often, especially in the Sidman avoidance paradigm, eventually paired with shock. Finally, a subtle shift was taking place in the hypothesized source of reinforcement for the avoidance response. Mowrer,(1947) who maintained that fear-reduction reinforced avoidance behavior, talked of only one reinforcement operation: CS termination. Schoenfeld (1950) rejected fear reduction as the reinforcement mechanism. He proposed that avoidance behavior is reinforced both by the termination of conditioned

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A number of authors (e.g., Bolles, 1972a; Herrnstein, 1969) have questioned the necessity of substituting the term "aversion" for "fear", arguing that the two terms are synonomous. This criticism will be discussed in detail on pages 80-83 of this thesis.

aversive stimulation and the presentation of avoidance response-dependent proprioceptive and tactile feedback. Dinsmoor, for the most part, emphasized CS termination as an important source of reinforcement, but it appears that he was also beginning to recognize that other events besides CS termination could reinforce avoidance behavior. This is evident in his statement that reinforcement for avoidance responses occurs when there is a response-contingent "change from an aversive to a nonaversive pattern of stimulation (p.38)". While CS termination meets this requirement, it is not necessarily the only possible event which could cause such a change in stimulation.

2.6 Anger's Version of Two-Factor Theory

2.6.1 "Shocks/Exposure" Analysis

The next contribution to the evolution of two-factor theory was made by Anger (1963, in press). Anger provided a quantitative and predictive measure of conditioned aversiveness and further elaborated on the kinds of stimuli that could function as conditioned aversive stimuli. Two-factor theorists prior to Anger had assumed that the conditioned aversiveness of a stimulus could be established by simply regarding the number of times it had been paired with shock (i.e., Pavlovian conditioning). Anger noted that the number of times the CS is presented alone in the absence of shock (i.e., Pavlovian extinction) will also affect the overall aversive properties conditioned to the CS. Anger (1963) proposed that the conditioned aversiveness of a stimulus is a function of the number of CS-US pairings divided by the total exposure-time to the stimulus. Total exposure-time not only includes the presentations of the CS which are followed by the US (reinforced exposures) but also may include CS presentations in the absence of the US (nonreinforced exposures). In other words, the conditioned aversiveness of a stimulus is related to the conditional probability of shock given the presence (or recent occurrence) of the CS. According to this "shocks/exposure" formulation, the conditioned aversiveness of a stimulus will be strengthened the more times it is paired with shock, but it will also be weakened by numerous nonreinforced exposures. Thus, if two stimuli, A and B, are paired with shock an equal number of times but stimulus A is also presented in the absence of shock, then stimulus A will have a lower shocks/exposure value than stimulus B. Consequently, stimulus B will be the more aversive of the two. A situation in which two stimuli have an equal number of pairings with shock but one stimulus receives a great amount of exposure in the absence of shock occurs in the discrete-trial signalled avoidance paradigm. In this procedure both the apparatus cues and the explicit CS are paired with shock an equal number of times on escape trials. The apparatus cues, however, are also present during the intertrial interval when no shocks are presented. The CS, on the other hand, does not receive much exposure in the absence of shock. Thus, the shocks/exposure and therefore the conditioned aversiveness of the apparatus cues should be less than that of the explicit CS although the apparatus cues still should possess some conditioned aversiveness because they are occasionally paired with shock. According to Anger, reinforcement is provided for any response which removes stimuli with high shocks/exposure values and replaces them with stimuli with lower or zero shocks/ exposure values (cf. Dinsmoor, 1954, p.38). The greater the amount of overall reduction in conditioned aversiveness, the greater the reinforcement for the response associated with the change.

As Anger (in press) himself admits, the shocks/exposure formulation "is only considered the first step toward the measurement of conditioned aversiveness (p.83)". Indeed, it is but a primitive ordinal measure of average shock-rate which obviously is not the only variable affecting the total amount of aversiveness a stimulus could possess. Certainly, other factors such as the type, duration, and intensity of the US, the unconditioned aversive properties of the CS, prior exposures to the CS and the US, attentional variables, among many others, could all influence the functional aversive properties accrued to the CS. But, even with the above qualifications and limitations, Anger's shocks/exposure notion endows two-factor theory with enough explanatory and predictive powers to allow it to account for a host of data thought to be damaging to it. At the same time, the theory is now capable of making specific predictions concerning the likelihood for the acquisition of a response in different aversive situations by calculating the shocks/exposure values of stimuli present when the response occurs and stimuli present immediately after the response. If a comparison of shocks/exposure values reveals a significant decrease in conditioned aversive stimulation following a particular response (as opposed to other responses), then it is predicted that the responses should increase in frequency and be maintained. If no such response-contingent reduction in conditioned aversiveness occurs, then no learning is predicted. In summary, then, Anger's two-factor theory rests on the following testable assumptions:

1. as a result of being paired and unpaired with shock, different stimuli will take on different conditioned aversiveness values.
2. responses which replace highly aversive stimuli with stimuli lower in aversiveness will be reinforced.

Thus, in this latest version of two-factor theory classical conditioning is no longer seen as producing a drive state which mediates avoidance responding. Nor is its influence determined solely by CS-US pairings. Rather CS-US pairings and CS alone presentations combine to endow a stimulus with a specific conditioned aversiveness value relative to other stimuli in the situation. Furthermore, Anger's formulation takes Dinsmoor's (1954) account one step further and makes it very clear that reinforcement for avoidance behavior no longer rests exclusively on the operation of CS termination.

2.6.2 Role of CARS

As Dinsmoor (1954) pointed out, in order to determine whether a response will be reinforced by a reduction in conditioned aversiveness stimulation, it is important to take into account all possible sources of stimulation that the subject may be reacting to, besides the exteroceptive stimuli explicitly programmed in the experiment. Anger (1963, in press) has emphasized the important roles played by two such implicit sources of stimulation: conditioned aversive response-dependent stimuli (CARS) and conditioned aversive temporal stimuli (CATS). Anger's conception of CARS is similar to that of Dinsmoor (1954) who unlike Schoenfeld (1950) was unwilling to specify the nature of response-produced stimulation.

Some authors (e.g., Bolles, 1972a; Herrnstein, 1969) have argued that this strategy in effect creates stimuli that can never be seen or measured. This criticism is not valid, however, with respect to response-dependent stimuli since these stimuli are assumed to be generated directly from the responses themselves. Responses in a behavioral experiment must of course be easily observable and measurable. Thus, the response itself provides the necessary observable event that subsumes a number of different, not as easily observable, associated stimuli (e.g., proprioceptive, tactile, visual, auditory, olfactory, etc.). The question that critics are really asking then is which of these response-produced stimulus changes is actually controlling the behavior? This question, however, is not unique to response-dependent stimuli. Exteroceptive stimuli such as tones, lights, vibrations are also made up of a number of different properties such as intensity, frequency, location, etc. One could easily ask which of these aspects of an exteroceptive stimulus is actually responsible for the behavioral effects the stimulus elicits. Usually, however, when the experimenter uses an exteroceptive stimulus he simply reports the various characteristics of the stimulus without testing to see which property (or properties) of the stimulus is in fact controlling the behavior. If he wanted to, however, he could independently manipulate the intensity, frequency, etc. of the stimulus to answer this question. The difference between exteroceptive stimuli and response-dependent stimuli rests on the ease in which the experimenter can control the component characteristics of these two types of stimulation and the degree to which the response-dependent stimuli can be manipulated independently of the response. It appears, given present-day technology, to be easier to manipulate the intensity, frequency, location, etc., of exteroceptive stimuli than the proprioceptive, kinesthetic, visual, olfactory, etc., feedback of response-dependent stimuli. As the research of Taub (1968) and his associates demonstrates, however, some response-produced stimulation can be procedurally modified without changing the actual topography of the motor response. This does allow for an independent assessment of controlling response-dependent feedback.

2.6.2.1 CARS Reinforcement

Reinforcement based on CARS results when the total conditioned aversiveness of stimuli associated with making the avoidance response is less than the conditioned aversiveness of stimuli associated with any other response (cf. Dinsmoor, 1954; Sidman, 1953). A procedure then that would maximize "CARS reinforcement" would be one in which all behavior except the appropriate avoidance response is shocked frequently. Anger suggests that a Sidman avoidance procedure in which shocks occur at frequent intervals (e.g., every 5 sec.) unless the rat constantly holds down the lever in a Skinner box is a good example of such a procedure since most other behavior except lever-holding should be often paired with shock. Indeed, as predicted by a CARS reinforcement analysis, lever-holding occurs about 94% of the session time (Anger, in press, p.23).

2.6.3 The Role of CATS in Sidman Avoidance

In addition to CARS, Anger has stressed the role of conditioned aversive temporal stimuli (CATS). Anger (1963) introduced the notion of CATS because he felt that no complete analysis of Sidman avoidance behavior could ignore the fact that the actual behavior of rats run on Sidman avoidance schedules strongly suggested that the rats could somehow discriminate temporal intervals ("how soon to shock?"), sequential events ("what event came last?") or both. The data indicated quite clearly that many rats would respond differentially at different times in the R-S interval.

Responding appears more likely near the end of the interval than near the beginning or middle of the interval (see figures 3, 5, and 7 in Anger, 1963). In order to account for this pattern of responding observed in Sidman avoidance, Anger (1963) maintained that it is necessary to examine the relative shocks/exposure of temporal stimuli occurring at different points in the R-S interval. Anger argued that temporal stimuli closely paired with shock develop more conditioned aversiveness (i.e., have higher shocks/exposures) than temporal stimuli occurring further away from shock. A response which replaces temporal stimuli high in conditioned aversiveness with temporal stimuli low in conditioned aversiveness will be selectively reinforced. Thus, in Sidman avoidance, the temporal stimuli associated with the time just after a response or a shock would have relatively low shocks/exposure values since shock is some time away. Temporal stimuli near the end of the S-S or R-S intervals, on the other hand, would have relatively high shocks/exposure values since shock soon occurs. Therefore, responses which occur later in the R-S interval will be more strongly reinforced (via a greater reduction in conditioned aversiveness) than responses which occur earlier in the interval[5] (see Figure 3).

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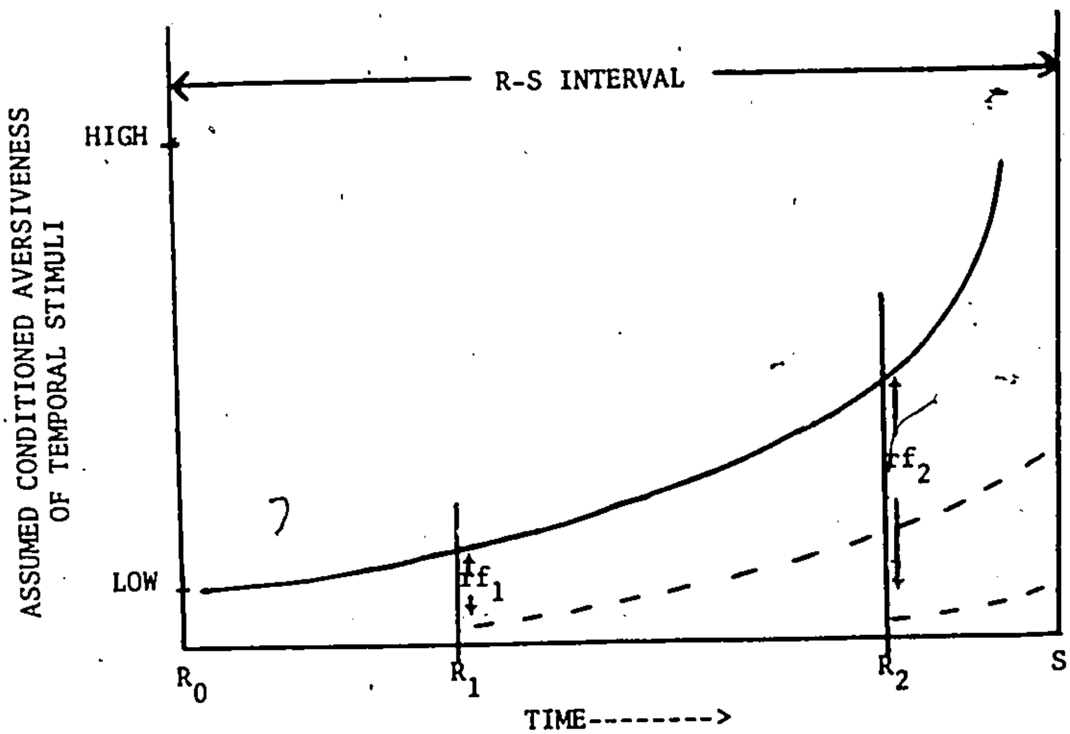
[5] Mowrer and Keehn (1958) advanced a similar notion but they assumed that fear was conditioned to the temporal stimuli and built-up until it "triggered" the response.

Figure 3. The hypothetical relative amounts of reinforcement for responses made at different times in the Response-Shock (R-S) interval (rf_1 = reinforcement for R_1; rf_2 = reinforcement for R_2). Adapted from Anger (1963, Figure 2).

FIGURE 3



Reinforcement in terms of aversiveness reduction is greater for a response occurring late in the R-S interval (R_2) than for a response made early in the R-S interval (R_1) (i.e., $rf_2 > rf_1$).

If the animal is able to make discriminations based on differential shocks/exposure values of temporal stimuli, then more responding is expected later in the R-S interval than early. This temporal patterning is typically observed by animals on Sidman avoidance schedules (Anger, 1963, Sidman, 1966). Thus, by appealing to the existence and functional role of temporal stimuli, Anger (1963) provided a two-factor account of Sidman avoidance learning which was a considerable improvement over Sidman's (1953) and Dinsmoor's (1954) efforts which were based on a CARS reinforcement analysis. Anger's formulation could account not only for how the lever-press response is selected but also for the temporal patterning of responding often observed.

Anger's shocks/exposure formulation of two-factor theory is to date the most comprehensive and cogent attempt to provide a strong theoretical statement designed to tie together much of the tremendous amount of data generated from studies of avoidance behavior and related phenomena. Anger's revision is able to account for some findings which appear to refute two-factor theory. These data and a two-factor explanation of them are reviewed in the next chapter.

CHAPTER III

CRITICISMS OF TWO-FACTOR THEORY AND REBUTTALS

In the 1950's and 1960's two-factor theory seemed to be able to handle the majority of experimental findings in avoidance learning. The acquired-drive studies (Brown & Jacobs, 1949; May, 1948; Miller, 1948) and the delayed-CS termination studies (Kamin, 1957a,b; Mowrer & Lamoreaux, 1942) provided strong support for Mowrer's (1947) basic assumptions that 1) Pavlovian conditioning of fear to a CS motivated avoidance responding, and 2) termination of the feared CS reinforced the avoidance response. Evidence was beginning to accumulate, however, which seemed to question the validity of these assumptions.[6]

3.1 Evidence Against Two-Factor Theory

Generally, the findings which were marshalled as evidence against two-factor theory included (1) preference for remaining

6 It should be kept in mind while reading this chapter that this evidence was used to criticize Mowrer's (1947) version of two-factor theory. The modifications and extensions made by Schoenfeld (1950), Dinsmoor (1954), and Anger (1963, in press) have for the most part been ignored or misinterpreted by critics of two-factor theory (e.g., Bolles, 1967; 1972a; Herrnstein, 1969; Rachman, 1976).

in an environment with an aversive CS present (Lockard, 1963; Sidman, 1955; Sidman & Boren, 1957), (2) avoidance learning in the absence of an explicit CS (Herrnstein & Hineline, 1966; Sidman, 1953), (3) failure to achieve avoidance learning with CS termination but without an avoidance contingency (Bolles, Stokes, & Younger, 1966; Kamin, 1956), (4) perseverance of avoidance responding during extinction of fear to the CS (Kamin, Brimer, & Black, 1963; Solomon, Kamin, & Wynne, 1953; Solomon & Wynne, 1954), and (5) avoidance learning in the absence of a CS termination contingency (Black, 1963; Bolles & Grossen, 1969; D'Amato, Fazzaro, & Etkin, 1968; Kamin, 1954; Warner, 1932).

3.1.1 Preference to Remain in the Presence of an Aversive CS

3.1.1.1 Preference for Signalled vs. Unsignalled Inescapable Shock

Lockard (1963), in her prototypic study, placed rats in a shuttlebox made up of two identical looking compartments and a grid floor. Occasionally a 2 sec. inescapable shock was presented through the grid floor of both compartments. In one compartment of the shuttlebox the shock was reliably preceded by a 5 sec. light. In the other compartment the shock was not signalled. Using total time spent in one compartment as opposed to the other during the experimental session as a measure of preference, Lockard found that rats preferred the signalled inescapable shock compartment to the unsignalled inescapable shock compartment. Control rats for which the signal was presented randomly in time with respect to shock showed no overall preference for either compartment.

Subsequent studies by Badia and his colleagues (Badia, Coker, & Harsh, 1973; Badia, Culbertson, & Harsh, 1973) have replicated this finding and have further demonstrated that rats still prefer the signalled shock evén when it is stronger, longer or more frequent that the unsignalled shock.

Some researchers (e.g., Bolles et al, 1966; Herrnstein, 1969, Lockard, 1963) have argued that the finding of a preference for signalled over unsignalled shock suggests that a CS paired with shock may not become aversive but rather becomes a discriminative stimulus or informational cue letting the animal know shock is soon scheduled. Perhaps, as Perkins (1968) has suggested, the signal gives the rat an opportunity to make a preparatory response to reduce the pain produced by the shock. These authors maintain, then, that Lockard's results are inconsistent with (Mowrer's) two-factor theory. They have argued that two-factor theory would predict that the total amount of fear in the signalled compartment should be greater than in the unsignalled compartment since fear conditioned to the signal (as a result of it being paired with shock) should add to the fear already present due to the presentations of shock. The animal should therefore experience less total fear in the unsignalled compartment and prefer to stay there.

The above analysis obviously ignores the relative difference in shocks/exposure of the different stimuli involved. Anger (in press) points out that there are, in effect, three different compound stimulus conditions each having its own shocks/exposure value. First, there is the signal compartment cues plus signal on. This stimulus is always followed in 5 sec. by shock and thus has a high shocks/exposure. The second stimulus is the unsignalled compartment cues, which has a medium shocks/exposure value because while it is occasionally paired with shock it also has a large amount of exposure-time in the absence of shock. The third compound stimulus of importance is the signalled compartment minus the signal. This stimulus is never paired with shock and thus has the lowest shocks/exposure value. Thus, a shocks/exposure analysis would predict that subjects would prefer to go into, and stay in, the signalled compartment without the signal because it has the lowest shocks/exposure; leaving it increases rather than decreases aversiveness. This prediction is consistent with Lockard's (1963) findings. The reason that the animal doesn't leave when the signal comes on is simply that the rat is shocked 5 sec. after the signal comes on no matter which compartment it is in.

3.1.1.2 Signalled Sidman Avoidance

In the typical Sidman avoidance paradigm, no exteroceptive stimuli are presented. Some studies, however, have introduced an explicit stimulus which signals the occurrence of shock at the end of S-S and R-S intervals (Keehn, 1959; Sidman, 1955; Sidman & Boren, 1957). The results of these studies are also thought to be damaging to two-factor theory because they suggest, as did Lockard's (1963) findings, that a stimulus paired with shock may not become aversive. Subjects in these signalled Sidman avoidance experiments typically wait until the CS itself comes on before responding, although responses made prior to the onset of the CS are effective in postponing both the CS and the next shock. As Sidman (1955), and others (e.g., Bolles et al. 1966, Dillow et al. 1972; Herrnstein, 1969; Keehn, 1959) have argued, if as two-factor theory maintains, the CS paired with shock develops fear-arousing properties, why doesn't the animal avoid the aversive CS if given the chance? Thus, these authors imply that two-factor theory would predict that in the signalled Sidman avoidance paradigm animals should be more likely to respond earlier in the R-S interval before the CS is presented. The fact that most responses are rather made in the presence of the CS, has led critics of two-factor theory to reject the notion that a CS paired with shock becomes aversive. Instead, they have concluded that the results from the signalled Sidman avoidance paradigm suggest that the CS in this procedure and perhaps in all signalled avoidance situations simply acts as a discriminative stimulus signalling when reinforcement (i.e., shock postponement) is available. As Mackintosh (1974, p.313) has noted, the logic behind this reasoning is incorrect. The signal in a signalled Sidman avoidance study does not act as a discriminative stimulus since it does not uniquely cue reinforcement. Any response made during the session, regardless whether the stimulus was present or not, could postpone the shock for an equivalent period of time and thus be reinforced. Furthermore, as Anger (in press) points out, these results are consistent with a shocks/

exposure two-factor analysis. The signal, coming as it does at the end of the S-S and R-S intervals, is very high in conditioned aversiveness because it is often paired with shock. The greatest amount of reinforcement in terms of aversiveness reduction occurs if this highly aversive stimulus is replaced by stimuli low in conditioned aversiveness such as termination of the signal, CARS, and CATS associated with long time to shock, etc. While some conditioned aversiveness reduction may occur when responses are made in the absence of signal, the shocks/exposure associated with these CATS are not as high as the signal's shocks/exposure. There is much less reinforcement (i.e., aversiveness reduction) for responding at these times than during the signal itself (except possibly for responding just prior to the scheduled presentations of the signal where the CATS are almost but not quite as aversive as the signal itself).

3.1.2 Avoidance Learning in the Absence of an Explicit CS

As mentioned previously, the fact that animals could readily learn to avoid shock on an unsignalled Sidman schedule was thought to be damaging to a two-factor account that relied on fear conditioned to an explicit CS as the motivating factor and CS termination as the reinforcing agent. Sidman (1953) and Dinsmoor (1954) made early attempts to salvage two-factor theory by stressing the role played by response-dependent stimuli as potential conditioned aversive stimuli. Anger (1963) went one step further by emphasizing the role of temporal stimuli and he seemed to have provided an adequate two-factor account of Sidman avoidance. Critics of two-factor theory, notably Herrnstein (1969), however, were not impressed by two-factor theorists increasing appeal to "inferred stimuli (p.56)" to account for the data. Still, given the temporal regularities of the Sidman procedure and the temporal patterning of responding often observed, Anger's account seemed quite plausible. Anger's analysis was given further indirect support by the evidence already in existence, that temporal discriminations could be formed in a positive reinforcement situation by animals that had to keep the time between each of their succeeding responses relatively fixed in order to receive food reinforcement (Anger, 1956). Herrnstein and Hineline (1966) however, developed a "random-shock" procedure which lacked the temporal regularities of Sidman avoidance and which Herrnstein (1969) argued incorporated "no conditioned stimulus, either explicit or plausibly postulated (p.57)". Using this paradigm, Herrnstein and Hineline hoped to demonstrate conclusively that the "Pavlovian component of two-factor theory is not <u>necessary</u> (Herrnstein, 1969, p. 60)". The Herrnstein and Hineline procedure consisted of placing the rat in a Skinner box with one lever. Two tapes were programmed to deliver shocks at random intervals. One tape, the "high-density" tape, delivered shocks every 6.7 sec., on the average, while the other tape, the "low-density" tape, delivered shocks every 20 sec. on the average. The high-density tape was always in effect during the session unless the rat made a lever-press response.

This first response simply disconnected the high-density tape and started the low-density tape. The low density tape remained in effect until the next scheduled shock was delivered at which time the low-density tape was disconnected and the high-density tape was re-activated. Shocks on the low density schedule could not be avoided or postponed and additional responses during the low density tape had no programmed effects. Only the first response after a shock from either the high or low density tape could switch on or maintain the low density shock schedule. Thus, the overall effect of reliable responding after a shock would be to maintain the low density schedule and therefore lower the frequency or density of shock throughout the session, although no scheduled shocks could be actually avoided. The finding of excellent acquisition of the lever-press response on this schedule was taken as strong evidence against two-factor theory since, unlike the Sidman paradigm, the random-shock schedule did not contain fixed temporal relationships. Thus, supposedly there were no temporal stimuli being consistently associated with the presence or absence of shock that could function as conditioned stimuli. Moreover, each response did not necessarily produce stimuli associated with a relatively long period free from shock since due to the inherent nature of the random low density shock schedule, a shock could by chance occur contiguous with a response. Herrnstein (1969) anticipating a two-factor rebuttal, maintained that appeals to inferred stimuli in the random-shock procedure were "sheer tautology (p.59)". He further maintained that the Herrnstein and Hineline study demonstrates conclusively that avoidance behavior[7] can be reinforced directly via a reduction in shock density and Pavlovian events even if operating in more traditional avoidance procedures are not necessary for avoidance learning to occur.[8]

Anger (in press) attempted to show how the Herrnstein and Hineline (1966) findings could be handled by a shocks/exposure two-factor analysis. Remember, this analysis predicts that a response will be learned if aversiveness stimulation following the response is lower than at any other time. This appears to be the case for lever-press responses made on the random-shock schedule. That is, since a response triggers the low density tape while a shock triggers the high density tape the probability of shock following a response is on the average less than the probability of shock

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7 It must be pointed out that responses in the Herrnstein and Hineline (1966) paradigm are not true avoidance responses although Herrnstein (1969), himself, appears to have forgotten this as he says "The random shock procedure shows that...the avoidance of noxious stimulation is itself effective...(p.59)".

8 Sidman (1962) had suggested a similar "one-factor" shock-density reduction view of Sidman avoidance learning.

following a shock. As in Sidman avoidance, a response made during a S-S interval on the random schedule will on the average be followed by a relatively long period of time to the next shock. This results in decreased shocks/exposure for stimuli immediately following a lever-press response made after a shock. After a shock, the conditioned aversiveness is relatively high since a shock is usually quickly followed by another shock. A response occurring at this time will produce the greatest reduction in conditioned aversiveness. On the other hand, unlike the Sidman procedure, a response following a response in the random shock paradigm does not affect the occurrence of the next scheduled shock and is therefore not reinforced by a reduction in aversiveness. Thus, the shocks/exposure analysis leads to the prediction that the probability of a response occurring following a shock should be higher than the probability of responses occurring following a response. This distribution of responding was reported by Herrnstein and Hineline (1966).

3.1.3 Failure to Achieve Avoidance Learning with CS Termination but Without An Avoidance Contingency

According to Mowrer's two-factor theory, it is not the avoidance of shock per se that reinforces the avoidance response. Rather it is the termination of the fear-arousing CS that actually functions as the reinforcer. In effect, this view maintains that there is no such thing as true avoidance learning.

Instead of learning to avoid an upcoming shock, an animal learns to escape from an aversive CS. This analysis leads to the prediction that so-called avoidance learning should be more adversely affected if the response failed to terminate the CS than if the response failed to avoid shock. Bolles, Stokes, and Younger (1966) disagreed with this analysis. They maintained that the significant source of reinforcement for the avoidance response was indeed the avoidance contingency itself and not CS termination. Bolles et al. attempted to provide support for their alternative view by conducting a series of experiments in which CS termination and avoidance contingencies were factorially manipulated in the following manner: Group A received both an avoidance contingency and an immediate CS termination contingency; Group B could not avoid the shock, but the CS immediately terminated when a response was made; Group C received an avoidance contingency but CS termination was delayed following avoidance responses; Group D received neither the avoidance contingency nor the immediate CS termination contingency. This design was basically a replication of Kamin (1956, 1957a). Indeed, the results of the Bolles et al. (1966) experiments were consistent with Kamin's earlier findings. Bolles and Kamin both found that the groups were ordered -A > B, B = C, C > D- with respect to the total number of avoidance responses. Both the avoidance variable and the CS termination variable were statistically significant. Bolles et al. (1966) concluded that "there is reason to doubt whether CS termination serves as the principal source of reinforcement for the CR. The major factor in avoidance learning appears to be the avoidance or the nonoccurrence of shock (p.207)".

The findings in both the Kamin studies (1956, 1957a) and in the Bolles et al. (1966) study suggest that the avoidance contingency factor makes a significant contribution to avoidance learning in that the CS termination contingency was not effective unless the avoidance contingency was also in effect. This was thought to be embarrassing to a two-factor view which held that CS termination is the only reinforcer for avoidance behavior. If this version of two-factor theory is correct then it would have been expected that the group receiving CS termination but no avoidance contingency (Group B) would do as well as a group receiving CS termination plus avoidance (Group A). Both Kamin and Bolles et al. found, however, that avoidance learning in Group B was significantly poorer than in Group A, and no different from a group whose responses could avoid shocks but could not terminate the CS (Group C). Kamin (1956) tried to salvage two-factor theory by arguing that the reason Group B did not do as well as Group A was because Group B's responses were soon punished by the unavoidable shock and therefore declined. He also argued that the performance of Group C was equivalent to that of Group B because the former group received superstitious delayed reinforcement by CS termination for responses that occurred near the end of the CS. The CS in Group C remained on for a fixed 5 sec. duration regardless of whether a response was made or not.

It is not necessary, however, as Mackintosh (1974, p.316-318) notes, to appeal to mechanisms such as punishment and delayed reinforcement to account for the mediocre performance of Group B if an examination is made of shocks/exposure value of different stimuli following responses. Although responses in Group B do terminate the aversive CS, the fact that shock inevitably follows a response gives post-response stimuli high shocks/exposure. The reduction in conditioned aversiveness due to the termination of the CS is therefore negated by the increase in conditioned aversiveness associated with the presentation of post-response stimuli consistently paired with shock. Thus it would be expected that early in training avoidance responding should increase rapidly since as a result of CS-US pairings on escape trials the shocks/exposure value of the CS is very high. Initially the conditioned aversiveness reduction resulting from CS termination is greater than conditioned aversiveness increases associated with post-response stimuli which are just beginning to be paired with shock on early avoidance response trials. After a while, however, responding should decline as the conditioned aversiveness of post-response stimuli continue to rise and overcome any decrease in conditioned aversiveness resulting from CS termination. Indeed, this result was found in both of Kamin's studies.

A shocks/exposure analysis can also be applied to the stimuli encountered by Group C. Initially, in Group C, responses do not lead to a significant reduction in conditioned aversiveness due to the continuation of CS. Responses made during the CS, however, will not be followed by shock so that post-response stimuli should develop low conditioned aversiveness although the continued presence of the aversive CS may delay this process. Thus, a shocks/exposure analysis would predict that Group C's performance should initially remain below that of Group B but should increase gradually until it exceeds the maximum level of Group B. Again, these expectations are consistent with the reported data. As Mackintosh (1974, p.318) points out, although the overall performance (e.g., total number of avoidance responses) of Groups B and C was similar, a shocks/exposure analysis predicts differences in the pattern of the acquisition curves which are borne out by the actual results.

3.1.4 Perseverance of Avoidance Responding During Extinction of Fear to the CS

Solomon, Kamin, and Wynne (1953) reported a phenomenon which could not be adequately explained by (Mowrer's) two-factor theory. They found that dogs trained to avoid a very intense (sub-tetanizing) shock by jumping over a barrier in a shuttlebox continued to respond reliably for 200 extinction trials (where no shocks were ever given) with no sign of stopping. Furthermore, when responding was well-established, the animals did not show any overt signs of fear (e.g., barking, shivering, defecating, etc.) but rather they made many consecutive stereotyped short-latency avoidance responses.[9] Only when an animal made a long-latency response did the fear reactions appear, as if he had "scared himself" for taking so long to make the response (Solomon & Wynne, 1954). These findings pose a major problem for two-factor theory. When the animal has become a successful avoider and is responding on every trial, the fear established earlier to the CS should be extinguishing since the CS is not followed by the US on avoidance trials. The question that must be answered then is why does avoidance responding persist when each avoidance response should inevitably decrease the amount of fear associated to the CS?

3.1.4.1 The Principles of Anxiety Conservation and Partial Irreversibility

To explain this phenomenon within the confines of two-factor theory, Solomon and Wynne (1954) proposed that two additional principles - "anxiety conservation" and "partial irreversibility" were necessary. They maintained that every time the animal makes a successful response with a latency too short to elicit a full-blown anxiety reaction in the ANS, anxiety conditioned to the CS is conserved. If, however, anxiety is not being elicited on short-

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[9] Similarly, Wynne and Solomon (1955) observed that avoidance responding was not affected by blockage of ANS activity which reduced emotional reactions in dogs that had been given prior avoidance training.

latency avoidance trials then no anxiety reduction can follow the response on those trials. Consequently, the response strength decreases until the response latency increases to the point where once again anxiety is elicited by the CS and a response can now be reinforced by anxiety reduction. Thus, anxiety is conserved because "behavior borrows drive to build habit" (Bolles, 1967, p.325)". As evidence for anxiety conservation, Solomon and Wynne (1954) point to the observation that long-latency responses are often followed by a series of short-latency responses.

