AN EXAMINATION OF THE INVERTED-U CURVE: A BEHAVIOURAL AND A PHYSIOLOGICAL APPROACH

A thesis submitted in partial fulfilment of the requirements for the degree of Doctor of Philosophy.

by

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PREFACE

A portion of this research is being published in the following paper:

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ABSTRACT

According to activation theory, there is a continuum of "activation", i.e. greater and lesser degrees of neural activity extending from the reticular formation to the cortex, to the spinal cord and to the periphery, e.g. the autonomic nervous system. Increases in activation produce an inverted-U change, i.e. a sequence of improvement and impairment, in behaviour.

Chapter 1 reviews the evidence in support of activation theory.

In infra-human species, physiological studies tend to substantiate activation theory. In particular, Wayner's (1974) work suggests that there is a continuum of spinal reflex discharges in the brain stem motor control system.

In infra-human species, behavioural studies have not adequately tested activation theory. Nevertheless, inverted-U changes in behaviour as a function of the intensity of stimulation have occasionally, but reliably, been reported (Yerkes and Dodson, 1908; Broadhurst, 1957; Moyer and Korn, 1964).

The aim of the present thesis is to determine whether activation theory can predict the physiological and the behavioural functioning of intact, unanaesthetized rats which have not been chemically altered or lesioned.

Chapter 2 considers the type of paradigm in which activation theory may be evaluated. The common approach of correlating different indices of nervous system responses to external stimuli (Malmo, 1959)

appears to be unsatisfactory. Another approach, derived from investigations of the summation of "drives" (Bolles, 1967) and of the interaction of "stresses" (Wilkinson, 1969), allows more control over the sources of variance which influence nervous system responses.

Two predictions of activation theory are tested:

(i) that stimuli combine to heighten activation, as indexed by nervous system increases, and,

(ii) that stimuli combine to heighten activation, as indexed by either improvement or impairment in behaviour, depending on the intensity of stimulation; at low intensities, combinations alter activation from low to moderate levels and, thereby, improve behaviour and, at higher intensities, combinations alter activation from moderate to high levels and, thereby, impair behaviour.

The physiological prediction was considered in Chapter 4. Consistent with the expectations of activation theory, a loud burst of white noise plus a moderate shock elicited greater conditioned increases in skin conductance than a weak burst of white noise plus a moderate shock.

The behavioural prediction was considered in Chapter 3. An inverted-U trend in shuttleavoidance as a function of the intensity of either white noise or shock was obtained. Contrary to the expectations of activation theory, however, a decreasing monotonic trend in shuttle-avoidance as a function of the intensity of white noise plus shock did not eventuate.

While there seems to be support for the possibility of a continuum of activation in the nervous system, then, increases in activation are not sufficient to produce a sequence of improvement and impairment in shuttling. Accordingly, Chapter 5 appraises other ways of explaining this sequence (the so-called "inverted-U curve"). Most explanations, except those which contain postulates about competing responses, can be rejected.

Chapter 6 evaluates postulates about competing responses by means of the following assumptions: competing responses develop when subjects are required to approach shock-related cues and these responses do not develop when subjects are allowed to approach shock-unrelated cues; therefore, the supposed consequence of competing responses, *viz.* inverted-U curves, should occur in the former case but not in the latter case. Compared with subjects which approached shock-related cues, subjects approaching shock-unrelated cues evidenced better shuttling at a high intensity of shock as well as, inexplicably, at low intensities of shock.

An attempt to account for these data prompted the manipulation of two variables, i.e. the number and the type of CSs. This manipulation is reported in Chapter 7, where the effects on shuttle-avoidance of one CS and of two CSs were compared under three conditions:

(a) the presentation of a visual CS (light or darkness) in the occupied compartment and/or the presentation of a tone CS;

(b) the presentation of a visual CS (light or darkness) in both compartments either alone or together with a tone CS; and,

(c) the presentation of a visual CS (light or darkness) in the to-be-entered compartment either alone or together with a tone CS.

At high intensities of shock, a CS, presented in the occupied compartment only, appeared to eliminate competing responses and, thus, to enhance shuttling. At low intensities of shock, a CS, involving a dark-to-light change only, combined with a tone CS to facilitate shuttling. This facilitation appeared to represent a "sensitization" (Duffy, 1972; Hinde, 1966, 1970) of the tone by a sensory change of particular relevance to albino rats.

On the basis of these results, Chapter 8 argues that the inverted-U relationship between shuttleavoidance and shock is due to the antagonistic operation of incremental and of decremental influences, or reinforcements. In particular, inverted-U relations occur with the combination of these influences in the same situation; also, inverted-U relations seem to be predictable from an addition of the effects of the operation of these influences in separate situations.

The foregoing argument suggests a possible inadequacy in the experiments of Chapter 3 where white noise and shock were combined in a situation which confounded incremental and decremental influences. These stimuli may have heightened activation and, in consequence, may have simultaneously altered shuttling in opposite directions, so that shuttling appeared to be unaffected. Consequently, it seemed necessary to isolate incremental and decremental influences and, then, to re-examine combined and separate presentations of white noise and of shock. In accord with activation theory, white noise plus shock might be expected to improve shuttleavoidance compared to shock alone in the presence of the incremental influence and, in contrast, white noise plus shock might be expected to impair shuttleavoidance compared to shock alone in the presence of the decremental influence. These predictions were not confirmed in Chapter 9.

In general, there is evidence in support of the possibility of a continuum of activation in the nervous system. However, there is no evidence to suggest that increases in activation *per se* are related to the incremental and decremental influences which are responsible for sequences of improvements and impairments in behaviour.

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CHAPTER 1

ACTIVATION THEORY

1.1 OUTLINE

The concept of "activation", or "arousal", derives its name from the study of the activity of the reticular formation. This concept has been employed to construct an activation theory of motivation, which attempts to predict the physiological and the behavioural functioning of organisms.

The present chapter is divided into three sections considering, in turn, the reticular formation, the impact of activation theory on the study of motivation in humans and the impact of activation theory on the study of motivation in animals.

1.2 RETICULAR FORMATION

The concept of activation was introduced to describe the activity of the reticular formation, outlined below.

1.2.1 ANATOMY

Cajal (1909) depicted the reticular formation as a ventral core of neural tissue, composed of intermingled cell bodies and fibres with the appearance of a "reticulum" or network.

According to Brodal (1957), the neural tissue is located largely within the brain stem, but also extends into the tegmentum of the midbrain and diencephalon of the forebrain, including the hypothalamus and the thalamus; this tissue is penetrated by ascending pathways (the so-called "ascending reticular activating system" or ARAS) which relay sensory impulses to the cerebral cortex and descending pathways which send motor impulses to the spinal cord.

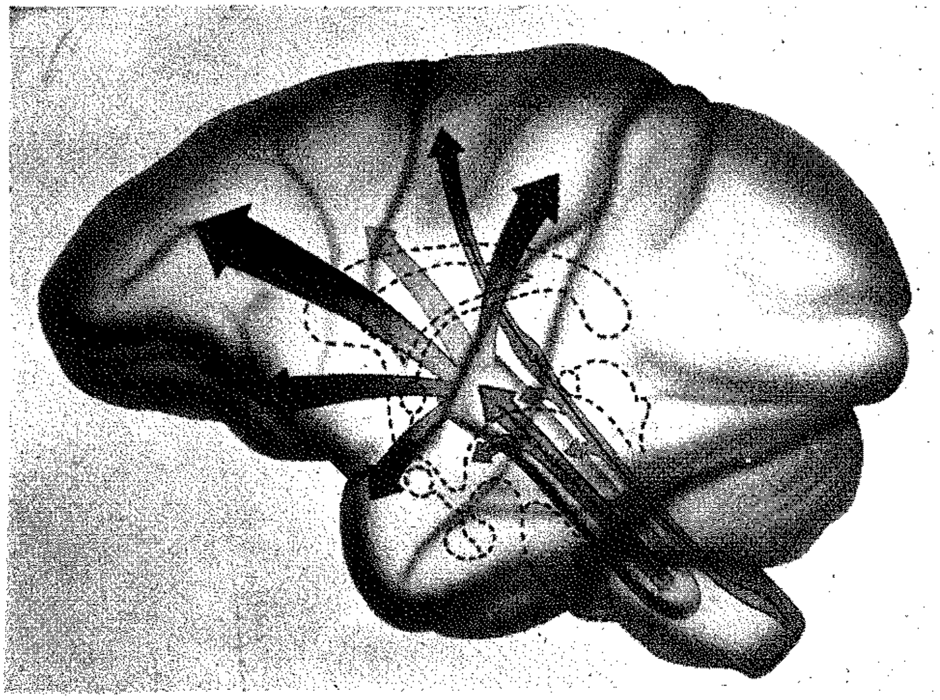
The ARAS receives input from the major sensory systems, and, in turn, conveys the input to the cortex (see Figure 1.1) either directly via diffuse extrathalamic projections through the ventrolateral diencephalon (Nauta, 1958), or indirectly via a number of reticulo-thalamic connections (Grossman, 1967; Thompson, 1967).

1.2.2 FUNCTION

Early workers in the field of electroencephalography (EEG) discovered distinctive wave patterns in the cortex characterizing the progression from deep sleep to highly alerted states (Jasper, 1941; Lindsley, 1951).

They demonstrated that, in light sleep, there is a predominance of high amplitude, low frequency waves of a regular, synchronized pattern. Drowsiness is associated with lower amplitude, higher frequency waves. In relaxed wakefulness, "alpha" waves, in the 8-13 cps range, are pronounced. When alerted, organisms exhibit an "activation pattern" characterized by the reduction or abolition of alpha rhythms and the induction of "beta" waves, in the 18-27 cps range, of an irregular, desynchronized pattern (Lindsley, 1958).

One function of the ARAS seems to be control of these sleep-waking waves. In particular, stimulation of the ARAS changes waves indicative of sleep to those manifesting wakefulness; conversely, lesions in the ARAS produce changes in the opposite direction. Thus, Moruzzi and Magoun (1949) reported that electrical stimulation of the



Ascending reticular activating system (ARAS) schematically projected on monkey brain. Reticular formation, consisting of multineuronal, multisynaptic central core of region from medulla to hypothalamus, receives collaterals from specific or classical sensory pathways, projects diffusely upon the cortex.

Figure 1.1. Lindsley's (1957) conception of the ascending reticular activating system.

ARAS transforms a sleep pattern into an activation pattern. In an experiment by Lindsley, Bowden and Magoun (1949) on an isolated cat's brain, severed from the spinal cord at the first cervical level, progressively higher transections of the brain stem gave rise to increasingly more synchronized, slow waves as more and more of the reticular formation and its collaterals from sensory pathways were eliminated. Finally, with lesions of the central reticular core, but with sensory pathways intact, or with lesions in the hypothalamus in the region of reticular projections, a chronic pattern of deep sleep was observed.

Although these general findings have been confirmed, more recent work does not suggest a necessary relation between neural activity in the ARAS and sleep-waking waves. For example, in the forebrain, some reticular cells show bursts of discharges during activation patterns but others do not (Machne, Calma and Magoun, 1955). Also, in the midbrain, some reticular cells fire at greater rates in the presence of synchronization than that of desynchronization (Thompson, 1967).

The link between neural activity in the ARAS and sleep-waking waves is further complicated by a consideration of behavioural measures. For example, extensive midbrain reticular lesions, performed in one operation, had the effect of inducing sleep waves as well as comatose behaviour, whereas similar lesions, performed in two operations did not (Adametz, 1959). Also, fairly extensive midbrain lesions had deleterious, but transitory, consequences; with extensive post-operative care, many subjects showed a marked recovery of waking waves and of alerted behaviour (Doty, Beck and Kooi, 1959). As Thompson (1967) concludes, therefore, the reticular formation may not be an "absolutely essential structure" in the production of activation patterns and of responsiveness to the environment.

This conclusion has been supported by data on the "dissociation" between sleep-waking patterns and behaviour under certain conditions (Lacey, 1967). For example, desynchronization may occur in the presence of drowsy or somnolent behaviour after the administration of drugs like physostigmine (Bradley, 1958), after lesions of the posterior hypothalamus (Feldman and Waller, 1952) and, also, in a number of hospitalized patients (Loeb, 1959). Conversely, behavioural wakefulness may occur in the presence of sleep waves with the administration of drugs like morphine (Wikler, 1952; Bradley, 1964), with lesions of the reticular formation (Feldman and Waller, 1952) and, also, in a number of schizophrenic patients (Dureman and Edström, 1964). These data have led Routtenberg (1968) to postulate that two systems control sleep-waking waves and behaviour, *viz.* Arousal System 1 or the ARAS and Arousal System 2 or the limbic connections. Although the ARAS normally exercises control, the limbic connections are thought to assume control in an emergency, e.g. in the case of damage to the ARAS.

Further, dissociation has been noted in deep sleep. In the 1930's, Klaue reported a particular sequence of sleep: a period of light sleep, in which the cortex produces slow waves, followed by a period of deep sleep, called rapid-eye-movement sleep or paradoxical sleep, where the cortical waves speed up but where there is muscle atony and unresponsiveness to non-intense levels of sound and of electrical stimuli.

Working with cats, Jouvet (1967) found suppression of ARAS activity by a light sleep centre in the raphé cells in the midline of the brain stem and by a rapid-eye-movement sleep centre in the locus coeruleus in the dorsal part of the pons. The raphé cells appeared to control light sleep by means of the secretion of serotonin, while the locus coeruleus appeared to control rapid-eye-movement sleep via the secretion of noradrenalin.

1.2.3 CONCLUSION

Activation patterns in the cortex and in behaviour may recover from extensive damage to the ARAS and may operate independently of each other (Routtenberg, 1968). Nevertheless, these patterns are usually controlled by ARAS mechanisms (Thompson, 1967) and are usually linked in a consistent way (Duffy, 1972).

At least in the waking state, then, the statement that activity of the ARAS regulates cortical EEG waves and behaviour in intact organisms, under normal circumstances, is tenable. In contrast, in the sleeping state, activity of the ARAS is, apparently, suppressed by sleep centres (Jouvet, 1967); accordingly, cortical EEG waves and behaviour exhibit a complex inter-relationship as, for example, in rapid-eye-movement sleep.

1.3 ACTIVATION THEORY

Incorporation of the foregoing work into psychology was facilitated by an experiment demonstrating the relationship between the ARAS and behaviour.

Electrical stimulation of the ARAS at moderate intensities enhanced the speed and the accuracy of visual discriminations in monkeys and that at higher intensities had the opposite effects, producing deteriorations in reaction times and in the number of correct responses (Fuster, 1958). In other words, increases in the level of bombardment of the ARAS, or "the level of activation" (Malmo, 1959), gave rise to inverted-U (curvilinear, non-monotonic, quadratic) changes, i.e. improvements and, then, impairments, in the efficiency of behaviour.

This experiment by Fuster provided the impetus for the use of ideas about the ARAS in the psychology of motivation, which is concerned with the "causes", "driving forces" or "energization" of behaviour.

Accordingly, statements about the ARAS and its relation to behaviour were developed into an activation "theory" of motivation by Hebb (1955), by Malmo (1959) and by Duffy (1962, 1967, 1972).

The impact of activation theory on the study of motivation is discussed below, first, in relation to human subjects and, secondly, in relation to animals.

1.3.1 IMPACT OF ACTIVATION THEORY ON THE STUDY OF MOTIVATION IN HUMANS

Historically, Duffy's (1934) concept of "energy mobilization" ("excitation", "intensity") preceded that of activation. In an early study, Stauffacher (1937) found inverted-U changes in the ability to recall nonsense syllables with the heightening of energy mobilization, manipulated by the degree of induced muscle tension.

The discovery of the ARAS together with Fuster's demonstration of the relation between the ARAS and behaviour lent credence to the Duffy-Stauffacher approach and generated new lines of physiological enquiry and of behavioural enquiry.

At the physiological level, the main interest consisted in examining whether activation was the major variable of the so-called "conceptual nervous system" (Hebb, 1955). This examination, which took the form of correlating different nervous system responses to stimuli, is considered in detail in Chapter 2.

At the behavioural level, research focused on the conditions under which behaviour is maximized. In accord with the expectations of activation theory, two hypotheses were tested:

(i) that there is optimal performance at, and preference for, the moderate levels of activation induced by moderate intensities of stimuli, and,

(ii) that performance is, in fact, determined by the level of activation induced by the intensity of stimuli.

1.3.1.1 PERFORMANCE-PREFERENCE AND THE INTENSITY OF STIMULI

A. Performance and the Intensity of Stimuli.

Optimal performance at moderate intensities has been regularly reported (Broadbent, 1971; Duffy, 1962, 1972; Poulton, 1970) in the case of physical stimuli, such as muscle tension (Shaw, 1956; Shore, 1958), noise (Broadbent, 1971; Reiter, *et al.*, 1963; Teichner, *et al.*, 1963), shock (Tuton, 1970) and sleep deprivation (Corcoran, 1964; Malmo and Surwillo, 1960) and in the case of nonphysical stimuli, such as "emotion" (Berry, 1962; Janis, 1967; Kleinsmith, *et al.*, 1963; MacGuire, 1969; Walker and Tarte, 1963) and "incentives" (Martens and Landers, 1970; Stennett, 1957).

B. Preference and the Intensity of Stimuli.

Since optimal performance was associated with moderate intensities of stimuli, it was thought that individuals would prefer to maximize exposure to these intensities (Hebb, 1955).

Using verbal expressions of choice as the measure of preference, Berlyne (1967), in particular, has investigated preferences for so-called "collative" attributes, e.g. complexity, congruity, novelty and predictability. These attributes have been mostly shown to manipulate nervous system indices of activation, like skin conductance and the desynchronization of cortical EEG waves (Berlyne, 1960, 1961; Berlyne, *et al.*, 1963; Berlyne and Lawrence, 1964; Berlyne and McDonnell, 1965; Berlyne, *et al.*, 1966).

According to Berlyne (1967), individuals seek a medium, compared to a low and to a high, degree of any collative variable in various modalities of stimulation, such as audition (Overmeir, 1962; Vitz, 1966b) and vision (Dorfman, 1965; Vitz, 1966a; Wohlwill, 1970). However, some authors have noted monotonic, rather than non-monotonic relations between preference and the degree of a collative attribute (Jones, *et al.*, 1961; Jones, 1964; Terwilliger, 1963; Thomas, 1966; Vitz, 1964). Other investigations have produced complex functions, with two major peaks, and often other subsidiary peaks as well, when preference was plotted against the degree of a collative attribute, such as complexity (Berlyne and Peckham, 1966; Day, 1965, 1967; Munsinger and Kessen, 1964).

Therefore, verbal expressions of choice as the measure of preference do not always support the postulate that individuals seek a medium degree of a collative attribute.

Nevertheless, if one assumption is made, then this postulate may be re-examined within the context of the literature on "sensory deprivation"-"sensory satiation" (Bexton, *et al.*, 1954; Zubek, 1969). In particular, it may be assumed that verbal expressions of choice of collative attributes, under normal circumstances, are related to behavioural indices of choice, e.g. changes in response probabilities, following the deprivation or the satiation of collative attributes.

Thus, for example, Jones and McGill (1967) evaluated the effects of deprivation-satiation on the selection of one kind of collative attribute, *viz.* predictability. After ten hours of auditory and of visual deprivation, subjects were given the opportunity of switching on sequences of predictable tones and sequences of unpredictable tones. The rate of switching was positively related to the unpredictability of the sequences. Also, subjects were exposed to, presumably, the differential satiation of unpredictability, i.e. subjects listened to unpredictable tones either for one hour or for five hours. Subsequently, the one-hour satiated subjects switched on sequences of greater unpredictability than the five-hour satiated subjects. In the view of Jones and McGill, deprivation or satiation induce a "drive" process, which attempts to maintain a medium degree of incoming sensory information.

Apart from the procedural problem that it is difficult to deprive subjects of only one collative attribute, the preceding experiment does suggest the seeking of a medium degree of a collative attribute. Similarly, the results of other experiments on "arousal-seeking" (Schubert, 1965), on "sensation-seeking" (Zuckerman, *et al.*, 1964) and on sensory deprivation-sensory satiation (Zuckerman, 1969) are consistent with this suggestion.

1.3.1.2 PERFORMANCE AND THE LEVEL OF ACTIVATION

A series of British studies attempted to demonstrate that performance is determined by the level of activation induced by the intensity of stimuli.

These studies hypothesized: if two stimuli, or, "stresses" have the same effects on the same measures of behaviour, then it is legitimate to think of a single mechanism, e.g. activation, mediating reactions to stress (Broadbent, 1963). Different stresses were found to have divergent effects (Broadbent, 1971; Poulton, 1970) and so stresses did not appear to affect a single mechanism. Divergent effects could, however, be interpreted as indicating that stresses affect a single mechanism, but in different ways (Broadbent, 1963).

In order to exclude this interpretation, Broadbent (1963) presented the following revised hypothesis. If two stresses operate by manipulating a related process in opposite directions (say, one by raising, and one by lowering, activation), then their outcomes should tend to cancel out; and, if two stresses operate by manipulating unrelated processes, their their outcomes should be independent of one another. In accord with this reasoning, noise and sleep loss were thought to manipulate a related process and, in contrast, noise and heat or sleep loss and heat were thought to manipulate unrelated processes (Broadbent, 1963; Pepler, 1959; Wilkinson, 1963).

Later, Broadbent's revised hypothesis was extended, post-hoc, to cover the remaining conceptual possiblity, *viz.* that stresses act upon a related process in the same direction. Thus, compared to normal conditions, incentive plus noise impaired responses, while incentive improved responding and noise did not change responding (Wilkinson, 1963). These data were interpreted by Poulton (1970) as follows. Incentive and noise together represent "excessive activation", which is the sum of "large increases" in activation, induced by incentive alone, and of "small increases" in activation, induced by noise alone.

Comparisons between combined stresses and separate stresses, except those involving heat, are most interpretable in terms of the postulate that stresses influence a related process, presumably activation, and thereby influence behaviour (Broadbent, 1971; Poulton, 1970; Wilkinson, 1969), even though "additional variables" and "extra factors" may require consideration.