Anxiety conservation by itself, however, still cannot completely account for the high resistance to extinction observed in the Solomon et al. (1953) study. Eventually during the extinction phase long latency responses inevitably occur, allowing enough time for the elicitation of anxiety reactions. Since these anxiety reactions will no longer be followed by shock during extinction, their excitatory strength should diminish to the point where they can no longer motivate behavior. At this time avoidance responding should cease. To make up for this deficit in the explanatory power of the anxiety conservation principle, Solomon and Wynne (1954) also proposed the principle of "partial irreversibility". This principle states that when a CS is paired with a very intense shock, the result will be "a permanent increase in the probability of occurrence of an anxiety reaction in the presence of that conditioned stimulus...(p.361)".

This attempt to reconcile the Solomon et al. (1953) findings within two-factor theory can be criticized for several reasons. First Solomon and Wynne's (1954) "explanation" was nothing more than a restatement in mentalistic and nontestable terms of the experimental observations themselves. That is, Solomon and Wynne argued post hoc that if a response fails to extinguish over a large number of trials then it is partially irreversible. How this response gains such a property is left unexplained. In addition, their appeal to internal mediating events was, in effect, a step backwards for two-factor theory. Indeed, some of Solomon and Wynne's contemporaries (e.g., Schoenfeld, Dinsmoor, and Sidman) had already rejected the use of such concepts and had strengthened two-factor theory by emphasizing the role of well-specified operations as opposed to poorly defined motivational states. Finally, it appears that a special explanation of a strong resistance-to-extinction effect in avoidance learning is not necessary. The perseverance of responding found in the Solomon et al. study appears to be an exception rather than the rule. Subsequent research has failed to find such strong maintenance of responding in extinction (see Mackintosh, 1974, p.332-333, and Uhl & Eichbauer, 1975).[10]

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[10] Seligman and Johnston (1973) argue strongly that no version of two-factor theory can account for high resistance to extinction in those cases where it does occur (e.g., Brush, 1957; Black, 1958; Solomon et al. 1953). Their point is well-taken and will be further dealt with later in this thesis where an attempt will be made to reconcile these data within a revised two-factor model.

3.1.4.2 Further Evidence of Extinction of Fear to the CS in Well-Trained Avoiders

The results of a study by Kamin, Brimer, and Black (1963) which suggest that a stimulus may still maintain control over avoidance responding even while it is losing its fear-arousing or aversive properties has also been taken as evidence against two-factor theory (Bolles et al. 1966; D'Amato, 1970; D'Amato et al. 1968; Seligman & Johnston, 1973; Weisman & Litner, 1972). In the Kamin et al. study, different groups of subjects were removed from the shuttlebox after making either 1, 3, 9, or 27 consecutive avoidance responses and were immediately placed in a Skinner box in which they had previously learned to lever-press for food. After allowing for a 20 min. lever-press recovery period wherein lever-press rates returned to their pre-avoidance experience levels, the 20 sec. tone that had served as the CS during shuttlebox avoidance conditioning was presented 24 times while the rat was lever-pressing for food. This procedure is often referred to as the "Conditioned Emotional Response" (CER) paradigm. In the CER paradigm, the amount of reduction or suppression in the rate of lever-press responding during the CS is calculated by comparing response-rate during the CS to the rate of lever-pressing in the period of time (equal to the CS duration) just prior to the presentation of the CS. Suppression of lever-press response rates during the CS is taken as an index of the amount of fear conditioned to the CS as a result of its pairing with shock either in the Skinner box or in another apparatus. It is assumed that the greater the amount of suppression in responding the greater the fear supposedly elicited by the CS. In the Kamin et al. (1963) study then the amount of suppression of lever-pressing to the CS was thought to represent the degree of fear conditioned to the same CS during avoidance training. Kamin et al. found a "U"-shaped function with the greatest suppression occurring in the group which had been removed from the shuttlebox after nine consecutive avoidance responses. Smaller amount of suppression were observed in the 1-, 3-, and 27-consecutive response groups. These results indicate that the conditioned aversiveness of a CS is reduced (at least as measured in the CER preparation) not only when the subject receives little avoidance training (e.g., has made only 1-3 consecutive avoidance responses) but also when the subject is well-trained (e.g., has made 27 consecutive avoidance responses). If the well-trained avoidance animals no longer exhibited fear to the CS, then what was motivating continued avoidance responding on their part? This finding led Kamin et al. (1963) to conclude that "variables other than fear of the CS are largely responsible for the maintenance of avoidance behavior (p.501)".

It is unclear, however, why Kamin et al. adopted this position for on the very same page they use a shocks/exposure analysis to adequately account for the data:

> "The median numbers of CS-US pairings received by the 1-, 3-, 9-, and 27-avoidance Ss were 2, 15, 12, and 15; the median numbers of avoidances were 1, 22, 31, and 59. The "U"-shaped function relating fear to the CS to avoidance criterion thus follows from the simple assumption that CS-US pairings increase fear, whereas unreinforced CS presentations extinguish it (p.501)".

Thus, according to this shocks/exposure analysis it would be expected that those subjects which have just made 27 consecutive responses should show diminished conditioned suppression since the shocks/exposure of the CS had been substantially reduced due to the extra nonreinforced trials in the latter part of avoidance training.[11]

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[11] It should be kept in mind that although suppression was less in the 27 consecutive response group than in the 9 consecutive response group, the former group was still showing substantial suppression when initially tested in the CER situation. Thus, it appears that the CS in the 27 consecutive avoidance response group was still aversive enough to allow for sufficient reinforcement of the avoidance response (via aversiveness reduction) to maintain the avoidance response. Of course, as Mackintosh (1974, p.334) notes, it is possible that the 27-group's responses may have already begun to extinguish, although they were still consistently avoiding. This would be indicated by longer latencies, less resistence to extinction, etc. (this data was not provided by Kamin et al. 1963) in the 27-consecutive response group as compared to the 9-consecutive response group.

If anything, then, the Kamin et al. (1963) study provides data which are consistent with a shocks/exposure formulation of two-factor theory.

3.1.5 Avoidance Learning in the Absence of a CS Termination Contingency

3.1.5.1 Trace-Conditioning Studies

As early as 1932, Warner had demonstrated that rats could adequately learn to avoid in a trace-conditioning paradigm in which the CS was only presented for a short fixed duration (1 sec.) and was followed after a fixed period of time (trace interval = 10 sec.) by shock which the rat could escape. If the rat shuttled during either the CS or the trace interval, shock was omitted. Kamin (1954), using dogs as subjects, also reported reliable avoidance learning with trace intervals of 5 and 10 sec. Other researchers (Black, 1963; Bolles & Grossen, 1969; Bolles et al. 1966; D'Amato et al. 1968), however, have not found consistent acquisition of avoidance responses in the trace-conditioning situation. Demonstrations of reliable conditioning in a trace-conditioning procedure where subjects learn to respond in the absence of the CS (i.e., during the trace interval) does pose problems for a version of two-factor theory that rests on CS termination as the sole source of reinforcement. Kamin tried to reconcile his findings with two-factor theory by arguing that many of his dogs often managed to respond during the 2 sec. trace CS and thus be superstitiously reinforced by the termination of the CS.

Indeed Black (1963) using only a .9 sec. CS reported that few of the rats in his trace groups reached an acquisition criterion of five consecutive avoidances responses in 100 trials. Bolles et al. (1966) also found poor trace-conditioning with a .5 sec. CS. D'Amato et al. (1968), who did not count responses made during the CS itself, also obtained poor learning of a lever-press avoidance response in the trace-conditioning group as compared to a delay group, in which the CS remained on until the subject responded. Thus, these poor results might be attributable, as Kamin implied, to the reduced opportunity for these subjects to have their response occur during the CS and be reinforced by its quick termination. Bolles and Grossen (1969), however, did use a 2 sec. CS with an 8 sec. trace interval but did not find reliable avoidance conditioning in their rats. Perhaps, the failure to replicate Kamin's (1954) results by Bolles and Grossen (1969) may have been due in part to their use of different species as subjects.

In general, then, the trace-conditioning paradigm does not seem to consistently result in adequate avoidance acquisition. This is predicted by two-factor theory and therefore the overall trace-conditioning findings do not appear to pose a serious threat to this theory. When animals do acquire an avoidance response in the trace situation, it is possible, as Kamin (1954) suggested, that these animals had made many responses during the short CS itself and were thus often superstitiously reinforced by CS termination.[12]

3.1.5.2 Feedback Stimulus Studies

As pointed out earlier, Kamin (1957c) had clearly demonstrated that delaying CS termination for a period of time following two-way avoidance responses seriously disrupted avoidance acquisition although the avoidance contingency remained in effect. These results have been replicated by Delprato (1969) in a one-way avoidance procedure. Furthermore, Katzev (1967) showed that delaying the CS after responses in extinction significantly increased the rate of extinction. Thus, there is strong evidence pointing to the importance of the CS termination contingency in the discrete-trial one- and two-way avoidance paradigms. Recently, however, it has been demonstrated (Bolles & Grossen, 1969, 1970; D'Amato et al. 1968; Katzev & Hendersen, 1971; Keehn & Nakkash, 1959) that the deleterious effects of delayed CS termination can be completely removed by simply making the presentation of a second exteroceptive stimulus - referred to as a feedback stimulus (FS) -

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12 Even if reliable avoidance learning could be demonstrated in a trace procedure using either a short CS or not counting responses made during the CS, a shocks/exposure formulation (Anger, in press) could account for the findings by appealing, as it does in Sidman avoidance, to the CATS that are present due to the temporal regularities of the trace paradigm.

contingent on avoidance responses. Moreover, presenting a FS contingent on avoidance responses made during the trace interval in a trace-conditioning procedure significantly improves avoidance conditioning (Bolles & Grossen, 1969, Expt. 1; D'Amato et al. 1968, Expt. 2). In addition, avoidance acquisition has been shown to be facilated in the lever-press (Dillow, Myerson, Slaughter, & Hurwitz, 1972), one-way (Weisman & Litner, 1972) and two-way Bolles & Grossen, 1969, Expt. 3) avoidance paradigms by the presentation of a response-contingent FS even when an immediate CS termination contingency is also in effect.

The findings of no decrement in avoidance conditioning in studies employing a FS when CS termination is delayed have been considered by some researchers (Bolles, 1972a; Bolles & Grossen, 1969, D'Amato et al, 1968; Herrnstein, 1969) to be quite damaging to a two-factor account that relies on CS termination and concommitant fear-reduction as the sole source of reinforcement for avoidance behavior. These FS studies supposedly provide a vivid demonstration that CS termination is not necessary for avoidance learning. A stimulus made contingent on avoidance responses can be just as effective a reinforcer as CS termination. On the basis of these findings, D'Amato et al. (1968) have argued that fear reduction via CS termination may not be the reinforcement mechanism in avoidance learning. Rather, an avoidance response is reinforced by the informational feedback provided by a salient response-contingent change in stimulation. Likewise, Bolles and Grossen (1969) maintain that any such change in stimulation, be it a novel FS or CS termination itself, "serves primarily an informational function (p. 90)"-presumably notifying the subject that it has just made the correct response and no shock is forthcoming in the immediate future. Additional evidence in support of the informational role of CS termination comes from a study by Bower, Starr, and Lazarovitz (1965) who showed that the amount of reduction in responding caused by delayed CS termination was a function of the post-response-contingent change in stimulation. The more the post-response stimulation resembled the original CS, the greater the decrement in avoidance performance.

3.1.5.2.1 Two-Factor Explanation of FS Findings

Neither Bolles and Grossen (1969) nor D'Amato et al. (1968) clearly specifies how informational stimuli operate to promote avoidance learning. It is evident, however, that they have rejected a two-factor approach on the basis of a phenomenon that can easily be handled by a two-factor analysis (Dinsmoor, 1954; Anger, 1963, in press) which does not rely on CS termination as the sole reinforcement operation. Instead, this formulation maintains that reinforcement involves response-contingent substitution of stimuli high in conditioned aversiveness with stimuli low in conditioned aversiveness. In the FS studies in which the CS remains on following the avoidance response and a FS is presented, the compound CS+FS is never paired with shock while of course the CS by itself had been paired with shock on escape trials. Thus, a response which changes the highly aversive CS alone stimulus to the less aversive CS+FS stimulus will be reinforced by aversiveness reduction. The case where superior avoidance acquisition is found in a CS termination plus FS group as compared to a CS termination alone group (Bolles & Grossen, 1969, Expt. 3; Dillow et al. 1972) can also be readily accounted for by a shocks/exposure formulation. Since the FS is never present when shock occurs, but the apparatus cues sometimes are, the FS will have lower shocks/exposure than the apparatus cues (although because of the great amount of exposure in the absence of shock, the apparatus cues will have less shocks/exposure than will the CS). Thus, a response which replaces the highly aversive CS with the apparatus cues will not receive as much immediate reinforcement (i.e., aversiveness reduction) as a response which replaces the CS with the FS. Consequently, more responding is observed in the latter case.[13]

3.2 An Alternative One-Factor Theory

The accumulation of evidence (reviewed above) thought to be damaging to two-factor theory has led some authors (e.g., Bolles,

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[13] It is worthwhile noting that Bolles and Grossen (1969, p. 98-99; 1970, p.168-169) adopt what is essentially a shocks/exposure view to explain how informational stimuli work to maintain avoidance behavior.

1972a; Bolles et al. 1966; D'Amato, 1970; D'Amato et al. 1968; Fantino, 1973; Herrnstein, 1969; Herrnstein & Hineline, 1966; Rachman, 1976; Sidman, 1962; Tarpy, 1975) to reject a two-factor account of avoidance learning. Basically, they have argued that the results from the five areas reviewed above strongly suggest that neither Pavlovian conditioning of fear nor fear-reduction via CS termination are necessary or even important components of the avoidance learning process. In addition, many critics of two-factor theory, although differing in their own approaches, have expressed a mutual uneasiness with two-factor theorists' (e.g., Schoenfeld, Dinsmoor, Anger) propensity to "interpret avoidance procedures post hoc, designating as the effective CS whatever would tend to substantiate the theory (Herrnstein, 1969, p. 63)". That is, the appeal to stimuli not directly observable or controllable (e.g., response-dependent, temporal) has, according to Bolles (1972a), "raised the specter of untestability" while Herrnstein (1969) warns that "the notion of a conditioned stimulus has retreated out of range of empirical scrutiny (p. 57)".

As an alternative to what was considered to be a irreparably damaged two-factor approach, Herrnstein (1969), revitalized and extended "one-factor" accounts offered earlier by Sidman (1962), Bolles et al. (1966), and Herrnstein and Hineline (1966). Herrnstein proposed that avoidance behavior is reinforced directly by a reduction in shock frequency or density (i.e., the omission or postponement of shock following avoidance responses). In addition, Herrnstein argued that the CS when presented simply serves as an informational cue or discriminative stimulus setting the occasion for an occurrence of the appropriate response to be reinforced (cf., Keehn, 1959). Herrnstein does not deny the possibility of Pavlovian conditioning occurring as a result of CS-US pairings experienced in the discrete-trial procedure, but he questions the functional role of such conditioning in mediating avoidance behavior via the conditioning of inferred motivational and emotional states. Rather, as in positive reinforcement situations (where Pavlovian conditioning has not generally been considered essential for instrumental learning) the occurrence of the CS simply signals a time when a particular response (or class of responses) will be reinforced.

Herrnstein, in his 1969 paper, marshalled the available evidence against two-factor theory and attempted to show that avoidance learning could be more parsimoniously and adequately explained in law of effect and stimulus control terms. As such, his review provides many valid criticisms of Mowrer's (1947) version of two-factor theory. Indeed, Mowrer's formulation was in serious trouble well before 1969. These inadequacies were soon recognized by other two-factor theorists, notably Schoenfeld (1950), Dinsmoor (1954), and Anger (1963, in press) who proposed changes which instead of pushing two-factor theory "over the line into irrefutability (Herrnstein, 1969, p. 56)", greatly strengthened its logic structure, explanatory power, and empirical testability. The theory can now easily account for the anomolous findings reviewed by Herrnstein (1969) and others (e.g., Bolles, 1972a; Bolles et al. 1966).

3.2.1 Weaknesses of One-Factor Theory

Of equal importance, however, is the question of whether a one-factor approach, based on shock-frequency reduction as the sole reinforcement variable, is equally capable of handling the avoidance phenomena. If it could, then perhaps it would be more parisimonious to accept a one-factor account with its fewer assumptions and underlying mechanisms even if a two-factor model can also account for the data.

As Anger (in press) has so cogently argued, however, Herrnstein's one-factor shock-density reduction view simply cannot handle a number of important empirical findings. First, one-factor theory is not able to account for the results of studies which have clearly demonstrated the powerful reinforcing effects of CS termination. The acquired drive studies (Brown & Jacobs, 1949; May, 1948; Miller, 1948) for example, demonstrated that a response which terminates a stimulus previously paired with inescapable shock could be acquired in the absence of shock-frequency reduction since shocks are no longer presented during the response-learning phase itself. In addition, Katzev (1967) showed that delaying CS termination in extinction (where no shocks are given) significantly speeded up the extinction process, although shock-frequency reduction, as in the acquired drive studies, was not a factor. Similarly, Kamin (1957b,c) gave different groups of rats either 0-, 2.5-, 5-, or 10-sec. delayed CS termination following avoidance responses and reported that differences between the 0-delay group and the other delay groups emerged after only one trial despite the fact that the same shock-frequency (i.e., avoidance) contingency was in effect for all groups. This finding attests to the powerful reinforcing effect of immediate CS termination.

Another important set of findings that a one-factor analysis has difficulty explaining is the temporal patterning of responses commonly found in Sidman avoidance (Anger, 1963) in which the majority of responses tend to occur near the end of the response-shock interval. In the Sidman procedure, all responses, no matter when they are emitted during the session, produce an equivalent postponement of shock. Thus, according to a one-factor view each response should be receiving the same amount of reinforcement in terms of shock-frequency reduction. Consequently, since this view does not predict differential reinforcement for responses occurring at different times in the R-S interval, it cannot account for the observed temporal patterning of responses. Nor can Herrnstein's formulation provide an adequate explanation of how the lever-press response is selected and reinforced in his own random-shock procedure (Herrnstein & Hineline, 1966). If, as he proposes, rats acquire those responses which lead to an overall reduction in shock density, then the rat must have the capacity to "calculate" changes in shock density over the entire session-time and then be able to attribute these changes to the particular response chosen by the experimenter. This view appears to endow the rat with capabilities that are much more complex and unspecified than those proposed by a two-factor analysis which rests on the assumption that rats can distinguish between stimuli that have different histories of association with shock. Indeed, it seems particularly difficult to maintain, as Herrnstein (1969) does, that the shock-frequency reduction view is "but the law of effect itself (p. 59)" when the proposed reinforcing consequence (shock-density reduction) is not immediately contingent on the functional response but rather occurs as the session wears on. As Mackintosh (1974, p.328) has noted, empirical evidence suggests that avoidance behavior is more sensitive to immediate, as opposed to later, salient environmental events as indeed the law of effect predicts. For example, Bolles and Popp (1964) were unable to condition rats to make a response that avoided subsequent shocks unless the response also avoided the first shock. Sheffield (1948), in his replication of Brodgen et al. (1938), reported that in the inescapable shock group (classical conditioning group) the increased likelihood of a running or standing-still response occurring on trial N was a function of whether the opposite response had been shocked on trial N-1. Baron, Kaufman, and Fazzini (1969) found that only a small number of response-contingent shocks were able to reduce Sidman avoidance responding below pre-punishment levels even though the avoidance contingency remained in effect. These data suggest that rats would not be particularly sensitive to changes in shock-density occurring throughout the session as Herrnstein maintains.

Thus, Herrnstein's one-factor analysis falls far short of being an acceptable, let alone superior alternative to two-factor theory. One-factor theory cannot account for data easily handled by even Mowrer's antiquated version of two-factor theory (e.g., acquired drive studies, delayed CS termination studies). Furthermore, a one-factor account even has trouble accounting for data originally gathered to support a shock-density reduction reinforcement mechanism (Herrnstein & Hineline, 1966; Sidman, 1962). Part of this failure rests on Herrnstein's refusal to admit that a rat can discriminate that it has just pressed a lever or that there has been a long time since the last shock even though the empirical evidence (e.g., patterning of responses in Sidman and random-shock schedules) strongly suggest that rats (and other species) can make such discriminations. In attempting to provide a "simpler" explanation of avoidance learning, free from references to "inferred" stimuli, Herrnstein has ignored what the animal is actually doing. It appears, therefore, that he has tried to develop a behavior theory without considering the actual behavior emitted by the animal. Thus, even if an alternative to two-factor theory was needed, Herrnstein's formulation can not be considered a viable replacement.

3.3 Misinterpretations of Recent Versions of Two-Factor Theory

The attempt by critics, such as Herrnstein, to disprove two-factor theory and replace it with alternative formulations of avoidance learning seems to have been premature. It is apparently based on a failure to keep up with or recognize the improvements that have made in the theory over the years. Rather the target that has bore the brunt of the attack has been Mowrer's antiquated 1947 proposal and the efforts of subsequent two-factor theorists (especially that of Anger) have been misrepresented or ignored.

3.3.1 "Conditioned Aversion is Synonomous with Conditioned Fear"

One of these misunderstandings has been equating the term "conditioned aversion" with the term "conditioned fear". The latter term implies a motivational or drive state which "energizes" the animal to make a response to reduce the internal tension created by this state. The concept of fear also implies that certain emotional responses or concommitant physiological activity mediate this drive state. As Rachman (1976) maintains, however, not all avoidance responses, at least in human experience, necessarily have a fear component. Taking an umbrella to avoid getting drenched or walking around a muddy field to avoid getting one's clothes dirty, are examples of avoidance responses in the apparent absence of fear-eliciting stimuli. Certainly, it is difficult to argue that getting wet or muddy is fear-arousing. Yet these events are no doubt aversive or unpleasant and are usually avoided. Also, as Anger (1963, in press) points out, the terms "conditioned aversiveness" and "conditioned aversive stimuli" do not encompass all of the possible properties a stimulus paired with aversive events might develop (e.g., elicitation of physiological and emotional responses, fighting, vocalization, etc.). Rather, "the term conditioned aversive stimulus selects and describes just one of the new effects of the stimulus, namely its acquisition of the same property that characterizes the primary aversive stimulus, the ability to reinforce a response by its termination after that response (in press, p.10)". This, of course, does not imply that some internal state of the animal has not changed; obviously it is something inside the animal, not the stimulus, that has changed; but, at present, this state can only be indexed reliably by the behavior of the animal itself. It is still not known which of the many internal events that are occurring are responsible for the change in the animal's response to a stimulus paired with shock. As the evidence from Wynne and Solomon (1955) and Taub and his associates (e.g., Taub, 1968; Taub & Berman, 1963) clearly indicate, committing a behavior theory to specific physiological mechanisms can greatly weaken its power even when the theory still adequately explains behavior. As Anger (in press) has cogently argued:

> "... it is tempting to use terms such as "fear" or "anxiety" that...seem to provide a physiological basis and support for the claim that the stimulus paired with shock does have a new behavioral effect. But what looks like a physiological basis of the behavioral effect is an illusion--we just have a welter of events whose relation to the behavioral effects is so obscure that we have no more "explained" the behavioral observations than we have in the case of the discriminative stimulus. When our measurements have repeatedly shown directly and empirically that the stimulus has acquired a certain new effect

> on behavior, that finding is not strengthened by data on associated physiological changes of unknown significance (p.8)".

Thus, present two-factor theory no more appeals to an underlying physiological, drive, emotional, or motivational state than does Herrnstein's concept of the discriminative stimulus.

3.3.2 "CS Termination is the Only Reinforcer of Avoidance Behavior"

Another misinterpretation of current two-factor theory is that it is thought to still specify CS termination as the sole reinforcement mechanism. In this regard, Herrnstein (1969), Bolles (1972a);Bolles and Grossen (1970);Bolles et al.(1966), D'Amato (1970) and others have, on the basis of the findings of avoidance learning in the absence of an explicit CS termination contingency (Sidman avoidance, Herrnstein and Hineline's random-shock paradigm, trace conditioning, feedback stimulus studies), rejected two-factor theory outright. As early as 1954, however, Dinsmoor had suggested that avoidance behavior is "reinforced by the change from an aversive to a nonaversive pattern of stimulation (p.38)". Certainly this change does not necessarily rest solely on CS termination. It is only one of a number of different operations that could produce such a change in stimulation. Consequently, two-factor theory has no real problems handling data from studies showing reliable avoidance learning in the absence of a CS termination contingency.

3.3.3 "Two-Factor Theory is Irrefutable"

Another serious criticism that has been leveled at two-factor theory is the claim that the theory has become "irrefutable" and "untestable" (Bolles, 1972a; Herrnstein, 1969) mainly because it appeals to so-called "invented" stimuli such as response-dependent and temporal stimuli which are not easily observable or controllable. Anger (in press) strongly argues that these stimuli are not "invented" but are clearly evidenced by the behavior of the animal. Thus in discussing the role of CATS in Sidman avoidance learning, Anger (in press) has noted that:

> "The behavioral evidence is strong that something is different for the S at 10 sec. after a press as compared with 5 sec. after a press. This evidence is the same kind of evidence that leads us to conclude something is different for the S when a sound is present as compared with when the sound is absent, namely a difference in response under the two conditions... (p.53)".

As pointed out earlier, by trying to ignore temporal discriminations, Sidman's (1962) and Herrnstein's (1969) one-factor alternatives could not adequately handle the data generated from unsignalled avoidance procedures. Thus, the argument that appeals to stimuli not specifically programmed by the experimenter makes two-factor theory irrefutable seems specious when various lines of behavioral evidence strongly suggest that the animals can recognize and make use of these stimuli.

The irrefutability argument is also not correct for another obvious reason: two-factor theory can certainly be refuted by certain empirical findings. That is, Anger (1963, in press) has developed a predictive measure of conditioned aversiveness (shocks/exposure) which assesses the degree to which a stimulus is paired with shock. Prior to the actual running of an avoidance study, a list of stimuli that will be present just before, during, and after the response occurs can be drawn up. This list should include not only explicit stimuli (e.g., tones, lights, apparatus cues, etc.) but also implicit stimuli (e.g., CARS, CATS, etc.). Also before the experiment actually begins, the expected shocks/exposure can be calculated and the stimuli can be rank-ordered with respect to their anticipated conditioned aversiveness. The theory could then predict which responses will likely increase in frequency and be maintained and which ones will drop out based on the assumption that a reduction in aversive stimulation serves as the reinforcing agent. The theory could thus easily be refuted by demonstrations that (other variables remaining constant) a response which replaced stimuli with high shocks/exposure with stimuli with low shocks/exposure is not increased in frequency or maintained, or conversely, that a response which produces an immediate increase in aversive stimulation is strengthened. That there as yet does not appear to be any data of this kind, attests to the validity and explanatory strength of the current two-factor formulation.

The above review has attempted to show how two-factor theory has evolved over the past 30 years into what Anger (in press) calls "the best example yet of a successful theory in the analysis of behavior: a theory that predicts a remarkable breath of experimental results (p.5)". The questions that now must be asked are: "what is the next stage in the evolution of two-factor theory?" "Are there recent findings with which even Anger's powerful version has difficulty?" "If there are, can two-factor theory be expanded to account for these new avoidance phenomena?" The answers to these questions will hopefully be found in the next chapters which look at the role of Pavlovian inhibitory processes in avoidance learning.

CHAPTER IV

THE RELATIONSHIP BETWEEN THE INHIBITORY AND REINFORCING PROPERTIES OF AVOIDANCE RESPONSE FEEDBACK STIMULI

4.1 Pavlovian Conditioned Inhibition and Avoidance Learning

Two-factor theorists have contributed substantially to a more thorough understanding of the role of Pavlovian conditioning processes in avoidance learning. They have, for the most part, limited their investigations to Pavlovian <u>excitatory</u> conditioning - the capacity of a CS to elicit a CR. Thus, two-factor theorists have traditionally studied the acquisition of conditioned fear or conditioned aversiveness to a stimulus that is a signal for shock.

Pavlov (1927), however, also elucidated a second associative process - "internal" or conditioned inhibition. Conditioned inhibition, as it will be used in this paper, refers to the conditioning of a "tendency opposite to that of a conditioned excitor (Rescorla, 1969c, p.78)". Thus, the inhibitory stimulus is thought to be able to actively suppress the occurrence of a excitatory CR. In terms of avoidance learning, then, the question arises whether conditioned inhibitors of fear or of avoidance responses exist in the avoidance situation and whether these stimuli are of functional significance in the establishment and/or maintenance of avoidance behavior. This issue has been largely ignored by two-factor avoidance theorists although evidence is accumulating that Pavlovian inhibitory processes do play a role in avoidance learning. Before examining this evidence, however, it might prove fruitful to first provide a more detailed analysis of Pavlovian conditioned inhibition.

4.2 Rescorla's Contingency View of Pavlovian Conditioning

Rescorla (1967, 1969a,c) has attempted to outline what he believes to be the necessary and sufficient conditions for establishing conditioned excitors and conditioned inhibitors. He argues that the important factor that must be considered in the formation of positive (excitatory) and negative (inhibitory) associations is the contingency that is established between a CS and a US. The contingency between a CS and US is defined as a set of two conditional probabilities: (1) the probability of the occurrence of the US given the presence of the CS and (2) the probability of the US given the absence of the CS (Rescorla 1967). When conditional probability (1) is greater than conditional probability (2), the contingency correlation between the CS and US is positive and the CS is assumed to possess excitatory properties. Conversely, when conditional probability (1) is less than conditional probability (2) the contingency is considered to be negative and the CS is assumed to develop inhibitory properties. According to this contingency formulation a conditioned inhibitor is thought to be at the opposite end of an associative continuum from a conditioned excitor. When the two conditional probabilities are equal (i.e., the US is equally likely to occur in both the presence and absence of the CS), no contingency is established and the stimulus is assumed to possess neutral associative qualities. In a series of papers, Rescorla (1966, 1968b, 1969a) has presented evidence in support of this contingency view of Pavlovian conditioning. He has shown that the amount of excitatory strength acquired by a CS decreases while the amount of inhibitory strength increases as the number of USs given in the absence of the CS increases. Furthermore, it appears that the amount of inhibition accruing to a stimulus negatively correlated with a US is also a function of the length of the US-free time interval predicted by the CS. Rescorla and LoLordo (1965), Moscovitch and LoLordo (1968), and Weisman and Litner (1971) have demonstrated that stimuli that predict relatively long periods free from shock (> 1 min.) develop the capacity to inhibit Sidman avoidance responding and that the longer the safety period signalled by the CS the more inhibition accrued to it. Thus, the evidence suggests that a stimulus which is negatively correlated with the occurrence of shock and which signals a shock-free safety interval will develop inhibitory properties.

4.3 Conditioned Inhibitors in Avoidance Learning

Inherent in most avoidance paradigms are stimuli that are negatively correlated with respect to shock. These stimuli are associated with the occurrence of the avoidance response itself which in both discrete-trial and Sidman procedures consistently result in both the omission of, and a period free from, conditioned and unconditioned aversive events. There is good reason to believe, then, that inhibitory conditioning may be occurring in the avoidance situation. The possible candidates for conditioned inhibitors in the avoidance situation include certain response-dependent stimuli (as suggested by Soltysik, 1963), the termination of the CS, and experimenter-programmed exteroceptive feedback stimuli. For the most part, however, experimental investigations of the inhibitory properties of response-contingent stimuli have centered on the study of experimenter-programmed exteroceptive FSs presumably because they are easier to manipulate. They eliminate many methodological and conceptual difficulties that would be encountered in trying to assess the characteristics of either response-dependent stimuli or CS termination itself.[14]

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14 One exception to this statement is a study by Soltysik (1963). He attempted to show directly that certain avoidance response-dependent stimuli themselves develop inhibitory properties. He found that his dogs showed a deceleration of heart-rate below pre-CS levels following the avoidance response and concluded that this reduction in autonomic activity represented the inhibitory nature of avoidance response stimuli.

4.3.1 Investigations of the Inhibitory Properties of Feedback Stimuli

The search for conditioned inhibition in the avoidance paradigm is a recent development. To date there appears to be only four published accounts of experiments designed to measure inhibitory properties of exteroceptive response-contingent feedback stimuli. In the first of these studies Rescorla (1968a, Expt. 3) presented a 5 sec. tone after each avoidance response in one group of dogs that had received six days of Sidman avoidance training. Thus, the tone functioned as a FS in this group. Another group of similarly trained dogs received the same number of tone presentations but the tone was presented at random times during the session. In this group, then, the presentation of the tone was not contingent on avoidance responses and therefore did not act as a FS. Rescorla reported that the insertion of the tones did not appreciably change avoidance responding in either group during the FS sessions. In order to measure the inhibitory properties of the tone in the two groups, Rescorla (1968a) employed an assessment technique developed by Rescorla and LoLordo (1965). On the test day, in the Rescorla (1968a) experiment, subjects were given an extinction session of Sidman avoidance responding in which shocks were not presented even if the subjects failed to respond during the R-S interval. The tone was presented independently of avoidance responding at random time intervals to both groups. Given the assumption that Sidman avoidance behavior is motivated by fear, then it was expected that the rate of responding will decrease when a fear inhibitor is presented. Rescorla and LoLordo (1965) had observed this effect when Pavlovian conditioned inhibitors were presented during ongoing Sidman avoidance responding. Rescorla (1968a) found a similar effect only in the group which had previously received the tone contingent on avoidance responses. The group which had previously received non-contingent tone presentations showed no change in response rates during the tone on the test day. Thus both conditioned inhibitors and avoidance response-contingent FSs appear to be able to reduce the rate of Sidman avoidance responding. Based on this finding Rescorla (1968a) concluded that avoidance response-contingent stimulation also develops inhibitory properties.

Weisman and Litner (1972) also provided evidence that an avoidance response-contingent FS acquires inhibitory properties over the course of avoidance training by assessing the inhibitory properties of the FS after various amounts of avoidance training. Furthermore, Weisman and Litner employed a yoked-control design[15]

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15 The yoked-control design, as used by Weisman and Litner (1972), pairs one member of the experimental group with one member of the control or "yoked" group. Each yoked subject receives the same exposure to the experimental conditions as its experimental partner or "master" except with respect to the independent variable (the condition being manipulated by the experimenter). In Weisman and Litner's study, the independent variable was the avoidance response contingency. The performance of each avoidance master rat determined the sequence and duration of exposure to the stimuli (tones, shocks, lights) that each yoked-control partner received. The yoked-controlled animals therefore received an identical patterning of stimulus presentations no matter how they themselves responded.

to show that the inhibition accruing to the FS is not due directly to the fact that the FS came on immediately after an avoidance response. Yoked-control animals which received the same number, patterning, and duration of CSs, USs, and FSs but in the absence of any response contingency, showed the same degree of inhibitory conditioning to the FS as their avoidance partners which had to make the appropriate escape or avoidance response to turn on the FS. These findings strongly suggest that the inhibition accruing to the FS over avoidance training is a result of the fact that the FS reliably signals the absence of shock. Being presented, as it was in Weisman and Litner's study, immediately following escape and avoidance responses, the FS always predicted a relatively long time (the intertrial interval) in which neither shock nor the aversive CS would occur. The fact that the avoidance response contingency does not appear crucial for the establishment of inhibitory properties to the FS suggests that this inhibitory conditioning is strictly Pavlovian in nature (i.e., it is due to stimulus-stimulus contingencies).[16]

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[16] It should be noted that the FS in Weisman and Litner's (1972) studies developed inhibitory properties even though it was a "redundant" cue for avoidance since an immediate CS termination contingency was also in effect.

One methodological problem with the Weisman and Litner (1972) studies, however, is that they programmed the FS to occur after escape as well as after avoidance responses so that on escape trials the FS was paired in a backward manner with shock. This situation is known to produce conditioned inhibition (Moscovitch & LoLordo, 1968; Siegel & Domjan, 1971). Thus, it may have been these backward pairings with shock rather than or in addition to the safety period signalled by the FS that was responsible for the inhibitory properties of the FS. This may have resulted in more rapid acquisition of inhibitory properties to the FS than would have occurred if the FS had only followed avoidance responses. Indeed, Weisman and Litner found that the inhibitory strength of the FS had reached asymptote after only 25 trials of which 60% involved the occurrence of shock. This suggests that the conditioned inhibition accruing to the FS in these studies might have resulted from the backward pairings of shock and the FS on early escape trials.[17]

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17 Of course, it is entirely possible that the reason inhibitory properties develop to a stimulus paired in a backward manner with a US is because after such a pairing the stimulus usually predicts a relatively long period free from the US (Moscovitch & LoLordo, 1968).

In a study partially similar to that of Rescorla (1968a), Dinsmoor and Sears (1973) trained three pigeons to press a foot-pedal to postpone shocks presented on a Sidman avoidance schedule. Each response was followed by a 1000 Hz tone during avoidance training. After considerable training in this manner, the birds were given test sessions in which the 1000 Hz tone FS and tones varying in frequency around 1000 Hz (e.g., 250, 500, 2000, 4000 Hz) where presented noncontingently with respect to responding at random intervals. No shocks were programmed during the test sessions. All the tones were found to consistently suppress the rate of responding. Furthermore, two out of the three birds showed a reliable generalization gradient of inhibition (Jenkins & Harrison, 1962). The reduction in rate of Sidman avoidance responding was greater the closer the resemblance (in frequency) between the test tones and the original 1000 Hz FS. Dinsmoor and Sears' (1972) findings also suggest that stimuli following avoidance responses become conditioned inhibitors of avoidance behavior.

In the most recent of the published studies investigating the inhibitory properties of a FS, Morris (1974), using the methodology of Weisman and Litner (1972), extended their findings by showing that a light-FS develops inhibitory properties during the acquisition of a two-way shuttlebox avoidance response. This result was obtained even when the FS followed avoidance responses only (Expt. 1). Morris (1974, Expt. 1) also replicated Weisman and Litner's finding of no difference between master and yoked subjects in the development of inhibitory properties to the FS. This result suggests that the acquisition of these properties is due to Pavlovian, not instrumental contingencies.

In a subsequent experiment, Morris (1974, Expt. 3) attempted to ascertain the relevant aspect of the Pavlovian contingency responsible for the FS becoming a conditioned inhibitor. He found that the inhibitory strength of the FS was a function of the shock-free intertrial interval predicted by the FS during avoidance training. Avoidance group rats that were trained with a 180 sec. intertrial interval and their yoked partners both evidenced more inhibitory conditioning to the FS then did master and yoked rats experiencing a 30 sec. intertrial interval. Morris also found, however, that the 180 sec. intertrial interval avoidance group acquired the avoidance response at a faster rate than the 30 sec. intertrial interval avoidance rats. It might be argued that the 180 sec. intertrial interval rats showed greater inhibitory learning because they learned the avoidance response faster than the 30 sec. intertrial interval subjects and not because of the long intertrial interval per se. To control for possible differences in amount of inhibitory training due to the faster rate of acquisition of the avoidance response found in groups receiving the 180 sec. intertrial interval as compared to the groups receiving the 30 sec. intertrial interval, Morris gave

180 sec. intertrial interval yoked subjects the identical pattern, number and duration of CSs, USs, and FSs of a 30 sec. intertrial interval master rat. He also gave 30 sec. intertrial interval yoked subjects the corresponding stimulus experiences of a 180 sec. intertrial interval master rat. The group yoked to the 30 sec. intertrial interval avoidance masters but which received these stimulus experiences with a 180 sec. interval between the FS and the start of the next trial still showed greater inhibitory conditioning to the FS than the groups receiving only a 30 sec. interval between the FS and the next trial. Thus, it appears that the inhibitory properties of the FS were a function of the intertrial interval signalled by the FS regardless of the actual differences between the 30 sec. and 180 sec. intertrial interval master subjects in the speed of avoidance learning per se. Morris (1974) concluded from these results that feedback stimuli "will only be fear inhibitors when associated with long intertrial intervals" and that "the development of these properties is independent of whether the animal is actually learning to avoid or passively receiving the equivalent noncontingent events (p.444)".

The four studies reviewed above have demonstrated that an avoidance response-contingent exteroceptive feedback stimulus becomes a conditioned inhibitor after training in (1) the Sidman avoidance paradigm with dogs (Rescorla, 1968a) and with pigeons (Dinsmoor & Sears, 1973); (2) discrete-trial one-way avoidance with rats (Weisman & Litner, 1972); (3) discrete-trial wheel-turn avoidance with rats (Weisman & Litner, 1972); and (4) two-way shuttlebox avoidance with rats (Morris, 1974). In addition, it seems likely, given the findings of no difference between master and yoked subjects (Morris, 1974; Weisman & Litner, 1972), that the FS develops inhibitory properties through Pavlovian processes and that the length of the shock-free interval signalled by the FS is probably an important factor (Morris 1974, Expt. 3). One problem that exists, however, is that all of the above studies have used the same assessment procedure to measure conditioned inhibition, namely a reduction in the rate of well-established Sidman avoidance responding during the stimulus. While this method does appear to be a sensitive measure of both excitatory and inhibitory properties of stimuli associated with shock, further evidence that a FS develops inhibitory properties using another technique (e.g., compound-summation test) to measure inhibition would provide needed convergent validity.

4.3.2 Inhibitory Feedback Stimuli as Reinforcers of Avoidance Behavior

Based on the findings that a FS develops inhibitory properties a number of investigators have suggested that the reinforcing powers of feedback stimuli may in fact be derived from the inhibitory properties they acquire. It has also been proposed that avoidance behavior in general may be reinforced by the presentation of response-associated conditioned inhibitors. Thus, Soltysik (1963) proposed a "three-component model" of avoidance learning where the first two-factors are the familiar Pavlovian conditioning of fear ("defense reactions") via CS-US pairings and the reinforcement of a response which terminates the CS. The third component, however, is considered to be the conditioned inhibition of fear developed to stimuli associated with the avoidance response which "intensifies" the rewarding nature of CS termination. Conditioned inhibition was also thought by Soltysik to "protect" the fear-eliciting CS from extinction. In apparent agreement with Soltysik's "three-component model", Rescorla (1968a) concluded that "the finding that response feedback is inhibitory of fear may provide a mechanism for the rapid reinforcement of avoidance responding in addition to the gradual subsiding of fear which might occur with the removal of a danger signal (p.59)". Likewise, Dinsmoor and Sears (1973) stated that "stimuli arising as a natural consequence of performing a given avoidance response, which of necessity are negatively correlated with the receipt of the shock, play a role in maintaining the response (p.285)". Thus, Soltysik (1963), Rescorla (1968a) and Dinsmoor and Sears (1973) suggest that the feedback following avoidance responses become conditioned inhibitors and their presentation may serve to reinforce avoidance behavior. At the same time, however, these authors do not rule out the functional role played by the removal of conditioned aversive stimuli-the traditional source of reinforcement for two-factor theory. Accordingly, these authors do not commit themselves to the view that the sole source of reinforcement for the avoidance behavior is the presentation of inhibitory stimuli.

Weisman and Litner (1969a,b;1972) on the other hand, appear to adopt this strong view. Weisman and Litner (1972) propose that avoidance learning may best be examined as an example of a positive reinforcement learning situation. In doing so they advocate a "revised two-process model of the reinforcement of avoidance behavior" which states that "Pavlovian inhibition of fear produced by the avoidance response provides the reinforcement mechanism in avoidance learning (p.256)". Moreover, this revised version of two-factor theory asserts that the development of inhibitory properties to a FS "is necessary if avoidance behavior is to be reinforced (p.262)"(emphasis added). Similarly, Morris (1974) has argued that "feedback stimuli will have little or no effect upon performance unless they are inhibitors of fear (p.444)".[18]

4.3.3 Is the Conclusion that the Reinforcing Property of a FS is Derived from Inhibitory Conditioning Justified?

There is now little doubt that FSs can reinforce avoidance behavior. The presentation of response-contingent FSs have been

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18 Morris (1974) appears to have adopted Weisman and Litner's (1972) revised two-factor theory only with respect to those avoidance situations employing an exteroceptive FS.

shown to serve as an effective reinforcer for avoidance behavior in the absence of an immediate CS termination contingency (Bolles & Grossen, 1969; D'Amato et al. 1968; Keehn & Nakkash, 1959). Moreover, using a FS may facilate acquisition even when the CS termination contingency is in effect (Bolles & Grossen, 1969; Dillow et al. 1972; Weisman & Litner, 1972). There has also been a recent accumulation of evidence (Dinsmoor & Sears, 1973; Morris, 1974; Rescorla, 1968a; Weisman & Litner, 1972) to suggest that a FS does indeed develop inhibitory properties.[19] As the above quotes indicate, however, there may have been a premature tendency of some investigators to conclude that conditioned inhibition accruing to the FS during avoidance training provides the mechanism for the reinforcement of avoidance behavior. Before this statement can be accepted, additional evidence is needed.

If the reinforcing qualities of the FS are related to its inhibitory properties then these two properties should covary in

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[19] The reader is reminded that all of these published studies have used the same measurement of inhibition - a reduction in the rate of well-trained Sidman avoidance behavior. Thus, this finding should be accepted with caution until converging evidence is provided using an alternative technique to measure the inhibitory properties of FSs (see Expt. 2 of this thesis).

a positive manner. The greater the inhibitory strength of the FS, the more powerful a reinforcer it should be. There is as yet only suggestive evidence that this is the case. As reported earlier, Dinsmoor and Sears (1973) found that the rate of Sidman avoidance responding in the presence of tones of differing frequencies decreased the closer the tones were in frequency to the original 1000 Hz. FS which itself produced minimal responding (in 2 out of 3 birds). Dinsmoor and Sears also reported, however, that the number of responses occurring in the absence of the tones increased sharply when responses produced the 1000 Hz. FS as opposed to the untrained tones of varying frequencies. Thus, when the FS was presented noncontingently with respect to responding, avoidance response rates decreased. This suggests that the FS had become a conditioned inhibitor. When the FS was made contingent on avoidance responses such that it was presented following each response, the overall rate of responding increased. This indicates that the FS could also function as an effective reinforcer of avoidance behavior. These "mirror image" effects on Sidman avoidance response rates of the inhibitory and reinforcing properties of the FS are to be expected if the reinforcing property of the FS is related to its inhibitory strength. Further suggestive evidence comes from Morris (1974, Expt. 3) who showed that when a 180 sec. intertrial interval was used in the two-way discrete-trial procedure both avoidance acquisition was facilated and the FS developed greater inhibitory strength than when a 30 sec. intertrial interval was employed. This finding, coupled with the observation (Bolles & Grossen, 1970) that avoidance acquisition is facilated only if the FS signals a relatively long intertrial interval, again suggests that the effectiveness of the FS as a reinforcer and the amount of conditioned inhibition accruing to it may be closely interrelated.

4.3.4 Purpose of Thesis - Provide Necessary Evidence that the Reinforcing Properties of FSsare Due to Pavlovian Conditioned Inhibition

It must be kept in mind that the above evidence is purely correlational. Some authors (e.g., Morris 1974; Rescorla, 1968a, 1969b; Soltysik, 1963; Weisman & Litner 1969b,1972) have argued that the reinforcing properties of the FS are derived from the conditioning of inhibition to it as a function of it predicting the nonoccurrence of shock. The available evidence cannot as yet support such a cause-and-effect statement. If the above hypothesis is correct, however, two converging findings would be expected. First, it would be predicted that with all other variables remaining equal, two stimuli which differ as to their effectiveness as feedback stimuli should show a corresponding difference as conditioned inhibitors such that the more effective FS should develop stronger inhibitory properties than the less effective FS. Experiments 1 and 2 of this thesis are designed first to identify two stimuli that differ as to their capacity to serve as reinforcing FSs and then to assess the relative power of these two stimuli to inhibit responding to a known excitatory CS in a summation test.

The above predicted results, if obtained, would still not by themselves justify concluding that the reinforcing property of FSs comes from their conditioned inhibitory qualities. The conditioned inhibition accruing to the FS may simply be a by-product of its placement in the avoidance paradigm such that it is negatively correlated with shock. Thus, the inhibitory nature of the FS may be of no functional significance. A second prediction, however, based on the hypothesis that reinforcement for avoidance is provided by inhibitory feedback is that a stimulus already possessing inhibitory properties should serve as a stronger re-inforcing FS from the very outset of avoidance training than would novel or neutral stimuli. These latter stimuli must first develop their inhibitory properties during the course of avoidance training itself. Experiments 3 and 4 are designed to first establish a training procedure which develops a strong Pavlovian conditioned inhibitor and then to test the capacity of this known conditioned inhibitor to reinforce avoidance behavior. Finally, Experiment 5 is designed to delineate the necessary and sufficient conditions for establishing an effective reinforcer for shock-motivated avoidance behavior and to provide a test of the FS contingency.

The demonstrations that (1) an effective FS develops greater inhibitory strength than a less effective FS, and (2) a known conditioned inhibitor serves as a more powerful reinforcer for avoidance behavior than a novel or neutral stimulus, would provide strong convergent evidence in support of the hypothesis that the reinforcing capacity of an FS is a function of the conditioned inhibitory properties accruing to it over the course of avoidance conditioning. Such findings would also have important implications for two-factor theory as well as for other theories of avoidance learning.

4.4 EXPERIMENT 1 - The Relative Effectiveness of a Tone-FS vs. a Clicker-FS

This study attempted to find two stimuli which differed with respect to their effectiveness as reinforcing FSs for avoidance responding in rats. If two such stimuli could be found, then a test could be made of their relative inhibitory strength after avoidance training. If the reinforcing property of the FS is in fact derived from its inhibitory strength, then it would be expected that the more effective FS found in this present study should show greater inhibitory strength in a subsequent experimental test of inhibition.

A number of studies have investigated the FS qualities of visual stimuli. Bolles and Grossen (1969) found that a group of rats which received immediate CS termination plus a "lights out" FS made more avoidance responses in 80 trials than a group which received only immediate CS termination following avoidance responses. Dillow et al. (1972) and Weisman and Litner (1972) reported that a "lights on" FS facilated avoidance performance in rats with an immediate CS termination contingency in effect. Thus, both the turning on or the turning off of lights appear to function as effective FSs in rats. The evidence concerning the reinforcing capabilities of auditory FSs is not as clear. In an early FS study, Keehn and Nakkash (1959) found that the use of a tone FS did ameliorate the deficit in responding caused by delayed CS termination. Katzev and Hendersen (1971), on the other hand, reported that their tone-FS was not very effective in maintaining avoidance responding in extinction. Their results are obscured, however, by the fact that they used a short intertrial interval (average = 18 sec.) during avoidance training. Indeed, Morris (1974, Expt. 3) and Bolles and Grossen (1970) have found that a FS is not very effective when short ITIs are used, possibly because the FS fails to become a signal for the absence of shock. The ineffectiveness of the tone-FS in Katzev and Hendersen's (1971) study may have been due to the fact that it signalled a short ITI and not because of its modality.

In the present experiment an attempt was made to compare the effectiveness of two auditory stimuli - a clicker and a tone-with respect to their ability to function as reinforcing FSs for avoidance responding. While pilot data had suggested that a tone functions as a poor FS (cf. Katzev & Hendersen, 1971), nothing was known about the potential effectiveness of a clicker as a FS. It was hoped, however, that the inferior reinforcing qualities of a tone-FS is unique and not a common feature of other auditory stimuli. To test the relative effectiveness of tone vs. clicker feedback, two groups received immediate CS termination plus either a tone- or a clicker-FS contingent on avoidance responses. These two groups were compared to a third group which received immediate CS termination but no FS following avoidance responses.

The same visual stimulus (lights on) served as the CS in all three groups, so that differences between the groups could be attributed only to differences in the type of FS (i.e., tone, clicker, nothing) and not to variations in the type of CS. It was hoped that this study would reveal that avoidance acquisition in the clicker-FS group would be significantly superior to either the tone-FS or no-FS groups. This would indicate that the clicker, although an auditory stimulus, could function as a more effective reinforcer than the tone.

4.4.1 Method

4.4.1.1 Subjects - Subjects were male $Fischer_{344}$ albino rats, weighing 250-300 grams and were obtained from Canadian Breeding Farms, Quebec. Each rat was housed in its own cage with food and water freely available.

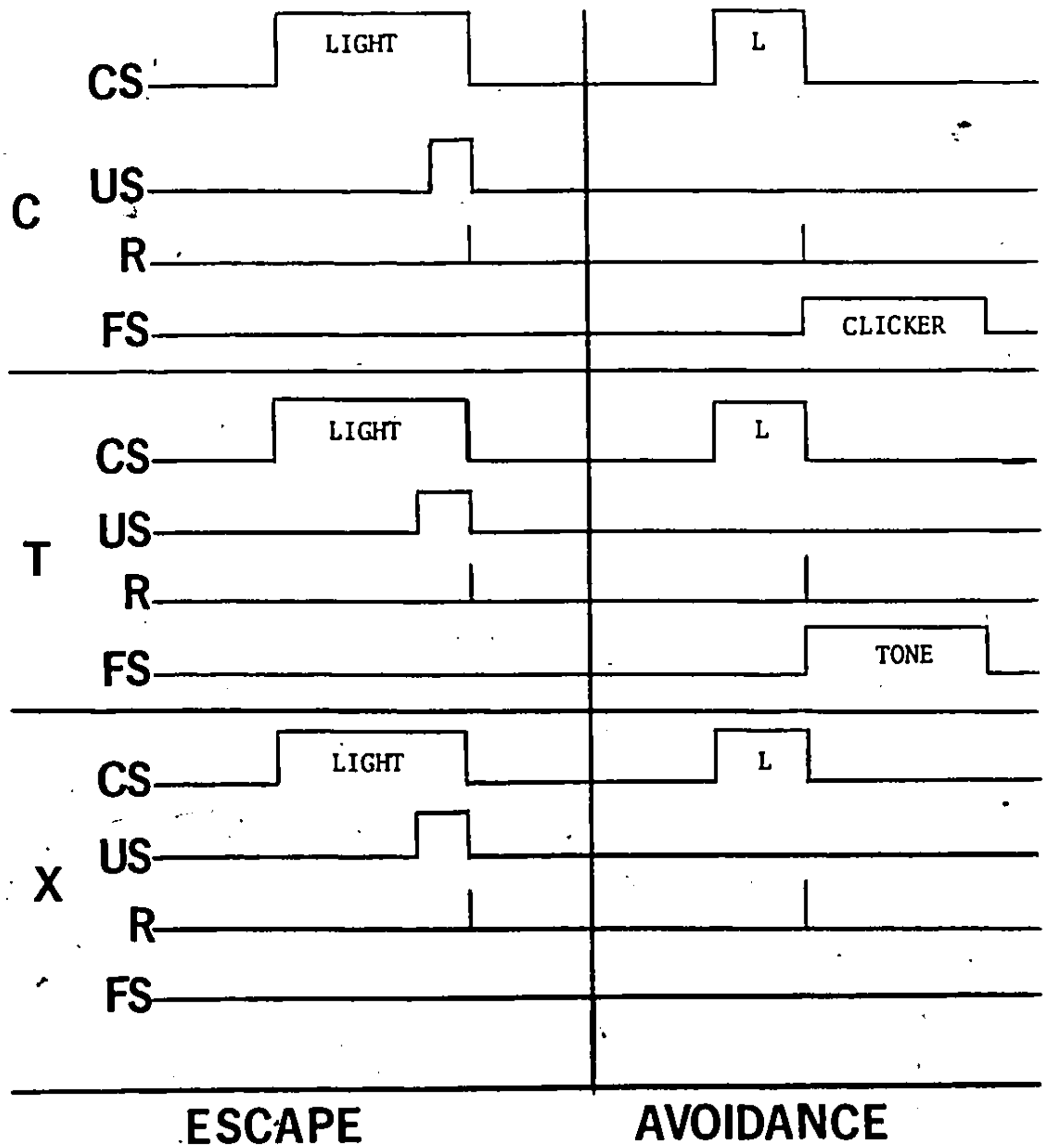
4.4.1.2 Apparatus - The experimental apparatus consisted of a Lehigh Valley Electronics automated two-compartment, toggle-floor shuttlebox (model #416-04), measuring 48.3 x 21.6 x 27.3 cm constructed of .64 cm thick clear Plexiglass (roof and side walls) and aluminium (2 end walls), and was housed in a sound-attenuating chamber. A 0.5 mA electric shock was delivered by a Grason-Stadler shocker-scrambler (model E1064 GS) to the pivoted grid floor of the shuttlebox. The grid floor consisted of forty .24 cm diameter stainless steel bars spaced 1.11 cm apart (center-to-center). The light stimulus, which served as the CS, was provided by the onset of a 6-watt light bulb mounted above the center of the shuttlebox on the roof of the sound-attenuating enclosure. A 2000 Hz, 75 db tone (re. 0.002 dynes/cm^2) which served as the feedback stimulus for one group, was generated by a Scientific Prototype 4015-J Audio Stimulator and delivered through a 6.35 cm, 4-ohm speaker located in the middle of the roof of the shuttlebox. The other auditory feedback stimulus consisted of a 65 db, 10 pulses/sec. clicker generated by a Scientific Prototype 4025-J Click-Flash Generator, and delivered through two speakers recessed into each side wall of the sound-attenuating chamber. Background noise level in the shuttlebox was 60 db. Response latencies were recorded to the nearest .1 sec. on a Grason-Stadler Print-out Counter (model #E460 C). Programming and recording equipment were housed in an adjacent room.

4.4.1.3 Procedure - Each subject participated in the experiment for a single session. The session consisted of a one-min. adaptation period followed by 80 avoidance training trials. Twenty-eight rats were randomly placed into one of three groups. One subject was discarded due to apparatus failure leaving nine subjects per group.

Figure 4 presents a schematic representation of the procedure for each of the three groups. As can be seen on the left half of Figure 4, each trial started with the onset of the light-CS for all three groups. If the subject failed to move from one compartment to the other (shuttle response) during the first 5 sec. of the CS, a continuous scrambled 0.5 mA shock was delivered to the rat via the grid floor. The CS and shock remained on until a shuttle response was made at which time both the CS and shock would terminate immediately. Shuttle responses were monitored by a microswitch which was triggered whenever the rat moved from one compartment to the other, displacing the pivoted grid floor. These escape trials were the same for all three groups. As the right half of Figure 4 indicates, the groups differed with respect to stimulus experiences following avoidance responses. For Group T (tone-FS), if the rat shuttled to the other compartment during the first 5 sec. of the CS, shock was avoided, the CS immediately terminated, and the tone-FS was presented for 5 sec. Additional responses during the 5 sec. feedback period had no programmed effects but were recorded. Group C (clicker-FS) received identical treatment as Group T except that the clicker was presented instead of the tone during the 5 sec. feedback period following avoidance responses. Group X (no-FS) was treated the same as the above two groups except that no exteroceptive feedback stimulus was programmed to followed avoidance responses. As in the above FS groups, extra responses were counted in the 5 sec. interval immediately following the avoidance response even though no FS was presented during this time. Training was carried out in darkness (except when the light on CS was presented)

Figure 4. A schematic representation of escape and avoidance trials for each of the three groups in Experiment 1 (C = clicker-FS; T = tone-FS; X = no-FS).

FIGURE 4


LIGHT
L
CS
US
C
R
FS
CLICKER
LIGHT
L
CS
US
T
R
FS
TONE
LIGHT
L
CS
US
X
R
FS
ESCAPE
AVOIDANCE

for all three groups. The intertrial interval following escape trials averaged 18 sec. (range: 12-24 sec.), but the ITI following avoidance trials averaged 3 min. (range: 2-4 min.). A record was also kept of the number of shuttle responses occurring during the intertrial interval (ITI responses).

4.4.2 Results

Figure 5 presents the mean percent avoidance responses for each of the three groups across the 80 acquisition trials (divided into eight blocks of 10 trials). As Figure 5 indicates, avoidance conditioning was superior in Group C as compared to Groups T and X. A mixed design analysis of variance revealed a significant Groups effect ($F[2,24] = 3.95$, $p < .05$), a significant Trials effect ($F[7,168] = 63.46$, $p < .001$), and a significant interaction of Groups X Trials ($F[14,168] = 1.85$, $p < .05$). Figure 6, side "A", shows the mean number of avoidance responses for each group collapsed across the 80 acquisition trials. The Newman-Keuls method of paired comparisons showed that Group C made significantly more avoidance responses during the 80 trials than Group X ($p < .05$). No other paired comparisons were significant. While a one-way analysis of variance computed on the number of trials to reach the fifth avoidance response revealed no differences between groups ($F[2,24] = 2.85$, $p > .1$), differences did emerge in subsequent rates of acquisition. Figure 6, side "B", presents the mean number of trials that each

Figure 5. Mean percent avoidance responses over eight blocks of 10 avoidance training trials in Experiment 1 (n = 9 per group).

FIGURE 5

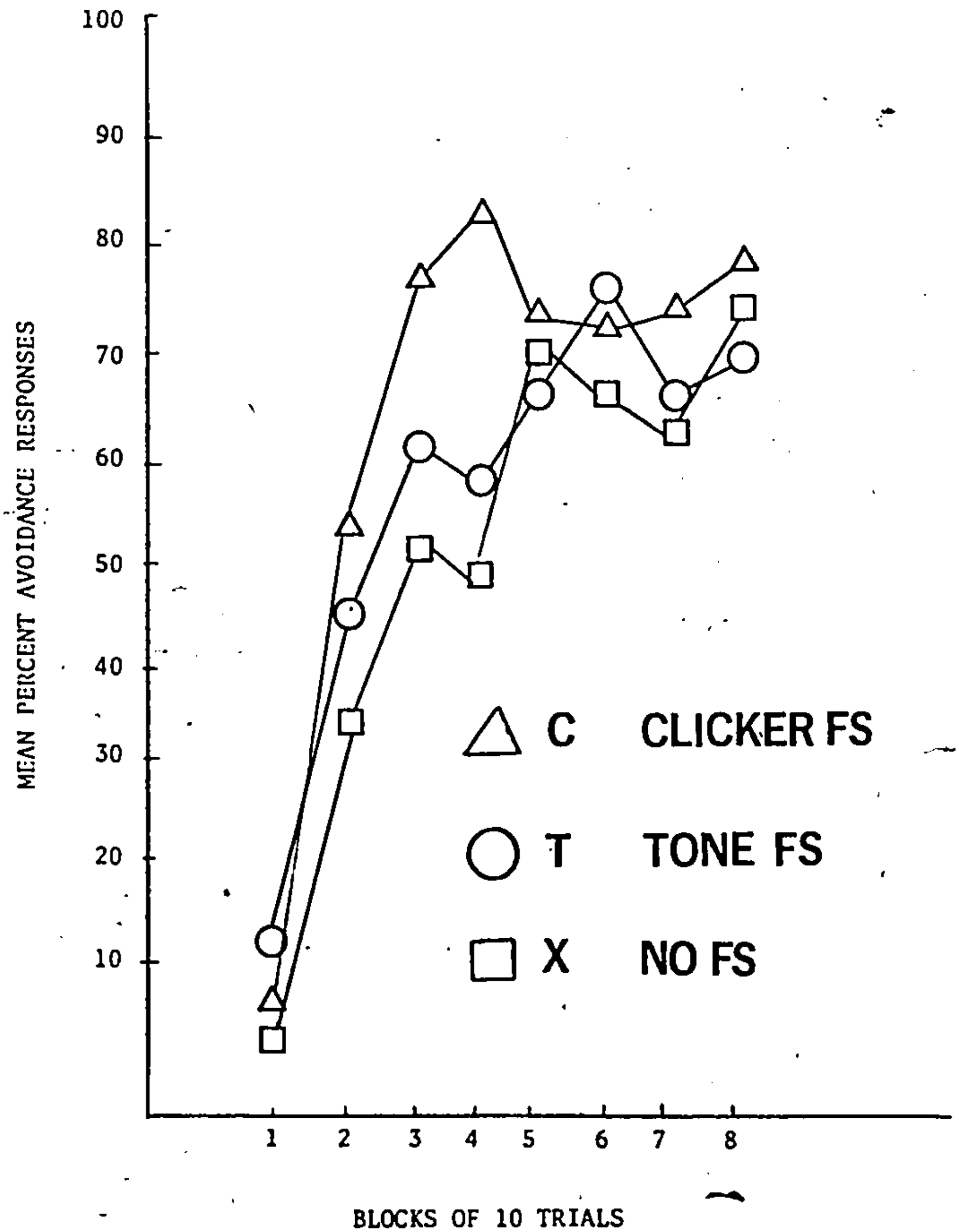

100
90
80
70
60
50
40
30
20
10
MEAN PERCENT AVOIDANCE RESPONSES
1
2
3
4
5
6
7
8
BLOCKS OF 10 TRIALS
C CLICKER FS
T TONE FS
X NO FS

Figure 6. A: Mean number of total avoidance responses in the 80 acquisition trials for each of the three groups in Experiment 1. B: Mean number of trials to reach avoidance acquisition criterion of eight responses in a block of 10 trials (8/10) for each of the three groups in Experiment 1.