However, since comparisons between combined stresses and separate stresses have not normally been made across a range of values of stimulation, these comparisons are almost always interpretable in terms of the postulate that stresses influence activation and thereby influence behaviour (see Chapter 3 for an extended discussion). If two stresses together facilitate behaviour, then each of their separate intensities can be classified as "low"; hence, these intensities sum to increase activation from low to moderate levels, improving behaviour. Conversely, if two stresses together suppress behaviour, then each of their separate intensities may be classified as "moderate"; hence, these intensities sum to increase activation from moderate to high levels, impairing behaviour. The vacuity of such post-hoc classifications was inadvertently demonstrated by

Poulton (1970), who could "explain" the effects of combining alcohol and other stresses by making either one of two contradictory assumptions, *viz.* that alcohol is de-activating or that alcohol is over-activating.

1.3.2 IMPACT OF ACTIVATION THEORY ON THE STUDY OF MOTIVATION IN ANIMALS

Since the present thesis aims to test activation theory using rats, the impact of this theory on physiological and behavioural studies of animals will be discussed in some detail.

1.3.2.1 PHYSIOLOGICAL STUDIES - OUTLINE

The impact of activation theory on physiological studies was somewhat delayed owing to methodological problems in measuring nervous system activity. Eventually, the following hypotheses came to be examined:

(i) that there is a "continuum" of activation, i.e. greater degrees and lesser degrees of neural activity, extending from the ascending reticular activating system to the cortex, to the spinal cord and to the periphery, e.g. the autonomic nervous system

and

(ii) that different indices of the continuum correlate.

The first hypothesis was considered by Steiner (1962) and by Hockman (1964) at the level of the cortex and by Wayner (1974) at the level of the spinal cord, or, more generally, of the brain stem motor control system. The second hypothesis may be considered in terms of data on the concurrent measurement of conditioned responses at the level of the autonomic nervous system.

1.3.2.2 CORTEX

In accord with activation theory, Steiner (1962) tested the prediction that deprivation produces greater degrees of cortical and sub-cortical activity than satiation.

In rats, electrodes were implanted in the anterior cortex, in the posterior cortex and in various locations of the hypothalamus and of the septum. The rats were either water deprived for twenty-three hours or water satiated. Water deprivation was associated with lower amplitudes-higher frequencies in cortical and in subcortical waves than water satiation. Steiner interpreted this finding as supporting activation theory. There were, however, a number of interactions between deprivation-satiation, measure and frequency of waves and electrode site. Contrary to the expectations of activation theory, then, deprivation did not produce an undifferentiated increase in neural activity compared to satiation. In any case, the behaviour of subjects was neither restricted nor recorded and so the influence of deprivation-satiation cannot be isolated from that of external stimulation and that of movement.

Using Steiner's approach, Hockman (1964) investigated the relation between the cortical or subcortical effects and the behavioural effects of food deprivation.

In rats electrodes were implanted in the anterior cortex, in the dorsal hippocampus, in the lateral and ventromedial areas of the hypothalamus, and in the mesencephalic reticular formation. The rats were food deprived for either forty-eight hours or twenty-three hours or were food satiated. Food deprivation was mostly associated with lower amplitudes-higher frequencies in cortical and in sub-cortical waves and with greater rates of bar-pressing than food satiation.

Hockman interpreted these findings as supporting activation theory. There are, however, a number of inadequacies in his study. Deprivation and satiation did not always differ, depending on the electrode site and on the measure of neural activity. Also, scores from the two intervals of deprivation were pooled, precluding a sensitive test of activation theory which expects neural differences and behavioural differences between these intervals.

1.3.2.3 SPINAL CORD

In support of activation theory, Wayner (1974) demonstrated systematic changes in the frequency of neural impulses in the spinal cord or, more generally, in the brain stem motor control system.

As outlined below, Wayner postulated relations between the frequency of neural impulses in the brain stem motor control system and behaviour. His postulates have not been tested but do not, apparently, require testing.

The functioning of the lateral hypothalamus has been found to influence that of the brain stem motor control system (including the caudal lateral hypothalamus. the ventral tegmentum, the mesencephalic reticular formation and the brain stem reticular fomation), which determines the normal level of reflex excitability and of movements. Electrical stimulation of the lateral hypothalamus increased spinal reflex discharges and spontaneous motor activity (Wayner, 1970); conversely, bilateral destruction of the lateral hypothalamus gave rise to decreases in spinal reflex discharges (Miles and Gladfelter, 1969) and in spontaneous motor activity (Brobeck, 1962).

Wayner (1974) used the foregoing data to explain the sterotyping of certain responses, e.g. post-food drinking induced by the intermittent presentation of food following bar-pressing. These responses have been called "adjunctive behaviour" by Falk (1971).

According to Wayner, enhancement of the frequency of spinal reflex discharges produces a non-specific facilitation of behaviour, i.e. an indiscriminate increase in response probabilities. Under these conditions, certain variables, such as the type of organism and the type of environment, interact to elicit a particular response, e.g. post-food drinking, and, thereby, to stimulate the lateral hypothalamus, which is known to receive input from a large number of receptors (e.g. auditory, gastric, muscle, olfactory, oropharyngeal, tactile, taste and visual receptors; Brooks, *et al.*, 1962; Kawamura, *et al.*, 1970; Nicolaidis, 1969a,b; Norgren, 1970). In turn, stimulation of the lateral hypothalamus maintains a high degree of neural activity in the motor system, increasing the probability that post-food drinking will recur.

The foregoing analysis may be summarized as follows: the lateral hypothalamus influences the brain stem motor control system which influences post-food drinking which influences the lateral hypothalamus which influences the brain stem motor control system etc. This analysis is quite true and quite trivial. Wayner makes no attempt to predict specific responses in specific situations, e.g. different schedules of the intermittent presentation of food following bar-pressing.

1.3.2.4 AUTONOMIC NERVOUS SYSTEM

Since there is some indication of a continuum of activation, i.e. greater degrees and lower degrees of neural activity, it might be expected that different indices of the continuum correlate.

This expectation can be assessed in terms of data on the concurrent measurement of autonomic responses during classical conditioning and during instrumental conditioning. In particular, autonomic responses should evidence the same direction, at least, of conditioned change in activation. For example, if one response shows conditioned increases, representing increased activation, then another response should also show conditioned increases, representing increased activation.

It must be noted that some activation theorists, particularly Malmo and Bélanger (1967), might view conditioned changes as "brief" physiological reactions, and not as shifts in the physiological levels which supposedly define activation. Since these theorists do not present a criterion of "brief", it is not clear what their views are.

In classical conditioning, concurrent measurement findings suggest that different physiological responses sometimes do, and sometimes do not, evidence the same direction of conditioned change in activation.

Some experiments report the same direction of conditioned changes (e.g. Cohen and Durkovic, 1966; Fitzgerald and Wallach, 1966; Hein, 1969; Santibanez, *et al.*, 1963; Smith and Stebbins, 1965). For example, Smith and Stebbins (1965) trained monkeys in a discrimination in which one light was followed by shock and another light was not paired with shock. In five of the six subjects, the shock-associated light produced increases in blood flow and in heart rate compared to the other light. In other words, as activation theory expects, blood flow increased, representing increased activation, and, at the same time, heart rate increased, representing increased activation.

Other experiments report the opposite direction of conditioned changes (e.g. Anderson and Brady, 1971, 1972, 1973; Yehle, *et al.*, 1967; Yehle, 1968). For example, Yehle, *et al.* (1967) compared an experimental group of rabbits, which received paired presentations of a tone and of a shock, and a control group of rabbits receiving non-paired presentations of these stimuli. The experimental group exhibited blood pressure elevation and heart rate deceleration compared to the control group. In other words, as activation theory would not expect, blood pressure increased, representing increased activation, and, at the same time, heart rate decreased, representing decreased activation.

The findings of the foregoing study might be taken to suggest that other variables, e.g. homeostatic mechanisms, are super-imposed on the variable of activation due to excessive levels of stimulation and so this study, as an atypical case, fails to demonstrate consistent changes in the two physiological measures. Unfortunately, without further experimentation, post-hoc rationalizations are unfalsifiable.

In fact, the findings of studies on concurrent autonomic measurement during classical conditioning are certain to be inconsistent with activation theory, since these findings are inconsistent with each other. For example, under similar conditions, some researchers have observed increases in heart rate and other researchers have observed decreases in heart rate (c.f. Harris and Brady, 1974). Since the paradigm of classical conditioning does not give reliable data, it would seem necessary to delineate the uncontrolled variables, responsible for the unreliability, before using this paradigm to evaluate activation theory.

In instrumental conditioning, concurrent measurement results suggest that different physiological responses do not necessarily evidence the same direction of conditioned change in activation.

Indeed, in many experiments, one response has been found to condition independently of other responses (e.g. DiCara and Miller, 1968; Harris, *et al.*,1973; Pappas, *et al.*,1970). For example, DiCara and Miller (1968) rewarded curare-immobilized rats by means of electrical brain stimulation for increasing vasodilation in one ear and, concurrently, for decreasing vasodilation in the other ear. The rats made vasomotor responses in one ear that were independent of those in the other ear and that were independent of vasomotor activity in the forepaw and in the tail and independent of heart rate and of temperature.

Contrary to the expectations of activation theory, then, vasodilation is remarkably specific, rather than non-differentiated, throughout the nervous system.

Nevertheless, for some reason, these results have proven difficult to replicate since 1972 (Harris and Brady, 1974; Miller, 1972). Until it can be demonstrated that the paradigm of instrumental conditioning is still giving reliable data, it would seem inappropriate to use this paradigm to reject activation theory.

1.3.2.5 PHYSIOLOGICAL STUDIES - SUMMARY

In the animal literature, physiological studies at the level of the cortex and of the spinal cord tend to support activation theory. Greater degrees and lesser degrees of neural activity have been observed in the cortex in experiments with rather suspect methodologies (Steiner, 1962; Hockman, 1964); also, greater degrees and lesser degrees of neural activity have been demonstrated in the spinal cord, or, more generally, in the brain stem motor control system, but have not been adequately related to behaviour (Wayner, 1974).

In contrast, physiological studies at the level of the autonomic nervous system do not support activation theory. Greater degrees and lesser degrees of autonomic activity have not always been consistently indexed by different kinds of conditioned changes; there is some question, however, about the reliability of conditioned changes.

1.3.2.6 BEHAVIOURAL STUDIES - OUTLINE

The impact of Hebb's (1955) introduction of activation theory on behavioural studies was virtually non-existent. At the time, animal researchers were occupied with Hullian learning theory.

Nevertheless, some behavioural data is relevant to testing the following hypotheses of activation theory, *viz*:

(i) that there is optimal performance at, and preference for, moderate levels of activation induced by moderate intensities of stimuli, and,

(ii) that performance is determined by the level of activation induced by the intensity of stimuli.

1.3.2.7 PERFORMANCE-PREFERENCE AND THE INTENSITY OF STIMULI

A. Performance and the Intensity of Stimuli.

According to Broadhurst (1959), optimal performance at moderate intensities of stimuli, depicted by inverted-U changes in behaviour as a function of the intensity of these stimuli, is "ubiquitous". Indeed, a particular response is normally sub-optimal at weak intensities of any stimulus and at damaging intensities of any stimulus.

At a less trite level, inverted-U changes in behaviour have been demonstrated only occasionally, under appetitive (e.g. hunger, thirst) conditions (Finch, 1938; Young, *et al.*, 1958; Malmo and Bélanger, 1967) and under aversive (e.g. shock, suffocation) conditions (Yerkes and Dodson, 1908; Broadhurst, 1957; Moyer and Korn, 1964). While all of the appetitive findings may be questioned on methodological grounds, the aversive findings seem to be adequate.

Finch (1938) deprived dogs of food for periods which ranged from 0 hours to 96 hours. The presentation of dog biscuits in a classical conditioning paradigm elicited the greatest amount of conditioned and unconditioned salivation at 72 hours of deprivation.

Apart from a procedural inadequacy in this study, *viz.* that all dogs were tested in the same deprivation sequence (0-, 24-, 72- and, finally, 96 hours without food), a number of variables, such as physical weakness, might have produced the declines in conditioned and in unconditioned salivation.

Young, *et al.* (1958) examined the speed of running to water with a percentage concentration of salt ranging from .1 to 8.1. Running was fastest to a percentage concentration of salt of 2.7.

Contrary to the assertions of Broadhurst (1957), however, running did not show a sequence of improvement-impairment with increases in the percentage concentration of salt. Instead, only the impairment reached significance.

Malmo and Bélanger (1967) described their experiments on the relation between deprivation, heart rate and bar-pressing. Lengthening the number of hours without food or water gave rise to linear increases in heart rate and, concurrently, to inverted-U changes in bar-pressing.

These experiments are not entirely satisfactory. There were no measures of physically-debilitating effects of long hours without food or water, e.g. 72 hours. Also, heart rate is known to reflect the influence of many variables, such as skeletal muscle movement (de Toledo, 1971). Indeed, Hufford and Chambers (1963) and O'Kelly, *et al.* (1965) reported decreases in heart rate with increasing hours without water in rats which were stationary, not bar-pressing.

Yerkes and Dodson (1908) investigated the difficulty of the discrimination between a shocked black box and an unshocked white box at values of shock designated "low", "medium" and "high". The value designated medium was more favourable to the acquisition of the discrimination than that designated low or that designated high. Also, an increase in the difficulty of the discrimination resulted in the systematic lowering of the value which optimized choice of the unshocked box.

Although there was a slight procedural problem in this study, i.e. half of the subjects should have been shocked in the black box and the others in the white box, Broadhurst (1957) replicated the Yerkes-Dodson findings. He investigated the difficulty of the discrimination between a successful and an unsuccessful escape route in an underwater escape task at different intervals of underwater detention. Under difficult conditions, discrimination showed a sequence of improvement-impairment with the lengthening of the detention interval (Brown, 1965). Also, an increase in the difficulty of the discrimination resulted in the systematic lowering of the detention interval which maximized successful escape.

Moyer and Korn (1964) heightened shock in a shuttlebox and found inverted-U changes in shuttleavoidance. These findings have been replicated a number of times, by Wolfe, *et al.* (1964), by Beatty and Beatty (1970), by Gallon (1972) and by Lind (1976).

At least under aversive conditions, then, the foregoing demonstrations of optimal performance at moderate intensities of stimuli, depicted by inverted-U changes in behaviour as a function of the intensity of these stimuli, seem to be adequate and reliable, but hardly universal. In Duffy's (1972) view, the lack of universality is not surprising since there may be restrictions in the range of stimulation, which may not be sufficiently high to reveal the predicted impairment. This view conveniently makes the predicted impairment unfalsifiable.

B. Preference and the Intensity of Stimuli.

Since optimal performance has sometimes been found at moderate intensities of stimuli, Hebb's (1955) hypothesis that organisms will prefer to maximize exposure to these intensities has been examined, often by manipulating the "collative" attributes (e.g. novelty, predictability) of stimuli.

Hebb's hypothesis is supported by a great deal of anecdotal evidence. For example, chimpanzees appeared to be socially facilitated by moderate intensities of stimulation (Mason, 1963). Social contact was enhanced and, then, suppressed as situational novelty increased.

Similarly, in the experimental literature, rats altered their rates of bar-pressing to obtain moderate intensities of stimulation, i.e. long durations of self-exposure to light when dim illuminations were available, and short durations of self-exposure to light when intense illuminations were available (Lockhard, 1965). However, interpretations of changes in behaviour to obtain light-dark changes are difficult due to the possibility of species-specific effects of light-dark, particularly in albino rats (e.g. Hinde and Stevenson-Hinde, 1973), and due to some rather complex findings. For example, extending the period of the deprivation of light does not systematically increase the ability of light to alter behaviour (Morrison, 1965) whereas, of course, extending the period of the deprivation of food systematically increases the ability of food to alter behaviour (e.g. Bolles, 1967).

The preceding studies, which involve preference for collative attributes under normal circumstances, are difficult to compare with those involving preferences for collative attributes following the sensory or the social deprivation of these attributes. Most studies loosely manipulate different collative attributes. Also, as noted previously, the influence of deprivation on all collative attributes, such as those altered by light onset-offset (possibly novelty or predictability) may not be similar.

Nevertheless, in the 1950's, a number of drives, notably curiosity, exploration and manipulation (Berlyne, 1950; Harlow, 1950; Montgomery, 1952), were investigated by various kinds of sensory deprivation.

It was shown, for example, that the degree of deprivation of visual stimuli produced systematic increases in responses which allowed access to visual stimuli (Butler, 1957). Monkeys, confined in a small box, were permitted to push a panel and, thereby, to look at the visual surroundings in the laboratory. Their rates of pushing the panel incremented as a function of the hours of confinement, until an asymptotic level of responding was reached. When various procedural artefacts were controlled, this type of finding was replicated by Fowler

(1963, 1965, 1967) and by Fox (1962). Unfortunately, the degree of satiation of visual stimuli has not been demonstrated to heighten responses which terminate exposure to visual stimuli.

This kind of sensory deprivation also includes social deprivation which has been investigated in its own right.

Latane, *et al.* (1972) housed rats in pairs or alone for periods ranging from 15 minutes to 15 months. Long-term isolation led to increases in social affiliation. Conversely, contact with other rats of 15-360 minutes in duration gave rise to decreases in social affiliation.

In a later experiment, Sloan and Latane (1974) exposed rats to human activity, handling or no intervention during the period of social isolation. The two kinds of human exposure eliminated the increments in gregarious behaviour which were observed with no intervention. Thus, it seemed that either human exposure or sociability could satisfy the apparent need of certain, i.e. medium, degrees of "complex, dynamic and unpredictable" sensory input.

Preferences for collative attributes under normal circumstances and preferences for collative attributes following the sensory-social deprivation of these attributes suggest that organisms maximize exposure to moderate intensities of stimuli. This suggestion is inconclusive, however, since most studies must be regarded as self-contained, rather than as comparable. Indeed, lack of comparability has been emphasized by data on the differences between monkeys and rats, pointing to the operation of unknown or of uncontrolled variables. The same researcher found that rhesus monkeys and chimpanzees show less exploration and less interest in complex visual patterns with increasing durations of deprivation and, in contrast, that rats show the greatest exploration and the greatest interest in complex visual patterns at intermediate durations of deprivation (Sackett, (1972).

1.3.2.8 PERFORMANCE AND THE LEVEL OF ACTIVATION

Evidence in support of the hypothesis of optimal performance at, and preference for, moderate intensities of stimuli is weak. Accordingly, demonstrating that performance-preference is determined by the level of activation induced by the intensity of stimuli has hardly generated great excitement.

Furthermore, there has been a growing cynicism about the tenability of concepts, like activation, which refer to internal, energizing states. For example, tests of Hull's (1943) idea of a diffuse, internal state called "general drive" have not been encouraging. Similarly, tests of Hall's (1938) idea of a specific, energizing state called "emotionality" have not been heartening.

As outlined below, however, some of the negative evidence in relation to the concept of general drive does not apply to that of activation, since these concepts make different predictions; also, the negative evidence in relation to the concept of emotionality, which is indexed by behavioural measures, does not necessarily apply to activation which is indexed physiologically.

1.3.2.9 GENERAL DRIVE

In Hull's (1943) view, general drive is a non-specific energizer which arises from a number of sources, such as hunger and shock. Therefore, combinations of these sources should increase general drive and thereby improve behaviour, until some asymptotic level of responses is reached. Similarly, activation is regarded as a diffuse, energizing state that may be induced by every exteroceptive stimulus, such as hunger or shock (Duffy, 1972). Thus, combinations of these stimuli should increase activation, producing changes along the presumed inverted-U baseline of behaviour as a function of the intensity of stimulation; that is, combinations of low intensities of stimulation should improve responding and those of higher intensities of stimulation should impair responding.

In other words, general drive theory expects improvements, and activation theory expects either improvements or impairments, in behaviour as a result of combining stimuli. Unfortunately, a review of the relevant literature does not allow an evaluation of these predictions. Most experiments have not manipulated a range of intensities of stimulation and most experiments are not readily comparable due to differences in methodologies. Thus, a post-hoc classification cannot accurately categorize those concerned with combinations of stimulation of low intensities and those concerned with combinations of stimulation of higher intensities.

Nevertheless, consistent with the expectations of activation theory, different kinds of stimuli, or their presumed internal representatives, i.e. "drives", have been found to facilitate and to suppress each other's effects. Furthermore, a number of ethologists have observed this kind of facilitation and of suppression in sequence, as a function of the intensity of drives (e.g. Fentress, 1973).

Ignoring hunger and thirst which have not usually been varied independently (Verplanck and Hayes, 1953), many combinations of drives have been examined (Bolles, 1967; Hinde, 1966, 1970). In some cases, drives facilitated each other's effects (Amsel, 1950; Amsel and Maltzman, 1953; Barfield and Sachs, 1968; Beach, *et al.*, 1955; Beach and Fowler, 1959; Braun, *et al.*, 1957; Brown, 1961; Hall, 1956; Jerome, *et al.*, 1957; Ley, 1965; McKinney, 1965; Munsinger, *et al.*, 1952; Siegel and Brantley, 1951; Siegel and Siegel, 1949). In other cases, drives suppressed each other's effects (Dachowski, 1964; Griffiths, 1962; Strange, 1954). Finally, drives sometimes facilitated and sometimes suppressed each other's effects (Strongman, 1965; Tugendhat, 1960a,b).

This kind of facilitation-impairment, which is consistent with the expectations of activation theory, appears, however, to be influenced by a large number of situational variables, such as the temporal locus of stimulation (Sterritt, 1962) and the compatibility of different responses (Amsel and Maltzman, 1953).

Thus, in comparisons among different combinations of drives, it is difficult to isolate indices of internal states. In consequence, these comparisons may not be an appropriate basis for evaluating activation theory.

Nevertheless, some relevant observations have been reported in the ethological literature. For example, Fentress (1973) observed that low intensities of one drive may facilitate the performance of the pattern of responses associated with another drive, whereas higher intensities of such an "irrelevant" drive may suppress these same patterns.

1.3.2.10 INDIVIDUAL DIFFERENCES IN EMOTIONALITY

In Hall's (1938) view, emotionality is a specific energizer which is inherited. Thus, it might be thought that "emotional" subjects operate at higher levels of activation than "non-emotional" subjects.

Unfortunately, definitions of emotionality are not satisfactory. Different indices of emotional behaviour, e.g. biting, defecating and hiding, do not notably correlate (Bolles, 1967); for example, factor-analytic studies of different indices of emotional behaviour yielded different numbers of factors, with Billingsworth (1942) and Willingham (1956) reporting, respectively, three and six.