FIGURE 6

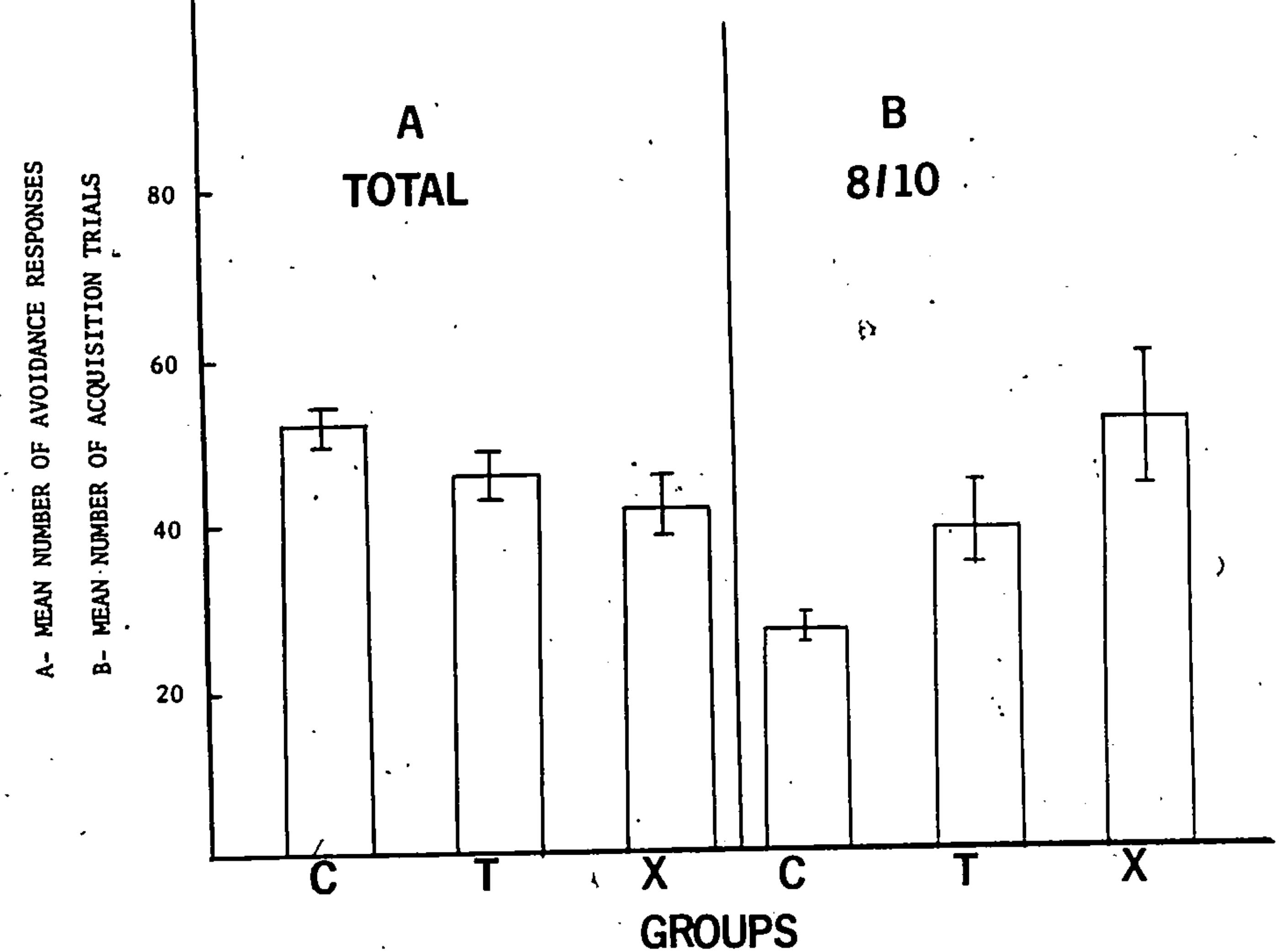
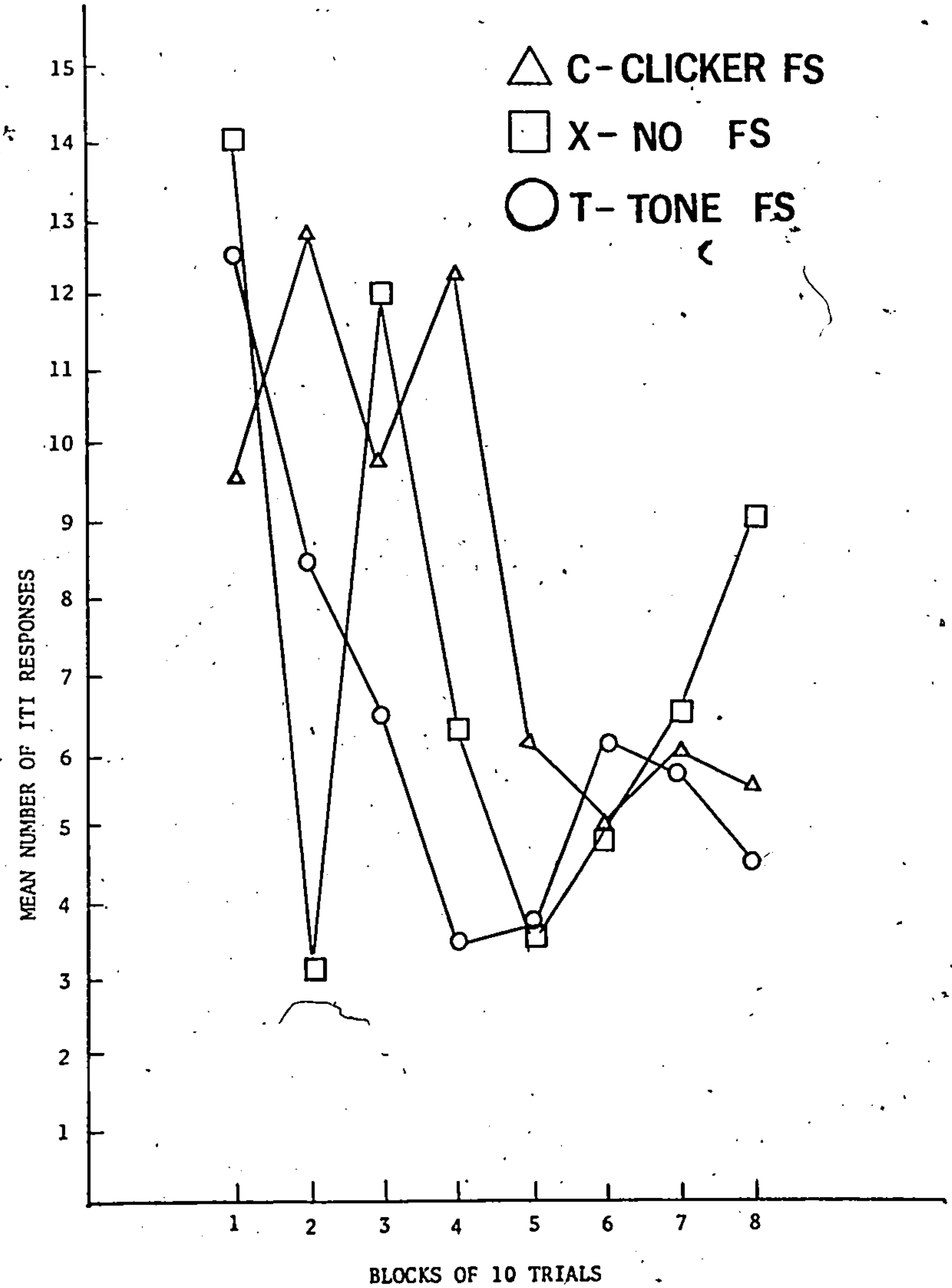

A
TOTAL
B
8/10
A- MEAN NUMBER OF AVOIDANCE RESPONSES
B- MEAN NUMBER OF ACQUISITION TRIALS
80
60
40
20
C
T
X
C
T
X
GROUPS

Figure 7. Mean number of intertrial interval (ITI) responses over eight blocks of 10 avoidance training trials in Experiment 1.

FIGURE 7


C-CLICKER FS
X- NO FS
T- TONE FS
MEAN NUMBER OF ITI RESPONSES
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
1
2
3
4
5
6
7
8
BLOCKS OF 10 TRIALS

group required to meet an acquisition criterion of eight avoidance responses in a block of 10 trials (8/10). A one-way analysis of variance on the number of trials to reach the 8/10 criterion was significant ($F[2,24] = 4.17$, $p < .05$). Newman-Keuls comparison again showed that Group C differed significantly from Group X ($p < .05$), but no other comparisons were significant. Figure 7 presents the mean number of ITI responses over the eight blocks of 10 trials. An analysis of variance of ITI data revealed a significant trials effect ($F[7,168] = 3.09$, $p < .01$), but both the groups effect and the interaction between groups and trials were nonsignificant. As can be seen in Figure 7, ITI responses tended to decrease over the session. While ITI responses were decreasing over trials, however, avoidance responses were increasing. This suggests that the rats were learning to discriminate that shuttle responses were only effective in the presence of the CS.

4.4.3 Discussion

The results of Experiment 1 demonstrate that presenting a clicker feedback stimulus contingent on avoidance responses (Group C) facilated discrete-trial two-way shuttlebox avoidance conditioning as compared to a group (X) which received no feedback stimulus. On the other hand, introducing a tone feedback stimulus following avoidance responses (Group T), while improving conditioning somewhat, (see Figure 5), did not significantly increase avoidance performance above that of Group X. The results suggest that a clicker, like a visual stimulus (Bolles & Grossen, 1969; Dillow et al. 1972, Weisman & Litner, 1972) can, when used as a FS, supply additional reinforcement for avoidance behavior above that provided by CS termination alone. The reinforcing effects of the tone, however, are not as apparent.

4.4.3.1. Speculations as to Why the Clicker-FS is More Effective than the Tone-FS

It is unclear why the clicker-FS was shown to be superior to the tone-FS in the present study. Perhaps, an unconditioned property of the clicker but not of the tone is to increase generalized motor activity. Thus a rat which is in a environment in which it occasionally hears a clicker will be more active than a rat which occasionally hears a tone. If this were the case, then increased avoidance responding in the clicker-FS group could be attributed to its overall higher operant baseline rate of shuttling throughout the session. Consequently, there might be an increased probability of making a shuttle response during the first 5 sec. of the light-CS in the clicker-FS group simply because animals in this group are moving about at a high rate. A comparison of ITI responding (see Figure 7), however, did not reveal any differences in shuttling rates between the three groups. Furthermore, responding during the 5 sec. period following avoidance responses was not significantly different regardless of whether a clicker, tone, or no FS was presented (the mean number of responses during the feedback period over the entire 80 trial session was 3.89, 3.11, and .78 for groups C, T, and X, respectively).

Selective attentional mechanisms (Sutherland & Mackintosh, 1971) may also be responsible for the fact that the clicker was a more effective FS than the tone. Sutherland and Mackintosh (1971) have proposed that an animal has only a limited capacity to attend to simultaneously presented stimuli. The likelihood of a stimulus being attended to by the animal (stimulus salience)is a function of a number of factors including the intensity of the stimulus, its distinctiveness from background cues, past history of reinforcement in the presence of the stimulus, etc. A salient stimulus is assumed to be more likely to enter into associations with the US than a less salient stimulus. Indeed, Pavlov (1927) and Kamin (1969) have shown that the more salient of two simultaneously presented stimuli may "overshadow" or prevent conditioning to the less salient stimulus. In this experiment, at the time an avoidance response was made, not only was the FS presented, but also the CS was terminated. If CS termination can be thought of as a stimulus, then a compound stimulus consisting of the FS and CS termination (plus probably a host of response-dependent stimuli as well) was presented following avoidance responses. Certainly, the removal of a conditioned aversive stimulus can be considered a salient stimulus. If, in the present situation, the tone was less salient than CS termination, then the conditioning of reinforcing properties to the tone may have been overshadowed by the removal of the CS. If the clicker, on the other hand, was a more salient stimulus than the tone, then it would less likely be overshadowed by CS termination. Thus, the clicker was able to develop effective reinforcing properties. Of course, this account is purely speculative. Whether selective attentional processes or some other mechanism is responsible for the observed differences in the reinforcing strength of the clicker and the tone can not of course be determined by the results of this study and an investigation into this matter is beyond the scope of this thesis. Nevertheless, this study did succeed in identifying two stimuli that are differentially effective as FSs.

4.5 EXPERIMENT 2 - Summation Tests of the Inhibitory Properties of Clicker and Tone Feedback Stimuli

The results of Experiment 1 suggests that, at least in the discrete-trial avoidance paradigm, the 10 pulses/sec. 65 db clicker used in Experiment 1 functions as a better FS than does a 2000 Hz, 75 db tone. According to the present hypothesis, the reinforcing power of a FS is a function of the conditioned inhibition that has accrued to it over the course of avoidance training. It would be expected, then, that after training, tests of the inhibitory properties of a clicker-FS and a tone-FS will reveal that the more effective FS, the clicker, possesses greater inhibitory strength than the less effective tone-FS.

Previous studies (Dinsmoor & Sears, 1973; Morris, 1974; Rescorla, 1968a; Weisman & Litner, 1972) that have assessed the inhibitory properties of a FS have all used the same measurement procedure - a change in the rate of well-established Sidman avoidance responding during presentations of the FS. These authors assumed that if a FS possessed fear inhibitory properties, it would slow the rate of Sidman avoidance responding which presumably is being motivated by fear. Indeed, the above studies have shown that during the presentation of a previously established FS, a significant reduction in the rate of avoidance responding occurs. It would be worthwhile, at this point, to provide convergent evidence using a different assessment technique that effective FSs become conditioned inhibitors. A number of investigators (e.g., Bull & Overmier, 1968; Hearst, 1972; Pavlov, 1927; Reberg, 1972; Reberg & Black, 1969; Rescorla, 1969c) have recommended the summation test as a direct way of determining the amount of inhibition accruing to a stimulus. In a summation test, the inhibitory properties of the stimulus are assessed by compounding it with a known excitatory stimulus. If the stimulus in question possesses inhibitory properties, then a decrement in responding to the excitatory CS should be observed when the inhibitory stimulus is compounded with it. In this experiment (#2), rats received avoidance training in which a light served as the CS and either a tone or clicker served as the FS as was the case in Experiment 1. After 80 avoidance trials, the subjects were given extinction trials in which the shock was no longer presented and the light-CS was compounded with either the same auditory stimulus used as the FS during acquisition or with the other novel auditory stimulus. On the basis of the findings from Experiment 1, it was predicted that the group which receives their clicker-FS compounded with the light-CS in extinction should show more inhibition of responding (i.e., make fewer responses) to the CS than the groups which receive their tone-FS or a novel stimulus compounded with the CS.

4.5.1 Method

4.5.1.1 Subjects - Subjects, as in Experiment 1, were male albino $Fischer_{344}$ rats, 250-300 grams, maintained on ad lib food and water and housed in individual cages.

4.5.1.2 Apparatus - The apparatus, the light-CS, shock, and tone and clicker FSs were the same as that used in Experiment 1.

4.5.1.3 Procedure - Each subject participated in the experiment for a single session which consisted of a one minute adaptation period followed by 80 acquisition trials and then 80 extinction trials. Rats were randomly assigned to one of four groups. Ten rats were discarded: five due to apparatus failures and five for failing to meet the arbitrary acquisition criterion of at least

50 avoidance responses by the end of acquisition training. This criterion was set in order to reduce the differences in acquisition between the clicker and tone feedback groups observed in Experiment 1. This was done so that subjects from all four groups would enter the extinction phase of the experiment after reaching approximately the same level of acquisition regardless of whether they had the tone-FS or clicker-FS in the acquisition phase. Had this not been achieved and had the groups differed in their asymptotic performance at the end of acquisition training, then differences in the rate of extinction could have been attributed to acquisition differences rather than to the independent variable (the stimulus summated with the CS in extinction). The subjects that were discarded were replaced with naive subjects until each of the four groups had five rats apiece.

The acquisition phase of the experiment began after a one-minute adaptation period (as in Experiment 1). Figure 8 depicts the experiences of each of the four groups on escape, avoidance, and extinction trials. As can be seen in the first row of Figure 8, subjects in Group C-C (clicker-FS in acquisition-clicker summated with the light-CS in extinction) received identical avoidance training as Group C in Experiment 1. At the start of a trial the light-CS was presented. If the rat failed to respond within 5 sec., a continuous 0.5 mA electric shock was delivered. Moving to the other compartment of the shuttlebox terminated the CS and the shock. If the rat shuttled during the 5 sec. CS-US interval, shock was avoided, the CS terminated immediately, and the clicker-FS was presented for 5 sec. The FS was presented following avoidance but not escape responses. The ITI following escape trials averaged 18 sec. (range: 12-24 sec.); the ITI following avoidance responses averaged 3 min. (range: 2-4 min.). Thus, the FS was the only stimulus that reliably predicted a relatively long period free from aversive events.

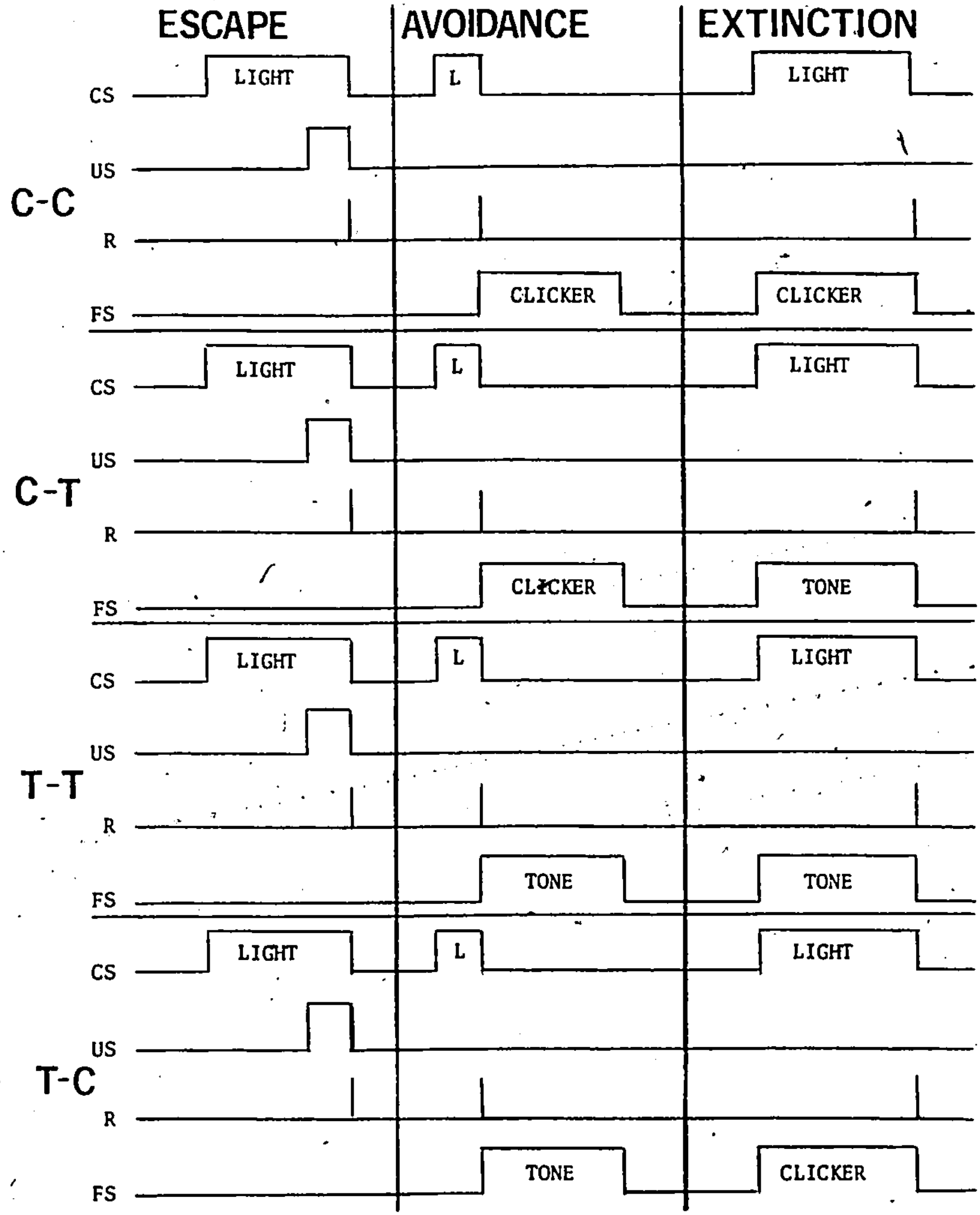
Immediately following the 80 acquisition trials, extinction was initiated. Extinction trials for Group C-C consisted of simultaneous presentations of the light-CS and the clicker-FS. A response immediately terminated this compound stimulus. No other stimulus followed a response in extinction nor was any shock ever given. If a response did not occur within 20 sec. of the start of the trial, the light + clicker stimulus automatically terminated. Eighty extinction trials were given in this manner with an ITI of 18 sec. (range: 12-24 sec.). Response latencies in both acquisition and extinction were recorded on a Grason-Stadler Print-Out Counter. The second row of Figure 8 shows that Group C-T (clicker-FS in acquisition-tone summated with the light-CS in extinction) received identical acquisition training as Group C-C described above, but differed in the compound stimulus presented on extinction trials. On a trial in the extinction-summation test in this group, the light-CS was compounded not with the 10 pulses/sec. clicker that had been used as the FS during acquisition, but with a novel stimulus,the 2000 Hz, 75db tone. Except for this difference extinction was the same in all respects to Group C-C. The third row of Figure 8 reveals that Group T-T (tone-FS in acquisition-tone summated with light-CS in extinction) received similar treatment in acquisition and extinction as the above two groups except that the tone was used as the FS during acquisition (cf., Group T in Experiment 1) and was compounded with the light-CS during extinction. As can be seen in the fourth row of Figure 8, Group T-C (tone-FS in acquisition-clicker summated with light-CS in extinction) was treated identically to Group T-T in acquisition but had the clicker compounded with the light CS on extinction trials. Thus, the novel tone and clicker stimuli compounded with the CS in extinction in Groups C-T and T-C, respectively, were the same stimuli that served as the FS in acquisition and were compounded with the CS in extinction in Groups T-T and C-C, respectively.

4.5.2 Results

4.5.2.1 Acquisition - The setting of the arbitrary criterion of 50 avoidance responses in the 80 acquisition trials reduced the differences observed in Experiment 1 between clicker-FS and tone-FS groups (see Figure 5). Figure 9 presents the mean percent avoidance responses for each of the four groups over the 80 acquisition and 80 extinction trials divided into eight blocks of

Figure 8. A schematic representation of escape, avoidance, and extinction trials for each of the four groups in Experiment 2, (C-C = clicker-FS in acquisition-clicker summated with CS in extinction; C-T = clicker-FS in acquisition-tone summated with CS in extinction; T-T = tone-FS in acquistion-tone summated with CS in extinction; T-C = tone-FS in acquisition-clicker summated with CS in extinction).

FIGURE 8


ESCAPE
AVOIDANCE
EXTINCTION
C-C
CS
US
R
FS
LIGHT
L
LIGHT
CLICKER
CLICKER
C-T
CS
US
R
FS
LIGHT
L
LIGHT
CLICKER
TONE
T-T
CS
US
R
FS
LIGHT
L
LIGHT
TONE
TONE
T-C
CS
US
R
FS
LIGHT
L
LIGHT
TONE
CLICKER

20 trials. As the left half of Figure 9 indicates, there was considerable overlap in mean percent avoidance responses over the entire course of acquisition in the clicker- and tone-FS groups in this experiment. As in Experiment 1, subjects receiving a tone-FS did not perform as well in acquisition as subjects receiving a clicker-FS. Five subjects in the tone-FS condition did not make at least 50 avoidance responses, while only one subject in the clicker-FS groups failed to meet this criterion. A mixed design analysis of variance revealed a significant Trials effect ($\underline{F}[3,48] = 101.16$, $\underline{p} < .001$), but neither the main effect of Groups nor the interaction of Groups X Trials was significant.[20]

4.5.2.2 Extinction - The right half of Figure 9 shows that the groups differed considerably in responding during extinction. Responding in Group C-C dropped off much more rapidly than in the other three groups. Group C-T, on the other hand, showed an increased rate of responding after an initial decline. Groups T-T and T-C evidenced about the same degree of extinction. A three-way mixed design analysis of variance (FS modality in acquisition

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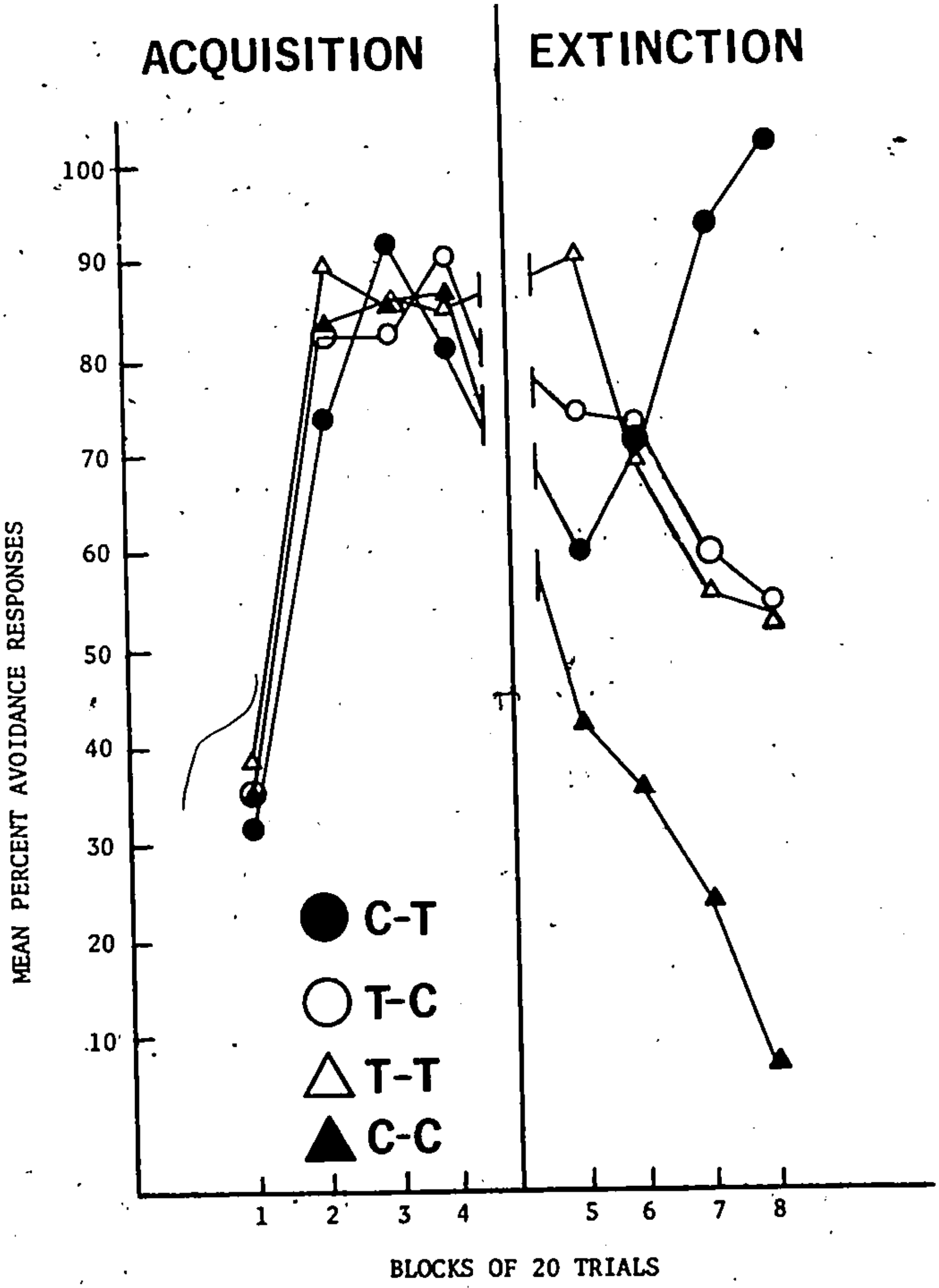
[20] Even when discarded subjects are included in an analysis of acquisition data, the four groups still do not differ significantly on total number of avoidance responses, number of trials to the fifth avoidance response, and number of trials to eight responses in a block of 10 trials (although as in Experiment 1, statistically insignificant trends do emerge).

Figure 9. Mean percent avoidance responding over four blocks of 20 acquisition trials and four blocks of 20 extinction trials in Experiment 2 (n = 5 per group).

FIGURE 9


ACQUISITION
EXTINCTION
MEAN PERCENT AVOIDANCE RESPONSES
100
90
80
70
60
50
40
30
20
10
C-T
T-C
T-T
C-C
1
2
3
4
5
6
7
8
BLOCKS OF 20 TRIALS

X Summated stimulus modality in extinction X Trials blocks) was performed on the total number of avoidance responses (defined as responses with latencies $\leq$ 5 sec. - i.e., the CS-US interval used in acquisition) emitted per 20 trial block. The main effects of FS modality in acquisition and Trials were insignificant as was the interaction of FS modality in acquisition X Summated stimulus modality in extinction. The main effect of whether a tone or clicker was compounded with the light-CS in extinction (Summation stimulus modality) was significant ($F[7,16] = 4.90$, $p < .05$). In addition, the interactions of FS modality in acquisition X Trials ($F[3,48] = 2.80$) and Summated stimulus modality in extinction X Trials ($F[3,48] = 2.72$) were marginally significant ($p \simeq .05$). These results are qualified by the existence of a signfiicant three-way interaction ($F[3,48] = 5.56$, $p < .01$). An examination of Figure 9 suggests that this interaction may be due mainly to Group C-T which instead of falling off in extinction actually increased its rate of responding after an initial decline.

The interaction effects observed in this extinction data should not detract from the important finding of this study that only Group C-C showed a rapid and consistent deterioration of responding in extinction. This result suggests that the clicker-FS became a conditioned inhibitor during acquisition. Newman-Keuls paired comparisons revealed that Group C-C differed at the .05 level from Groups C-T, T-T, and T-C. There was no evidence, however, that the tone-FS also developed inhibitory properties since Group T-T did not differ from Groups T-C and C-T.[21]

4.5.3 Discussion

The results of Experiment 2 provide additional evidence that a FS can become a conditioned inhibitor of avoidance behavior. Unlike all previous demonstations of this phenomenon (Dinsmoor & Sears, 1973; Morris, 1974; Rescorla, 1968a; Weisman & Litner, 1972) which measured inhibition as a reduction in the rate of free-operant unsignalled avoidance responding during the FS (cf. Rescorla and LoLordo, 1965), this study obtained evidence for FS inhibition using a summation test procedure in a discrete-trial signalled avoidance paradigm (cf. Bull & Overmier, 1968).

An equally important finding of this study is that the clicker-FS developed greater inhibitory strength than the tone-FS.

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21 The author is aware of the fact that by discarding subjects who failed to meet an arbitrary acquisition criterion, the assumption of random assignment to groups is being violated. The bias created by the fact that more animals were discarded from the tone-FS groups than the clicker-FS groups should be working against the expected finding of less inhibition in Group T-T than Group C-C. If the reinforcing properties of the FS covary in a positive manner with the amount of inhibition accruing to it, and instances of ineffective tone-FSs are removed, then there is a greater chance that the sample made up of effective tone-FSs only, will show more conditioned inhibition than a sample of effective and ineffective tone-FSs.

This finding together with the results of Experiment 1, that the clicker was a more effective FS than the tone, suggests that not all FSs share the same capacity to become conditioned inhibitors. Moreover, the effectiveness of the FS as a reinforcer of avoidance behavior is mirrored by and perhaps closely related to the accrual of inhibitory properties to it.

The fact that the reinforcing and inhibitory properties of the FS covary in a positive manner provides partial support for the hypothesis that the reinforcing capabilities of a FS actually result from its inhibitory properties (Dinsmoor & Sears, 1973; Morris, 1974; Rescorla, 1968a; Soltysik; 1963; Weisman & Litner, 1972). These findings are also consistent with Morris' (1974, Expt. 3) demonstration that a FS which predicted a relatively long ITI (3 min.) was associated with superior avoidance performance and was a more powerful conditioned inhibitor than a FS which signalled a shorter ITI (30 sec.). It can not be determined from Morris' experiments, however, whether the FS signalling the long ITI or some other factor independent of the presentation of the FS was responsible for the superior avoidance performance observed in the 3 min. ITI group since Morris failed to include a no-FS or random-FS avoidance training group (e.g., Group X in Experiment 1). It should also be pointed out that Morris (1974) concluded that the differences he found in the inhibitory strength of the FSs in his study were a function of the length of the ITI signalled by the FS. In Experiment 1 and 2 reported here, however, the ITI signalled by the effective clicker-FS and the less effective tone-FS was the same (average - 3 min.). In fact every aspect of avoidance training except the modality of the FS was identical for the FS groups in both experiments. This result coupled with Morris' findings suggests that predicting a relatively long ITI may be necessary but is not a sufficient condition for a FS to develop inhibitory properties. Some other factors related to some specific qualities unique to the stimulus itself (e.g., salience) can also influence the ability of that stimulus to develop inhibitory properties and function as an effective reinforcer for avoidance behavior. In general, the results of Experiments 1 and 2 of this thesis show that the reinforcing and inhibitory properties of a FS are closely related and provide additional support for Morris' (1974) statement that "feedback stimuli will have little or no effect upon avoidance performance unless they are conditioned inhibitors... (p.444)".

4.6 Implications for Two-Factor Theory: An Extension Based on Contingency Theory

As mentioned earlier, until recently two-factor theorists have, for the most part, ignored the possibility that inhibitory Pavlovian conditioning may be occurring in the avoidance situation.

The demonstrations such as in Experiment 2, above, that response-contingent feedback may under certain conditions become conditioned inhibitors provide the impetus to revise and expand the strongest version of the theory (e.g., Anger, in press) such that it could account for both excitatory and inhibitory conditioning in avoidance learning. This could be done by incorporating a contingency model of Pavlovian conditioning (Rescorla, 1967, 1968b, 1969a,c) to produce a more accurate measure of conditioned aversiveness.

It turns out that Anger's two-factor analysis can be easily extended to consolidate a contingency view. Conditioned aversiveness (CA), according to Anger (1963, in press) is assumed to be a function of the number of CS-US pairings divided by the total exposure-time to the CS (CA = f [shocks/exposure]). This measure of excitatory strength represents an improvement over previous attempts which had simply examined CS-US pairings only and had ignored the effects of nonreinforced CS exposure. Anger's shocks/exposure formation, however, still falls short in predicting the full range of aversive strength that might develop to a particular stimulus. The <u>lowest</u> possible aversiveness value a stimulus can possess according to the above equation is zero. According to a contingency view, however, the probability of shock given the <u>presence</u> of the CS is only half the story. It is also important to take into account the probability of shock given the <u>absence</u> of the CS. Thus, the conditioned aversiveness of a stimulus will be affected not only by the average shock-rate signalled by the presence of the CS (shocks/exposure) but also by the average shock-rate signalled by the absence of the CS (shocks/nonexposure). It is suggested here that Anger's shocks/exposure measure of conditioned aversiveness be expanded to include a shocks/nonexposure component. Since shocks/nonexposure is assumed to reflect inhibition (Rescorla, 1969a,c; Weisman & Litner, 1971) a negative sign is ascribed to it. Thus, the revised conditioned aversiveness equation reads: CA = f(shocks/exposure - shocks/nonexposure). This formula provides a measure of CA along a continuum of potential excitation and inhibition that may accrue to a stimulus depending upon its relation to the occurrence of shock. Unlike a simple shocks/exposure analysis, the above formulation can provide a measure of the relative inhibitory strength of a stimulus since it allows for the possibility of a negative CA value. That is, if the shocks/nonexposure of a stimulus is greater than its shocks/exposure, then its total CA would be less than zero, and the stimulus is assumed to be inhibitory.

The incorporation of a contingency model of Pavlovian conditioning in the form discussed above, enhances the explanatory and predictive strength of two-factor theory without drastically modifying any of its basic assumptions. Thus, while it continues to provide as adequate an explanation of a large body of avoidance data as does Anger's formulation, this extended version also allows for an accounting of inhibitory phenomena. Thus, the theory can now handle both the apparent development of inhibitory properties to response-contingent feedback and, as will be shown in the next chapter, it can also effectively handle the suggested functional role of this inhibitory feedback in the acquisition, maintenance, and extinction of avoidance behavior.[22]

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[22] Of course the contingency view, itself, is not free from methodological and theoretical problems. For example, it as yet can provide but an ordinal measure of excitation and inhibition. In addition, it has failed to specify the relevant temporal parameters involved in identifying the "presence" and "absence" of the CS. Finally, there is accumulating evidence that the contiguity between the CS and US cannot be completely ignored and that the animal may indeed be learning something about a CS even when it is uncorrelated with the US. See papers by Seligman, 1969; Kremer, 1971; Kremer and Kamin, 1971; Quinsey, 1971; Benedict and Ayres, 1972; and Mackintosh, 1973; for critiques and pertinent data related to these matters.

CHAPTER V

THE FUNCTIONAL SIGNIFICANCE OF CONDITIONED INHIBITION IN AVOIDANCE LEARNING

5.1 Conditioned Inhibition in Avoidance - Functional or Epiphenomenonal?

The findings that avoidance response-contingent feedback stimuli become conditioned inhibitors have led a number of investigators (e.g., Dinsmoor & Sears, 1973; Rescorla, 1968a, 1969b; Soltysik, 1963; Weisman & Litner, 1969b, 1971, 1972) to conclude that inhibitory feedback may serve as the reinforcing mechanism for avoidance behavior in addition to, or instead of CS termination. This conclusion is not justified on the basis of these findings alone. As D'Amato et al. (1968) have argued, the inhibition accruing to the FS may be nothing more than an "epiphenomenon" resulting from the fact the FS happens to signal a period free from aversive events. It is quite possible that some other aspect of the FS (e.g., its salience, its informational characteristics, etc.), but not its inhibitory properties, is actually responsible for its reinforcing function. The results of Experiment 1 and 2 show that a more effective (reinforcing) FS develops greater inhibitory strength than a less effective FS. This provides suggestive evidence that conditioned inhibition is the source of the reinforcing capabilities of feedback stimuli. It must also be shown, however, that a known Pavlovian conditioned inhibitor can actually function as a reinforcer of avoidance behavior before any strong statements can be made regarding the functional nature of inhibition in avoidance learning.

5.2 Predictions Derived from Current Theories of Avoidance Learning

Different theoretical formulations make diverging predictions concerning either the possible functional role of inhibitory feedback stimuli or the mechanism by which FSs operate to reinforce avoidance behavior.

5.2.1 Anger's Shocks/Exposure Formulation

Anger's (1963, in press) two-factor account ignores the possibility that stimuli in the avoidance situation can acquire inhibitory properties. Thus, it would not predict that a stimulus negatively correlated with shock would have any more reinforcing properties, thus functioning more effectively as a feedback stimulus, than a novel or neutral stimulus. That is, according to a simple shocks/exposure formulation, the conditioned aversiveness of an inhibitory FS cannot be less than zero- the same as a novel or neutral FS. Thus, an avoidance response, which replaces a highly aversive CS with a FS, will receive the total amount of reinforcement available in terms of aversiveness reduction regardless of whether the FS is inhibitory or not. Anger's formulation, then, does not ascribe a special functional role to inhibitory stimuli following avoidance responses.

5.2.2 Contingency Version of Anger's Theory

The extended version of Anger's theory proposed earlier takes into account both excitatory and inhibitory processes in assessing the total conditioned aversiveness of a stimulus. This proposal does suggest that inhibitory FSs could function as effective reinforcers. Expanding the definition of CA to include a negative shocks/nonexposure component in addition to a positive shocks/exposure factor allows the lower boundary of CA to be less than zero. An inhibitory stimulus which is negatively correlated with the occurrence of shock will have greater shocks/nonexposure than shocks/exposure. This results in the inhibitory stimulus acquiring a total CA value less than zero which would be less than a novel or neutral FS which would have CA = 0. If the inhibitory stimulus with its negative CA value is used as a FS, then the total amount of reinforcement in terms of aversiveness reduction following avoidance responses made in the presence of an aversive CS will be greater than when a non-inhibitory stimulus serves as a FS.

5.2.3 Positive Reinforcement Formulations and Relaxation Theory

"Positive reinforcement" views of avoidance learning (Denny, 1971; Dinsmoor & Sears, 1973; Rescorla, 1968a, 1969b; Weisman & Litner, 1969a,b, 1972) also predict that conditioned inhibitors should function as effective reinforcers for avoidance behavior. Weisman and Litner (1972), in fact, argue that their "revised two-process theory demands that a stimulus established as an inhibitor of fear...function as conditioned positive reinforcers (p.266)" (emphasis added). Although Weisman and Litner fail to specify how conditioned inhibitors become reinforcers, Denny (1971) has proposed a mechanism by which feedback stimuli are thought to acquire conditioned positive reinforcing properties. Denny suggests that the termination of conditioned and unconditioned aversive stimuli elicits an unconditioned consumatory-like long-latency response which he calls "relaxation". Stimuli (e.g., ITI cues, feedback stimuli) which are present in the safe compartment or during the safe interval when this relaxation response occurs become, via classical conditioning, conditioned relaxers. Thus, according to Denny, avoidance behavior is not reinforced directly by CS termination but rather first by unconditioned relaxation (elicited by CS termination) and then by conditioned relaxation (resulting from the pairings of feedback and ITI stimuli with the unconditioned relaxation response). A number of studies generated from Denny's laboratory have provided support for this view (Denny & Weisman, 1964; Weisman, Denny, Platt, & Zerbolio, 1966; Weisman, Denny, & Zerbolio, 1967; Zerbolio, 1968 - see reviews by Denny, 1967, 1971). These studies in general, have shown that those variables which are assumed to facilate conditioned relaxation (e.g., increasing length of ITI, dissimilarity of shock and safety compartments) also facilate avoidance acquisition. According to relaxation theory, Pavlovian conditioned inhibitors having been associated with the termination of aversive stimuli will also become conditioned relaxers. Presenting these stimuli following avoidance responses will provide an additional source of reinforcement in the form of immediate relaxation.

5.2.4 Stimulus-Stimulus Expectancy Theory

Another formulation of avoidance learning that seems to predict that conditioned inhibitors can reinforce avoidance behavior is a stimulus-stimulus expectancy notion (Bolles, 1972b; Mackintosh, 1974, p.308-10; Ritchie, 1951). According to this view, avoidance learning is mediated by the formation of an expectancy developed early in training that when the CS is presented shock is to follow. The avoidance response prevents the occurrence of the expected shock and is thereby strengthened. Extending this analysis to conditioned inhibition, the animal learns that the inhibitory stimulus predicts the nonoccurrence of shock such that when the inhibitory stimulus occurs the animal expects no shock for a certain period of time. By presenting inhibitory stimuli following avoidance responses made in the presence of the CS that predicts shock, the animal not only learns that the response is associated with the omission of the expected shock, but also finds that the response produces stimuli that signal a time free from shock. The presentation of a signal for no shock presumably strengthens the tendency to make the response that produced the safety signal.

5.2.5 Informational Theory of FS Reinforcement

There are a number of theoretical formulations besides Anger's (1963, in press) which also do not predict that Pavlovian conditioned inhibition plays a special reinforcing role in avoidance learning. D'Amato et al. (1968) and Bolles and Grossen (1969) have argued that avoidance response-contingent changes in stimulation (e.g., CS termination, feedback stimuli, etc.) serve as "discriminative" or "informational" cues signalling to the subject that it has just made the correct response to avoid shock. According to this view, it is not expected that Pavlovian inhibitory training would have any effect on the informational value of the FS. The stimulus-stimulus contingency encountered during the Pavlovian sessions should not provide the subject with any relevant information concerning the actual avoidance response contingency. Thus, an informational account of the nature of feedback stimuli would predict that Pavlovian conditioned inhibitors should not be effective reinforcers for avoidance behavior unless they also provide information concerning the response contingency itself.

5.2.6 Response-Outcome Expectancy Theory

Seligman and Johnston (1973) also propose that what is important in avoidance conditioning is what the animal learns about the response-shock contingency. According to their "response-outcome" expectancy theory, the animal comes to expect that making a particular response in the CS-US interval will result in no shock; failure to respond, however, does result in shock occurring. The avoidance response is reinforced each time the former expectancy is confirmed. If the response-no-shock expectancy is the crucial variable affecting avoidance learning, then the Seligman and Johnston formulation would predict that a Pavlovian conditioned inhibitor should not necessarily provide reinforcement for avoidance behavior. The presentation of a conditioned inhibitor following avoidance responses does not further confirm the response-no-shock expectancy already present in the avoidance contingency.[23]

5.2.7 One-Factor Shock-Density Reduction Theory

It also seems that a one-factor shock-density reduction view (Bolles et al. 1966; Herrnstein, 1969; Herrnstein & Hineline,

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23 This view differs from a stimulus-stimulus expectancy notion in that Seligman and Johnston do not consider the possibility that the animal forms an expectancy based on the signalling properties of stimuli. They concern themselves only with what the animal expects to happen if it responds (or fails to respond). Of course without too much trouble a response-outcome expectancy theory can incorporate stimulus-stimulus expectancies (or vice versa). Indeed, Bolles (1972b) has developed just such a "two-factor" expectancy theory.

1966; Sidman, 1962) would not predict that a Pavlovian conditioned inhibitor could serve as a reinforcer of avoidance behavior. According to this analysis, the sole reinforcer in the avoidance situation is the avoidance contingency itself, or more generally, a reduction in shock-density or frequency. As long as this contingency is equated among groups there should be no significant differences in avoidance responding regardless of the kinds of conditioned stimuli presented after the avoidance response.[24] Thus, this formulation which eschews a functional role of Pavlovian excitatory conditioning (i.e., the CS simply serves as a S^D and this function is independent of Pavlovian conditioning mechanisms) also fails to assign such a role to Pavlovian inhibitory processes.

5.2.8 A Test of Diverging Predictions

It appears that an examination of the potential reinforcing properties of conditioned inhibitors may help to assess the relative strengths of the various theories of avoidance discussed above. If a reinforcing effect is found and is shown to be due to the Pavlovian

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24 It has previously been pointed out (p.76) that this formulation cannot adequately handle the results of the delayed CS termination studies (Kamin, 1957b,c; Mowrer & Lamoreaux, 1942) and the acquired drive studies (e.g., Brown & Jacobs, 1949).

inhibitory contingency then this would provide support for 1) a positive reinforcement view of avoidance (Soltysik, 1963; Weisman & Litner, 1972), and relaxation theory (Denny, 1971; Denny & Weisman, 1964), 2) stimulus-stimulus expectancy theory (Bolles, 1972b; Mackintosh, 1974 p.308-10; Ritchie, 1951), and 3) a revised contingency model of two-factor theory proposed here. If conditioned inhibitors are not shown to possess the ability to reinforce avoidance behavior above that of non-inhibitory stimuli, then this would support 1) Anger's (1963, in press) shocks/exposure analysis, 2) an informational view of response-contingent feedback (Bolles & Grossen, 1969; D'Amato et al. 1968), 3) response-outcome expectancy theory (Seligman & Johnston, 1973), and 4) a one-factor shock-density reduction view (Bolles et al. 1966; Herrnstein, 1969; Herrnstein & Hineline, 1966; Sidman, 1962).

5.3 Evidence Concerning the Ability of Conditioned Inhibitors to Reinforce Avoidance Behavior

The available evidence, although scarce, does suggest that conditioned inhibitors can indeed reinforce avoidance behavior to a greater extent then non-inhibitory stimuli. Rescorla (1969b) trained dogs to press two panels, one on each side of the dog's head, to avoid shock on a Sidman avoidance schedule. Since the same Sidman avoidance schedule was programmed to both panels, a press of either panel was equally effective in postponing shock. After 9 days of Sidman avoidance training, the panels were removed and the dogs were given 5 days of Pavlovian inhibitory conditioning in which a tone (CS-) predicted a 1.5 min. (mean) interval free from shock. Following this Pavlovian phase, subjects were retrained on the panel-pressing Sidman avoidance task using correction procedures to insure equal pressing of panels. On the next day the CS- tone could be produced by a response on one panel while another tone of a different frequency not presented during the Pavlovian sessions was produced by a response made to the other panel. The finding that dogs showed a distinct preference for pressing the panel that produced CS-, irrespective of that panel's spatial position, was taken by Rescorla as evidence that the CS-, a Pavlovian conditioned inhibitor, could function as a positive reinforcer for avoidance behavior. Extrapolating from this finding Rescorla (1969b) suggested "that feedback stimuli associated with the response in signalled avoidance would also become reinforcing (p.263)" presumably as a result of inhibitory properties conditioned to them.

It might be argued that Rescorla's (1969b) use of a relative preference measure was not a direct substantiation of the reinforcing properties of a conditioned inhibitor since absolute response rates did not increase. A more direct demonstration that Pavlovian conditioned inhibitors can reinforce avoidance behavior was presented by Weisman and Litner (1969a).

After rats were trained to the point of steady-state responding on a Sidman avoidance schedule, they were given Pavlovian conditioning trials in a separate chamber. One group ("CS-") received inhibitory conditioning such that a tone signalled an average 1.5 min. interval free from shock (cf. Rescorla, 1969b; Rescorla, & LoLordo, 1965). Another group ("TRC") received random presentations of tones and shocks and a third group ("No-CS") was not placed in the Pavlovian conditioning chambers. Following three days of Pavlovian conditioning (alternated with three days of continued Sidman avoidance training), the tone was presented while the animals were responding on the Sidman schedule. In Expt. 1 the tones were presented noncontingently with respect to responding. It was found that the tone in the CS- group produced a reliable decrease in the rate of ongoing responding while the tone in the TRC and No-CS groups did not affect baseline responding. This was basically a replication of Rescorla and LoLordo's (1965) findings. Thus, the tone in the CS- group was considered to have developed inhibitory properties during the Pavlovian phase. In Expt. 2, Weisman and Litner (1969a) attempted to assess the reinforcing properties of the CS-. They reasoned that if the CS- is a reinforcer, its contingent presentation can be used to modify existing rates of responding. That is, if the CS- is a reinforcer, presenting it only if the animal responds at a fast rate (e.g., at least 10 responses per 5 sec. were required to turn on the tone) should increase the rate of responding; presenting the CS- contingent on slow rates (only zero or one response per 5 sec.could turn on the tone) should decrease the overall rate of responding. Using the same subjects from the CS-, TRC, and No-CS groups of Expt. 1, Weisman and Litner (1969a, Expt. 2) first presented the tone contingent on high rates of responding. The presentation of the tone in this manner increased the rate of responding in the CS- group only. Likewise, when the tone was made contingent on low rates of responding, a decrease in responding occurred only in the CS- group. These findings support Rescorla's (1969b) demonstration that a Pavlovian conditioned inhibitor can modify previously established free-operant avoidance responding and suggest that conditioned inhibitors can function as effective reinforcers of avoidance behavior.

As Bolles (1972a; Bolles & Moot, 1972) points out, the Rescorla (1969b) and Weisman and Litner (1969a) studies demonstrate that a response-contingent conditioned inhibitor can modify existing patterns of previously established avoidance behavior but they do not show that a conditioned inhibitor can be used to reinforce a new response. Perhaps a stronger test of the reinforcing properties of a conditioned inhibitor would be to use a known conditioned inhibitor as a FS from the outset of avoidance conditioning. If a FS develops inhibitory strength during the course of avoidance training, and it is this inhibition that provides the FS with the capacity to reinforce avoidance responses, then it would be expected that using a FS which already possesses inhibitory properties (due, for example, to prior Pavlovian inhibitory conditioning) should facilate avoidance acquisition. A pre-established conditioned inhibitor should provide a greater source of reinforcement from the very beginning of conditioning than would a novel or neutral FS which must first develop its prerequisite inhibitory strength during early avoidance training itself. If the inhibitory properties per se are not responsible for the observed reinforcing capabilities of a FS then a conditioned inhibitor should not facilate avoidance behavior any more than would a non-inhibitory stimulus. Experiments 3 and 4 were therefore designed to first provide a Pavlovian paradigm in the shuttlebox which reliably produces a conditioned inhibitor and then use this pretrained Pavlovian conditioned inhibitor as a FS during the acquisition of a two-way shuttlebox avoidance response.

5.4 EXPERIMENT 3: Summation Test of the Inhibitory Properties of a Stimulus Negatively Correlated with Shock

The purpose of this experiment was to find a Pavlovian training procedure which produces a conditioned inhibitor in the shuttlebox environment. According to a contingency view of Pavlovian conditioning (Rescorla, 1967; 1969c) a stimulus that is negatively correlated with the occurrence of shock should become a conditioned inhibitor. Indeed such a stimulus (referred to as a CS-) associated with shock in this manner has been shown to inhibit responding in the Sidman avoidance paradigm (Grossen & Bolles, 1969; Moscovitch & LoLordo, 1968; Rescorla & LoLordo, 1965; Weisman & Litner, 1969a,b, 1971), in the discrete-trial signalled avoidance procedure (Bull & Overmier, 1968) and in the CER preparation (Hammond, 1967; Reberg & Black, 1969; Rescorla, 1969a; Siegel & Domjan, 1971). In addition, the inhibitory strength of the CS- also appears to be partly a function of the length of the shock-free interval it signals (Moscovitch & LoLordo, 1968; Weisman & Litner, 1971). For example, Weisman & Litner (1971, Expt. 1) found that a CS- which predicted a 5 min. period free from shock developed stronger inhibitory properties and at a faster rate than did a CS- signalling only a one min. shock-free period. Weisman and Litner (1971, Expt. 2) also found that the inhibitory strength of a CS- was not only a function of the length of its shock-free interval but also was correlated with the length of the safety period signalled by other stimuli occurring in the same situation. Thus, a CS- which signalled a 200 sec. shock-free ITI evidenced less inhibition when trained with another stimulus that signalled a 290 sec. or 390 sec. ITI than when the same 200 sec. CS- was trained with another stimulus which predicted only a 10 sec. or 110 sec. ITI. These findings, taken together, suggest that a stimulus will most likely develop strong inhibitory properties if it 1) is negatively correlated with shock, 2) predicts a long safety period (>1 min.) free from shock, and 3) is the only stimulus that reliably signals a long safe interval.

Thus, the purpose of Experiment 3 was to measure the potential inhibitory effects on avoidance behavior of a stimulus that had predicted a time free from shock in a prior Pavlovian inhibitory training phase. If this procedure reliably produces a conditioned inhibitor then it can be used in Experiment 4 to condition inhibitory properties to a stimulus prior to its use as a FS during avoidance acquisition. The inhibitory properties of this pretrained stimulus was assessed in Experiment 3 by using the same compound-summation test procedure during the extinction of a two-way avoidance response that had been employed in Experiment 2. If a stimulus which is negatively correlated with respect to shock such that is uniquely predicts a long safety period becomes a conditioned inhibitor, it is expected that when presented simultaneously with a known excitatory stimulus (e.g., a CS that had been paired with shock during avoidance training) the pretreated stimulus should reduce responding to the excitatory CS. A stimulus presented randomly with respect to shock during the pretreatment phase should not acquire such inhibitory properties.

This experiment (#3) consisted of three phases: 1) Pavlovian pretreatment, 2) avoidance conditioning, and 3) avoidance extinction. Subjects differed either in terms of pretreatment or extinction experiences. One group (Group CI +) received conditioned inhibition pretreatment (CI) in which a stimulus signalled a period free from shock in the first phase, avoidance conditioning in the second phase, and a summation test (+) in which the pretreated stimulus was compounded with the avoidance CS in the third phase. A second group (Group CI 0) received the same conditioned inhibition and avoidance training as Group CI + but did not have a summation test during extinction (0). A third group (Rdm +) received random presentations of the stimulus and shock during the pretreatment phase (Rdm), avoidance conditioning in the second stage, and a summation test in extinction (+). The fourth group (Rdm 0) received the same pretreatment as Group Rdm +, avoidance conditioning, but then no summation test during extinction (0). The inhibition accrued to the pretreated stimulus was assessed by comparing the rate of extinction in the two groups receiving the summation test (Groups CI + and Rdm +) to the two groups not receiving the summation test (Groups CI 0 and Rdm 0). A faster rate of extinction in Group CI + as compared to CI 0, Rdm +, and Rdm 0 would indicate that only the CI pretreatment produced a conditioned inhibitor.

5.4.1 Method

5.4.1.1 Subjects - As in Experiments 1 and 2, subjects were male Fischer$_{344}$ rats weighing between 225-300 grams, housed in separate cages with free access to food and water.

5.4.1.2 Apparatus - The Lehigh Valley Electronics shuttlebox and tone and light stimuli were the same as that used in Experiments 1 and 2 (the clicker stimulus was not used).

5.4.1.3 Procedure - Six rats were randomly assigned to each of the four groups. Two rats were discarded due to apparatus failures and were replaced. The tone and light were counterbalanced with respect to their use as the pretreated stimulus (PS) and the CS.

5.4.1.3.1 Pretreatment - Two groups, CI + and CI 0 received Pavlovian conditioned inhibition training during this phase. This phase lasted 3 days and consisted of presenting the 5 sec. tone or light such that is always predicted at least a 2 min. interval free from shock. The occurrence of a .5mA shock, on the other hand, never signalled more than a 40 sec. shock-free interval. Thus the tone or light stimulus was the only externally programmed event which predicted a relatively long safety period. No more than three events of the same kind were programmed to occur in a row. On each of the three pretreatment days the tone or light stimulus and shock were each presented 25 times and total session time per day for each rat lasted approximately 100 min. Subjects in the present study were given the opportunity to escape from all shock presentations during the pretreatment phase by shuttling from one compartment to the other. This procedure was adopted because an earlier pilot study had revealed that inescapable shocks during the pretreatment phase seriously disrupted subsequent avoidance conditioning.[25]

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[25] This phenomenon has been observed and studied by Seligman, Maier, and Solomon (1971) and they have called it "learned helplessness".

If the subject failed to shuttle within 30 sec. after the onset of shock, the shock was automatically terminated. Latencies of pretreatment escape responses were recorded to the nearest .1 sec. on a Grason-Stadler Print-Out Counter.

Two additional groups, Rdm + and Rdm 0, also received 3 days of pretreatment in which they were exposed daily to 25 presentations of shock and 25 presentations of either the tone or light stimulus. These Rdm (random) groups differed from the CI groups in that the stimulus did not consistently predict a period free from shock but rather occurred randomly with respect to shock. The 25 shocks for each of the 3 pretreatment days for the Rdm groups were scheduled to occur at the same intervals that they were delivered to the CI groups. The 25 presentations of the stimulus, however, were placed randomly throughout the session by dividing the total session time into 5 sec. intervals, consecutively assigning each 5 sec. interval a three-digit number, and then selecting 25 three-digit numbers from a random numbers table. The number selected represented the particular 5 sec. interval on which the stimulus was presented. As in the CI groups the Rdm groups could also terminate the shock by shuttling.

5.4.1.3.2 Avoidance Acquisition - On Day 4, following the 3 days of the pretreatment phase, subjects in all groups received avoidance training, consisting of 80 trials with a mean ITI of 60 sec. Figure 10 presents a schematic representation of escape, avoidance, and extinction trials for each of the four groups. As can be seen in the first two columns of Figure 10, a trial started with the onset of the CS. If the rat failed to shuttle within the first 5 sec. of the CS, shock was delivered until the rat responded at which time the CS and shock both terminated (first column). If the rat did shuttle during the 5 sec. CS-US interval, shock was avoided, and the CS immediately terminated (second column). No FSs were used in this experiment.

5.4.1.3.3 Avoidance Extinction - Immediately following the 80 avoidance training trials the CI and Rdm groups were split in half and each half was given one of two extinction procedures which are schematically represented in the third column of Figure 10. As Figure 10 shows, Groups CI + and Rdm + (+ = summation test) received the stimulus that they had experienced in the pretreatment phase compounded with the CS used during the avoidance conditioning phase. Thus, an extinction trial for these groups involved a summation test procedure which consisted of the simultaneous onset of the CS and the pretreated stimulus. Subjects in these summation groups could terminate both stimuli by shuttling within 20 sec.; after 20 sec., the stimuli were automatically terminated. No shocks were presented during the 50 extinction trials.

Extinction for Groups CI 0 and Rdm 0 (0 = no summation test) differed from Groups CI + and Rdm + in that the former groups did not have any stimuli compounded with the CS. Groups CI 0 and Rdm 0 did not have a summation test during extinction but simply continued to have the light or tone CS presented alone as during avoidance acquisition except that no shocks were given and the CS automatically terminated after 20 sec. if a response did not occur. Thus, including stimulus modality, the design of this experiment involved independent manipulations of three factors each with two levels: Pretreatment stimulus modality (tone or light) X Pretreatment experience (CI or Rdm) X Extinction experience (+ [summation test] or 0 [no summation test]). The data of primary interest are the number of responses made during extinction.

5.4.2 Results and Discussion

5.4.2.1 Pretreatment - Figure 11 presents the mean latency of escape responses for the CI and Rdm groups over the 3 days of the Pavlovian pretreatment phase. A three-way mixed-design analysis of variance (Pretreatment X Modality X Days) revealed no significant main effects of pretreatment or modality (Fs < 1) nor a significant interaction between these variables ($F[1,20] = 1.85$). Groups tended to escape more quickly with increasing escape training, as revealed by a significant trials effect ($F[2,40] = 7.95$, $p < .01$), although no interactions involving the trials variable were significant. Thus, the different pretreatment experiences of subjects in groups CI and Rdm did not appear to differentially affect their escape behavior.

Figure 10. Schematic representation of escape, avoidance, and extinction trials for each of the four groups in Experiment 3. (CI + = conditioned inhibition pretreatment (CI) - summation test in extinction (+); Rdm + = random pretreatment (Rdm) - summation test in extinction (+); CI 0 = conditioned inhibition pretreatment (CI) - no summation test in extinction (0); Rdm 0 = random pretreatment (Rdm) - no summation test in extinction (0)). (PS = pretreated stimulus).