Even if a particular index of emotionality, such as defecation, is arbitrarily selected, there is still no evidence of cross-situational generalities in this index. For example, Tobach and Schneirla (1962) did not find uniform trends in defecation in individual mice across different situations at different stages of development.

In spite of these difficulties, Broadhurst (1957) examined the hypothesis that rats with inherited, high rates of defecation operate at higher levels of drive and, by implication, of activation than rats with inherited, low rates of defecation. In most of the manipulations and in most measures of behaviour, there was no difference between high- and low-defecators.

Thus, there is no evidence suggesting that emotionality energizes non-defecating behaviour or that the degree of emotionality is related to the level of activation. However, there is no necessity to expect a relation between emotionality, which is indexed by behavioural measures, and activation, which is indexed physiologically.

1.3.2.11 BEHAVIOURAL STUDIES - SUMMARY

Activation receives some support from the occasional, but reliable, reports of optimal performance at moderate intensities of stimuli, depicted by inverted-U changes in behaviour as a function of the intensity of stimuli, and some support from the literature on preferences for moderate intensities of stimuli. While these kinds of support are extremely weak, the hypothesis that performance is determined by the level of activation induced by stimulation has not been tested. It hardly seems appropriate to reject this hypothesis on the grounds of negative findings with the related, but dissimilar constructs of general drive and of emotionality.

1.3.2.12 THE IMPACT OF ACTIVATION ON THE STUDY OF MOTIVATION IN ANIMALS - GENERAL SUMMARY

According to activation theory, there is a continuum of activation, i.e. greater degrees and lesser degrees of neural activity extending from the ascending reticular activating system to the cortex, to the spinal cord and to the periphery, e.g. the autonomic nervous system. With increasingly greater degrees of this activity, there are inverted-U changes in the efficiency of behaviour.

Physiological studies tend to support activation theory. While experiments on the cortex and on the autonomic nervous system are not satisfactory, Wayner's (1974) work clearly points to systematic changes in the frequency of spinal reflex discharges in the brain stem motor control system.

Behavioural studies have not adequately tested activation theory.

The aim of the present thesis is to determine whether activation theory can predict the physiological functioning and the behavioural functioning of unanesthetized rats, which have not been chemically altered or lesioned. Chapter 4 reports a test of the assumption that a continuum of activation underlies changes in a particular autonomic measure, *viz.* skin conductance, and Chapter 3 reports a test of the assumption that a continuum of activation underlies inverted-U changes in a particular behavioural measure, *viz.* shuttle-avoidance.

CHAPTER 2

CORRELATION TESTS OF ACTIVATION THEORY

2.1 OUTLINE

In the last chapter, the various ways of assessing activation theory were described.

The present chapter considers the most comprehensively-studied method, *viz.* that of correlating different physiological indices of activation in human subjects. This method points to a number of sources of variance which must be estimated in the examination of activation theory.

It will be argued that variability may be controlled by means of another paradigm, without the inherent errors of correlations. This paradigm, based on investigations of the interactions between "drives" (Bolles, 1967), or "stresses" (Wilkinson, 1969), may provide a basis for deriving physiological predictions, as well as behavioural predictions, from activation theory.

2.2 NATURE OF ACTIVATION

According to activation theorists, there is a "continuum" of activation, i.e. greater degrees and lesser degrees of neural activity, extending from the ascending reticular activating system to the cortex, to the spinal cord and to the periphery, e.g. the autonomic nervous system. They were not particularly explicit, however, about what they meant by neural activity.

There were references to "diffuse" bombardment (Hebb, 1955), and to higher-lower "degrees" of bombardment (Malmo, 1959), of the cortex by the ascending reticular activating system. Whether bombardment changed as a function of the total number or of the rate of neural impulses was not always clear. On some occasions, the number of neural impulses was suggested, e.g. Malmo (1959) referred to "extraneous" neurons which fire "all at once". On other occasions, the frequency of neural impulses was suggested, e.g. Lindsley (1957) referred to increases in the discharge rate of neurons.

In any case, if a stimulus manipulates a single, undifferentiated continuum of neural activity, then the stimulus should produce correlated degrees of changes in different indices of cortical activity and of autonomic activity (Duffy, 1967; Malmo, 1959).

There was some debate, however, about the time locus of the changes which were to be correlated. For example, Berlyne (1967) talked about the correlation between different components of the "orienting reaction", which is the immediate effect of a stimulus (Sokolov, 1963); and, similarly, Duffy (1972) talked about the correlation between the "first" responses to a stimulus. As far as Malmo and Bélanger (1967) were concerned, however, the proper data of correlations were physiological levels, i.e. long-term variations, resulting from stimulation. However, no criterion has been proposed to distinguish short-term variations and long-term variations. Furthermore, it seems arbitrary to correlate the latter variations exclusively. For these reasons, Malmo's and Bélanger's views have been generally ignored.

According to activation theorists, then, any particular stimulus will induce correlated degrees of changes in different physiological responses. This hypothesis was modified by Duffy (1972). Since a number of sources of error may reduce the magnitude of correlations, e.g. differences in the latency of responses and homeostatic influences on responses at high levels of stimulation, correlations between responses are likely to be modest, rather than near-perfect (Duffy, 1972).

2.3 CORRELATIONAL STUDIES

2.3.1 AN APPROPRIATE METHODOLOGY OF CORRELATIONAL STUDIES: THE SPECIFIC-GENERAL DICHOTOMY

The foregoing approach was somewhat over-simplistic. In particular, there was no recognition of the implications of the universally-accepted dichotomy between specific and general correlations. At a research level, no control of the potential sources of variance in correlations was attempted.

Any stimulus is likely to have unique effects, as well as more general consequences which can be produced by other kinds of stimulation. Thus, activation theorists referred to specific and general "factors" (Berlyne, 1967) and to localized and generalized "activation" (Duffy, 1972) in correlations between physiological reactions. Similarly, other authors talked about specificity and generality (Lacey, 1967; Lazarus, 1967) and, again, specificity and non-specificity (Stern, 1967) in the inter-dependency of nervous system changes.

The specific-general dichotomy has research implications which are quite crucial to the examination of correlations. For example, the failure to isolate specific-general factors may produce a high degree of variability in obtained correlations due to:

(i) physiological channels reacting to different aspects of stimuli, e.g. one organ may respond to the specific nature of a particular stimulus, while others may respond to the general attribute (Stern, 1967), and,

(ii) different individuals reacting to different aspects of stimuli.

In their experiments on correlations, the proponents of activation theory, listed in the next section of this chapter, investigated the correspondence between physiological changes to (usually) one stimulus within the same subject. In the absence of comparisons between stimuli and between individuals, there is no way of estimating the contribution of specific-general differences to the variance of correlations.

In contrast, a critic of activation theory, Lacey (1967), who was particularly interested in specific correlations, chose paradigms which allowed the comparison of different stimuli (or "stresses"), irrespective of subjects, and the comparison of different subjects, irrespective of stimuli. The former situations isolated the specific-general effects of stimuli, by comparing correlations between physiological changes to the same stimuli across individuals. Similarly, the latter situations separated the specific-general variations within individuals, by comparing correlations between physiological alterations in the same individuals across stimuli.

On the basis of specific-general considerations, correlational studies may be reviewed. Activation theorists and Lacey are considered in terms of the appropriate conclusions which may be derived from their choice of experimental methods.

2.3.2 THE PARADIGM OF ACTIVATION PROPONENTS

According to activation theorists, the assumption of a continuum of nervous system activity may be tested by determining whether "significant" intra-individual correlations occur (Duffy, 1967; Malmo, 1959).

These correlations mean that, with the heightening of stimulation, different responses concordantly increase within a subject. For example, using dynamometer values of induced muscle tension in humans, Pinneo (1961) recorded two electroencephalographic measures, i.e. amplitude in alpha (8-13 cps) and in beta (18-27 cps) ranges, as well as heart rate, muscle potentials from arms and from legs, skin conductance and respiration rate during a three-hour, pedal tracking task. With the heightening of induced muscle tension, all measures (except respiration rate) concordantly increased within subjects.

Some studies, like that of Pinneo, have found high correlations (Malmo and Bélanger, 1967), while other studies have reported low correlations (Lacey, 1967).

Malmo and Bélanger (1967) have reviewed a number of human studies which measure the correlations between changes in physiological responses to different intensities of a wide variety of stimuli (such as "stressful" films and white noise) over different durations of stimulation (ranging from several seconds to several hours). These studies suggest that the concordance between the degree of change in different measures is sufficiently high to justify the assumption of a single continuum of inter-dependent nervous system activity within an individual (Bartoshuk, 1956; Davies and Krkovic, 1965; Dykman, *et al.*, 1959; Eason and Dudley, 1971; Lazarus, *et al.*, 1963; MacNeilage, 1966; Malmo, 1965, 1966; Malmstrom, *et al.*, 1965; Pinneo, 1961; Schnore, 1959; Stennett, 1957; Uno and Grings, 1965). For example, Uno and Grings (1965) studied the effect of repetitions of two-second white noise bursts, from 60 dB to 100 dB in intensity, on several autonomic measures, i.e. finger blood volume, heart rate, pulse volume, skin conductance and skin potential. In general, response magnitudes and latencies were directly related to stimulus intensity and inversely related to number of repetitions. It was concluded that stimulus differences can be detected by "use of any one of the various response parameters of electrodermal and cardiovascular systems (p. 351)". Since Duffy (1972) demonstrated high Pearson correlations, from .68 to .78, within and between the electrodermal and cardiovascular measures, this conclusion seems appropriate.

In contrast, however, Lacey (1967) has reviewed a number of human studies which (also) measure the correlations between changes in physiological responses to different intensities of a wide variety of stimuli (such as auditory cues and mental arithmetic) over different durations of stimulation (ranging from several minutes to several hours). These studies suggest that the concordance between the degree of change in different measures is not sufficiently high to justify the assumption of a single continuum of inter-dependent nervous system activity within an individual (Eason, *et al.*, 1964; Johnson, 1965; Johnson and Lubin, 1966; Kreitman and Shaw, 1965; Sternbach, 1960a,b,c). For example, Eason, *et al.* (1964) recorded heart rate, skin conductance, and tension in the forearm flexor and in the neck muscles while subjects either lifted weights or gripped a hand dynamometer during a one-hour memory task. Over time, the two indices of muscle activity increased whereas heart rate and skin conductance decreased.

Also, with increments in weights and in force of dynamometer grip, forearm flexors and heart rate showed linear changes, while neck muscles showed U-shaped changes and skin conductance did not change. As Duffy (1972) acknowledged, it may not be concluded that any stimulus has equivalent consequences on different physiological systems.

In their reviews, then, Malmo and Bélanger (1967) and Lacey (1967) have described experiments which yield contradictory findings. As noted previously, however, these experiments use a paradigm that confounds specific and general changes, with respect to both stimuli and individuals and, therefore, that lacks control over the potential sources of variance. As a result, experimental error, and the range of obtained correlations, should be substantial. For example, in some situations, such as those reported by Malmo and Bélanger, specific variables might be over-shadowed by the general effect and hence high correlations between changes in physiological responses may occur; in other situations, such as those cited by Lacey, the specific-general pattern may be reversed, producing low correlations.

2.3.3 LACEY'S PARADIGMS

With an interest in specific correlations, Lacey (1967) investigated patterns of response in the same individuals under several conditions of stimulation or stress, and patterns of response to the same stresses irrespective of individuals. These kinds of physiological relationships, which were described as "individual response specificity" and "situational sterotypy", respectively, will be considered in turn.

A. Specificity of Correlations within Individuals.

Lacey examined the extent to which, for example, an individual's heart rate shows similar changes to different types of stresses. Individuals were found to exhibit idiosyncratic, but consistent patterns of autonomic and of somatic changes across stresses (Lacey, 1950; Lacey and Van Lehn, 1952; Lacey, *et al.*, 1952, 1953; Lacey and Lacey, 1958, 1962).

For example, Lacey, *et al.* (1953) subjected students to four brief stresses in sequence, i.e. mental arithmetic for two minutes, hyperventilation for 45 seconds, letter association for two minutes and the cold pressor test for 60 seconds. With two techniques of measurement and the three autonomic measures of heart rate, variability in heart rate and palmar conductance, it was found that there were marked individual differences in autonomic changes. Nevertheless, a given individual did not vary haphazardly either in the physiological system showing maximum changes, or in the pattern of changes across systems. Instead, a subject tended to show maximal responses in the same physiological system, whatever the stress. Also, the rank order of a subject's responses across systems tended to be the same, whatever the stress.

B. Specificity of Stress Patterns.

Also, Lacey, and others, examined the extent to which the general pattern of physiological responses changed from one stress to another, irrespective of individuals. Different stresses were found to be associated with different patterns of autonomic and of somatic responses (Ax, 1953; Davis, 1957; Davis, *et al.*, 1955; Funkenstein, *et al.*, 1957; Lacey, 1957; Lacey, *et al.*, 1963; Schachter, 1957).

For example, Ax (1953) induced fear in students by giving them unexpected electric shocks in an atmosphere of "alarm and confusion" and aroused their anger with insults from a "rude" experimenter. A number of autonomic measures discriminated between fear and anger states, irrespective of subjects. Diastolic blood pressure rises, heart rate decreases and muscle potential increases were greater for anger than for fear, whereas skin conductance and respiration rate increases were more pronounced in fear than in anger.

Generally, Lacey has studied two types of correlations between physiological changes: those to more than one stimulus within an individual and those to a particular stimulus, irrespective of individuals. Both types of correlations showed consistent patterns, suggesting an isolation of specific-general sources of variance. For example, with variations in stimuli and the same individuals, specific-general effects are constant at the level of the subject. Under these circumstances, the consistent patterns of correlations are produced by any stimulus and hence are, by definition, general effects. Also, with variations in individuals and the same stimuli, specific-general effects are constant at the level of the stimulus. Under these circumstances, the consistent patterns of correlations are unique or specific to a particular stimulus.

2.3.4 THE TENABILITY OF ACTIVATION THEORY

Within-subject and within-stimulus consistencies in correlational patterns may provide a basis for evaluating activation theory. In particular, the idea of a continuum of inter-dependent nervous system activity predicts the former regularities, but does not account for the latter ones.

Thus, individual response specificity, in Lacey's terminology, demonstrates the same pattern of physiological changes in response to different stimuli. This pattern can readily be labelled as an "activation pattern" (Schnore, 1959).

On the other hand, situational stereotypy, in Lacey's terminology, demonstrates different patterns of physiological changes in response to different stimuli. While Duffy (1972) labelled these patterns as "specific" activation patterns, activation is non-specific, by definition.

Indeed, activation theorists, such as Malmo and Bélanger (1967), have seen a fundamental disagreement between situational stereotypy and activation. These authors attempted to resolve the disagreement by arguing that situational stereotypy has been established with measures of "brief" physiological reactions, whereas activation refers to non-brief physiological levels. Accordingly, the observations of situational stereotypy are "taken out of the category of activation as we have defined it (p. 307)". Since Malmo and Bélanger did not present criteria for distinguishing between brief and non-brief, any observation can be arbitrarily taken out of the category of activation as they have defined it.

In relation to consistencies in correlational patterns, therefore, the hypothesis of a continuum of inter-dependent nervous system changes predicts the response relationships within subjects, but not within stimuli. While the foregoing conclusions seem generally valid, there is a class of variables which complicates a simple interpretation of correlations. For example, Elliott (1964) found that age alters the pattern of physiological changes to incentive stimuli. While adults tended to show some degree of concordance between nervous system responses to these stimuli, children did not. An explanation of the difference between adults and children does not seem to be important; rather, the implication of the difference, *viz.* that many factors may alter correlations in largely unknown ways, questions the precision of correlational methods.

2.4 THE ADEQUACY OF CORRELATIONAL METHODS OF TESTING ACTIVATION THEORY

There seem to be a number of problems in using correlational methods to test activation theory. The value of a correlation which will be considered to falsify activation theory has not been delineated. At a practical level, the procedure of obtaining correlations contains sources of error and unpredictability.

According to activation theorists, notably Duffy (1967) and Malmo (1959), there are "significant" and "substantial" correlations among physiological measures. This expectation, however, is difficult to evaluate since no criteria of significant and substantial have been presented. For example, a correlation of .5 between two variables accounts for 25% of their shared variance. While the correlation may be statistically significant, this percentage of the variance might not be regarded as substantial.

Sources of error appear to be inherent in the data of correlations. For example, Duffy (1972) described the usual technique of measuring the nervous system with surface electrodes as "gross" and "imperfect". When imprecise records are correlated, there must be an unidentifiable degree of inaccuracy.

Apart from the foregoing difficulties, correlational methods do not normally control variables and, consequently, have unpredictable outcomes. For example, in experiments on naive subjects, the likely form of the expected within-subject consistencies in the pattern of correlations will be unknown.

2.5 AN ALTERNATIVE METHOD OF TESTING ACTIVATION THEORY

On the assumption that correlational methods do not provide controlled tests of activation theory, the present thesis uses another methodology, which manipulates stimuli and selects experimental designs to reduce subject variability.

Following the rationale of animal studies of drive summation (Bolles, 1967) and of human work on the interactions between stresses (Wilkinson, 1969), the present thesis will investigate the physiological and behavioural consequences of single, as compared to multiple, stimulation. The manipulation of specific-general sources of variance in stimuli, then, is achieved by gauging the additivity or non-additivity of the general effects of different kinds of sensory input. The reduction of the variance attributable to specific-general patternings in subjects is attempted by the selection of experimental designs which are described below.

Consider a situation where the same organisms respond to stimulus X, to stimulus Y, and to the combination of X and Y.

Here, specific-general varability in subjects is held constant by employing each subject in all conditions. In this way, Chapter 4 examines the expectation of activation theory that X or Y alone will have less activating effects on physiological activity than X and Y together.

Consider another situation where organisms A and B respond to stimulus X, organisms C and D respond to stimulus Y and organisms E and F respond to the combination of X and Y.

Here, in spite of the fact that specific-general variability in subjects is not controlled, the assumptions of activation theory may be used to gain precision. The idiosyncrasies of physiological patterns are not thought to be reflected at the level of behaviour. For example, Malmo (1959) argued that different individuals show unique physiological patterns of low, moderate and high levels of activation, but that increases in the level of activation are always associated with the same, inverted-U behavioural effects. Again, while Duffy (1972) expected individuals from heterogeneous populations, e.g. "anxious" subjects and "non-anxious" subjects, to behave in different ways under identical conditions, individuals from the one population were hypothesized to produce similar behaviour with a particular intensity of stimulation and to produce similar, inverted-U alterations in behaviour across a range of intensities of stimulation. Thus, within subjects, systematic rises in the amount of change in nervous system activity, regardless of the pattern of change, are postulated to generate the same trends in behaviour; and, in a given population of subjects, any situation should result in an efficiency of behaviour which is comparable across individuals. According to activation theorists, then, behavioural measures are less variable, within and between subjects, than physiological measures which reflect response specificity.

Using between-subject comparisons of behaviour, Chapter 3 examines the expectation of activation theory that X or Y alone will have less activating effects on the performance of a task than X and Y together. In particular, if increases in the intensity of either X or Y give rise to inverted-U changes in a response, then X and Y should combine to heighten activation, producing monotonic decreases in the response.

2.6 SUMMARY

According to activation theory, there should be correlations between physiological changes to a stimulus within an individual. In their investigation of correlations, activation theorists have not adequately controlled a number of sources of variability. Hence, their findings show the full range of possible correlations. In contrast, Lacey demonstrated consistent patterns of correlations within individuals, irrespective of stimuli, and within stimuli, irrespective of individuals. The conception of a continuum of inter-dependent nervous system activity is supported by the former consistencies, but does not allow prediction of the latter regularities. Since there are some queries about the precision of the correlational method, it seems desirable to test activation theory with another approach, which is further outlined in the next two chapters.

CHAPTER 3

THE BEHAVIOURAL ADDITIVITY OF STIMULI; A TEST OF THE ASSUMPTION THAT A CONTINUUM OF ACTIVATION UNDERLIES INVERTED-U CHANGES IN BEHAVIOUR

3.1 RATIONALE

If two stimuli alone manipulate a continuum of activation and, thereby, produce inverted-U changes in behavioural efficiency as a function of the intensity of stimulation, then the two stimuli together should manipulate this continuum and, thereby, produce decreasing monotonic changes in behavioural efficiency. In particular, when the stimuli have low intensities, they should combine to increase activation and to improve behaviour; when the stimuli have moderate intensities, they should combine to increase activation and to impair behaviour; and, finally, when the stimuli have high intensities, they should combine to increase activation, impairing behaviour even further.

The foregoing predictions were tested in three experiments which examined changes in behavioural efficiency as a function of the intensity of white noise, of shock and of white noise plus shock.

3.2 GENERAL METHOD

3.2.1 SUBJECTS

Ss were 200 naive male albino rats obtained from the John Curtin School of Medical Research, Canberra, Australia. They were between 100 and 120 days old at the beginning of the experiments and were maintained on ad lib. food and water.

3.2.2 APPARATUS

The apparatus was a shuttlebox, consisting of two 12" x 7" x 10" compartments covered throughout with stainless steel and separated by a motor-driven, stainless steel door. The raising or lowering of the door took approximately .1 second. The ceiling of each compartment was covered with 1/7" Plexiglass. In the centre of each compartment at ceiling level, two 1.5-w. clear light bulbs provided an increase in illumination of approximately 8 lux ca. This increase in illumination served as CS. The floor of each compartment consisted of 1/4" stainless steel rods spaced 1" apart. Scrambled electric shock was delivered by a Grass Constant Current Stimulator. In the centre of each compartment 1" above floor level, a photocell allowed the recording of response latencies. At the side of the shuttlebox, a 5" speaker was mounted and overlapped equally into the two compartments. The speaker was powered by a Scott 811-B Random Noise Generator and provided white noise of 1200-4800 cps. All stimulus presentations and timings were programmed by means of Digital K-Series Logic. Response latencies in .1 second units were printed out by a Sodeco PL103 Counter.

3.3 EXPERIMENT 1 - WHITE NOISE

3.3.1 PROCEDURE

Fifty Ss were randomly assigned to five groups. Each group received one of five white noise intensities as the UCS in the shuttlebox. The intensities were 75 dB, 85 dB, 95 dB, 105 dB and 115 dB.