FIGURE 10

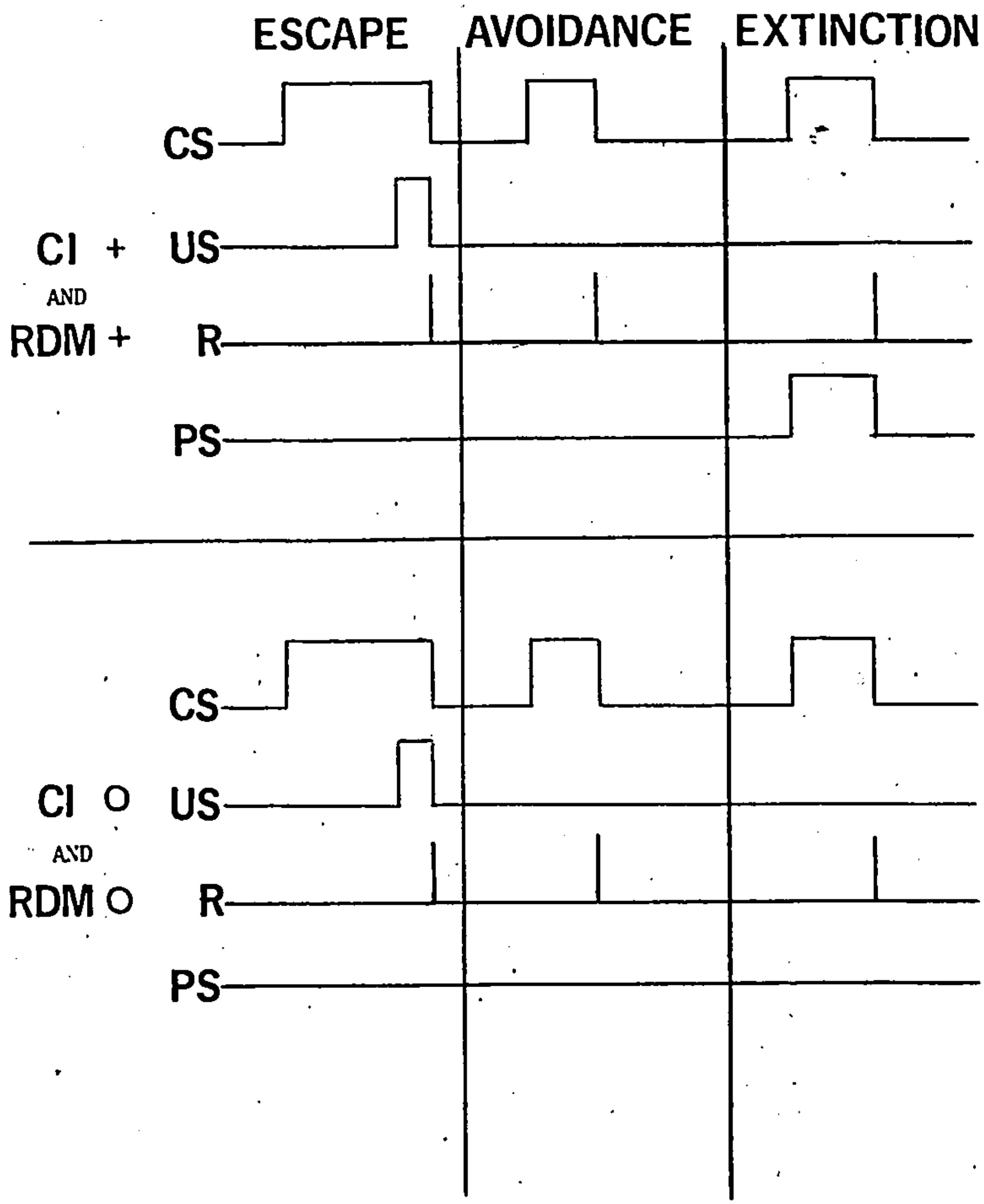
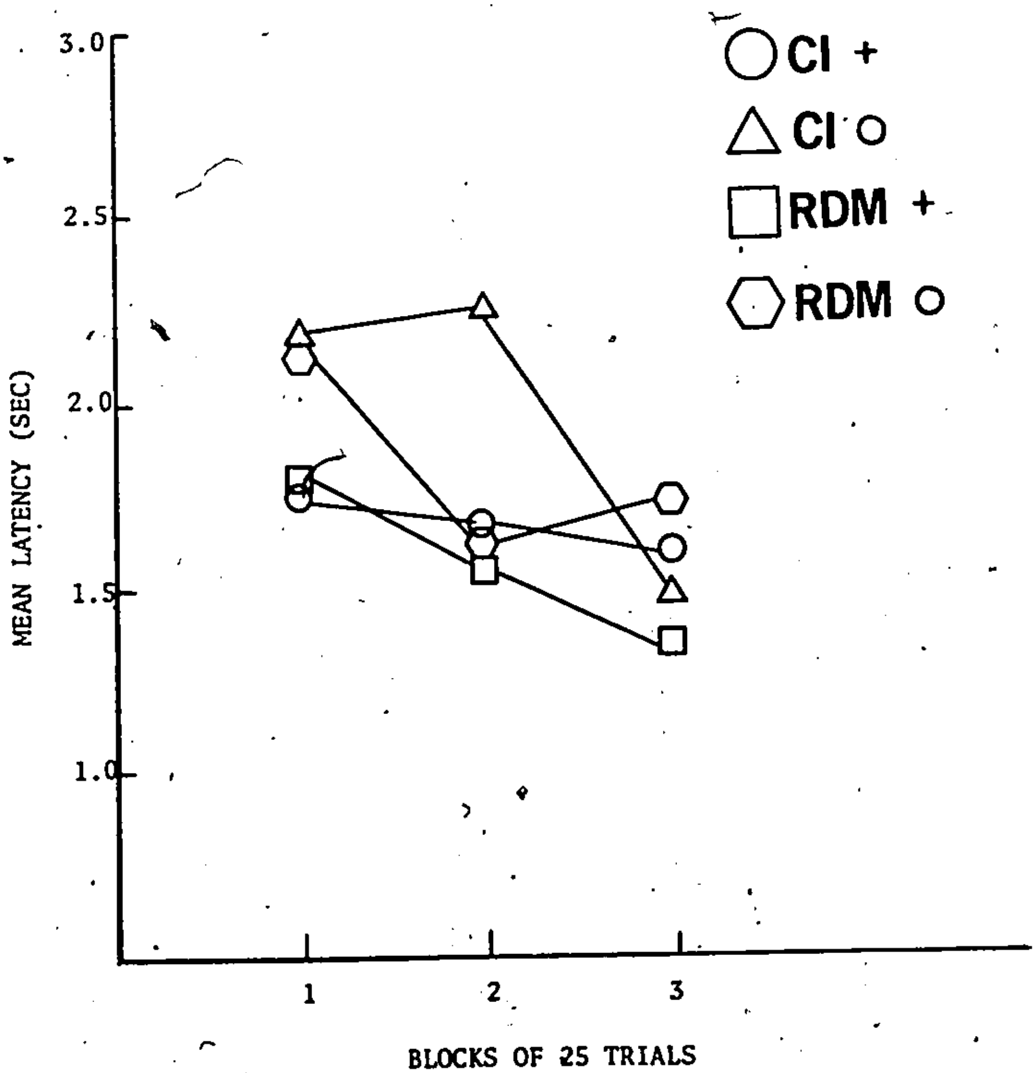

ESCAPE
AVOIDANCE
EXTINCTION
CS
CI +
US
AND
RDM +
R
PS
CS
CI O
US
AND
RDM O
R
PS

Figure 11. Mean pretreatment escape response latencies over the 3 pretreatment days (25 trials per day) in Experiment 3 (n = 6 per group).

FIGURE 11

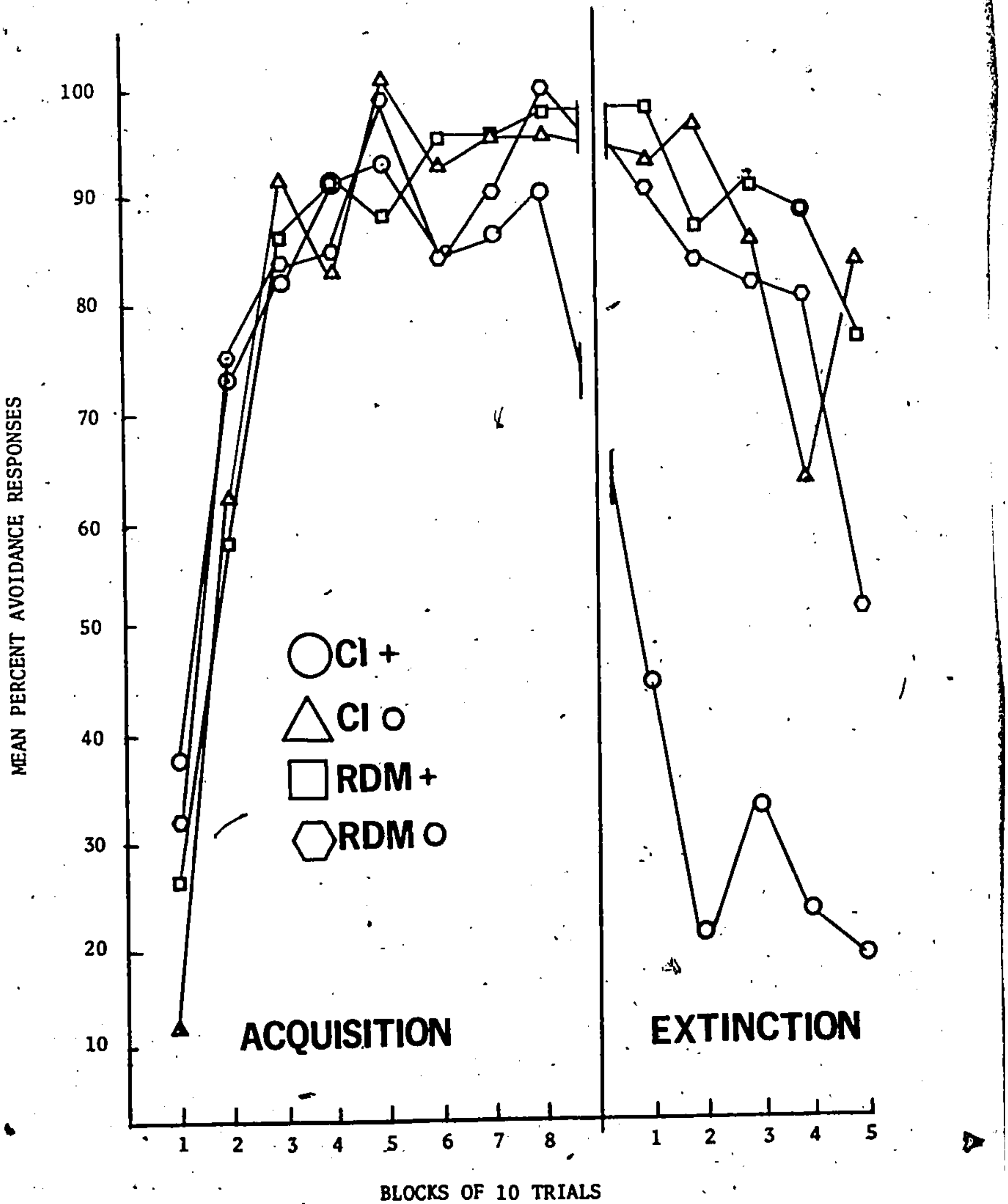

CI +
CI o
RDM +
RDM o
3.0
2.5
2.0
1.5
1.0
MEAN LATENCY (SEC)
1
2
3
BLOCKS OF 25 TRIALS

5.4.2.2 Acquisition - The left side of Figure 12 shows mean percent avoidance responding of the four groups over the 80 avoidance training trials (divided into eight blocks of 10 trials each). As indicated in Figure 12, there was considerable overlap between groups across trials. Indeed, a three-way analysis of variance (Pretreatment X Modality X Trials) yielded only a significant trials effect ($F[7,140] = 84.10, p < .001$) and a significant three-way interaction ($F[7,140] = 2.93$, $p < .01$). This interaction is probably due to the variability in performance between groups during the last 5 blocks of avoidance training. The fact that no main effects or other interactions were significant indicates that the amount of avoidance conditioning at the end of the training phase was similar for all the groups.

5.4.2.3 Extinction - The right side of Figure 12 shows the mean percent avoidance responses (defined as responses with latencies $\leq$ 5 sec.) for each group over the 50 extinction trials. The rapid deterioration in the performance of Group CI + as compared to Groups CI 0, Rdm + and Rdm 0 is evident. A four-way analysis of variance (Summated Stimulus Modality (tone or light) X Pretreatment (CI or Rdm) X Extinction Experience (+ or 0) X Trials) performed on number of avoidance responses in extinction revealed significant main effects of CI vs. Rdm pretreatments ($F[1,16] = 9.94$, $p = .006$) and summation test (+) vs. no summation test (0) in extinction ($F[1,16] = 6.92$, $p = .017$). No effect was found for the modality of the summated stimulus ($F < 1$). A significant interaction was

Figure 12. Mean percent avoidance responding over eight blocks of ten avoidance training trials and five blocks of ten extinction trials in Experiment 3.

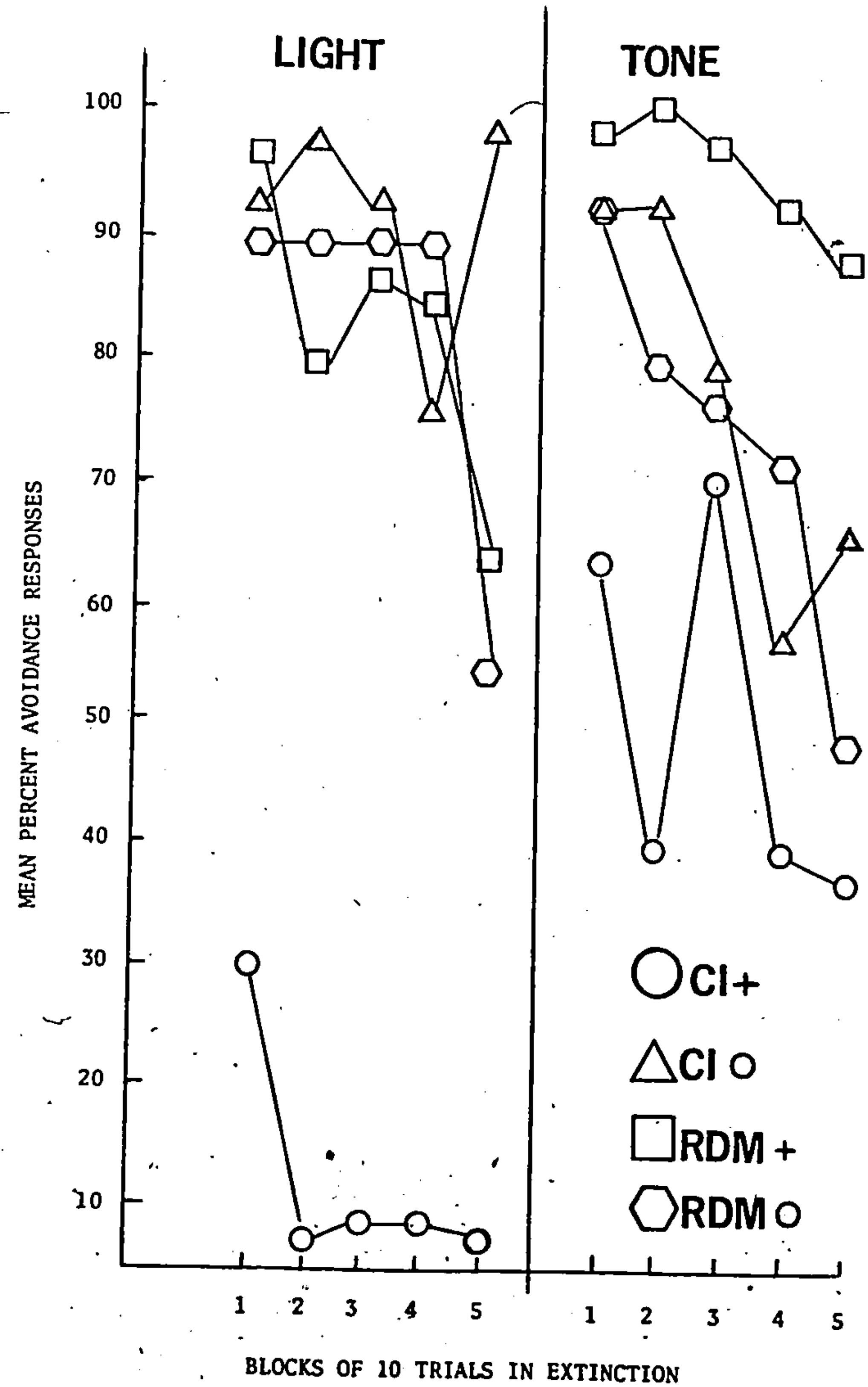
FIGURE 12


MEAN PERCENT AVOIDANCE RESPONSES
100
90
80
70
60
50
40
30
20
10
CI +
CI ○
RDM +
RDM ○
ACQUISITION
EXTINCTION
1
2
3
4
5
6
7
8
1
2
3
4
5
BLOCKS OF 10 TRIALS

found between pretreatment (CI or Rdm) and extinction experience factors (+ or 0) ($F[1,16] = 15.34$, $p = .0015$). The interaction between modality of pretreated stimulus (tone or light) and extinction experience ($F[1,16] = 5.52$, $p = .03$) was also significant. Newman-Keuls paired comparisons indicated the Group CI + made significantly fewer responses in extinction than Groups CI 0, Rdm +, and Rdm 0 ($ps < .01$). The latter three groups did not differ significantly from each other. Because of the significant interaction between modality of pretreated stimulus and extinction experience, a closer study was made of the mean percent responses in extinction across the five extinction trial blocks for the counterbalanced modality conditions ($n = 3$) of each of the four groups. These data are represented in Figure 13. Side A of the figure shows extinction performance when the light served as the pretreated stimulus. Side B of Figure 13 shows extinction performance when the tone served as the pretreated stimulus. A comparison of sides A and B of Figure 13 suggests that the differences between Group CI + and the other groups were greater when the light served as the pretreated stimulus than when the tone was used. Thus, after inhibitory pretraining the light evidenced more conditioned inhibition than the tone. This is consistent with the finding of Experiment 2 that a tone does not seem to acquire much inhibition (as compared to a clicker-FS) when it is used as a FS in avoidance training. In general, the results of the present

Figure 13. Mean percent avoidance responding over the five blocks of 10 extinction trials for the counterbalanced conditions in Experiment 3. A: extinction performance for the groups which had the light as the pretreated stimulus. B: extinction performance for the groups which had the tone as the pretreated stimulus ($\underline{n}$ = 3 per group).

FIGURE 13


LIGHT
TONE
100
90
80
70
60
50
40
30
20
10
MEAN PERCENT AVOIDANCE RESPONSES
1
2
3
4
5
1
2
3
4
5
BLOCKS OF 10 TRIALS IN EXTINCTION
CI+
CI o
RDM +
RDM o

experiment (#3) show that when a stimulus is negatively correlated with shock such that it alone predicts at least a 2 min. interval free from shock, it will develop the ability to inhibit avoidance responding to an excitatory CS. This training procedure was thus employed in the next experiment (#4) to establish a conditioned inhibitor. The pretrained conditioned inhibitor was then used as a FS in subsequent avoidance conditioning.

5.5 EXPERIMENT 4: A Test of the Reinforcing Properties of a Pre-established Pavlovian Conditioned Inhibitor

The results of Experiment 3 suggest that a stimulus given 3 days of Pavlovian pretreatment such that it predicts at least a 2 min. interval free from shock will become a conditioned inhibitor of avoidance behavior. A stimulus that is presented randomly with respect to shock, however, does not appear to develop inhibitory properties. The present study is designed to assess the ability of these pretreated stimuli as well as a novel stimulus to reinforce newly acquired avoidance behavior. According to the contingency view of two-factor theory outlined earlier, a pre-established conditioned inhibitor should, when used as a FS from the outset of avoidance training, facilate avoidance acquisition. An inhibitory FS should provide more reinforcement in terms of aversiveness reduction than either a neutral or a novel feedback stimulus. Positive reinforcement views of avoidance (e.g., Denny, 1971; Weisman & Litner, 1972) as well as stimulus-stimulus expectancies formulations (Bolles, 1972b; Mackintosh, 1974, p. 308-10) apparently would also predict that a FS pretrained as a conditioned inhibitor should facilate avoidance acquisition although these theories differ as to the proposed mechanism of reinforcement. A number of avoidance theories, however, do not predict that a conditioned inhibitor should provide any additional reinforcement from that provided by the avoidance contingency itself. These theories are those that postulate 1) an informational role of response-contingent stimulation (Bolles & Grossen, 1969; D'Amato et al. 1968), 2) that reinforcement is based on the confirmation of a response-no-shock expectancy (Seligman & Johnston 1973), and 3) that reinforcement is based solely on a reduction in shock frequency contingent on avoidance responses (Bolles et al. 1966; Herrnstein, 1969; Herrnstein & Hineline, 1966; Sidman, 1962).

Thus, Experiment 4 should provide a test of the diverging predictions concerning the reinforcing capacity of a conditioned inhibitor made by various theoretical analyses of avoidance learning. In this study four groups of rats were first given different pretreatment experiences and then received avoidance training in which the CS was delayed and a FS was presented following avoidance responses. The pretreatments for two of the groups, CI (conditioned inhibition pretreatment) and Rdm (random pretreatment), were equivalent to that of Groups CI and Rdm in Experiment 3. The CI and Rdm pretreatments were employed in

Experiment 4 to make the stimulus used as a FS in subsequent avoidance training either inhibitory or neutral, respectively. Besides Group Rdm two additional control groups were included. One group, US, (US alone pretreatment) received pretreatment exposure to shock-escape training but not to the stimulus to be used as a FS in subsequent avoidance conditioning. The other group, NT, served as a "no-treatment" control and was not exposed to either the to-be-used FS or shock during the 3 days of pretraining. Thus, the FS for these latter two groups (US and NT) was novel at the start of avoidance training. If the reinforcing property of the FS is a function of the inhibitory properties accruing to it over the course of avoidance training then it is expected that Group CI, whose FS already possesses inhibitory properties, will acquire the avoidance response faster than Groups Rdm, US, and NT, whose FS must first develop inhibitory properties during avoidance training itself.

5.5.1 Method

5.5.1.1 Subjects - Subjects were male, albino rats of the Wistar strain[26] weighing approximately 225-300 grams, housed in

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[26] Since the purpose of this study was to examine possible facilation of acquisition effects, Wistar rats, which are poorer avoiders than the $Fischer_{344}$ rats, were used in the present experiment to reduce the chance of observing ceiling effects due to the generally very rapid acquisition rates of $Fischer_{344}$ rats.

individual cages with food and water freely available.

5.5.1.2 Apparatus - The experimental apparatus and stimuli used in the present experiment were the same as Experiment 3 except that the shock was increased to 1.0mA.[27]

5.5.1.3 Procedure - The study was divided into two phases: Pretreatment and Avoidance Training. Forty-eight rats were randomly assigned to one of four groups which differed in pretreatment procedures. Two rats were replaced due to sickness and four rats were replaced as a result of apparatus failures. The light and tone stimuli were counterbalanced with respect to their use as the CS and FS.

5.5.1.3.1 Pretreatment - Subjects in Groups CI and Rdm in this experiment received equivalent presentations of the stimulus (tone or light) and escapable shocks as did Groups CI and Rdm in Experiment 3. Briefly, for Group CI, the tone or light stimulus (that was used as the FS in subsequent avoidance conditioning) always signalled at least a 2 min. interval free from shock; for Group

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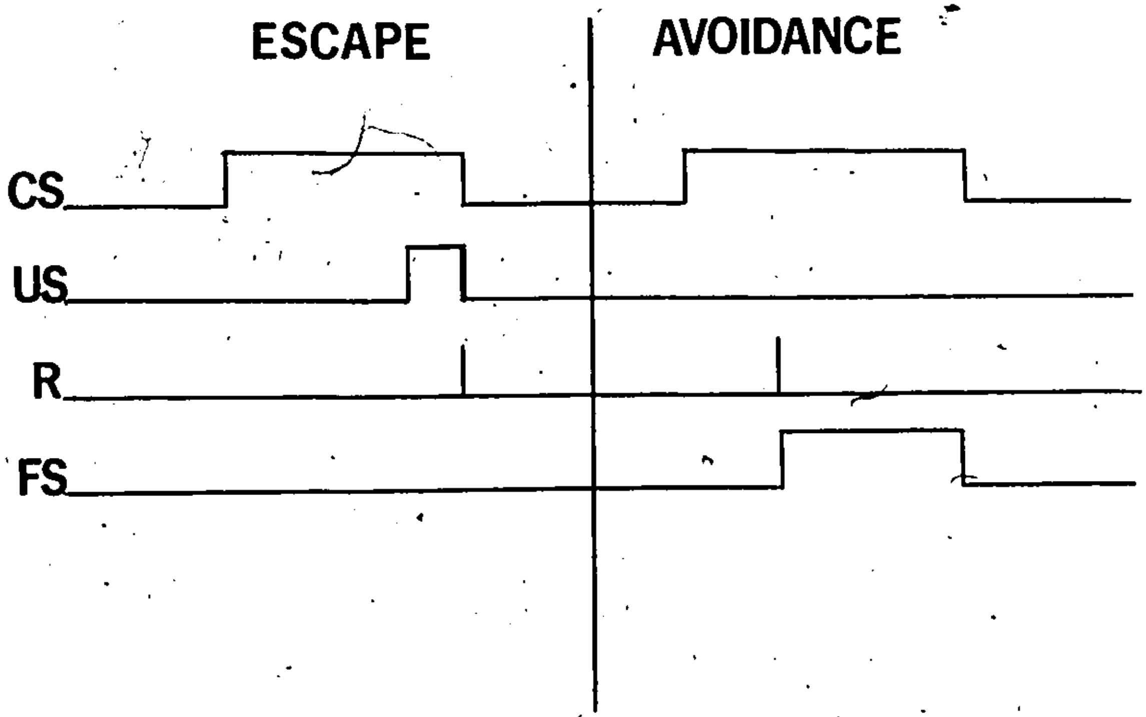
27 It has often been found (e.g., Kurtz & Shafer, 1967; Levine, 1966) that increasing shock intensity slows down the acquisition of a two-way shuttle avoidance response. This procedure was also employed to reduce the chance of a ceiling effect complicating the interpretation of the results of this experiment.

Rdm, however, the stimulus was randomly presented with respect to shock. Both groups received 25 presentations of the stimulus and shock each day for 3 days. Group US received 25 presentations of escapable shocks only, for each of the 3 pretreatment days. The shock schedule for Group US was the same as for Groups CI and Rdm. The tone or light stimuli, however, were not presented to Group US. Thus, Group US served as a control for prior exposure to shock-escape training during the pretreatment phase. The fourth group, NT (no-treatment), was simply placed in the shuttlebox for the same period of time as subjects in the above three groups for the 3 pretreatment days prior to the avoidance conditioning phase. This group was neither exposed to the tone or light stimuli nor shock.

<u>5.5.1.3.2 Avoidance Training</u> - On day 4, following the 3 days of pretreatment outlined above, all subjects were given discrete-trial two-way avoidance training. Figure 14 depicts avoidance training for all groups in Experiment 4. A trial started with the onset of the CS. If the rat failed to go from one compartment of the shuttlebox to the other within 5 sec. after the onset of the CS, a continuous shock was delivered which remained on until a shuttle response was made or 30 sec. elapsed whichever came first. The CS terminated with the shock. If the rat responded during the initial 5 sec. of the CS, shock was avoided, the CS remained on for an additional 5 sec., and the FS was presented. Five sec. after the avoidance response was made both the CS and FS terminated.

Figure 14. Schematic representation of escape and avoidance trials for all groups in Experiment 4.

FIGURE 14



Responses during the 5 sec. feedback period had no programmed effects. Avoidance training lasted for 100 trials and the mean ITI, as in Experiment 3, equalled 60 sec. (range 30-90 sec.).

5.5.2 Results

5.5.2.1 Pretreatment - Figure 15 presents the mean escape latencies for the groups (CI, Rdm, US) exposed to shock during the 3 day pretreatment phase. As can be seen in Figure 15, escape latencies of the groups were similar. A three-way mixed-design analysis of variance (Modality X Pretreatment X Days) confirmed this observation. No significant main effects or interactions were found.[28]

5.5.2.2 Acquisition - Mean percent avoidance responding for each of the four groups over the 100 training trials (divided into 10 blocks of 10 trials each) is shown in Figure 16. It is apparent from observation of Figure 16 that avoidance acquisition in Group CI is far superior to the other three groups. A three-way analysis of variance (Modality X Pretreatment X Trials) revealed significant Pretreatment ($\underline{F}[3,40] = 3.72$, $\underline{p} < .05$), Trials ($\underline{F}[9,360] = 86.72$, $\underline{p} < .001$), and Modality X Trials ($\underline{F}[9,360] = 3.03$, $\underline{p} < .001$) effects.

[28]No trials effect was found in the pretreatment phase of this study although one was found in the pretreatment phase of Experiment 3. Also, the overall escape latencies tended to be longer in this experiment. These disparities may be due to the fact that Fischer 344 rats and a .5mA shock US were used in Experiment 3 but Wistar rats and a 1.0mA shock US were used in this experiment.

Figure 15. Mean pretreatment escape response latencies over the 3 pretreatment days (25 trials per day) in Experiment 4 (n = 12 per group).

FIGURE 15

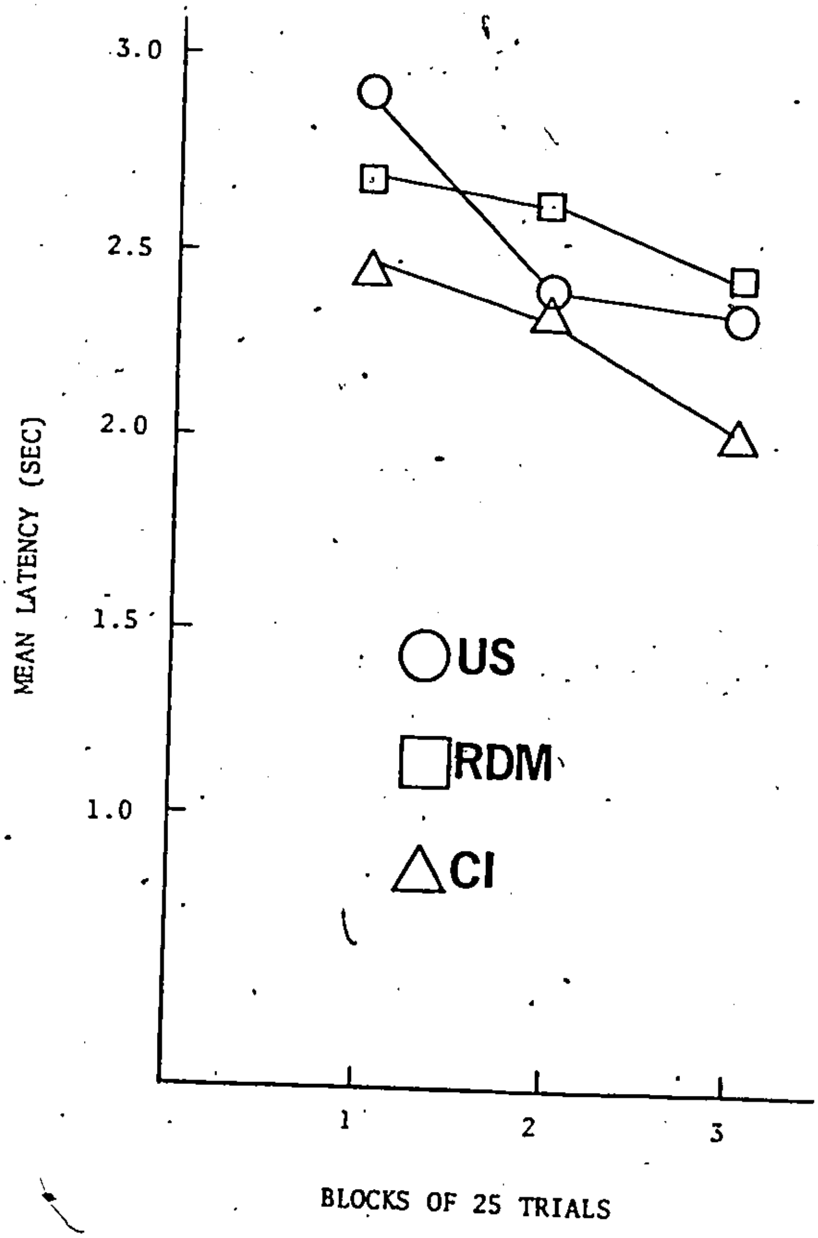

3.0
2.5
2.0
1.5
1.0
MEAN LATENCY (SEC)
US
RDM
CI
1
2
3
BLOCKS OF 25 TRIALS

Figure 16. Mean percent avoidance responding over 10 blocks of 10 avoidance acquisition trials in Experiment 4 (CI = conditioned inhibition pretreatment; NT = "no treatment" pretreatment; Rdm = random pretreatment; US = US alone pretreatment) (n = 12 per group).