On the first day, S was gentled for 10 minutes and then placed into one of the compartments of the shuttlebox, chosen at random. Following Theios, *et al.* (1966), pre-test trials were given and consisted of opening the door, presenting the CS in the occupied compartment for 11.5 seconds and, finally, lowering the door. Pre-test trials were given until S reached a criterion of five consecutive failures to leave the occupied compartment within 5 seconds following onset of the CS.

On the second day, S was placed into one of the compartments of the shuttlebox, chosen at random. One hundred test trials, with a CS-UCS interval of 5 seconds and an inter-trial interval of 20 seconds, were given. A trial consisted of opening the door and presenting the CS in the occupied compartment. If S responded by running into the other compartment within 5 seconds, the door lowered and the CS terminated. These responses were defined as avoidance responses. If S failed to respond, white noise came on either until he ran into the other compartment or until 30 seconds had elapsed. In both cases, the door lowered and the CS and the UCS terminated.

Ss were run in batches of 10 per two days, with two Ss being from each group. The order of running Ss in each batch was randomized.

3.3.2 RESULTS

Means and standard deviations of the percentage of trials on which S avoided the UCS and of the latency of these responses in all groups are presented in Table 3.11.

An analysis of variance on percent avoidance in these groups was followed by a partitioning of the sum of squares between groups into orthogonal components, representing the trend in percent avoidance as a function of the intensity of white noise (c.f. Winer, 1962). The quadratic trend and the linear trend were calculated. The quadratic trend was significant ($F_{1,45} = 6.0$, $p < .05$) while the linear trend was not significant.

A routine check indicated that the variances of the latency scores violated the assumption of homogeneity of variances ($F_{5,9\text{max}} = 8.5$, $p < .05$). Therefore, the logarithms of the latency scores were computed (c.f. Winer, 1962). Following an analysis of variance on the logarithms of the latency scores, the quadratic trend and the linear trend were calculated. The quadratic trend was marginally significant ($F_{1,45} = 3.6$, $p = .07$) and the linear trend was not significant.

The foregoing results are summarized in Table 3.12. Also, Figure 3.11 and Figure 3.12 show mean percent avoidance and mean latency, respectively, in all groups.

TABLE 3.11

Means and standard deviations of percent avoidance and of latency in the white noise groups (N = 10 per group).

	75 dB	85 dB	95 dB	105 dB	115 dB
1. Percent avoidance					
Means	33.10	50.60	46.50	51.40	38.20
Standard deviations	23.77	18.52	11.34	17.24	17.21
2. Latency					
Means	3.36	2.87	2.95	2.76	3.03
Standard deviations	0.86	0.49	0.30	0.50	0.29

TABLE 3.12

Analysis of variance of percent avoidance and of latency in the white noise groups.

1. Percent avoidance

Source	SS	df	MS	F	p
Between groups	2,540.68	4	635.17	1.96	ns
Quadratic trend	1,946.31	1	1,946.31	6.02	<.05
Linear Trend	116.64	1	116.64	F < 1	ns
Within groups	14,561.00	45	323.58		
Total	17,101.68	49			

2. Latency-logarithms of raw scores

Source	SS	df	MS	F	p
Between groups	.0356	4	.0089	1.68	ns
Quadratic trend	.0191	1	.0191	3.60	.07
Linear trend	.0001	1	.0001	F < 1	ns
Within groups	.2370	45	.0053		
Total	.2917	49			

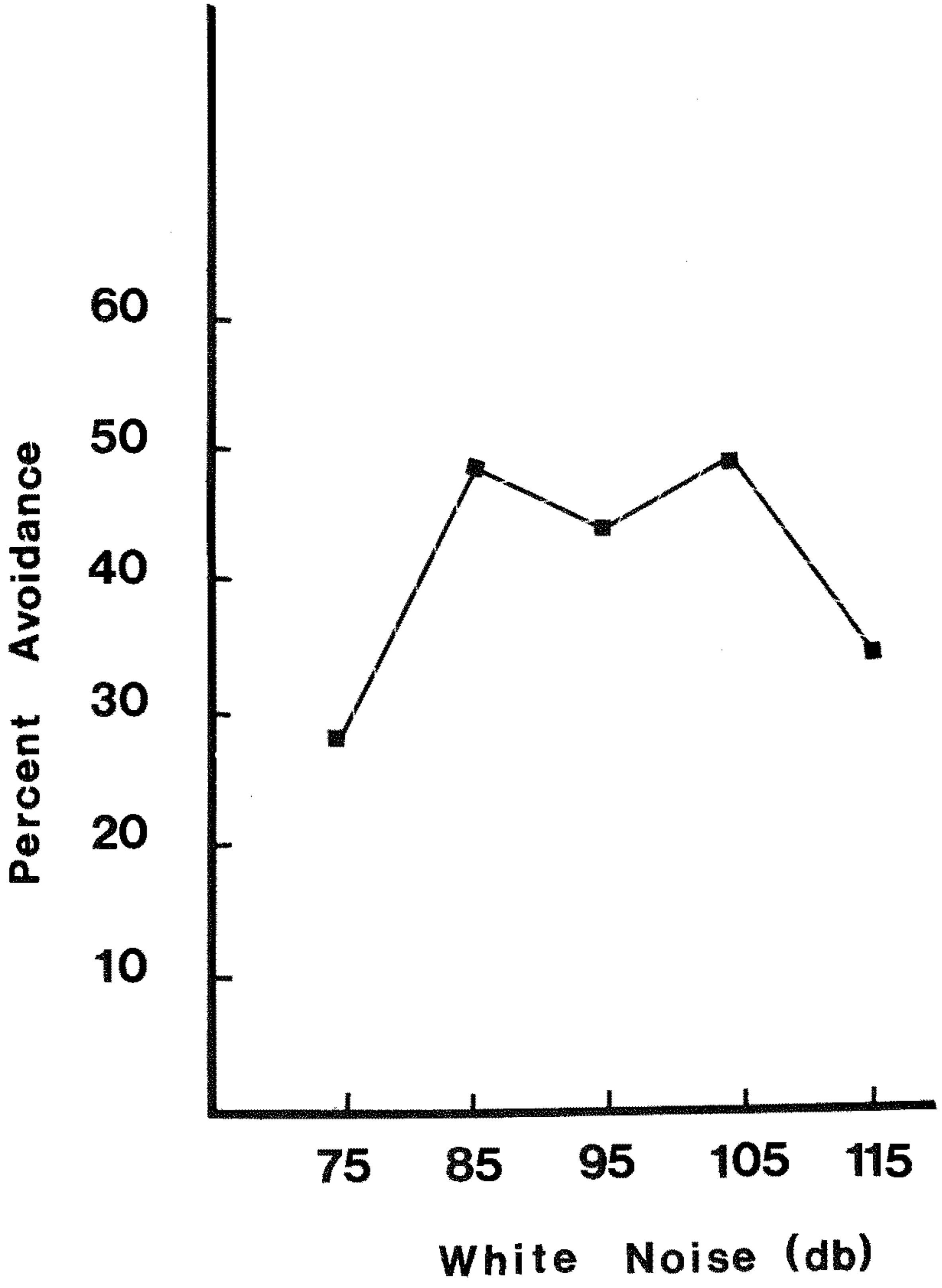


Figure 3.11 Mean percent avoidance as function of white noise (N = 10 per data point).

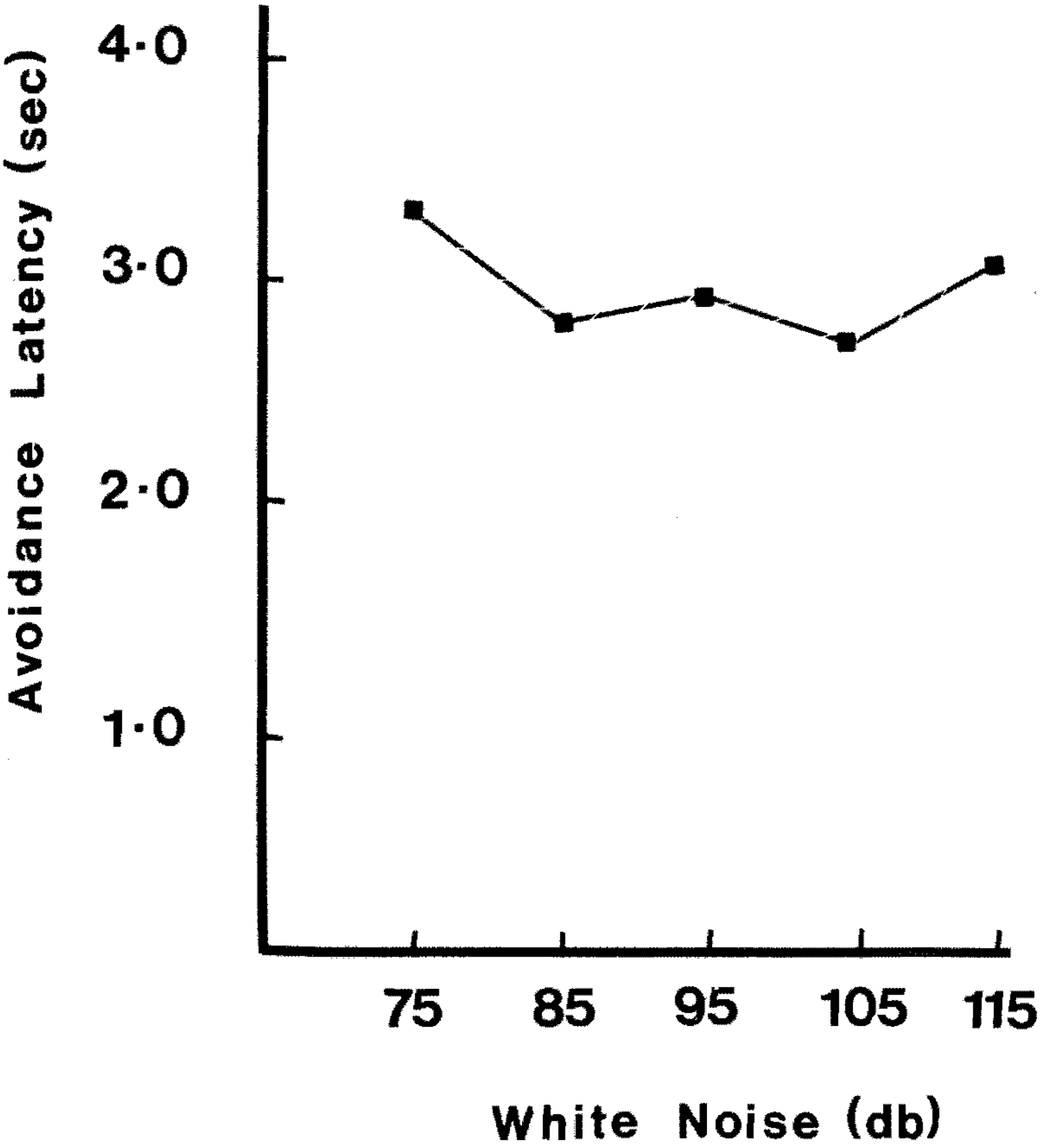


Figure 3.12 Mean latency as a function of white noise (N = 10 per data point).

3.4 EXPERIMENT 2 - SHOCK

3.4.1 PROCEDURE

Fifty Ss were randomly assigned to five groups, each receiving one of five shock intensities as the UCS. The intensities were .1 ma, .4 ma, .7 ma, 1.0 ma and 1.3 ma.

On the first day, the pre-test trials, described in the previous experiment, were given. On the second day, the test trials, described in the previous experiment, were given.

3.4.2 RESULTS

Means and standard deviations of percent avoidance and of latency in all groups are presented in Table 3.21.

For percent avoidance, the quadratic trend ($F_{1,45} = 6.1$, $p < .05$) and the linear trend ($F_{1,45} = 6.3$, $p < .05$) were significant.

A routine check indicated that the variances of the latency scores ($F_{5,9\max} = 13.5$, $p < .01$), and the variances of the logarithms of the latency scores ($F_{5,9\max} = 20.8$, $p < .01$), violated the assumption of homogeneity of variances.

Therefore, the latency scores were compared non-parametrically. The Mann-Whitney U test (Edwards, 1967) revealed that latencies in the .7 ma group and in the 1.0 ma group did not differ, that latencies in the .7 ma group were less than those in the .1 ma group ($U = 67$, $p < .01$), in the .4 ma group ($U = 75$, $p < .05$) and in the 1.3 ma group ($U = 74$, $p < .05$) and, similarly, that latencies in the 1.0 ma group were less than those in the .1 ma group ($U = 65.5$, $p < .01$), in the .4 ma group ($U = 74.5$, $p < .05$) and in the 1.3 ma group ($U = 76$, $p < .05$).

The foregoing results are summarized in Table 3.22. Also, Figure 3.21 and Figure 3.22 show mean percent avoidance and mean latency, respectively, in all groups.

TABLE 3.21

Means and standard deviations of percent avoidance and of latency in the shock groups (N = 10 per group).

	.1 ma	.4 ma	.7 ma	1.0 ma	1.3 ma
1. Percent avoidance					
Means	34.50	53.40	46.90	26.60	20.60
Standard deviations	13.38	18.94	28.15	23.08	22.43
2. Latency					
Means	3.34	2.89	2.34	2.46	2.91
Standard deviations	0.16	0.38	0.60	0.53	0.45

TABLE 3.22

Analysis of variance of percent avoidance and of latency in the shock groups.

1. Percent avoidance

Source	SS	df	MS	F	p
Between groups	7,485.40	4	1,871.45	3.96	<.05
Quadratic trend	2,889.26	1	2,889.26	6.12	<.05
Linear trend	2,981.16	1	2,981.16	6.30	<.05
Within groups	21,290.60	45	473.12		
Total	28,776.00	49			

2. Latency - Mann-Whitney comparisons

	1. ma	.4 ma	.7 ma	1.0 ma	1.3 ma
.1 ma		70**	67**	65.5**	67**
.4 ma			75**	74.5**	102
.7 ma				93.5	74*
1.0 ma					76*
1.3 ma					

** $p < .01$, * $p < .05$

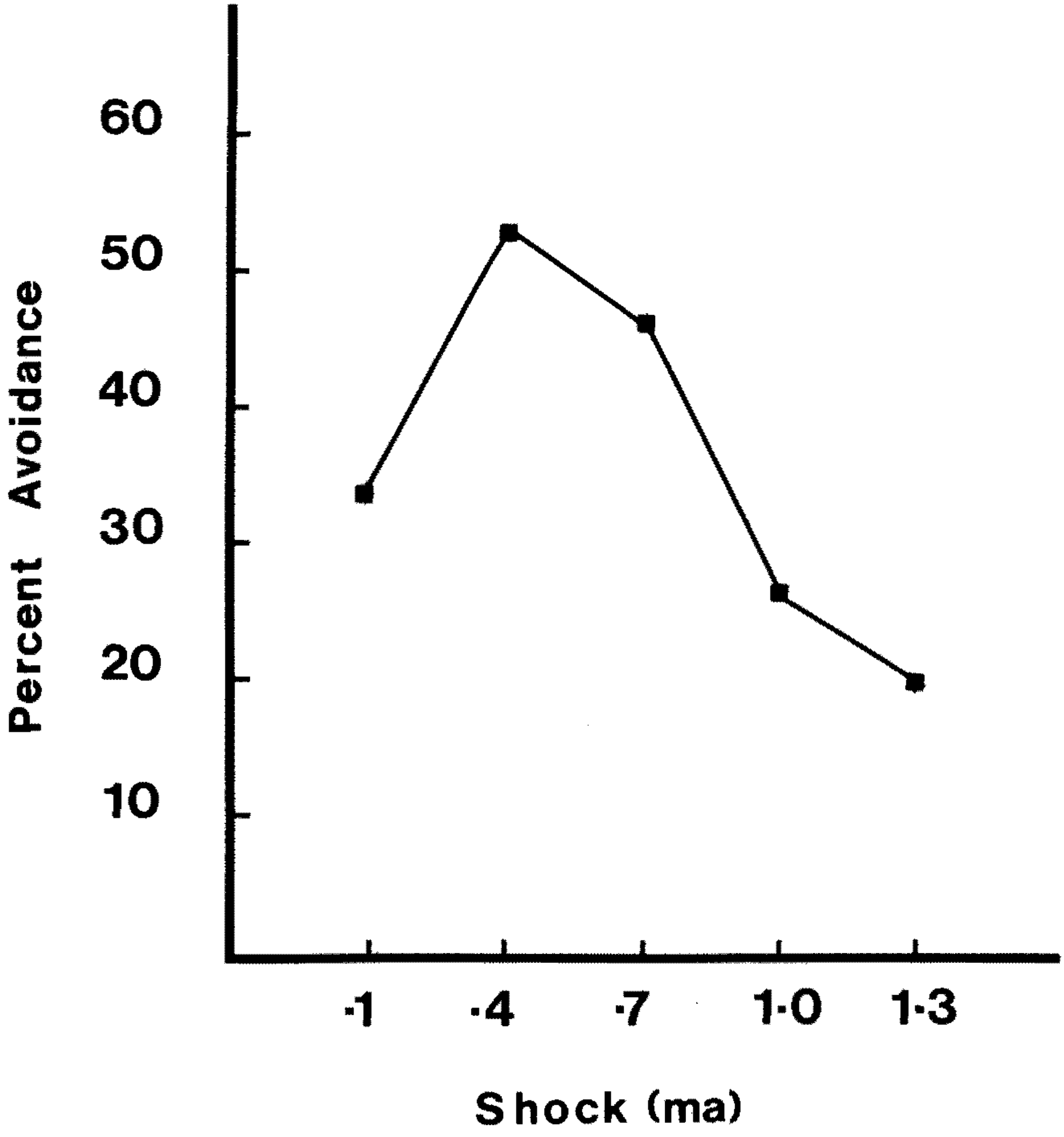


Figure 3.21 Mean percent avoidance as a function of shock (N = 10 per data point).

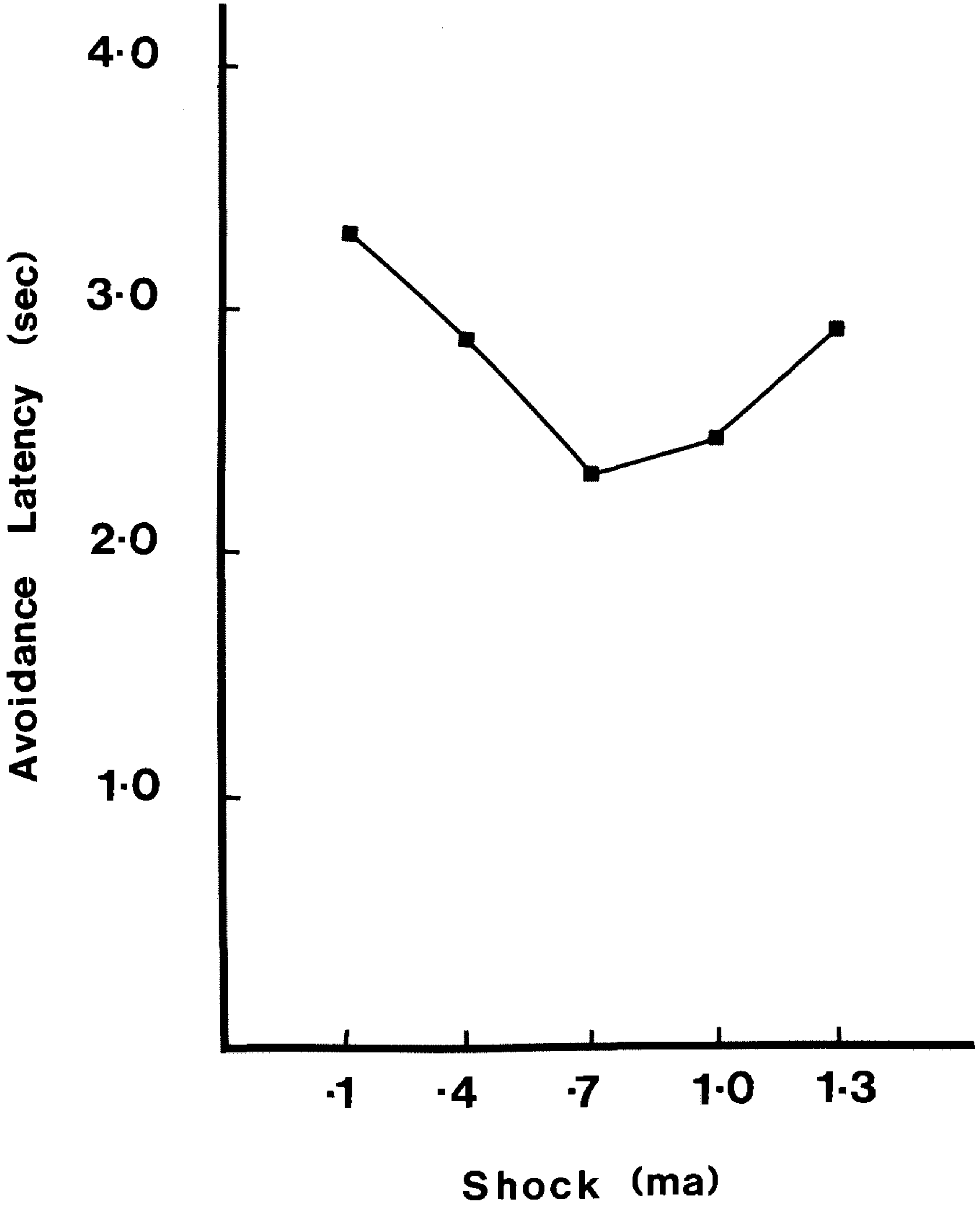


Figure 3.22 Mean latency as a function of shock (N = 10 per data point).

3.5 EXPERIMENT 3 - WHITE NOISE PLUS SHOCK

3.5.1 PROCEDURE

One hundred subjects were randomly assigned to five groups, each receiving one of five intensities of white noise plus shock as UCS. The intensities were 75 dB + .1 ma, 85 dB + .4 ma, 95 dB + .7 ma, 105 dB + 1.0 ma and 115 dB + 1.3 ma.

On the first day, the pre-test trials, described in the previous experiment, were given. On the second day, the test trials, described in the previous experiment, were given.

3.5.2 RESULTS

Means and standard deviations of percent avoidance and of latency in all groups are presented in Table 3.31.

For percent avoidance, the linear trend was not significant. However, there was a significant quadratic trend ($F_{1,95} = 5.5$, $p < .05$).

For latency, the linear trend was not significant. Again, however, there was a significant quadratic trend ($F_{1,95} = 7.6$, $p < .01$).

The foregoing results are summarized in Table 3.32. Also, Figure 3.31 and Figure 3.32 show mean percent avoidance and mean latency, respectively, in all groups.

TABLE 3.31

Means and standard deviations of percent avoidance and of latency in the white noise plus shock groups (N = 20 per group).

	75 dB + .1 ma	85 dB + .4 ma	95 dB + .7 ma	105 dB + 1.0 ma	115 dB + 1.3 ma
1. Percent avoidance					
Means	25.30	40.35	40.65	32.90	27.00
Standard deviations	19.45	24.24	26.24	28.94	26.89
2. Latency					
Means	3.53	3.09	2.77	2.89	3.19
Standard deviations	.68	.79	.78	.84	1.09

TABLE 3.32

Analysis of variance of percent avoidance and of latency in the white noise plus shock groups.

1. Percent avoidance

Source	SS	df	MS	F	p
Between groups	4,151.14	4	1,037.79	1.61	ns
Quadratic trend	3,564.29	1	3,564.29	5.54	<.05
Linear trend	32.81	1	32.81	F < 1	ns
Within groups	61,083.00	95	642.98		
Total	65,234.24	99			

2. Latency

Source	SS	df	MS	F	p
Between groups	6.96	4	1.74	2.48	<.05
Quadratic trend	5.32	1	5.32	7.59	<.01
Linear trend	.45	1	.45	F < 1	ns
Within groups	66.63	95	.70		
Total	73.59	99			

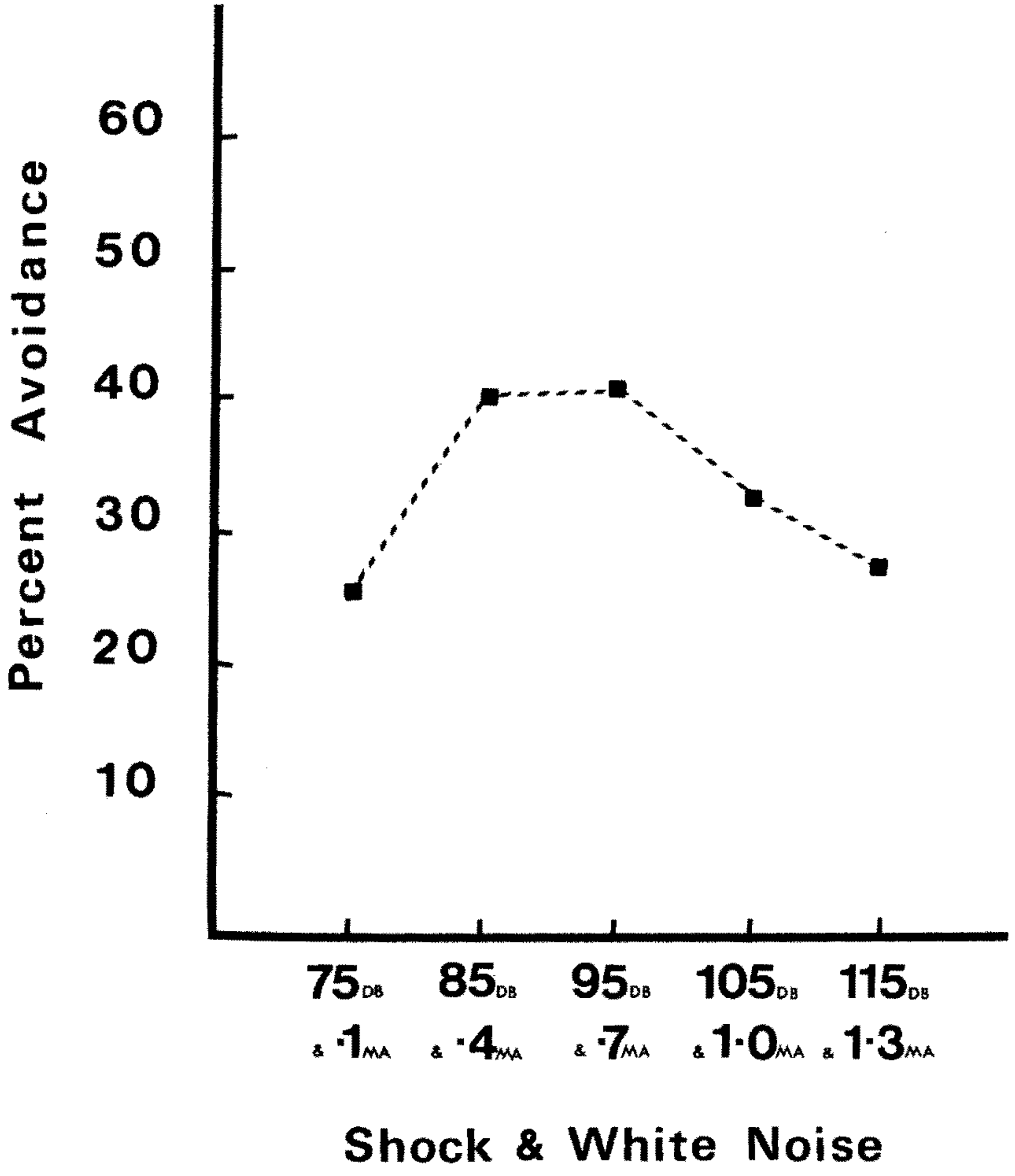


Figure 3.31 Mean percent avoidance as a function of shock and white noise (N = 20 per data point).

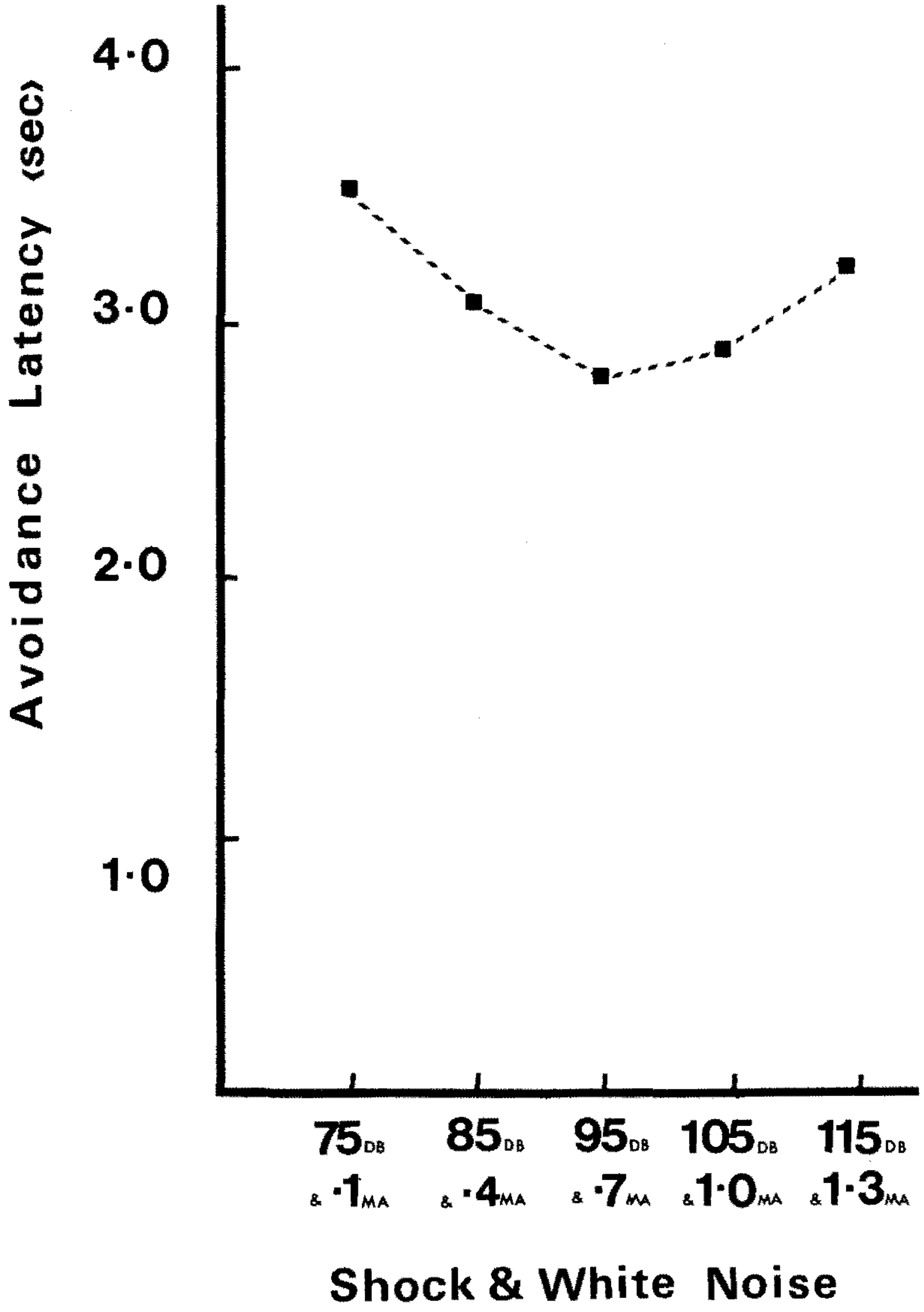


Figure 3.32 Mean latency as a function of shock and white noise (N = 20 per data point).

3.6 COMPARISONS OF WHITE NOISE AND OF SHOCK WITH WHITE NOISE PLUS SHOCK

3.6.1 COMPARISONS OF DATA POINTS

One analysis compared white noise and shock with white noise plus shock at each data point. Scores from the 75 dB group were added to scores from the .1 ma group and the mean of this combined group ($N = 20$) was compared to that of the 75 dB + .1 ma group ($N = 20$); scores from the 85 dB and .4 ma groups were added and the mean of this combined group was compared with that of the 85 dB + .4 ma group, and so on.

For percent avoidance, the results of planned, orthogonal contrasts for the five comparisons in order were $F_{1,190} = 1.4$ ($p > .1$), $F_{1,190} = 2.5$ ($p > .1$), $F_{1,190} < 1$, $F_{1,190} < 1$ and $F_{1,190} < 1$.

A routine check indicated that the variances of the latency scores ($F_{10,19\max} = 8.5$, $p < .01$), and the variances of the logarithms of the latency scores ($F_{10,19\max} = 6.3$, $p < .01$), violated the assumption of homogeneity of variances.

Therefore, the latency scores were compared non-parametrically. The results of the Mann-Whitney U test for the five comparisons in order were $U = 192.5$ ($p > .1$), $U = 171.5$ ($p > .1$), $U = 182.5$ ($p > .1$), $U = 155$ ($p > .1$) and $U = 178.5$ ($p > .1$).

3.6.2 COMPARISONS OF FUNCTIONS: PERCENT AVOIDANCE ONLY

Since percent avoidance was consistently higher for an addition of white noise and of shock than for white noise plus shock, another analysis compared the functions of white noise and of shock with the function of white noise plus shock. Following Snedecor's and Cochran's (1967) comparisons of linear combinations of means, a test(1)

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(1) Dr. David Chant, Department of Statistics, A.N.U., devised this test; see Appendix 1.

was devised to examine the hypothesis that an addition of the linear coefficients of the functions of white noise and of shock did not differ from the linear coefficient of the function of white noise plus shock and, simultaneously, that an addition of the quadratic coefficients of the functions of white noise and of shock did not differ from the quadratic coefficient of the function of white noise plus shock. That is, the hypothesis was $\beta_1 + \beta_2 - \beta_3 = 0$ and, simultaneously, $\gamma_1 + \gamma_2 - \gamma_3 = 0$, where the linear coefficients of the white noise function, of the shock function and of the white noise plus shock function were $\beta_1 = 1.1$, $\beta_2 = 5.9$ and $\beta_3 = -.4$, respectively, and the quadratic coefficients of the preceding functions were $\gamma_1 = -3.7$, $\gamma_2 = -4.5$ and $\gamma_3 = -3.5$, respectively. This hypothesis was rejected at the .05 level.

The foregoing results are summarized in Table 3.4.

TABLE 3.4

Comparison of the functions of white noise and of shock with the function of white noise plus shock.

1. Linear and quadratic coefficients.

	White noise function	Shock Function	White noise plus shock function
Linear coefficient	$\beta_1 = 1.10$	$\beta_2 = 5.96$	$\beta_3 = -.41$
Quadratic coefficient	$\gamma_1 = -3.74$	$\gamma_2 = -4.52$	$\gamma_3 = -3.57$

2. Comparison: $\beta_1 + \beta_2 - \beta_3 = 0$ and $\gamma_1 + \gamma_2 - \gamma_3 = 0$.

Source	SS	df	MS	F	p
Comparison	3,464.00	2	1,732.00	3.21	<.05
Within groups	101,403.30	188	539.38		

3.7 DISCUSSION

Two comparisons suggested that the behavioural effects of two stimuli together did not differ from those of either stimulus alone. Statistical trends, which described the relation of either the percentage or the latency of avoidance responses to the intensity of stimulation, were predominantly quadratic for two stimuli together and for either stimulus alone. Furthermore, in comparisons of these trends, the percentage or the latency of avoidance responses at each intensity of the two stimuli together did not differ from the mean of the percentage or of the latency of avoidance responses at each intensity of these stimuli alone. Accordingly, there appears to be little evidence to support the assumption of a continuum of activation with quadratic, or inverted-U(2) effects on behaviour.

Curiously, however, percent avoidance was lower at every intensity for white noise and shock together than for an addition of white noise and of shock. In fact, the linear and the quadratic coefficients of the function of white noise plus shock differed from an addition of those of the functions of white noise and of shock. This difference is not predicted by activation theory, or by any other theory.

Before attempting to present post-hoc rationalizations, it seems wise to establish the reliability, i.e. the replicability of the foregoing data. Until then, any firm conclusion that the behavioural effects of two stimuli together do not differ from those of either stimulus alone is incautious.

In contrast to the present results, animal studies of white

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(2) A significant quadratic trend does not necessarily imply a significant inverted-U trend. Therefore, analyses reported in Appendix 1, Section 1.1, established that the functions of white noise, of shock and of white noise plus shock show significant inverted-U trends.

noise and of shock, and human studies of the interaction between "stresses", implicate a continuum of activation in changes in behaviour. These studies are not satisfactory.

Campbell (1968) found that rats prefer to enter one compartment and receive a shock, rather than to enter another compartment and receive the shock plus white noise. Thus, the rats would seem to regard shock plus white noise as being more "aversive" than shock alone. Also, Myers (1969) demonstrated lower response rates when a response terminated either a shock or a burst of white noise than when the response terminated the shock plus the burst of white noise. Thus, shock plus white noise would seem to be more "reinforcing" than either stimulus alone.

However, Campbell (1968) and Myers (1969) compared the effects of multiple stimuli and those of single stimuli at one intensity, not over a range of intensities. Since activation theory predicts that combining stimuli will sometimes improve, and sometimes impair, behaviour, it is not clear whether these comparisons are confirmatory or disconfirmatory.

In a series of British studies of humans, reviewed by Broadbent (1971), by Poulton (1970) and by Wilkinson (1969), multiple stimuli, or "stresses", were shown either to improve performance compared with a single stress (e.g. sleep loss and low levels of blood alcohol combine to improve performance, whereas sleep loss alone impairs performance and alcohol alone has no effect on performance; Wilkinson and Colquhoun, 1968) or to impair performance compared with a single stress (e.g. hypoxia and alcohol combine to impair performance, whereas hypoxia alone improves performance and alcohol alone has no effect on performance; Pearson, 1968).

The effects of combining stresses have been widely interpreted in terms of changes in activation (Broadbent, 1971; Poulton, 1970; Wilkinson, 1969). Indeed, according to some authors, such as Broadbent (1963), combinations of stresses may alter activation in opposite directions and, thus, fail to alter performance.

However, most studies of humans have not established the intensity at which each stress is associated with optimal performance; therefore, it becomes "unhappily apparent" (Duffy, 1962) that almost any effects of combining stresses can be interpreted in terms of changes in activation. For example, if two stresses combine to improve performance, then the intensity of each stress can be classified as "low"; hence, these intensities combine to increase activation from low to moderate levels, improving performance. In contrast, if two stresses combine to impair performance, then the intensity of each stress can be classified as "moderate"; hence, these intensities combine to increase activation from moderate to high levels, impairing performance.

The present work established the intensity at which each stress is associated with optimal performance and so the effects of combining stresses could test activation theory. In this way, the possibility of activation theory providing post-hoc "explanations" was eliminated.

In conclusion, the present study demonstrated quadratic trends in behavioural efficiency as a function of the intensity either of white noise or of shock. Contrary to the expectations of activation theory, there was not a decreasing monotonic trend in behavioural efficiency as a function of the intensity of white noise plus shock.

3.8 SUMMARY

If two stimuli alone manipulate a continuum of activation and, thereby, produce inverted-U changes in behavioural efficiency as a function of the intensity of stimulation, then the two stimuli together should manipulate this continuum and, thereby, produce decreasing monotonic changes in behavioural efficiency. While white noise and shock alone produced quadratic trends in shuttleavoidance, white noise and shock together also produced this type of trend. It was concluded that the assumption of a continuum of activation with inverted-U effects on behaviour was not confirmed. Other studies have presented data in support of the assumption of a continuum of activation, but have not examined a range of intensities of stimulation. Under these circumstances, any data would seem to "support" the assumption.

CHAPTER 4

THE PHYSIOLOGICAL ADDITIVITY OF STIMULI: A TEST OF THE ASSUMPTION THAT A CONTINUUM OF ACTIVATION UNDERLIES CHANGES IN PHYSIOLOGICAL ACTIVITY

4.1 RATIONALE

If two stimuli alone manipulate a continuum of activation and, thereby, produce changes in physiological activity, then the two stimuli together should manipulate this continuum and, thereby, produce greater changes in physiological activity.

A test of the foregoing expectation required consideration of two methodological problems, *viz.* the selection of a measure of physiological activity, as an index of activation, and the selection of an experimental paradigm which isolates the effects of activation.

Of all the possible indices of activation, outlined by Duffy (1972), only a few have been extensively investigated. In particular, central measures, such as amplitude of alpha and of beta waves (Pinneo, 1961) and amplitude of evoked cortical potentials to a light stimulus (Eason and Dudley, 1971) have shown concomitant changes with alterations in induced muscle tension and in shock, respectively. Similarly, peripheral measures, such as heart rate, muscle activity and skin conductance, have shown concomitant changes with alterations in induced muscle tension (Neva, 1969; Pinneo, 1961) as well as in shock (Eason and Dudley, 1971; Tuton, 1970).

These indices of activation need to be employed in appropriate experimental paradigms, i.e. those which allow the isolation of the effects of activation from the effects of irrelevant variables, especially movement (de Toledo, 1971). For example, Roberts and Young (1971) reported that a classical conditioning paradigm with partially-restrained rats did not confound "motivation", or activation, and movement in one measure of the nervous system, *viz.* that of skin conductance. Whereas heart rate was found to increase, to decrease or to remain constant with corresponding variations in overt movements by subjects in the presence of a shock-associated stimulus, skin conductance always increased following presentation of this stimulus. Apparently, skin conductance reflected only a motivational, or activational, state.

On the basis of these considerations, it was decided to determine whether white noise and shock together would elicit greater changes in skin conductance than either stimulus alone in a classical conditioning paradigm with partially-restrained rats. The first experiment, described below, used two intensities of white noise and of shock. A second experiment investigated a possible inadequacy in the choice of these intensities.

4.2 EXPERIMENT 1

4.2.1 METHOD

4.2.1.1 SUBJECTS

S̲s were six naive male albino rats obtained from the John Curtin School of Medical Research, Canberra, Australia. They were between 100 and 120 days old at the beginning of the experiment and were maintained on ad lib. food and water.

4.2.1.2 APPARATUS

*S*s were partially restrained in a circle of brass rods between two clear perspex stands (see Figure 4.0). This type of restraint prevented them from interfering with the recording electrodes (Roberts, personal communication).

Following Holdstock and Schwartzbaum (1965), a Grass Model 79 polygraph, operating at a paper speed of 100 mm./second, was used to obtain records of skin resistance. The polygraph passed a 50 microamperes DC current through two silver-silver chloride electrodes, 10 mm. x 20 mm. Electrodes were covered by a one mm. coating of Nikkoh Kirokushi electrode paste and were embedded one mm. deep in a rectangular rubber container, extending three mm. in each direction from the electrode. The purpose of the rubber container was to control contact area as much as possible and to minimize variation in contact pressure (Roberts and Young, 1971).

Before electrodes were secured, the paws were sponged with distilled water and were dried with cotton wool. Electrodes were secured over the inter-digital and the metatarsal sweat glands on the hind paws (Ring and Randall, 1947) with plastic strips.

S were placed in a 68 mm. x 48 mm. x 44 mm. darkened, soundproofed compartment. They faced a 6 mm. x 6 mm. speaker which produced an 80 dB, 650 cps tone through a BWD 181 Sine and Square Wave Generator, and they faced a 120-w. clear light bulb, which produced an increase in illumination of approximately 5,500 lux ca. Shock was administered to the distal third of the rat's tail through a pair of 5 mm.^{2} zinc electrodes spaced approximately 10 mm. apart. Electrodes were coated lightly with electrode paste and were secured with plastic strips.