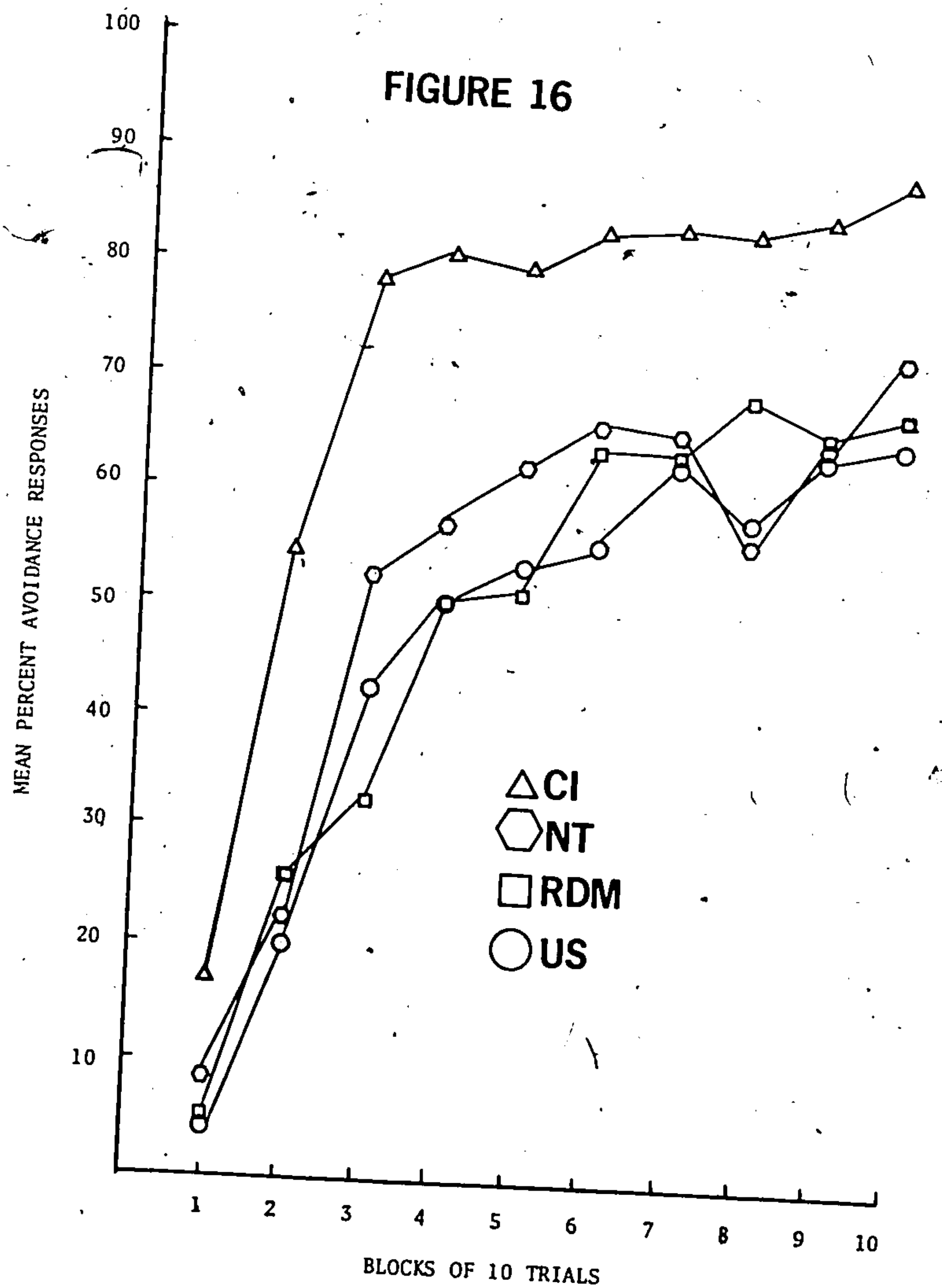


FIGURE 16
MEAN PERCENT AVOIDANCE RESPONSES
100
90
80
70
60
50
40
30
20
10
1
2
3
4
5
6
7
8
9
10
BLOCKS OF 10 TRIALS
CI
NT
RDM
US

A Newman-Keuls test revealed that Group CI differed from Groups US and Rdm (ps < .05) in total number of avoidance responses; no other paired comparisons were significant. Clearer differences are revealed in a study of acquisition criteria data. Figures 17 and 18 present the mean number of responses required by each group to meet various acquisition criteria. One-way analyses performed on these acquisition criteria revealed that while there were no significant differences on number of trials to the first avoidance response ($F[3,44] = 2.18$) or to the fifth avoidance response ($F[3,44] = 2.17$) (see Figure 17), differences did emerge in the number of trials required to make eight avoidance responses in a block of 10 trials (8/10) ($F[3,44] = 4.02$, $p < .025$) and in the number of trials needed to make 10 consecutive avoidance responses (10/10) ($F[3,44] = 8.44$, $p < .001$) (see Figure 18). Newman-Keuls paired comparisons of the 8/10 criterion revealed that Group CI reached this criteria in significantly fewer trials than Groups NT, Rdm, and US (ps < .05). There were no differences among the latter three groups. Similar results were obtained for the 10/10 criterion. Group CI reached this point significantly faster than Groups NT, Rdm, and US (ps < .01). Again, no other paired comparisons were significant. In order to find the source of the Modality X Trials interaction, t-tests were performed on 8/10 and 10/10 acquisition criteria data between the counterbalanced conditions ($n = 6$) of each group. The only group in which the counterbalanced conditions differed was Group NT. Those NT subjects which received a tone as the CS and light

Figure 17. A: Mean number trials to first avoidance response for each of the four groups in Experiment 4. B: Mean number of trials to fifth avoidance response for each of the four groups in Experiment 4.

FIGURE 17

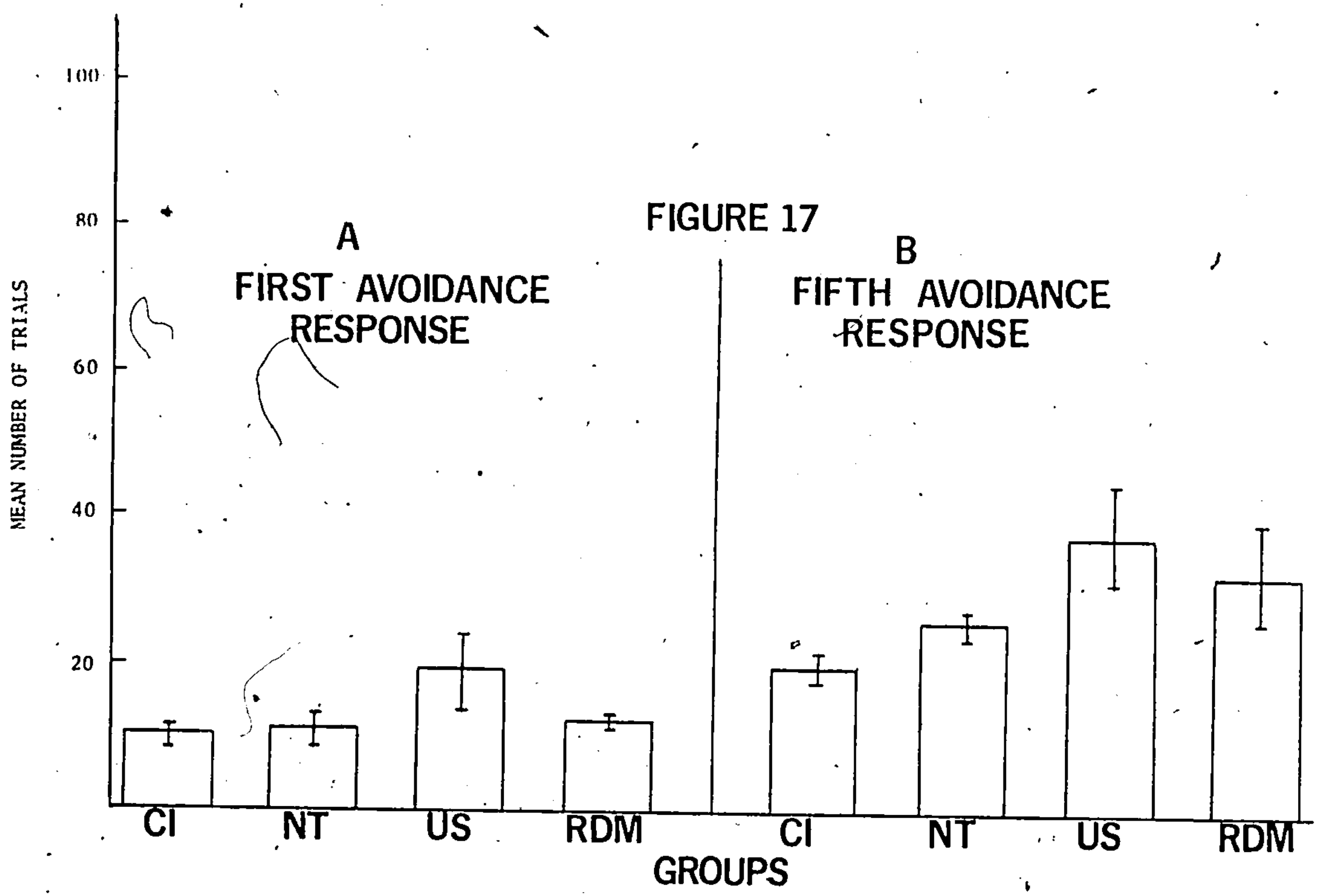
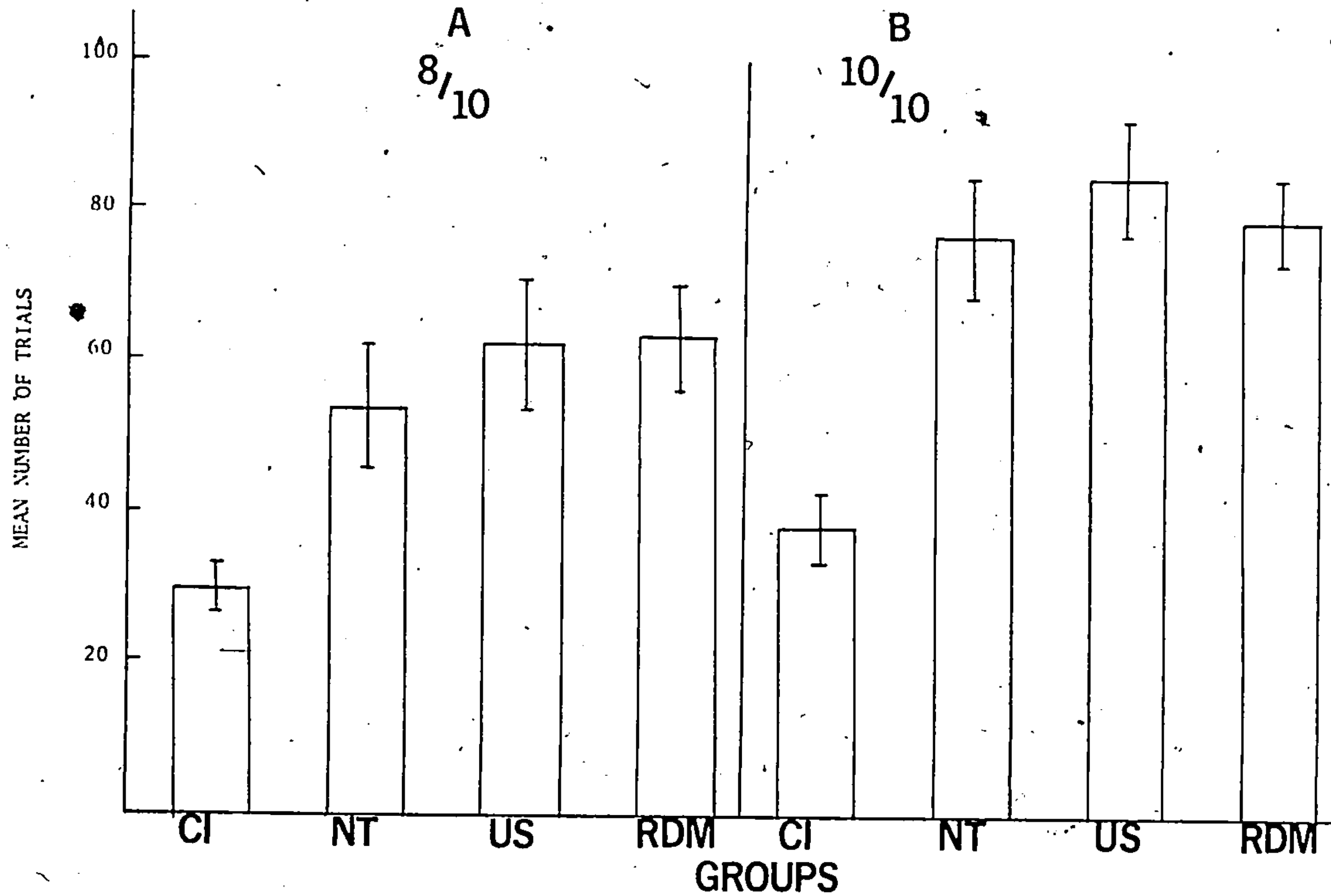

A
FIRST AVOIDANCE RESPONSE
B
FIFTH AVOIDANCE RESPONSE
MEAN NUMBER OF TRIALS
100
80
60
40
20
CI
NT
US
RDM
CI
NT
US
RDM
GROUPS

Figure 18. A: Mean number of trials required to make eight avoidance responses in a block of 10 trials (8/10) for each of the four groups in Experiment 4. B: Mean number of trials required to make 10 avoidance responses in a block of 10 trials (10/10) for each of the four groups in Experiment 4.

FIGURE 18


A
8/10
B
10/10
MEAN NUMBER OF TRIALS
100
80
60
40
20
CI
NT
US
RDM
CI
NT
US
RDM
GROUPS

as the FS took significantly fewer trials to reach the 8/10 criterion than their light-CS, tone-FS counterparts ($t_{10} = 2.85$, $p < .02$).

5.5.3 Discussion

The results of Experiment 4 demonstrate that a pretrained Pavlovian conditioned inhibitor when used as a FS facilitates the acquisition of a two-way avoidance response to a greater extent than a non-inhibitory FS. It is interesting to note that the prior Pavlovian inhibitory training used in this experiment was able to turn a usually ineffective tone-FS (see Experiment 1) into a powerful reinforcer of avoidance behavior. It might be argued that the superior performance of Group CI was due to the fact that Groups US and Rdm evidenced a retardation of acquisition effect. Indeed there is evidence (Mackintosh, 1973; Siegel & Domjan, 1971) that prior exposure to US alone or random schedules does retard subsequent acquisition of a conditioned response in a number of classical conditioning paradigms. In the present study, however, acquisition performances of Groups US and Rdm were no different from Group NT which received no preexposure to stimuli or shocks. This finding suggests, therefore, that in the present study preexposure to the US or to a random schedule did not produce a retardation of acquisition effect. Thus, the superior performance of Group CI is attributable to the extra reinforcing property possessed by its inhibitory FS and not to deficits in acquisition in the comparison groups.

The finding of the present study that a conditioned inhibitor facilitates the acquisition of a new response in a discrete-trial signalled avoidance situation extends the findings of Weisman & Litner (1969a) and Rescorla (1969b). They had previously demonstrated that a conditioned inhibitor can modify existing patterns and rates of well-trained free-operant unsignalled avoidance responding. The results are also congruent with Weisman and Litner's (1972) finding that a stimulus which develops inhibitory properties as a result of its use as a FS in a discrete-trial avoidance task (one-way or wheel-turn) can increase the number of responses made in a subsequent Sidman avoidance task if the pretrained FS is made contingent on high rates of responding. Similarly, Morris (1975) and Moot (cited in Bolles, 1972a) have shown that a pretrained FS can also facilate the acquisition of a new avoidance response.[29]

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29 Unlike Morris (1975), Moot apparently failed to find this pretrained FS facilation effect in yoked-control subjects. This discrepency may be partly due to the fact that in Morris' study the yoked subjects received the stimulus experiences of master rats given two-way shuttlebox training before they, themselves, were run in the shuttlebox. Moot, on the other hand, yoked subjects to rats run on the two-way shuttlebox task but then trained these yoked animals on a lever-press avoidance task. Perhaps, being yoked to a rat trained to make a two-way avoidance response some how provides more relevant Pavlovian experiences for subsequent learning of a two-way running response in the shuttlebox than for learning a lever-press response in the Skinner box.

5.6 Implications for Theories of Avoidance

In general the results of the first 4 experiments, taken together, strongly suggest that a FS develops inhibitory properties and that this inhibition has a functional role in the reinforcement of avoidance behavior.

5.6.1 Theories Not Supported by Data

A number of theories of avoidance do not fair well in the light of these findings. Generally, these theories state that one need not look any further than the response-shock (i.e., avoidance) contingency itself to locate the source of reinforcement or information provided by response-contingent feedback. According to these formulations it would not be expected that Pavlovian inhibitory training would have any effect on instrumental avoidance behavior. The stimulus-stimulus contingencies encountered in the Pavlovian session would not provide the subject with any relevant information concerning the avoidance response contingency it will later encounter. Thus, as mentioned earlier, neither an informational view (Bolles & Grossen, 1969; D'Amato et al. 1968), nor response-outcome expectancy theory (Seligman & Johnston, 1973), nor a shock-density reduction analysis (Bolles et al. 1966; Herrnstein, 1969; Herrnstein & Hineline, 1966) would have predicted the results of Experiment 4. The differences in avoidance acquisition found between the inhibitory FS group (CI) and the neutral FS (Rdm) and novel FS (US, NT) groups would not be expected since the response-outcome information provided by the FS and the avoidance contingency itself was identical for all groups during avoidance training.

5.6.2 Reaffirmation of Pavlovian Processes in Avoidance Learning

Experiment 4 does furnish evidence which supports a basic premise of two-factor theory - that Pavlovian processes are implicated in avoidance learning. Like the acquired drive studies (e.g., Brown & Jacobs, 1949), Experiment 4 attempted to procedurally separate the Pavlovian component from the instrumental component. The findings of the acquired drive studies and Experiment 4 provide evidence that both Pavlovian excitatory and inhibitory processes play an important role in avoidance learning. The acquired drive studies showed that prior Pavlovian excitatory conditioning can affect the aversive property of the CS used in subsequent avoidance training. The likelihood of a subject making a response which terminated the CS was shown (e.g., Brown & Jacobs, 1949) to be a function of CS-shock forward pairings during the initial Pavlovian phase. Experiment 4, on the other hand, demonstrates that prior Pavlovian inhibitory conditioning can affect the reinforcing property of a FS. The capacity of a FS to reinforce avoidance responses was shown in Experiment 4 to be a function of the negative contingency established between the FS and shock during the Pavlovian pretreatment phase.

5.6.3 Anger's Theory in Light of New Data

Ironically, although Experiment 4 provides additional evidence that Pavlovian events are important in avoidance learning, at least one version of two-factor theory and perhaps (until now) the strongest version (Anger, in press), would not have predicted the results of Experiment 4. The theory simply ignores the possibility that certain stimuli in the avoidance situation may develop inhibitory properties which can provide an additional source of reinforcement for the avoidance response. Constrained by a shocks/exposure measure of CA, Anger could not have predicted that a FS already established as a conditioned inhibitor would facilate avoidance acquisition anymore than would a novel or neutral FS. The amount of aversiveness reduction ($CA_{CS}-CA_{FS}$) following an avoidance response is assumed to be approximately equal if other factors are held constant (e.g., the conditioned aversiveness of the CS is the same in both FS conditions).

5.6.4 Contingency Revision of Anger's Theory Adequately Handles the New Data

The contingency version of two-factor theory maintains that the amount of reinforcement in terms of aversiveness reduction is greater when an inhibitory stimulus (with CA < 0) is used as a FS than when a novel or neutral stimulus (with CA = 0) is used as a FS. Thus, the contingency version of two-factor theory correctly predicts that avoidance conditioning is faster with an inhibitory FS than with a non-inhibitory FS.

5.6.5 Aversiveness Reduction vs. Positive Reinforcement Views of Avoidance

It should be recognized that the contingency version of two-factor theory, while assigning increased reinforcing properties to conditioned inhibitors, still maintains that aversiveness reduction serves as the reinforcement mechanism for avoidance behavior. Conditioned inhibitors with their negative CA values simply provide greater aversiveness reduction than non-inhibitory stimuli when they are presented in aversive situations. A number of investigators (Denny, 1971; Dinsmoor & Sears, 1973; Rescorla, 1968a, 1969b; Soltysik, 1963; Weisman & Litner, 1969a,b, 1972), however, have argued that the accumulation of evidence showing that stimuli following avoidance responses develop inhibitory and reinforcing properties suggests that "Pavlovian inhibition of fear produced by the avoidance response provides the reinforcement mechanism in avoidance learning (Weisman & Litner, 1972, p.256)". Some of these investigators, particularly Weisman and Litner and Denny, have further concluded that "avoidance learning is an instance of positive reinforcement (Weisman & Litner 1972, p.267)" wherein inhibitory feedback from the avoidance response functions "as a conditioned positive reinforcer in much the same manner as a stimulus correlated with the presentation of food (Weisman & Litner, 1969b, p.667)".[30] The superior reinforcing ability of a conditioned inhibitor demonstrated in Experiment 4 certainly provides strong support for a positive reinforcement view.

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[30] This position is similar to one taken years earlier by Schoenfeld (1950).

5.6.5.1 Is A Distinction Between Aversiveness Reduction And Positive Reinforcement Necessary?

The question arises as to whether it is important to make a distinction between an aversiveness reduction view of two-factor theory (as advocated in this thesis) and a positive reinforcement view (as favored by Denny and Weisman and Litner). It appears that the available evidence does not allow one to conclude with confidence that in all avoidance situations it is the presentation of inhibitory stimuli rather than the removal of aversive stimuli which serves as the sole source of reinforcement for the avoidance response. The evidence does suggest that response-associated feedback stimuli become conditioned inhibitors and reinforce avoidance behavior upon their occurrence. This does not mean, however, that it is always the presentation of such stimuli rather than the simultaneous offset of aversive stimuli (e.g., the CS) which functions as the effective reinforcer. Indeed, this would be difficult to empirically demonstrate. Thus, while there is evidence (Experiment 4) that the presentation of a conditioned inhibitor can reinforce avoidance behavior in the absence of immediate CS termination, one cannot totally rule out the role of negative reinforcement when the subject is removed from highly aversive stimulation. Support for this latter view comes from studies which show that reliable avoidance learning can still occur at very short ITIs (< 30 sec.) when the CS termination contingency is in effect (Katzev & Hendersen, 1971; Morris, 1974) without the FS developing inhibitory properties (Morris, 1974, Expt. 3). This finding strongly suggests that the presentation of a response-contingent conditioned inhibitor may not be a necessary condition although it may be sufficient to reinforce avoidance behavior.

5.6.5.2 Are Both Kinds of Reinforcement Present?

The issue raised as to whether avoidance learning is an example of positive or negative reinforcement has been side-stepped by a number of investigators who maintain that both types of reinforcement can occur in the avoidance situation. For example, Soltysik (1963) proposed a "three-component model" in which the first two components are those of traditional two-factor theory (i.e., classical conditioning of fear to a CS paired with shock and the negative reinforcement via fear reduction of a response which terminates the CS). The third component, however, involves the positive reinforcement of avoidance behavior by the occurrence of inhibitory feedback associated with the avoidance response. Likewise, Rescorla (1969b) suggested that "it is possible that an additional source of reinforcement in the signalled avoidance situation besides fear reduction is the positive reinforcing effect of the response and its associated feedback (p. 263)" (emphasis added).

The postulation of two reinforcing mechanisms for avoidance behavior is unattractive, unparsimonious, and as it turns out, unnecessary. The positive reinforcement view, as has been shown, runs into trouble in trying to rule out negative reinforcement effects. The positive reinforcement view also cannot account for avoidance learning with short ITIs where it is unlikely that response-produced stimuli become effective conditioned inhibitors. The dilemma as to whether avoidance responses are reinforced by the removal of conditioned aversive stimuli or by the occurrence of conditioned inhibitory stimuli becomes an irrelevant issue under the contingency version of the two-factor theory presented in this thesis. According to this formulation, either the termination of highly aversive stimuli or the presentation of conditioned inhibitors can function as reinforcing events as long as there is an overall significant reduction of aversive stimulation contingent on the avoidance response. The greater the reduction in CA, the larger the magnitude of reinforcement. Thus the present theory would predict that reinforcement (in terms of aversiveness reduction) would be greater if stimuli high in CA (e.g., the CS) are replaced by stimuli with negative CA values (e.g., conditioned inhibitors) than being replaced by stimuli with slightly positive or zero CA values (e.g., apparatus cues, neutral or novel FSs, etc.). The important consideration, then, is not whether stimuli are presented or removed but rather what is the overall response-contingent change in aversive stimulation (cf., Anger, 1963, in press; Dinsmoor, 1954). Thus, it appears that those authors who have advocated either a positive reinforcement view of avoidance learning (e.g., Weisman & Litner, 1969a,b; 1972) or both a positive and negative reinforcement view (e.g., Dinsmoor & Sears, 1973; Rescorla, 1968a, 1969b; Soltysik, 1963) have apparently confused the operation of presenting a stimulus contingent on a response with the underlying reinforcing mechanism needed to account for avoidance learning. The fact that certain stimuli are presented following responses does not necessarily mean that the observed increase in behavior must be due to an underlying positive reinforcement mechanism.

5.6.6 Stimulus-Stimulus Expectancy Theory

It also appears that stimulus-stimulus expectancy theory (Bolles, 1972b; Mackintosh, 1974, p.308-10; Ritchie, 1951) is supported by the demonstration in Experiment 4 that a conditioned inhibitor reinforces avoidance behavior. According to this view, as a result of prior inhibitory training the animal learns not to expect shock for a period of time if the inhibitory stimulus has just been presented. During early avoidance training the subject learns that the CS leads to shock so he comes to expect shock in the presence of the CS. When he makes avoidance responses his expectation of shock is disconfirmed and he is reinforced "by the omission of an expected shock (Mackintosh, 1974, p. 308)". If, upon making the avoidance response, not only is the expected shock omitted, but also a conditioned inhibitor which is associated with time free from shock is presented, then the avoidance response should be further reinforced by the added confirmation that the response omits the expected shock and, moreover, produces a safety signal.

The most recent version of stimulus-stimulus expectancy theory (Mackintosh, 1974, p. 308-10) proves very difficult to distinguish from the revised two-factor theory proposed above. In fact, Mackintosh's analysis is, up to a point, very similar to the present formulation. Thus, he maintains,

> "If avoidance responding is reinforced by a reduction of fear [aversiveness], the external event responsible for such a reduction is a change in the stimulus situation from one associated with a high probability of shock to one associated with a low probability of shock. The usual way to ensure that stimuli will enter into such associations is to schedule shock in the presence of one set of stimuli and to omit shock in the presence of another (p.330)".

At this point, however, Mackintosh parts company with revised two-factor theory as he argues that "it will be equally correct to say that avoidance responding is usually reinforced by the omission of a scheduled shock" (cf., Bolles et al. 1966; Herrnstein, 1969) and that "this is not so very different from saying that the subject learns to expect shock in the presence of one set of stimuli, and that a given response is followed by the omission of this expected shock (p.330)".

5.6.6.1 Criticisms of Expectancy Theory

As the above three quotes indicate, Mackintosh appears to be trying to first unify two-factor theory with one-factor theory and then to tie them both under a "common-sense" expectancy rubrid. It is unclear whether Mackintosh is justified in doing so. First, the one-factor shock-density reduction formulation of Herrnstein (1969), Bolles et al. (1966), and Sidman (1962) simply cannot be equated with a two-factor view. One-factor theory cannot account for avoidance data easily handled by two-factor theory (e.g., acquired drive studies, delayed CS termination studies, patterning of responding in Sidman and random-shock avoidance paradigms, etc.). Moreover, the statement that avoidance responses are reinforced by a change from high to low aversive stimulation is not the same as saying that responses are reinforced "by the omission of a scheduled shock" because the latter statement does not necessarily implicate Pavlovian conditioning in establishing the functional role of stimuli that immediately proceed and follow the response; there is now considerable evidence, however, pointing to the significant part played by Pavlovian excitatory and inhibitory processes in avoidance learning.

It is obvious, however, that Mackintosh (1974) does not wish, as did Herrnstein and Bolles et al., to eschew the role of Pavlovian conditioning in avoidance learning. Rather Mackintosh is concerned with which of two mechanisms mediates avoidance learning: "classically conditioned motivational states or...the development of expectations about the consequences of responding (p.331)".[31] Thus, Mackintosh appears to be attacking motivational two-factor theories (e.g., Mowrer, 1947; Rescorla & Solomon, 1967). By doing so, Mackintosh is ignoring those formulations (e.g., Dinsmoor, 1954, Anger, 1963, in press) which make no attempt to identify the specific internal state of the animal that is changed after it experiences stimuli paired and unpaired with shock and begins to make avoidance responses. Furthermore, if a comparison is made between motivational theories and expectancy theories, the adoption of the expectancy construct seems to be even more unnecessary than the use of motivational constructs. At least motivational theorists have tried (although often without success) to independently

31 This expectancy view now has the ring of a response-outcome expectancy notion (Seligman & Johnston, 1973). Mackintosh jumps from explanations based on the formation of stimulus-stimulus expectancies to response-outcome expectancies with considerable ease without considering the conceptual differences between the two.

validate their constructs of fear, anxiety, fear-reduction, and the like, by looking for correlated changes in different response systems (usually physiological). The expectancy construct, on the other hand, has no status independent of the behavior it is posited to explain and it is not evident by what means it can be independently validated. Indeed, the operations required to produce an expectancy are the very ones that produce the behavior itself. These factors make it difficult to assign a causal function to the expectancy construct. Consequently, using the term expectancy does not appear to provide any additional information that can foster a better understanding of the behavioral phenomena. Thus, the utility of expectancy as a mediating variable in avoidance learning is not obvious and the loose terminology often associated with its use may indeed obscure important factors that directly influence the behavior in question.[32]

5.7 Two-Factor Theory and Extinction of Avoidance Behavior

From its inception, two-factor theory has been plagued by studies purporting to find extremely high persistence of avoidance responding (e.g., Baum, 1970; Black, 1958; Brush, 1957;

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32 Other critiques of expectancy theories of behavior can be found in Miller (1948), Nevin (1973) and in Skinner (1965; 1974).

Seligman & Campbell, 1965; Solomon et al. 1953). High resistance to extinction (as well as rapid rates of acquisition) appears to be a function of a number of factors including type of avoidance response required (one-way vs. two-way vs. lever-press - see Bolles, 1971), intensity of shock, type of shock (e.g., continuous vs. discontinuous), intensity of CS, type of CS (modality, location, etc.), species (and strains within species), the interactions among these variables, and others too numerous to mention.[33] A survey of the avoidance literature, for the most part, reveals that high resistance to extinction is not as widespread as might be thought.[34] This may be due, however, to the more frequent use of certain species (albino rats) and procedures (two-way shuttlebox and lever-press) that do not generally yield persistent avoiders.

There is no doubt that durable responding is a fact in many studies. This is especially true in one-way avoidance with rats

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33 See recent reviews by Olton (1973), Fantino (1973), Tarpy (1975, p. 90-113), Mackintosh (1974, p. 299-347).

34 A recent study by Uhl and Eichbauer (1975) has in fact demonstrated that shock-avoidance behavior in rats and pigeons is no more resistant to extinction than instrumental behavior that produces an appetitive reinforcer.

(e.g., Seligman & Campbell, 1965) and in shuttlebox avoidance using high intensity shocks with dogs (e.g., Solomon, et al. 1953). Thus, no adequate theory of avoidance can ignore this phenomenon. If two-factor theory is going to retain its position as the most "successful" theory of avoidance behavior (Anger, in press) then it must be able to satisfactorily account for persistent avoidance responding when it does occur.

5.7.1 Problems for Previous Versions of Two-Factor Theory

Unfortunately, most versions of two-factor theory are simply incapable of explaining this high resistance to extinction. The traditional fear-motivated versions (Mowrer, 1947; Miller, 1948) inherited this theoretical flaw from the simple classical conditioning model (Hull, 1929). Both formulations were forced to encounter the fact that as the subject continued to make more and more avoidance responses fear to the CS should be extinguishing since the subject was not receiving sufficient CS-US pairings needed to maintain fear. When fear was extinguished to the CS, what was motivating continued responding in its presence? Furthermore, where was the reinforcement for continued responding? If there was no fear prior to the response how could there be any fear reduction after the response? Solomon and Wynne (1954) tried to salvage two-factor theory by postulating the "principles" of "anxiety conservation" and "partial irreversibility". These terms, however, proved to be nothing more than a restatement of the phenomena in mentalistic and nontestable language and as such failed to provide an adequate solution to the problem for two-factor theory.

Subsequent two-factor formulations have also failed to provide a satisfactory explanation of persistent avoidance responding. Even Anger's (1963, in press) strong version, while solving many other problems for two-factor theory, does not get the theory out of this dilemma. According to a simple shocks/exposure analysis the conditioned aversiveness of a CS should decrease steadily after many consecutive avoidance responses since the absolute number of shocks, per exposure, is drastically decreasing. Concurrently, with this decrease in the CA of the CS, reinforcement in terms of a reduction in conditioned aversiveness is also diminishing. Thus, Anger's analysis would also predict that in extinction, where no shocks can be received to bolster the shocks/exposure of the CS, avoidance performance should deteriorate relatively rapidly.

5.7.2 An Explanation Based on the Contingency Version of Two-Factor Theory

It is conceivable, however, that the contingency version of two-factor theory proposed in this thesis may finally provide two-factor theory with the ability to account for persistent avoidance responding. Rather than trying to suggest some way to slow down or prevent the inevitable reduction of conditioned aversiveness to the CS (cf., Solomon & Wynne, 1954), perhaps the answer lies with the properties that develop to response-contingent feedback stimuli. As has been shown in a number of previous studies (Dinsmoor & Sears, 1973; Morris, 1974; Rescorla, 1968a; Weisman & Litner, 1972) and in Experiment 2 of this thesis, certain feedback stimuli (at least most experimenter-programmed exteroceptive stimuli) develop inhibitory properties over the course of avoidance training. Thus, even while the conditioned aversiveness of the CS may be beginning to decrease (e.g., Kamin et al. 1963, Weisman & Litner, 1972), the relative reduction of conditioned aversiveness following an avoidance response is still being maintained, if not indeed increasing. This is due to the fact that the inhibitory strength of the FS should continue to increase as it is contrasted more and more with shock (i.e., the conditioned aversiveness of the FS should continue to decrease below zero). When shock is no longer presented in extinction, the inhibitory properties of the FS may be maintained because it still signals a long shock-free safety period. This leads to the prediction that even when shock is discontinued, the inhibition accrued to a conditioned inhibitor will extinguish very slowly, if at all. This prediction has recently been confirmed in a study by Zimmer-Hart and Rescorla (1974). Thus, in the avoidance situation, reinforcement in terms of a significant response-contingent reduction in conditioned aversiveness will still be maintained in extinction even as the conditioned aversiveness of the CS is itself diminishing towards zero. This view does not suggest, however, that extinction might never occur (cf., Solomon & Wynne's "partial irreversibility"). The point will eventually be reached where the CA of the CS is so low (shocks/exposure → 0) that the aversiveness reduction supplied by a conditioned inhibitor simply will not be enough to maintain continued responding and extinction will occur.[35] Although the assumptions of this extinction formulation remain to be empirically validated,[36] the revised contingency version of two-factor theory proposed here seems to offer a pausible solution to an enigma that has haunted two-factor theory from the very beginning of its long and rocky existence.