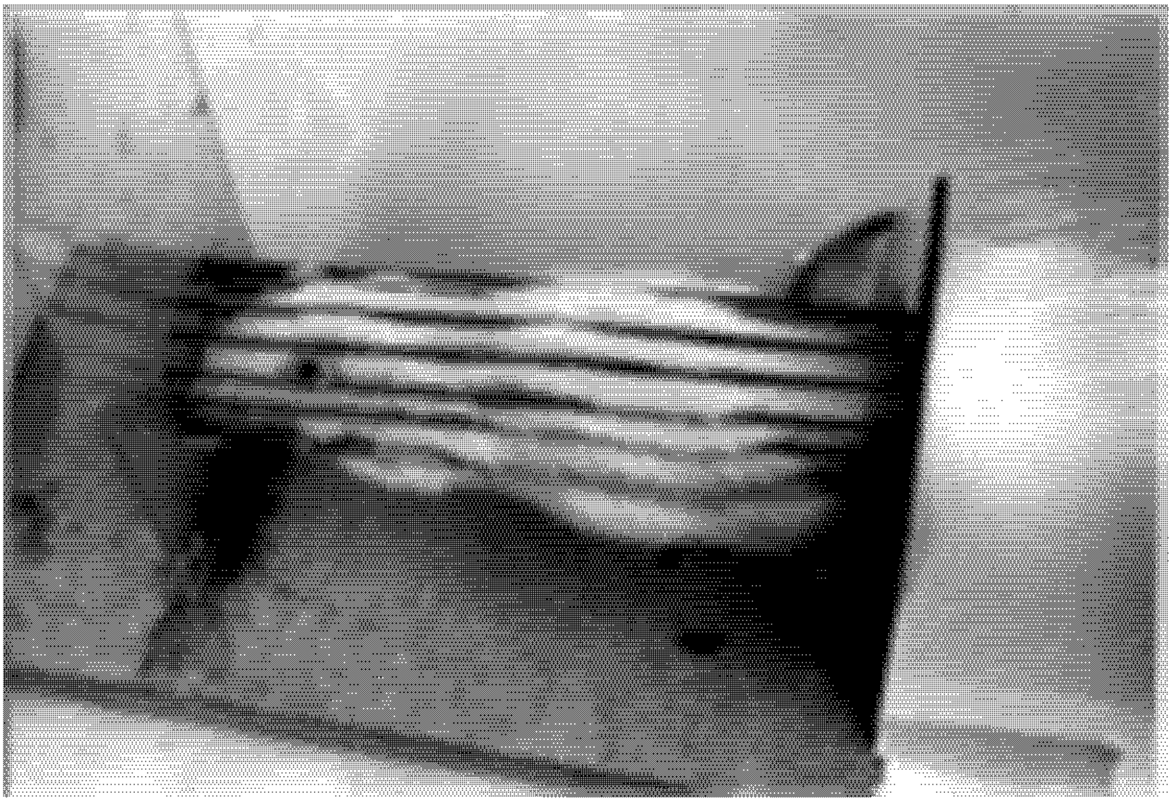

Figure 4.0 Aerial view of a rat in the restraining device.

White noise of 1200-4800 cps was presented through a 12 mm. x 12 mm. speaker via a Scott 811-B Random Noise Generator. The speaker was mounted at the top of the compartment.

4.2.1.3 DESIGN

A number of factors point to the appropriateness of within-subject designs, in which S is exposed to all conditions, in peripheral physiological measurement (Carroll, 1972). Several variables may influence the nature and the magnitude of physiological responses, other than the conditions of interest. For example, the law of initial values (Wilder, 1957) postulates that the magnitude of change to a stimulus is related to the pre-stimulus level of any physiological system; and, there are large individual differences in these pre-stimulus levels. Further, the Laceys' work (e.g. 1956, 1958) on response stereotypy points to consistent individual differences in the efficacy of responding within any physiological system.

Accordingly, the present experiment used a within-subject design to gain precision (e.g. Winer, 1962). Of course, this kind of design has problems, *viz.* the occurrence of order or carry-over effects from one condition to the next. These effects were minimized in two ways. The sequence of conditions was counter-balanced across subjects by means of a Latin Square. Also, each of the conditions was followed by an extinction session which attempted to eliminate the influence of the conditions.

4.2.1.4 PROCEDURE

S were run in random order and were habituated to the apparatus in four daily sessions. On the first occasion, they were simply placed in the darkened compartment for one hour. On each subsequent occasion, they were presented with 25 tones and 25 lights. These stimuli were 10 seconds in duration and were presented in random order with a 60 second inter-trial interval.

Subsequently, each S received either an experimental session or an extinction session at the same time each day. An experimental session consisted of 50 CS+ trials and 50 CS- trials. The CSs were ten seconds in duration and were presented in random order with a 60 second inter-trial interval. A .5 second UCS immediately followed offset of the CS+ whereas no UCS followed offset of the CS-. In each of the six experimental sessions, one of six UCSs was used, i.e. 75 dB, 115 dB, .1 ma, 2.5 ma, 115 dB + .1 ma and 115 dB + 2.5 ma.(1) For half of the Ss, chosen randomly, tone was CS+ and light was CS-; for the other Ss, tone was CS- and light was CS+. The order of UCSs was determined by a 6 x 6 Latin Square, selected by procedures outlined in Kirk (1968). Each experimental session was followed by an extinction session the next day, consisting of 25 presentations of each CS in the absence of any UCS. Extinction sessions attempted to eliminate any differential responding to CS+ and to CS-.

4.2.2 RESULTS

4.2.2.1 SKIN CONDUCTANCE CHANGES

Following Grings and Lockhart (1965) and others, changes in skin resistance to each CS were scored as the difference between the point of response initiation and the lowest value reached during a particular interval (see Figure 4.00). Recent experiments suggest that the latency of resistance responses in rats averages between 1.22

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(1) It became obvious in a pilot study that 75 dB did not affect skin conductance. Accordingly, 75 dB was not combined with either .1 ma or 2.5 ma.

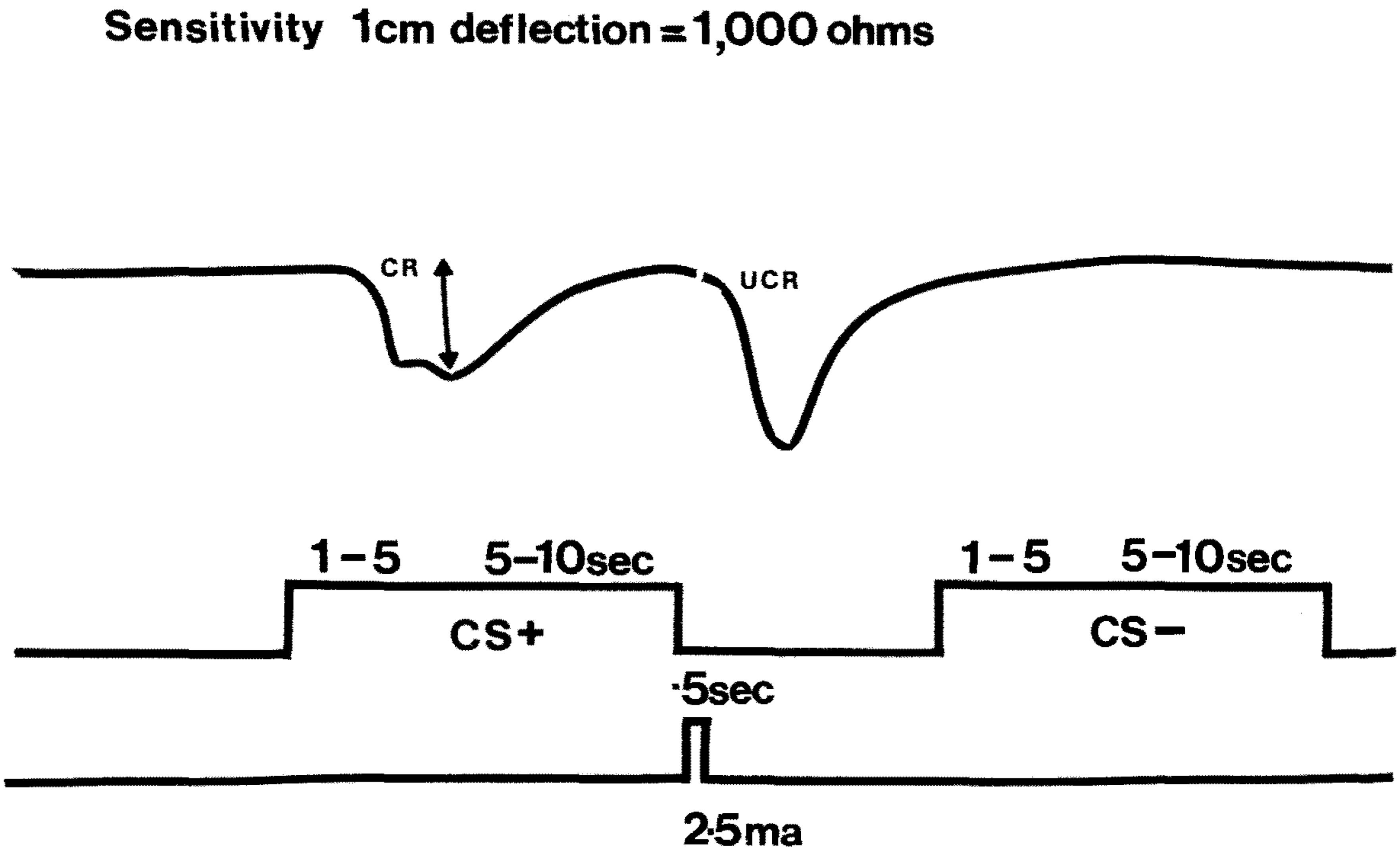


Figure 4.00 Example of conditioned changes in skin resistance to shock. The CR was scored as the difference between the point of response initiation and the lowest level reached in one of two intervals following CS onset, ie 1-5 and 5-10 sec. The record is broken at the point of shock onset, where the immediate physiological consequence of this stimulus is not shown.

seconds and 1.35 seconds (Holdstock, 1969) and ranges between 1.12 seconds and 1.44 seconds (Holdstock and Schwartzbaum, 1965). These latencies are quite similar to those in humans and, because of the author's interest in inter-species comparisons, resistance responses were scored in two intervals which are typical of human work, i.e. one second to five seconds after CS onset (Interval 1) and five seconds to ten seconds after CS onset (Interval 2) (e.g. Dawson and Biferno, 1972; Lind, 1973). Resistance measures or ohms were converted into conductance measures or micromhos.

A. Interval 1: One Second to Five Seconds Following CS Onset

Change scores to CS+ and to CS- for each S were computed as the mean of a block of five consecutive CS+ trials and the mean of a block of five consecutive CS- trials. Blocks were sampled at the beginning (i.e. CS+/CS- trials 1-5, CS+/CS- trials 6-10), in the middle (i.e. CS+/CS- trials 21-25, CS+/CS- trials 26-30) and at the end (i.e. CS+/CS- trials 41-46, CS+/CS- trials 46-50) of each of the experimental sessions. It should be noted that a small percentage (6.3%) of records was lost due to various artefacts, usually movement by the subject. Whenever this occurred, the missing trial was assigned the average of the other trials within a block. The difference between a CS+ block and the corresponding CS- block (e.g. the difference between a CS+ block, representing the first five CS+ trials, and the corresponding CS- block, representing the first five CS- trials) provided the data for an analysis of variance.

Mean change to CS+ and to CS- across subjects for all of the CS+/CS- blocks within all of the experimental sessions (i.e. UCSs) are presented in Table 4.11, in Figure 4.11 (white noise UCSs), in Figure 4.12 (shock UCSs) and in Figure 4.13 (white noise plus shock UCSs).

An analysis of variance indicated that there was no difference in CS+/CS- discrimination between the tone CS+/light CS- Ss and the tone CS-/light CS+ Ss ($F_{1,4} < 1$), that there was a significant difference in CS+/CS- discrimination with different types of UCS ($F_{5,20} = 9.0$, $p < .01$), that there were no differences in CS+/CS- discrimination as a function of trials ($F_{5,20} = 1.1$, $p > .1$) and that there were no interactions. These results are summarized in Table 4.12.

Following Winer (1962), Newman-Keuls comparisons were used to investigate differences in CS+/CS- discrimination between UCSs. These comparisons used the mean square error for the UCS factor (i.e. the UCS factor x subjects within groups; Winer, 1962).

It was found that CS+/CS- discrimination did not differ between the 75 dB UCS and the 115 dB UCS ($W = .14$); that CS+/CS- discrimination was less with the .1 ma UCS than with the 2.5 ma UCS ($W = .20$, $p < .01$) and that CS+/CS- discrimination was less with the 115 dB + .1 ma UCS than with the 115 dB + 2.5 ma UCS ($W = .14$, $p < .05$).

Also, it was found that CS+/CS- discrimination did not differ between the 115 dB + .1 ma UCS and the 115 dB UCS ($W = .12$) or between the 115 dB + .1 ma UCS and the .1 ma UCS ($W = .14$); that CS+/CS- discrimination was greater with the 115 dB + 2.5 ma UCS than with the 115 dB UCS ($W = .20$, $p < .01$) but did not differ between the 115 dB + 2.5 ma UCS and the 2.5 ma UCS ($W = .12$).

Since the absence of differences in CS+/CS- discrimination as a function of trials seemed odd, a final series of analyses of variance compared the six CS+ blocks and the six CS- blocks within each UCS.

For the 75 dB UCS, there were no significant factors; for the 115 dB UCS, there were greater increases in conductance to CS+ than to

CS- ($F_{1,5} = 9.1$, $p < .05$). For the .1 ma UCS, there were no significant factors; for the 2.5 ma UCS, there were greater increases in conductance to CS+ than to CS- ($F_{1,5} = 59.5$, $p < .01$), there were differences between blocks of trials ($F_{5,25} = 6.5$, $p < .01$) and, the interaction between the foregoing two factors was marginally significant ($F_{5,25} = 2.1$, $p = .09$). This interaction suggested that the greater increase in conductance to CS+ than to CS- was more pronounced in the last blocks of trials than in the first blocks of trials. Finally, for the 115 dB + .1 ma UCS, there were greater increases in conductance to CS+ than to CS- ($F_{1,5} = 6.7$, $p < .05$); for the 115 dB + 2.5 ma UCS, there were greater increases in conductance to CS+ than to CS- ($F_{1,5} = 48.3$, $p < .01$), there were differences between blocks of trials ($F_{5,25} = 2.8$, $p < .05$) and, the interaction between the foregoing two factors was significant ($F_{5,25} = 5.2$, $p < .01$). This interaction suggested that the greater increase in conductance to CS+ than to CS- was more pronounced in the last blocks of trials than in the first blocks of trials.

TABLE 4.11

Mean increases in skin conductance (micromhos) to CS+ and to CS− during Interval 1 (N = 6).

Blocks of five trials.

	1		2		3		4		5		6	
	CS+	CS−	CS+	CS−	CS+	CS−	CS+	CS−	CS+	CS−	CS+	CS−
.1 ma	.36	.17	.26	.14	.26	.20	.28	.11	.20	.17	.24	.18
2.5 ma	.33	.15	.36	.17	.53	.24	.64	.20	.70	.34	.73	.24
75 dB	.22	.10	.25	.12	.15	.12	.14	.15	.12	.07	.16	.10
115 dB	.41	.25	.35	.25	.34	.18	.32	.26	.35	.21	.39	.24
115 dB + .1 ma	.49	.23	.41	.24	.52	.36	.53	.36	.45	.26	.47	.28
115 dB + 2.5 ma	.38	.17	.43	.28	.57	.19	.75	.28	.63	.16	.63	.13

TABLE 4.12

Analysis of variance - Interval 1.

Source	SS	df	MS	F	p
Between subjects	.58	5			
Type of CS	.10	1	.10	F < 1	ns
Subjects within groups	.47	4	.12		
Within subjects	11.91	210			
Type of UCS	3.00	5	.60	8.95	< .01
Type of UCS x Type of CS	.64	5	.13	1.91	ns
Type of UCS x Subjects within groups	1.34	20	.07		
Trials	.16	5	.03	1.07	ns
Trials x Type of UCS	.27	5	.05	1.74	ns
Trials x Subjects within groups	.61	20	.03		
Type of UCS x Trials	1.14	25	.05	1.22	ns
Type of UCS x Trials x Type of UCS	1.01	25	.04	1.08	ns
Type of UCS x Trials x Subjects within groups	3.74	100	.04		

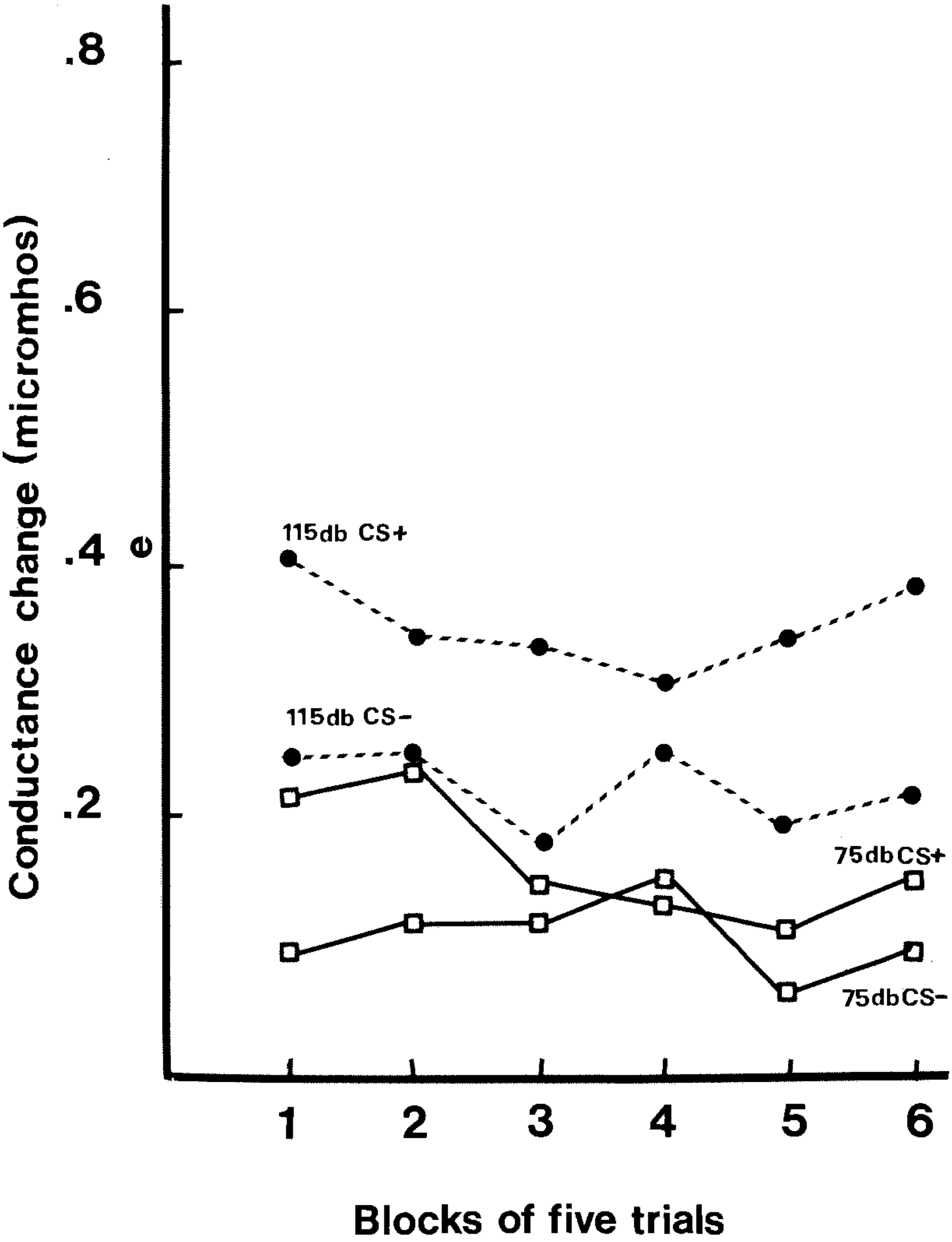


Figure 4.11 Mean conductance change from 1-5 sec following CS onset with a 75 dB UCS and an 115 dB UCS. Blocks of trials were sampled at the beginning (1 and 2), middle (3 and 4) and end (5 and 6) of each conditioning session (N = 6).

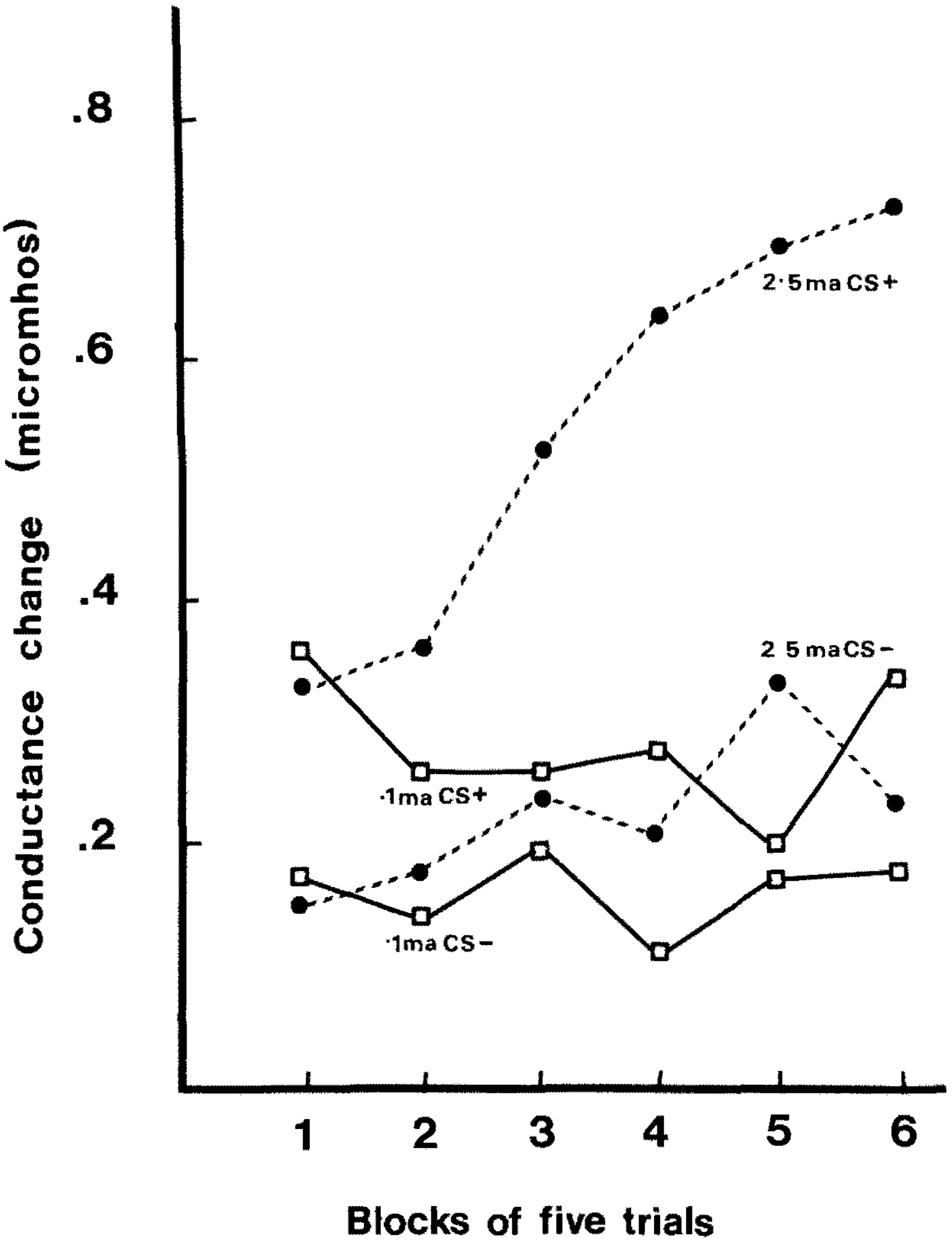


Figure 4.12 Mean conductance change from 1-5 sec following CS onset with a .1 ma UCS and a 2.5 ma UCS. Blocks of trials were sampled at the beginning (1 and 2) middle (3 and 4) and end (5 and 6) of each conditioning session (N = 6).

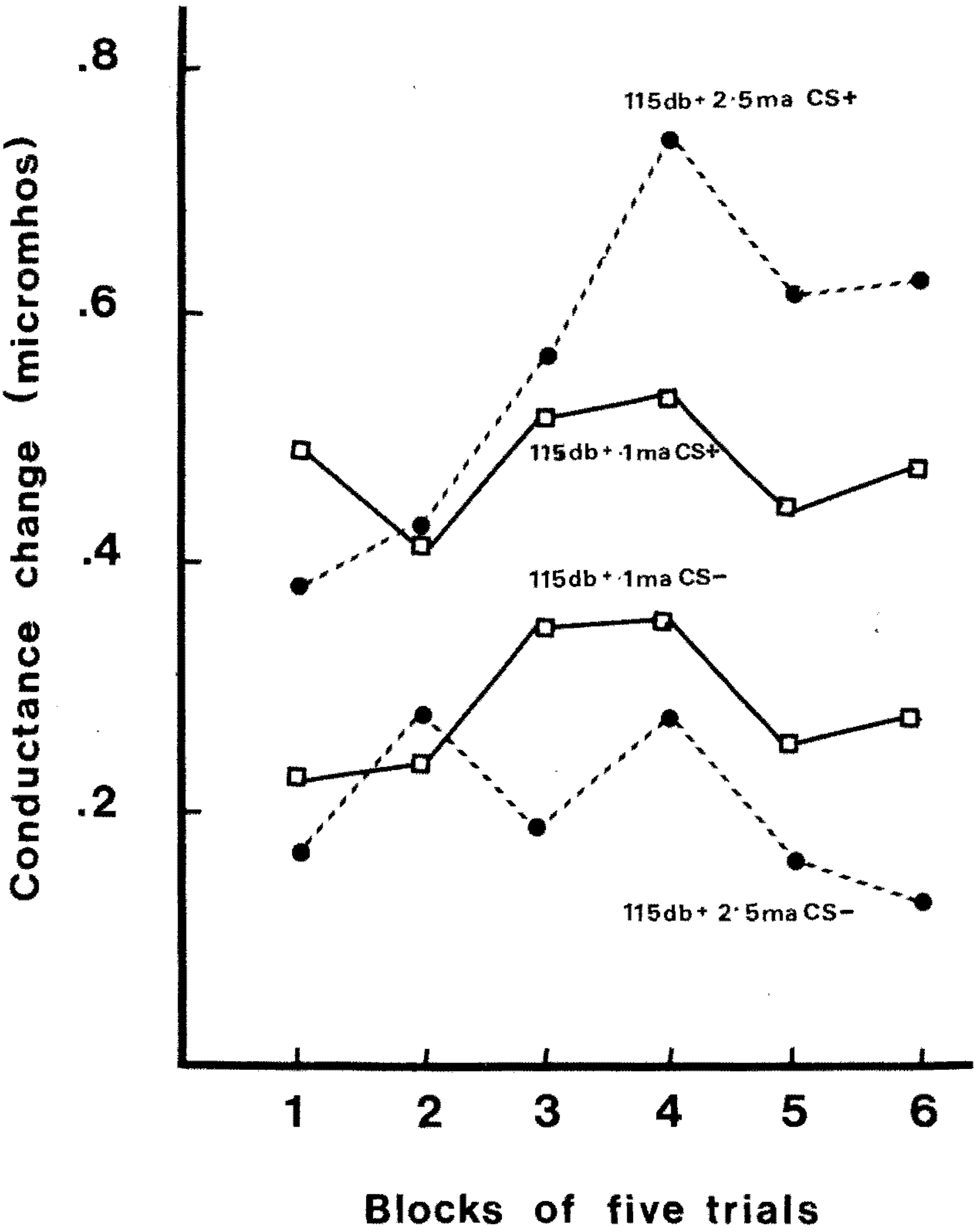


Figure 4.13 Mean conductance change from 1-5 sec following CS onset with an 115 dB + .1 ma UCS and an 115 dB + 2.5 ma UCS. Blocks of trials were sampled at the beginning (1 and 2), middle (3 and 4) and end (5 and 6) of each conditioning session (N = 6).

B. Interval 2: Five Seconds to Ten Seconds Following CS Onset

Change scores to CS+ and to CS- were computed as before on CS+/CS- trials 1-5, on CS+/CS- trials 6-10, on CS+/CS- trials 21-25, on CS+/CS- trials 26-30, on CS+/CS- trials 41-45 and on CS+/CS- trials 46-50 in each of the experimental sessions. The difference between a CS+ block and the corresponding CS- block provided the data for an analysis of variance.

Mean change to CS+ and to CS- across subjects for all of the CS+/CS- blocks within all of the experimental sessions (i.e. UCSs) are presented in Table 4.13.

An analysis of variance indicated that there was no difference in CS+/CS- discrimination between the tone CS+/light CS- S̲s and the tone CS-/light CS+ S̲s ($F_{1,4} < 1$), that there was no difference in CS+/CS- discrimination with different types of UCS ($F_{5,20} = 1.4$, $p > .1$), that there were no differences in CS+/CS- discrimination as a function of trials ($F_{5,20} < 1$), and that there were no interactions. These results are summarized in Table 4.14.

Data on Interval 1 and on Interval 2 are comparable to those from human subjects, typically showing reliable first-interval, skin conductance conditioning compared to weak, or non-existent, second-interval skin conductance conditioning (Dawson and Biferno, 1972; Furedy and Schiffman, 1972; Lind, 1973). Although some authors (e.g. Stern, *et al.*, 1961) have argued that first-interval responses are orienting, non-associative responses whereas second-interval responses are associative responses, indicative of "true" conditioning, second-interval changes appear to be an unreliable index of conditioning.

TABLE 4.13

Mean increases in skin conductance (micromhos) to CS+ and to CS- during Interval 2 (N = 6).

Blocks of five trials.

	1		2		3		4		5		6	
	CS+	CS-	CS+	CS-	CS+	CS-	CS+	CS-	CS+	CS-	CS+	CS-
.1 ma	.12	.22	.17	.15	.12	.16	.17	.22	.12	.17	.15	.21
2.5 ma	.13	.16	.14	.12	.17	.19	.22	.22	.38	.30	.20	.27
75 dB	.12	.20	.20	.20	.23	.11	.19	.12	.15	.10	.10	.17
115 dB	.12	.11	.19	.19	.21	.11	.12	.19	.23	.15	.29	.23
115 dB + .1 ma	.31	.20	.24	.22	.39	.23	.31	.20	.28	.42	.35	.29
115 dB + 2.5 ma	.09	.12	.15	.13	.22	.13	.24	.15	.21	.14	.22	.18

TABLE 4.14

Analysis of variance - Interval 2.

Source	SS	df	MS	F	p
Between subjects	.26	5			
Type of CS	.02	1	.02	F < 1	ns
Subjects within groups	.25	4	.06		
Within subjects	5.58	210			
Type of UCS	.25	5	.05	1.38	ns
Type of UCS x Type of CS	.40	5	.08	2.28	ns
Type of UCS x Subjects within groups	.71	20	.04		
Trials	.15	5	.03	F < 1	ns
Trials x Type of CS	.17	5	.03	F < 1	ns
Trials x Subjects within groups	.81	20	.04		
Type of UCS x Trials	.66	25	.03	1.36	ns
Type of UCS x Trials x Type of CS	.48	25	.02	F < 1	ns
Type of UCS x Trials x Subjects within groups	1.94	100	.02		

4.2.2.2 SKIN CONDUCTANCE LEVELS

Conductance levels were sampled at three points, i.e. immediately before the 20th, the 60th and the 100th trial, for each S in each of the experimental sessions.

Mean conductance level across subjects at these trials within all of the experimental sessions (i.e. UCSs) are presented in Table 4.15.

An analysis of variance indicated that there was no difference between the tone CS+/light CS- Ss and the tone CS-/light CS+ Ss ($F_{1,4} < 1$), that there was no difference with different types of UCS ($F_{5,20} < 1$), that there were significant increases across trials ($F_{2,8} = 22.94$, $p < .01$), and that there were no interactions. These results are summarized in Table 4.16.

Following Winer (1962), Newman-Keuls comparisons were used to investigate differences in conductance levels between trials. These comparisons used the mean square error for the trials factor (i.e. the trials factor x subjects within groups; Winer, 1962).

It was found that conductance levels were lower at the 20th trial than at the 60th trial ($W = 6.65$, $p < .01$) and, in turn, that conductance levels were lower at the 60th trial than at the 100th trial ($W = 4.56$, $p < .05$).

TABLE 4.15

Mean conductance level (micromhos) (N = 6).

	Trial		
	20	60	100
.1 ma	12.33	19.29	22.12
2.5 ma	22.94	26.69	37.07
75 dB	19.28	31.86	37.82
115 dB	13.22	16.68	19.37
115 dB + .1 ma	14.53	20.54	26.87
115 dB + 2.5 ma	18.88	29.34	37.94

TABLE 4.16

Analysis of variance - conductance level.

Source	SS	df	MS	F	p
Between subjects	3748.09	5			
Type of CS	181.51	1	181.51	F < 1	ns
Subjects within groups	3566.59	4	891.65		
Within subjects	33324.06	102			
Type of UCS	3434.85	5	686.97	F < 1	ns
Type of UCS x Type of CS	4901.62	5	980.33	1.18	ns
Type of UCS x Subjects within groups	16673.76	20	833.69		
Trials	3218.17	2	1609.09	22.94	< .01
Trials x Type of CS	24.42	2	12.21	F < 1	ns
Trials x Subjects within groups	561.25	8	70.16		
Type of UCS x Trials	529.70	10	52.97	F < 1	ns
Type of UCS x Trials x Type of CS	917.83	10	91.78	1.20	ns
Type of UCS x Trials x Subjects within groups	3062.46	40	76.56		

4.2.3 DISCUSSION

With respect to changes from one second to five seconds following CS onset, there were two important findings, *viz.* that heightening of the intensity of white noise alone did not produce conditioning, i.e. progressively greater increases in conductance to CS+ than to CS- as a function of trials, whereas heightening of the intensity of shock alone did produce conditioning; and, that combinations of white noise and of shock had virtually the same effect on CS+/CS- discrimination as shock alone.

The first finding is consistent with results of Campbell and Bloom (1965) who showed that white noise is a weaker stimulus than shock. The second finding supports Goldberg's (1966) demonstration of the same autonomic variations in response to combined "stresses" as those in response to the stronger of the separate stresses.

Campbell and Bloom (1965) examined rats' avoidance of different intensities of white noise or of shock in a choice situation. A potentially damaging intensity of white noise (125 dB) was equally avoided, i.e. equally "aversive", compared to a harmless intensity of shock.

Similarly, in the previous chapter, white noise alone and shock alone were associated with inverted-U changes in shuttleavoidance as a function of the level of stimulation; however, in the case of white noise, shuttling began to decline beyond 105 dB, which approaches the damaging intensities, while, in the case of shock, shuttling started to show impairments beyond .4 ma, which is well below the tetanization threshold.

The comparative strength of white noise and of shock is particularly relevant to the present experiment, where a partial-restraint technique was used to measure skin conductance. The significant increase in conductance levels within each of the experimental sessions is probably due to restraint, which is capable of inducing stress reactions, such as ulceration, in rats (Goldenberg, 1973). Accordingly, restraint may preclude a sensitive gauge of the effects of any stimulus, and especially of a weak stimulus.

Differences in the strength of white noise and of shock could influence autonomic conditioning in a number of ways; e.g. the former UCS might habituate faster (Buchwald and Humphrey, 1973), or might not always elicit an unconditioned response (Gormezano and Kehoe, in press), compared to the latter UCS. In one theoretical analysis, Young (1965) presents a possible relation between strength of a UCS and the extent of autonomic conditioning. She argues that a UCS must elicit sensory impulses with strong "attention" value, i.e. with the ability to induce strong orienting responses (Sokolov, 1963), before autonomic conditioning will occur. Thus, the strength of a UCS is defined by its sensory feedback, which determines the extent of autonomic conditioning. Casual observations are consistent with this possibility. For example, there are less overt responses to white noise, e.g. shrieking, struggling, than to shock.

Combinations of white noise and of shock had virtually the same effect on CS+/CS- discrimination as shock alone.

This finding supports that of Goldberg (1966), who required humans to place their hand in cold water (seven degrees Centigrade) as well as to raise their leg for two minutes, or to perform either of the two activities for two minutes. Except for blood pressure, autonomic variations in response to these combined "stresses" were the same in five measures as those in response to the stronger of the separate stresses.

However, Goldberg's work was not replicated by Patton (1970), who required humans to bathe in moderately cold water (fifty degrees Fahrenheit) and to solve anagrams for sixty minutes, or to perform either of the two activities for sixty minutes. Except for pulse rate, autonomic variations in response to these combined "stresses" were significantly greater in six measures than those in response to either of the separate stresses.

In order to reconcile the apparently conflicting data obtained from humans, Patton suggested that stresses of low intensities and of moderate intensities summate to heighten autonomic responding and, in contrast, that those of high intensities may separately give rise to a ceiling level of this responding, beyond which further stimulation has no effect. In other words, stresses will be additive in their influence on physiological changes within a restricted range of intensities.

Patton's suggestion may provide a basis for questioning the adequacy of the present experiment. At the low end of the continuum of intensities, white noise of 115 dB and shock of .1 ma may be too weak to show additive influences; for example, .1 ma did not induce any CS+/CS- discrimination at all. Again, at the high end of this continuum, white noise of 115 dB and shock of 2.5 ma may be too strong to show additive influences. For example, CS+/CS- discrimination with a 2.5 ma UCS may be compared to that with a 3.2 ma UCS in another investigation of classical conditioning in rats (Roberts and Young, 1971). The absolute level of skin conductance increases with each of these intense UCSs was very similar. Thus, a ceiling level of skin conductance increases may well have been reached.

4.3 EXPERIMENT 2

In the previous study, the failure to obtain differences in skin conductance between white noise and shock together and shock alone, may have been due to the selection of shock intensities which were either too low or too high. Accordingly, an intermediate value of shock was examined.

In particular, two UCSs were compared, one involving white noise of 115 dB plus a shock of .8 ma and another involving white noise of 75 dB plus a shock of .8 ma. The sensitivity of this comparison was maximized by running a large number of conditioning trials.

4.3.1 METHOD

4.3.1.1 SUBJECTS

Ss were eight naive male albino rats obtained from the John Curtin School of Medical Research, Canberra, Australia. They were between 100 and 120 days old at the beginning of the experiment and were maintained on ad lib. food and water.

4.3.1.2 APPARATUS

The apparatus was the compartment described previously.

4.3.1.3 DESIGN

The preceding study used a within-subject design to gain precision in the comparison of physiological responses between conditions. This design has one rather unfortunate consequence, *viz.*

that any influence of the order of conditions is completely entangled in the effects of conditions (e.g. Winer, 1962).

As far as the author is concerned, within-subject designs should contain some means of estimating the influence of order, e.g. order can be included as an experimental variable, allowing the demonstration that order does not yield a significant main effect or any significant interactions.

Unfortunately, restrictions in the time available to conduct the present series of experiments prevented the inclusion of order as an experimental variable. Due to this inadequacy, a more conservative between-subjects comparison was used.

4.3.1.4 PROCEDURE

Ss were run in random order and were habituated to the apparatus in four daily sessions. On the first occasion, they were simply placed in the darkened compartment for one hour. On each subsequent occasion, they were presented with 25 tones and 25 lights. These stimuli were five seconds in duration and were presented in random order with a 20 second inter-trial interval.

Subsequently, Ss were randomly assigned to two groups, one given 115 dB + .8 ma as UCS and another given 75 dB + .8 ma as UCS. Within each group, half of the Ss, chosen randomly, were presented with tone as CS+ and with light as CS- and the other Ss were presented with tone as CS- and with light as CS+.

Each S received four sessions at the same time each day. These sessions consisted of 100 CS+ trials and 100 CS- trials. The CSs were five seconds in duration and were presented in random order with a 20 second inter-trial interval. A .5 second UCS immediately followed offset of CS+ whereas no UCS followed offset of CS-.

4.3.2 RESULTS

4.3.2.1 BETWEEN-SUBJECT COMPARISONS OF PHYSIOLOGICAL RESPONSES

In between-subject comparisons of physiological responses, it has generally been thought that there should be a statistical correction for the observed co-variation between magnitude of conductance change and conductance level (described in the "law of initial values"; Wilder, 1957). Between-subject differences have been corrected in two ways. Firstly, analysis of co-variance has been proposed by Benjamin (1967) but has been extensively questioned (Heath and Oken, 1965; Hord, *et al.*, 1964; Lacey and Lacey, 1962; Lykken and Venables, 1971). Secondly, a range-correction procedure, in which an individual's response is scored as a proportion of his/her maximum possible response, has been suggested by Lykken and Venables (1971). This procedure produces some rather curious findings; e.g. range-correction increased the size of differences between different groups of subjects in skin conductance, but not in heart rate (Lykken, 1972). Also, this procedure assumes that an individual's maximum possible response is constant throughout an experimental session.

The foregoing assumption may not be reasonable in a long experimental session where fatigue, habituation etcetera are likely to occur. It seemed particularly unreasonable in the present experimental sessions where skin conductance levels were systematically increasing (see Experiment 1). Accordingly, no transformations were made on the conductance-change scores and hence comparisons between the two groups of subjects provide a conservative test of the hypothesis that different UCSs have different effects on skin conductance.

4.3.2.2 SKIN CONDUCTANCE CHANGES

Change scores to CS+ and to CS- for each S were computed as the mean of a block of five consecutive CS+ trials and the mean of a block of five consecutive CS- trials. Blocks were sampled at the end (i.e. the last five CS+ trials and the last five CS- trials) of each session. The difference between a CS+ block and the corresponding CS- block (e.g. the difference between a CS+ block, representing the last five CS+ trials of one session, and the corresponding CS- block, representing the last five CS-trials of this session) provided the data for an analysis of variance.

Mean change to CS+ and to CS- in the two groups of subjects for all of the CS+/CS- blocks within all of the four sessions are presented in Table 4.21 and in Figure 4.21.

TABLE 4.21

Mean increases in skin conductance (micromhos) to CS+ and to CS- in white noise plus shock groups (N = 4 per group).

Blocks of five trials.

	Session 1		Session 2		Session 3		Session 4	
	CS+	CS-	CS+	CS-	CS+	CS-	CS+	CS-
75 dB+ .8 ma	.13	.09	.35	.23	.29	.31	.38	.18
115 dB+ .8 ma	.54	.25	.36	.11	.68	.12	.68	.14

TABLE 4.22

Analysis of variance - white noise plus shock groups.

Source	SS	df	MS	F	p
Between subjects	1.81	7			
Type of UCS	.80	1	.80	4.75	.07
Subjects within groups	1.01	6	.17		
Within subjects	1.25	24			
Trials	.24	3	.80	1.87	ns
Type of UCS x Trials	.24	3	.80	1.91	ns
Trials x Subjects within groups.	.77	18	.04		

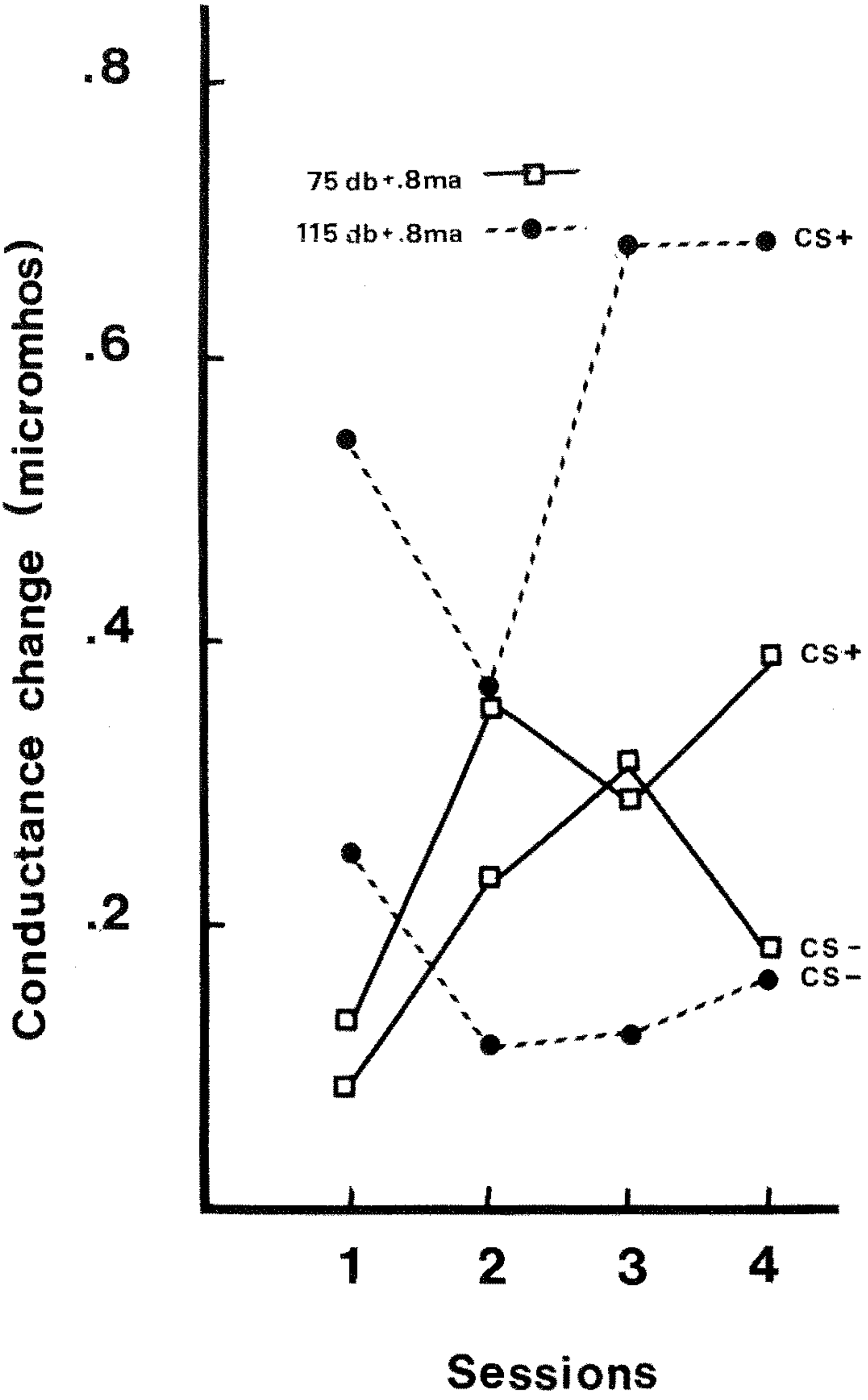


Figure 4.21 Mean conductance change to CS+ and CS- with a 75 dB + .8 ma UCS (N = 4) and an 115 dB + .8 ma UCS (N = 4). The abscissa numbers represent a block of 5 trials sampled at the end of each of 4 consecutive conditioning sessions.