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Nor does this formulation imply that presenting a conditioned inhibitor will reinforce behavior in nonaversive situations (cf., Grossen, 1971). As pointed out earlier according to the revised version of two-factor theory advocated here, it is not the presentation of conditioned inhibitors but rather a reduction in conditioned aversiveness that serves as the reinforcing event for avoidance. Obviously, there cannot be a reduction in CA if there is no CA to begin with.

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One experiment that could be tried would be to compare extinction rates in a group that gets, in extinction only, a pretrained CI as a FS to a group that has a neutral or novel FS in extinction. According to the present analysis, the group that has an inhibitory stimulus following avoidance responses in extinction should be slower to extinguish than the group which has a non-inhibitory stimulus following responses in extinction. The former group should experience greater aversiveness reduction for a longer time than the latter group. This finding would also question Katzev and Hendersen's (1971) contention that if a FS is to be effective in extinction it must first be used as an FS in acquisition. According to the present formulation, any stimulus possessing conditioned aversive inhibitory properties should be able to maintain responding during extinction even if it did not develop its inhibitory properties during avoidance acquisition per se.

5.8 EXPERIMENT 5: The Necessary Conditions for Establishing a Safety Signal: A Test of "Learned-Safety" in the Shock-Avoidance Paradigm

Experiment 4 demonstrated that one possible way to produce an effective FS or safety signal (SS) for avoidance behavior is to pretrain a stimulus as a Pavlovian conditioned inhibitor such that it is negatively correlated with, and predicts a time free from shock. It was also shown that when no contingency is established between a stimulus and shock (Group Rdm) the stimulus does not develop SS properties. Indeed, Rescorla (1967, 1969a,c) has maintained that an inhibitory SS can only be established if it is negatively correlated with an aversive event.

Recent developments in the taste aversion literature (e.g., Kalat & Rozin, 1973; Siegel, 1974), however, suggest that simple preexposure of a taste in the total absence of aversive consequences (e.g., toxicosis) may also result in the animal actively learning that the familiar taste is safe. If preexposure endows a taste with safety signal properties then it would be expected that rats might acquire a preference for the safe taste over a novel taste and thus be inclined to sample more of the familiar taste on subsequent occasions. Indeed, this is what Siegel (1974) has found. Moreover, actively learning that a taste signals the absence of aversive consequences should interfere with subsequent learning that the preexposed taste does predict sickness.

The finding of significant retardation of aversion learning to a preexposed taste associated with toxicosis has been confirmed on numerous occasions (e.g., Domjan, 1972; Kalat & Rozin, 1973; Maier, Zahorik, & Albin, 1971; McLaurin, Farley, & Scarborough, 1963; Revusky & Bedarf, 1967; Siegel, 1974).

Kalat and Rozin's (1973) original "learned-safety" hypothesis was meant to apply only to poison-avoidance situations. It is possible, as suggested by Siegel (1974), that their learned-safety analysis may also be relevant to a "latent inhibition" effects observed in learning settings employing peripheral CSs and USs. Latent inhibition (Lubow, 1965) refers to the well-documented finding (e.g., Ackil & Mellgren, 1968; Lubow, 1965; Lubow & Moore, 1959; Siegel, 1969)[37] of retardation in the acquisition of a conditioned response to a CS that had been repeatedly preexposed in the total absence of the US. It is possible that this phenomenon might also be due to a learned-safety mechanism. Thus, if a learned-safety analysis can be extended to conditioning situations employing peripheral CSs, then it suggests that any stimulus, be it a tone, light, clicker, etc., if preexposed in the absence of aversive events, will become a safety signal. Subsequent

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37 See Lubow (1973) for a complete review of the latent inhibition literature.

learning that this "safe" stimulus predicts the occurrence of aversive events, such as electric shock, should be retarded. This formulation also implies, however, that preexposure should not disrupt learning that the familiar stimulus predicts a safety period since preexposure itself presumably endows a stimulus with safety properties. As applied to avoidance conditioning then, learned-safety would predict that preexposing a feedback stimulus which signals that shock has been successfully escaped or avoided as well as signalling a relatively long shock-free interval should not disrupt subsequent avoidance conditioning. If anything, preexposing the FS should facilate avoidance acquisition since as a result of preexposure the FS should acquire safety properties. Indeed, the results of Experiment 4 suggest that any pretreatment which endows a FS with safety properties should make the FS an effective reinforcer of avoidance behavior from the very outset of training.

The extended version of learned-safety suggests that the necessary and sufficient condition to establish a stimulus as a safety signal is to preexpose it in the absence of aversive consequences. This hypothesis is at odds with Rescorla's contingency view of safety signal conditioning. Rescorla (1969a,c) has argued that a negative contingency between a stimulus and the US must be established if the stimulus is to become a conditioned inhibitor or safety signal. Simple preexposure, of course, does not meet this requirement since no US is presented. Rescorla (1969c, 1971) and others have argued that preexposure results in a reduction in stimulus salience; the subject stops attending to (Halgren, 1974; Lubow, 1965; Reiss & Wagner, 1972), or learns to ignore (Mackintosh, 1973), the familiar stimulus. This results in a reduction in the ability of the preexposed stimulus to enter into subsequent associations but without the stimulus developing inhibitory or safety properties. Indeed, Rescorla (1971) and Reiss and Wagner (1972) have presented evidence in support of this "salience-decrement" hypothesis. They have shown that while preexposure retards acquisition, the preexposed stimulus does not acquire the capacity to actively inhibit responses to an excitatory CS when the two stimuli are compounded in a summation test. These results must be viewed with caution, however, since Kremer (1972) has demonstrated, directly contrary to the findings of Rescorla (1971) and Reiss and Wagner (1972), that a preexposed stimulus can indeed inhibit responses to an excitatory CS in a summation test.

Although the learned-safety and salience-decrement hypotheses both agree that preexposing the CS that signals shock in avoidance training should retard subsequent avoidance conditioning, they make diverging predictions concerning the effects of preexposing the FS. The learned-safety account suggests that preexposing the FS should endow it with safety properties making it a potent reinforcer of avoidance behavior, thus facilitating avoidance acquisition. The salience-decrement view, on the other hand, holds that preexposure should disrupt safety signal conditioning. Ignoring the prexposed stimulus should result in a reduction in the ability of that stimulus to form subsequent associations, regardless of whether the association involves predicting the presence or absence of the US. Thus, if the animal is ignoring the preexposed FS, having an avoidance response followed by delayed CS termination plus the familiar FS should be functionally equivalent to delayed CS termination and no FS. This latter procedure has been shown (Bolles & Grossen, 1969; Delprato, 1969; Kamin, 1957 b,c; Mowrer & Lamoreaux, 1942) to seriously disrupt avoidance learning. Consequently, the salience-decrement view would predict that preexposing the FS should retard subsequent avoidance acquisition.

The purpose of the present experiment was to determine if, as learned-safety proposes, simple preexposure endows a stimulus with safety properties. This learned-safety hypothesis was tested against a salience-decrement account by comparing avoidance acquisition rates of three groups preexposed to the CS, FS, or neither and then trained on a two-way avoidance task in which CS termination was delayed and a FS was presented following escape and avoidance responses. Both the learned-safety and salience-decrement views predict that preexposing the CS should retard avoidance acquisition, but only the salience-decrement view predicts that preexposing the FS should also retard avoidance conditioning.

The learned-safety formulation, on the other hand, predicts that preexposing the FS should not interfere with avoidance conditioning and should perhaps facilate avoidance acquisition.

In addition to the above test, this experiment was also designed to provide an assessment of the FS contingency itself. A second nonpreexposed group was included which did not have the FS presented following escape and avoidance responses. If the FS contingency is important, then this group should not perform as well as the nonpreexposed group with the FS contingency in effect during avoidance training.

5.8.1 Method

5.8.1.1 Subjects - Subjects were male albino, Charles River rats, 275-325 grams, obtained from Canadian Breeding Farms, Quebec. Each rat was housed in its own cage with food and water freely available.

5.8.1.2 Apparatus - The shuttlebox used in the previous experiments again was used here. A 7.62 cm metal (nonelectrified) barrier which separated the shuttlebox into two identical compartments was added. The tone CS was changed to 1000 Hz. at 85 db (re. .002 dynes/cm^2) and constant white noise at 70 db was delivered by a Grason-Stadler White Noise Generator (model # 901A) through the two recessed speakers located on each side wall of the sound-attenuating enclosure. The light stimulus consisted of the simultaneous onset of the house light and two cue lights located 12.70 cm above the grid floor in the center of each end wall of the shuttlebox. The shock intensity was set at .5 mA.

5.8.1.3 Procedure - Each rat was run in a single session, which consisted of two phases: 100 preexposure trials followed immediately by 200 avoidance training trials. Total session time was approximately 5-1/2 hours. Subjects were randomly assigned to one of four groups. Four rats were discarded because they perched on the metal barrier during avoidance training and two additional rats were discarded because of apparatus failures. These six rats were replaced with naive rats until each of the four groups described below had a total of 10 subjects:

PE-CS - (preexposed to the conditioned stimulus) The first row of Figure 19 depicts the stimulus experiences of Group PE-CS during preexposure, escape, and avoidance trials. As can be seen in Figure 19, this group was placed in the shuttlebox and given 100 preexposures to the 5 sec. 85 db. tone which served as the conditioned stimulus in subsequent avoidance training. During the preexposure phase, the inter-stimulus interval averaged 60 sec. (range: 30-90 sec.). Shuttle responses during preexposure trials had no programmed effects on the presentation or termination of the stimulus. Following the last preexposure trial, the avoidance training phase was initiated. Each trial in this phase of the experiment started with the onset of the tone conditioned stimulus. If the rat failed to move from one compartment to the other during the first 5 sec. of the CS, a continuous .5 mA shock was delivered to the rat via the grid floor. The CS and shock remained on until a shuttle response was made, at which time the shock immediately terminated; the CS, however, remained on for an additional 5 sec. during which time the "lights on" feedback stimulus was presented. Five sec. following the response the CS and FS both terminated. If the rat shuttled to the other compartment during the first 5 sec. of the CS, shock was avoided, the CS remained on and was accompanied by the FS during the 5 sec. interval following the avoidance response. Additional responses during the 5 sec. feedback period had no effect on stimulus events. Training was carried out in darkness (except when the lights on FS was presented) with an intertrial interval continuing to average 60 sec.

PE-FS - (preexposed to the feedback stimulus) As the second row of Figure 19 indicates this group received similar preexposure and avoidance training as the PE-CS group except that preexposure consisted of 100, 5 sec. presentations of the lights on FS.

NPE - (nonpreexposed with feedback stimulus during avoidance training) - This group spent the same period of time in the darkened shuttlebox (108.33 min.) as the two preexposed groups prior to avoidance training. As shown in the third row of Figure 19, subjects in this group, however, were not exposed to either the tone or light stimuli used in subsequent avoidance conditioning which was identical to that in the above two groups.

NPE (NO FS) - (nonpreexposed with no feedback stimulus during avoidance training) - The fourth row of Figure 19 depicts the stimulus experience of Group NPE (NO FS). This group also spent 108.33 min. in the darkened shuttlebox prior to avoidance training with neither the tone or light stimuli presented. Avoidance training, however, was different in this group in that the light FS was omitted following escape and avoidance responses. Following these responses, the CS remained on for an additional 5 sec. but <u>no other</u> stimulus was presented. This group was included to assess the significance of the FS contingency in the other three groups.

5.8.2 Results

Figure 20 presents the mean percent avoidance responses in 10 successive blocks of 20 trials for the four groups. As indicated in Figure 20, avoidance conditioning in the two pre-exposed groups (PE-CS and PE-FS) and in the nonpreexposed group without the FS contingency (NPE (NO FS)) was retarded as compared to the nonpreexposed group with the FS contingency (NPE) over the entire 200 trial session. Side A of Figure 21 shows the mean percent avoidance responses for each group collapsed over the 200 avoidance training trials. A two-way mixed design analysis of variance yielded significant Groups ($F[3,36] = 7.99, p < .005$, Trials ($F[9,324] = 24.94$, $p < .001$), and Groups X Trials ($F[27,324] = 1.94$ $p < .01$) effects. Newman-Keuls tests of individual comparisons showed that Group NPE made significantly more avoidance responses

Figure 19. Schematic representation of preexposure, escape, and avoidance trials for each of the four groups in Experiment 5. (PE-CS = preexposed to the conditioned stimulus; PE-FS = preexposed to the feedback stimulus; NPE = nonpreexposed with FS during avoidance training; NPE (NO FS) = nonpreexposed without FS during avoidance training).

FIGURE 19

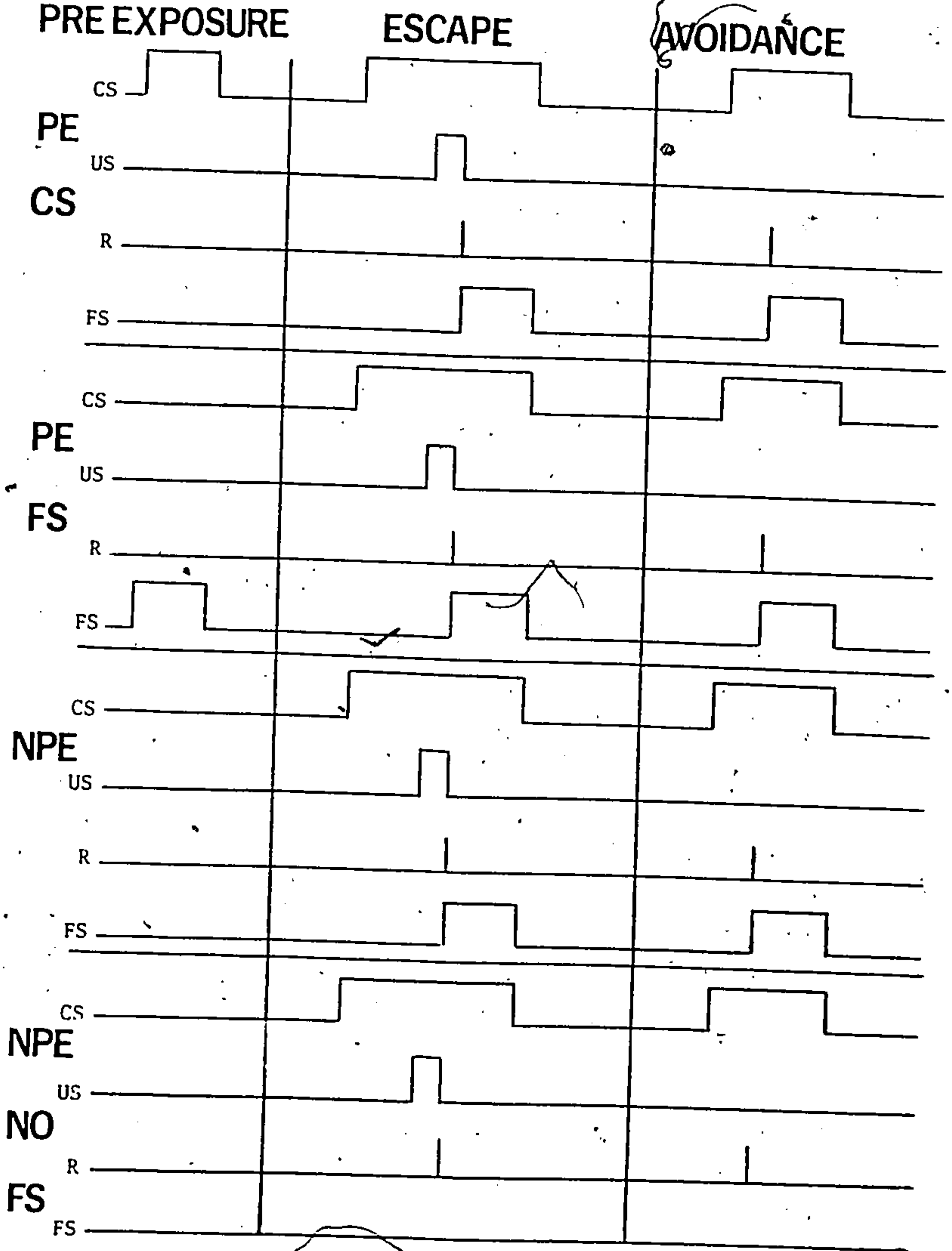
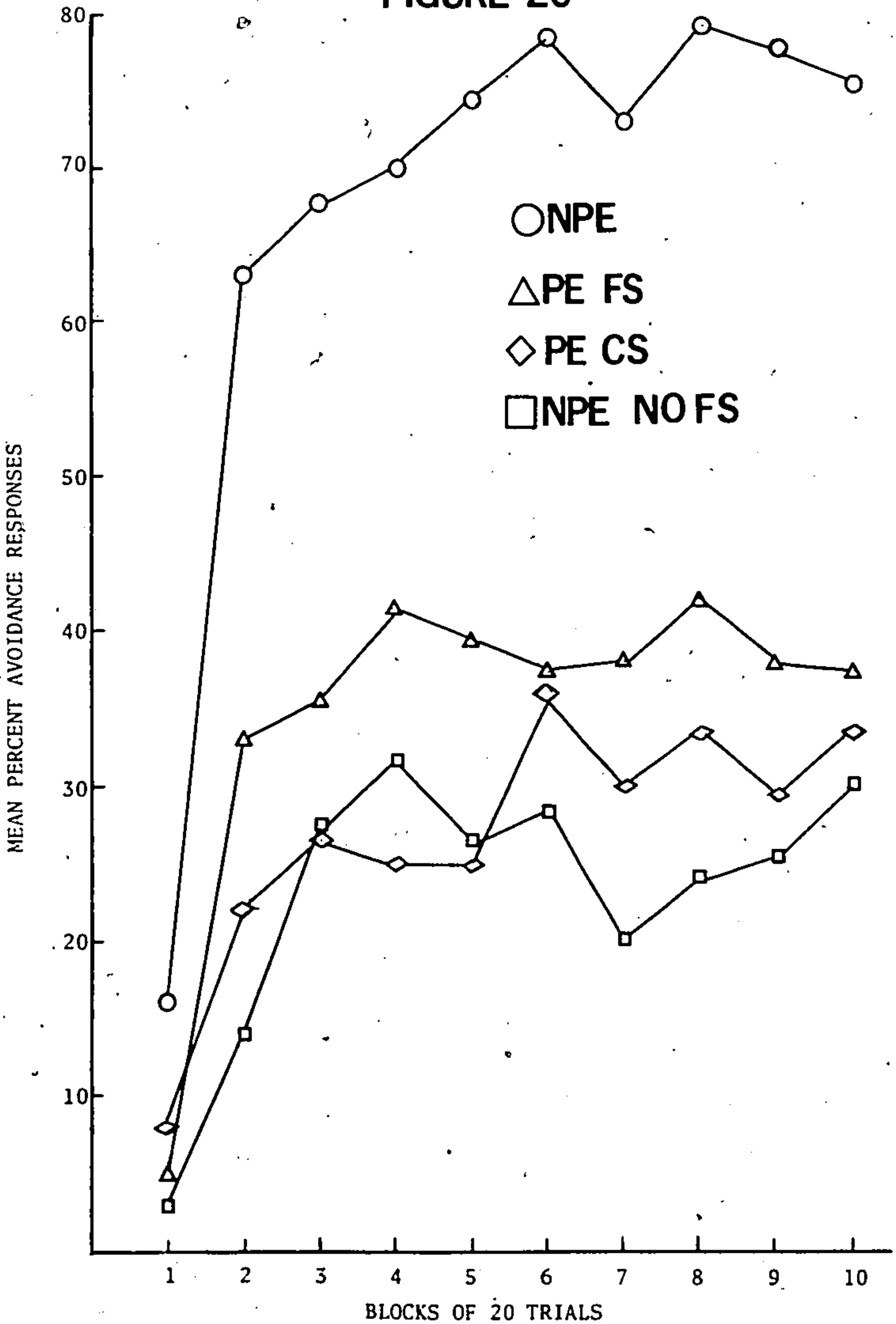

PRE EXPOSURE
ESCAPE
AVOIDANCE
PE CS
CS
US
R
FS
PE FS
CS
US
R
FS
NPE
CS
US
R
FS
NPE NO FS
CS
US
R
FS

Figure 20. Mean percent avoidance responses over 10 blocks of 20 avoidance training trials in Experiment 5 (n = 10 per group).

FIGURE 20



80
70
60
50
40
30
20
10
MEAN PERCENT AVOIDANCE RESPONSES
ONPE
△PE FS
◇PE CS
□NPE NO FS
1
2
3
4
5
6
7
8
9
10
BLOCKS OF 20 TRIALS

than Groups PE-CS, PE-FS, and NPE (NO FS) ($ps < .01$) but no other comparisons were significant.

Side B of Figure 21 depicts the mean number of trials required to meet an avoidance criterion of eight responses in a block of 10 trials (8/10). A one-way analysis of variance revealed a significant difference between groups in the number of trials required to reach the 8/10 criterion ($F[3,36] = 6.56$, $p < .005$). Newman-Keuls comparisons indicated that Group NPE reached the criterion in significantly fewer trials than Groups PE-CS ($p < .01$), PE-FS ($p < .05$) and NPE (NO FS) ($p < .01$). Again, no other paired comparisons were significant.

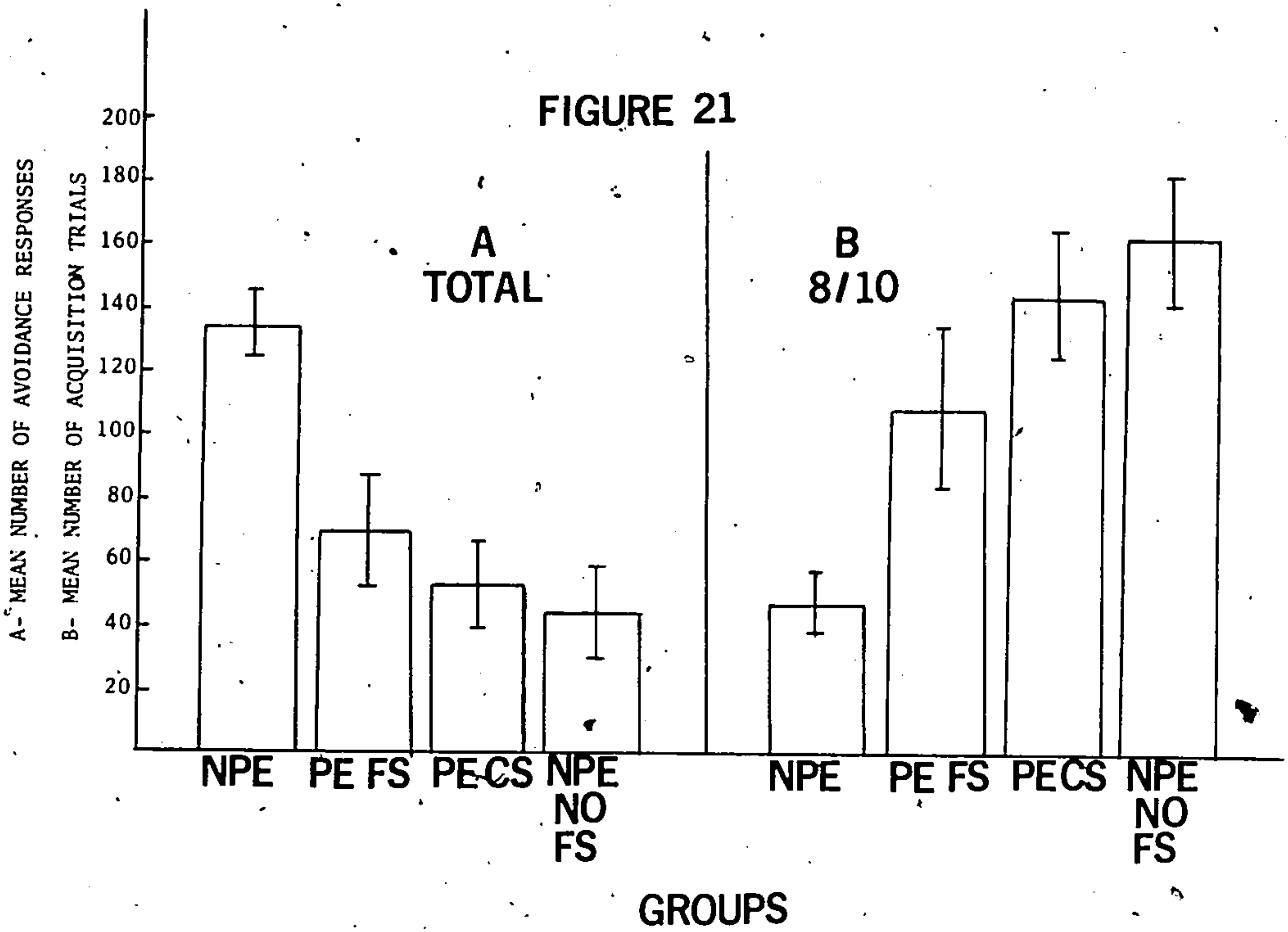
The groups also differed in terms of the percentage of subjects per group to reach the 8/10 acquisition criterion. Indeed, Group NPE was the only one in which all subjects reached this criterion in the 200 trial session. Tests of significance between two-independent proportions indicated that the differences in the number of subjects per group that reached the criterion were statistically significant between Group NPE and Groups PE-CS ($z = 2.58$, $p = .01$), PE-FS ($z = 2.24$, $p < .05$) and NPE (NO FS) ($z = 3.28$, $p < .01$ - all tests two-tailed).

5.8.3 Discussion

In this experiment (#5), nonpreexposed subjects learned to avoid reliably only when the feedback stimulus contingency was in effect (Group NPE). This finding supports previous demonstrations

Figure 21. A Mean number of avoidance responses in the 200 trial session for each of the four groups in Experiment 5. B Mean number of trials required to make eight avoidance responses in a block of 10 trials (8/10) for each of the four groups in Experiment 5.

FIGURE 21


A- MEAN NUMBER OF AVOIDANCE RESPONSES
B- MEAN NUMBER OF ACQUISITION TRIALS
200
180
160
140
120
100
80
60
40
20
A
TOTAL
B
8/10
NPE
PE FS
PE CS
NPE NO FS
NPE
PE FS
PE CS
NPE NO FS
GROUPS

(e.g., Bolles & Grossen, 1969) that the presentation of a response-contingent feedback stimulus prevents disruption of avoidance learning when CS termination is delayed following avoidance responses.

In addition, the large decrement in acquisition observed in the group preexposed to the conditioned stimulus (PE-CS) upholds previous demonstrations of a robust latent inhibition effect in the two-way avoidance learning paradigm (Ackil & Mellgren, 1968; Ackil et al. 1969). This result is predicted by both a learned-safety and a salience-decrement hypothesis of latent inhibition.

The performance of the group preexposed to the feedback stimulus (PE-FS) is perhaps most pertinent to the theoretical issues at hand. The retardation of avoidance acquisition observed in this group does not support a learned-safety analysis which predicts that acquisition in this group should have been facilated (or at least not retarded). Supposedly as a result of preexposure, the feedback stimulus enters the conditioning phase already possessing salient safety properties. This disconfirming finding is congruent with the results of recent studies which show that preexposure retards rather than facilates learning that the familiar stimulus predicts the absence of aversive consequences (Best, 1975; Rescorla, 1971, Expt. 2) or the occurrence of positive reinforcement (Halgren, 1974). These findings taken together suggest that a learned-safety hypothesis may not be a viable explanation of the latent inhibition effect.

According to a salience-decrement formulation, if a stimulus receives repeated nonreinforced exposures the subject stops paying attention to it. This could result in a reduction in the ability of that stimulus to form subsequent positive or negative associations. Thus, the finding that avoidance learning was retarded in both PE-CS and PE-FS groups is compatible with a salience-decrement account of latent inhibition (Lubow, 1965; Mackintosh, 1973; Rescorla, 1971).

In conclusion, the findings that preexposing either the CS or the FS leads to a significant decrement in subsequent acquisition of the avoidance response fail to support a learned-safety hypothesis. In addition these findings, along with those of Experiment 4, lend some support to Rescorla's (1969a,c; Rescorla & LoLordo, 1965) contention that in order for a stimulus to acquire safety properties it must be negatively correlated with the occurrence of the aversive event (i.e., reliably predict the absence of shock). Simply presenting a stimulus a number of times by itself does not appear to endow that stimulus with true inhibitory or safety properties.

CHAPTER VI

SUMMARY AND CONCLUSIONS

This thesis has attempted to extrapolate the role played by Pavlovian conditioned inhibition in avoidance learning. The working hypothesis throughout this paper has been that response-contingent feedback stimuli (FSs) develop inhibitory properties and these properties are involved in the observed reinforcing function of FSs. It was suggested that if the above hypothesis is correct, two converging findings should be obtained. First, the inhibitory strength of a FS should covary with its reinforcing capacity. Indeed, the results of Experiment 1 and 2 showed that the more effective clicker-FS also exhibited greater inhibition after avoidance training than a less effective tone-FS. While this finding is supportive, it alone did not provide sufficient evidence to conclude that inhibition accruing to the FS serves as the reinforcing mechanism. Before this statement could be accepted with confidence, it was also necessary to show that a known conditioned inhibitor is a more powerful reinforcer of avoidance behavior than a non-inhibitory stimulus. The results of Experiments 3 and 4 supported this hypothesis by providing a demonstration that a pretrained conditioned inhibitor (Experiment 3), when used as a FS, greatly facilated the acquisition of a new avoidance response (Experiment 4). Stimuli that were either randomly presented with respect to shock during pretreatment or novel did not possess this extra reinforcing property (Experiment 4). Moreover, Experiment 5 showed that a FS that received exposures in the total absence of shock prior to avoidance conditioning also did not develop reinforcing properties. Indeed, the results suggested that the potential for developing such properties during avoidance learning itself is retarded as a result of simple pre-exposure.

An attempt was also made in this thesis to outline, in detail, two-factor avoidance theory and, to a lesser extent, describe other current theoretical formulations of avoidance learning. Emphasis was placed on two-factor theory for a number of reasons. First, the history of the evolution of two-factor theory is interesting and offers insights into the nature of scientific inquiry and judgment. Second the theory seems to be the basis for much of the important experimental work in avoidance learning over the years. Third, and perhaps most importantly, a recent version of the theory (Anger, in press) appeared to be more successful than any other formulation in accounting for the vast array of avoidance phenomena. It was pointed out, however, that Anger's powerful version of two-factor theory had at least one serious flaw - it could not account for Pavlovian inhibitory processes that apparently play a part in avoidance learning.

Fortunately, this weakness of the theory was easily overcome by incorporating a contingency model of Pavlovian conditioning (Rescorla, 1967) into Anger's conditioned aversiveness (CA) formulation. By taking into account shocks/nonexposure as well as shocks/exposure two-factor theory can now measure and predict the full range of potential (positive or negative) conditioned aversiveness that can accrue to a stimulus. Moreover, it removes the necessity for positing cumbersome alternative mechanisms (e.g., conditioned relaxation, expectancies, positive reinforcement) to account for the existence and function of inhibitory stimuli in avoidance situations. The development of excitatory or inhibitory properties to a particular stimulus in the avoidance situation can be easily ascertained by examining both its shocks/exposure and its shocks/nonexposure values. The reinforcing nature of these stimuli can be handled by a straightforward conditioned aversiveness reduction view which looks at both the CA of stimuli preceding avoidance responses and the CA of stimuli immediately following responses. The degree of reduction in CA resulting from the substitution of the former set of stimuli by the latter will determine the relative amount of reinforcement available for the response that produces this change in stimulation. Thus, according to this view, inhibitory feedback stimuli, with their negative CA values, promote rapid acquisition and strong persistence of responding by providing a greater amount of aversiveness reduction following avoidance responses than non-inhibitory FSs.

This thesis has attempted to provide further support for the notion that Pavlovian processes are solidly implicated in avoidance learning. It appears that a large amount of avoidance data can be adequately explained only if appeals are made to Pavlovian excitatory and inhibitory mechanisms. The contingency version of two-factor theory proposed in this thesis does appear to satisfactorily handle the majority of avoidance phenomena. Although the contingency view has enhanced the explanatory and predictive powers of two-factor theory, the problems that are inherent in the contingency model itself cannot be ignored (see footnote 22). It is important, therefore, that avoidance theorists keep abreast of issues within the Pavlovian conditioning literature. By monitoring the latest theoretical trends and empirical findings, avoidance theorists will be able to extend their knowledge and understanding of the role that Pavlovian processes play in avoidance learning.

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