Since CS+/CS- discrimination between the tone CS+/light CS- Ss and tone CS-/light CS+ Ss of the previous study did not differ, this factor was assumed to be insignificant and so was not, again, estimated. Data from tone CS+/light CS- Ss and those from tone CS-/light CS+ Ss were combined.

An analysis of variance indicated that CS+/CS- discrimination between the 115 dB + .8 ma UCS Ss and the 75 dB + .8 ma Ss was marginally significant ($F_{1,6} = 4.7$, $p = .07$), that CS+/CS- discrimination across trials did not change ($F_{3,18} = 1.9$, $p > .1$) and that there was no interaction between the type of UCS and trials ($F_{3,18} = 1.9$, $p > .1$). These results are summarized in Table 4.22.

More detailed comparisons were made to investigate differences in CS+/CS- discrimination between UCSs within each of the four sessions.

Change scores to CS+ and to CS- for each S were computed as the mean of a block of five consecutive CS+ trials and the mean of a block of five consecutive CS- trials. Blocks were sampled at the beginning (i.e. CS+/CS- trials 1-5, CS+/CS- trials 6-10), in the middle (i.e. CS+/CS- trials 46-50, CS+/CS- trials 51-55) and at the end (i.e. CS+/CS- trials 91-95, CS+/CS- trials 96-100) of each session. The difference between a CS+ block and the corresponding CS- block (e.g. the difference between a CS+ block, representing the first five CS+ trials, and the corresponding CS- block, representing the first five CS- trials) provided the data for an analysis of variance.

Mean change to CS+ and to CS- in the two groups of subjects for all of the CS+/CS- blocks within all of the sessions are presented in Table 4.23 and, for the fourth session only, in Figure 4.22.

In the first session ($F_{1,6} < 1$), and in the second session ($F_{1,6} < 1$), the CS+/CS- discrimination between the 115 dB + .8 ma Ss and the 75 dB + .8 ma Ss was not significant. However, the F ratio, indexing this discrimination, increased from the third session ($F_{1,6} = 3.2$, $p = .1$) to the fourth session where it closely approximated significance ($F_{1,6} = 5.1$, $p = .06$). These results are summarized in Table 4.24.

TABLE 4.23a.

Mean increases in skin conductance (micromhos) to CS+ and to CS- in white noise plus shock groups (N = 4 per group).

Session 1

Blocks of five trials

	1		2		3		4		5		6	
	CS+	CS-	CS+	CS-	CS+	CS-	CS+	CS-	CS+	CS-	CS+	CS-
75 dB + .8 ma	.13	.03	.19	.07	.22	.03	.19	.11	.20	.01	.13	.09
115 dB + .8 ma	.23	.08	.32	.11	.60	.20	.50	.27	.51	.21	.54	.25

Session 2

Blocks of five trials

	1		2		3		4		5		6	
	CS+	CS-	CS+	CS-	CS+	CS-	CS+	CS-	CS+	CS-	CS+	CS-
75 dB + .8 ma	.44	.16	.44	.11	.27	.13	.25	.20	.35	.13	.35	.23
115 dB + .8 ma	.36	.15	.38	.25	.46	.15	.47	.15	.47	.21	.36	.14

TABLE 4.23b.

Session 3

Blocks of five trials

	1		2		3		4		5		6	
	CS+	CS-	CS+	CS-	CS+	CS-	CS+	CS-	CS+	CS-	CS+	CS-
75 dB + .8 ma	.35	.07	.28	.05	.21	.10	.30	.11	.18	.22	.29	.31
115 dB + .8 ma	.59	.28	.64	.32	.65	.31	.72	.31	.91	.25	.68	.12

Session 4

Blocks of five trials

	1		2		3		4		5		6	
	CS+	CS-	CS+	CS-	CS+	CS-	CS+	CS-	CS+	CS-	CS+	CS-
75 dB + .8 ma	.36	.08	.34	.11	.52	.11	.38	.40	.44	.20	.38	.18
115 dB + .8 ma	.43	.12	.42	.21	.55	.14	.72	.21	.65	.11	.69	.14

TABLE 4.24a.

Analysis of variance - white noise plus shock groups.

Session 1

Source	SS	df	MS	F	p
Between subjects	2.03	7			
Type of UCS	.25	1	.25	F < 1	ns
Subjects within groups	1.79	6	.30		
Within subjects	1.36	40			
Trials	.17	5	.30	F < 1	ns
Type of UCS x Trials	.06	5	.01	F < 1	ns
Trials x Subjects within groups	1.14	30	.03		

Session 2

Source	SS	df	MS	F	p
Between subjects	1.25	7			
Type of UCS	.03	1	.03	F < 1	ns
Subjects within groups	1.22	6	.20		
Within subjects	1.50	40			
Trials	.10	5	.02	F < 1	ns
Type of UCS x Trials	.29	5	.06	F < 1	ns
Trials x Subjects within groups	1.11	30	.04		

TABLE 4.24b.

Session 3

Source	SS	df	MS	F	p
Between subjects	3.31	7			
Type of UCS	1.14	1	1.14	3.15	ns
Subjects within groups	2.17	6	.36		
Within subjects	2.40	40			
Trials	.13	5	.03	F < 1	ns
Type of UCS x Trials	.62	5	.12	F < 1	ns
Trials x Subjects within groups	1.65	30	.06		

Session 4

Source	SS	df	MS	F	p
Between subjects	1.06	7			
Type of UCS	.49	1	.49	5.11	.06
Subjects within groups	.57	6	.09		
Within subjects	2.47	40			
Trials	.27	5	.05	F < 1	ns
Type of UCS x Trials	.51	5	.10	1.78	ns
Trials x Subjects within groups	1.71	30	.06		

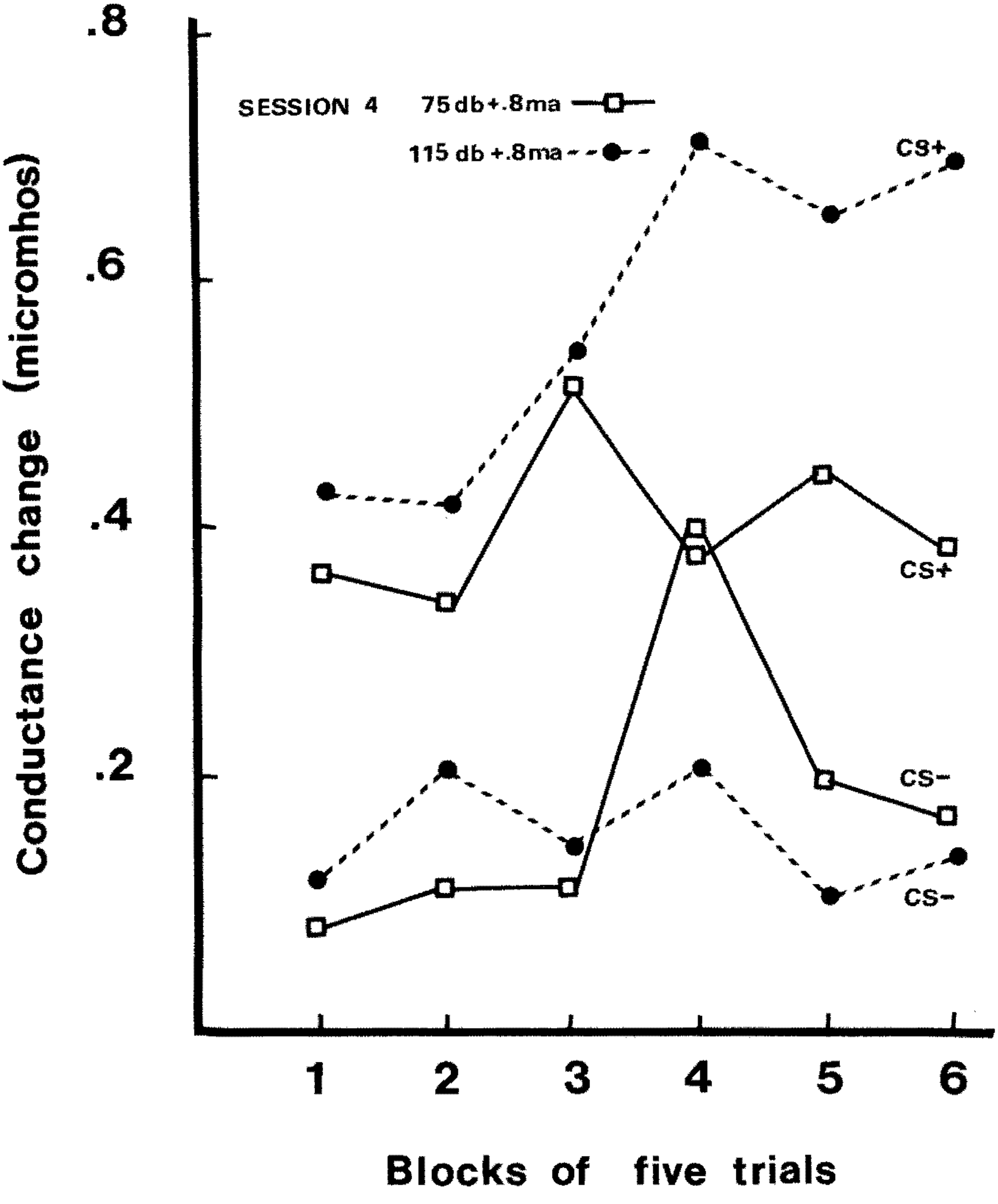


Figure 4.22 Mean conductance change to CS+ and CS- with a 75 dB + .8 ma UCS (N = 4) and an 115 dB + .8 ma UCS (N = 4). Blocks of trials were sampled at the beginning (1 and 2), middle (3 and 4) and end (5 and 6) of the fourth conditioning session.

4.3.3 DISCUSSION

A 115 dB + .8 ma UCS produced greater CS+/CS- discrimination than a 75 dB + .8 ma UCS. This greater discrimination approximated significance and tended to increase across four consecutive sessions. Thus, white noise and shock appear to combine to heighten skin conductance, at least within a certain range of intensities. This finding is consistent with Patton's (1970) data and, more generally, with the assumption of a continuum of activation in the nervous system.

Using Young's (1965) analysis of classical autonomic conditioning, it could be argued that 115 dB + .8 ma produces more sensory feedback than 75 dB + .8 ma. Differences in sensory feedback could be interpreted either as a simple summation of sensory inputs or as one input "sensitizing" another. For example, Duffy, (1972) and Hinde (1966, 1970) review experiments which show increased physiological responses to one sensory stimulus in the presence of another, "sensitizing" stimulus of a different modality. Sensitization supposedly represents a "priming" of the cortex by the reticular formation.

It must be admitted that the present study does not provide strong support for activation theory. However, this study is insensitive on a number of procedural grounds, *viz.* it used a small number of subjects, a conservative between-subjects design, a conservative, non-transformed estimation of skin conductance changes and a restraint technique which is probably stressful in rats.

In conclusion, a high intensity of white noise and a moderate shock elicited greater increases in skin conductance to a CS+ than to a CS- compared to a low intensity of white noise and the same shock.

This finding is consistent with the expectations of activation theory.

4.4 SUMMARY

If two stimuli alone manipulate a continuum of activation and, thereby, produce changes in physiological activity, then the two stimuli together should manipulate this continuum and, thereby, produce greater changes in physiological activity. In a classical conditioning paradigm, a high intensity of white noise and a moderate shock elicited greater increases in skin conductance to a CS+ than to a CS- compared to a low intensity of white noise and the same shock. It was concluded that the assumption of a continuum of activation was supported.

CHAPTER 5

EVALUATION OF ACTIVATION THEORY - 1

5.1 ACTIVATION THEORY AND THE EXPLANATION OF INVERTED-U CHANGES IN BEHAVIOUR

When different kinds of stimuli, or "stresses", are combined, activation theory predicts:

(i) that there is a heightening of activity in the nervous system, and, (ii) that there may be improvements or impairments in behaviour, depending on the intensity of stimulation; at low intensities, combinations increase activation from low to moderate levels and, thereby, improve responses and, at higher intensities, combinations increase activation from moderate to high levels, giving rise to impairments in responding.

Data in Chapter 4 support the former prediction but those in Chapter 3 do not support the latter prediction.

Since the same manipulation, *viz.* combining white noise and shock, altered skin conductance but did not markedly affect shuttle-avoidance, it may be concluded that the heightening of activation *per se* does not result in inverted-U changes in behaviour (the so-called "inverted-U curve"). In other words, activation is not sufficient to produce inverted-U curves.

In order to reject this conclusion, it seems necessary to question the adequacy of the experiments of Chapter 3. According to activation theorists' ideas about behaviour, however, these experiments appear to have controlled the two variables which determine responses. In the description and in the explanation of behaviour, activation theorists used two, and only two, variables, i.e. direction or "cue function", which depends on the requirements of a situation, and activation or "arousal function", which varies with the level of stimulation in a situation (Duffy, 1972; Hebb, 1955). When direction is constant, changes in activation systematically alter responding (Duffy, 1972). In the third chapter, white noise and shock alone were compared with white noise and shock together in the same situation; therefore, these comparisons isolated the influence of changes in the level of stimulation.

Since inverted-U curves do not seem, then, to result from activation *per se*, the problem of explaining these curves remains. Apart from the ideas of activation theorists, notably Malmo (1959) and Hebb (1955), explanations have been proposed in terms of reduction in the range of cue utilization (Easterbrook, 1959), in terms of drive stimuli (Jones, 1960) and in terms of competing responses either in the situation in which drives are manipulated (Spence, e.g. 1956) or in the manipulation of drives (Mandler and Sarason, 1952).

5.2 EXPLANATIONS OF INVERTED-U CHANGES IN BEHAVIOUR

According to Malmo (1959), circulation of neural impulses in a closed chain of neurons or, in Hebb's (1949) term, a "cell assembly", may be enhanced by impulses arriving from outside the chain, e.g. from the ascending reticular activating system, and so behaviour may be facilitated. At high levels of stimulation, however, repeated activity heightens the threshold of some neurons, which fail to transmit impulses.

In consequence, cell assemblies cease to function and behaviour deteriorates.

As noted previously, Malmo's postulates are not supported by the experiments of the previous chapters. A manipulation which increased skin conductance did not markedly affect shuttleavoidance.

In Hebb's (1955) view, low levels of cortical bombardment by the ascending reticular activating system maintain or strengthen concurrent activity in the cortex and hence improve a pattern of responses. In contrast, high levels of bombardment interfere with the "delicate adjustments" involved in cue function, by inducing irrelevant acts which compete with, and impair, a pattern of responses. Later, Hebb (1958) elaborated the mechanism of impairment. Too many sensory messages "get through", requiring too many types of responding at the same time. Accordingly, co-ordinated responding becomes impossible.

Irrelevant acts may, indeed, be responsible for declines in shuttleavoidance at high levels of stimulation. However, Hebb's postulates about the origin of these acts seem unlikely. The work of the previous chapter tends to preclude the possibility of "too many" sensory messages, or "over-stimulation", in the nervous system. Loud noises did not combine with high intensities of shock to increase conditioned changes in skin conductance, whereas a loud noise plus a moderate intensity of shock showed greater conditioned changes in skin conductance than a weak noise plus a moderate intensity of shock. Hence, there is probably a maximum or ceiling level to limit the number of stimuli with the capacity to affect the nervous system.

Easterbrook's (1959) explanation of inverted-U curves uses the concept of the "range of cue utilization". Increases in activation are assumed to be related to decreases in the number of cues which are employed in the solution of a task. At low levels of activation, organisms respond to task-irrelevant and task-relevant cues and so they perform poorly. At moderate levels of activation, the range of cue utilization narrows, task-relevant cues are selectively utilized and performance improves. As activation continues to heighten, organisms begin to ignore task-relevant cues and so they perform poorly.

Easterbrook is not proposing an alternative to the hypothesis that activation causes inverted-U changes in shuttleavoidance. Rather, he accepts this hypothesis and presents a possible mechanism by which activation could affect shuttleavoidance. Accordingly, assumptions about the range of cue utilization are subject to the same criticisms as those about activation. Combinations of white noise and of shock increased activation in the experiments of Chapter 4 and, thus, must have decreased the range of cue utilization. However, combinations of these stimuli of low intensities did not improve shuttleavoidance by heightening activation and by reducing the employment of task-irrelevant cues and, again, combinations of these stimuli of higher intensities did not impair shuttleavoidance by heightening activation and by reducing the employment of task-relevant cues (see Chapter 3).

Jones' (1960) explanation of inverted-U curves is best illustrated by reference to situations which involve discrimination between correct and incorrect, or positive and negative, cues. According to Jones, the discrimination of these cues takes place in a "stimulus complex", i.e. in the totality of situational cues. Part of the stimulus complex are stimuli elicited by drives (so-called "S_{Ds}"). The S_{Ds} of positive and of negative cues tend to be alike and, as drive intensifies, the S_{Ds} come to have an increasing share of the stimulus complex. Thus, fewer criteria for discriminating between these cues remain in the stimulus complex and an organism's ability to make the discrimination declines.

Jones is proposing that inverted-U changes in shuttleavoidance are the consequence of the progression from easy to difficult in an organism's capacity to determine the requirements of a successful response. Jones' hypotheses, which present the mechanism of the progression, are either false or circular. Many studies do not find an inverted-U relation between responses and drive (Bolles, 1967). In order to explain these findings, Jones needs to offer a definition of difficulty other than the variations in responding which are "explained" by variations in difficulty.

Finally, inverted-U curves have been postulated to result from competing responses, which arise in two ways. Following Spence (e.g. 1956), increases in drive might be thought to operate not only on the correct habit but also upon incorrect habits as well and, consequently, the emergence of the correct habit will be delayed. In other words, competing responses develop in the situation in which drives are manipulated. Again, following Mandler and Sarason (1952), drives might be thought to elicit stimuli-responses. As drive intensifies, these stimuli-responses become intense or more numerous and begin to interfere with the correct habit. In other words, competing responses are a consequence of the manipulation of drives.

According to Broadhurst (1959), competing-response hypotheses may be evaluated by work of Yerkes and Dodson (1908) and of Broadhurst (1957). These authors reported poorer performance in a difficult, compared to an easy, discrimination. Spence's approach can be extended, post-hoc, by arguing that the opportunity for incorrect habits is positively related to the difficulty of a situation, i.e. that there are more incorrect habits, and greater impairments, with increases in difficulty. In contrast, Mandler's and Sarason's approach cannot be extended, post-hoc, to account for the data of Yerkes-Dodson and of Broadhurst.

Competing-response hypotheses cannot be adequately evaluated in terms of post-hoc, and unsubstantiated, arguments. Consequently, the variants of these hypotheses, applied to explaining inverted-U changes in shuttleavoidance, are experimentally considered in the next chapter.

5.3 SUMMARY

Contrary to the suggestions of Malmo (1959) and of Hebb (1955), increases in activation *per se* were not found to produce inverted-U changes in shuttleavoidance in Chapter 3. Other explanations of these changes have been proposed in terms of the reduction in the range of cue utilization (Easterbrook, 1959), in terms of drive stimuli (Jones, 1960) and in terms of competing responses (Spence, e.g. 1956; Mandler and Sarason, 1952). The hypothesis about the range of cue utilization presupposes the tenability of the suggestions of Malmo and of Hebb and, thus, is subject to the same criticisms as these suggestions. The hypothesis about drive stimuli appears to be based on a circular concept of difficulty. Hypotheses about competing responses require further evaluation and are considered in the next chapter.

CHAPTER 6

THE INVERTED-U CURVE: COMPETING-RESPONSE HYPOTHESES

According to Hebb (1955), competing responses develop to impair behaviour at high levels of stimulation.

This "competing-response" hypothesis was evaluated by Malmo (1959) on the basis of the following rationale, which was derived intuitively, rather than experimentally. Complex responses, where the opportunity for habit interference is substantial, should show inverted-U (non-monotonic) relations between the efficiency of responding and the intensity of stimulation, while simple responses, where the likelihood of habit interference is low, should show monotonic relations. Unfortunately, Malmo failed to present criteria for distinguishing between "complex" and "simple" responses.

Accordingly, the present chapter aims to assess the competing-response hypothesis by developing a rationale that contains no undefined terms. To this end, it is proposed to review assumptions about competing responses in a particular task, *viz.* shuttleavoidance.

6.1 COMPETING-RESPONSE EXPLANATIONS OF SHUTTLEAVOIDANCE

In the original study of shuttleavoidance, Moyer and Korn (1964) reported improvements and, then, impairments in responding with the heightening of shock. These impairments were thought to be produced, in some unspecified manner, by the disruption of escape.

However, there is no evidence to link the proficiency of avoidance to that of escape. Moyer and Korn (1966) found a facilitation of one-way avoidance by shock levels which interfered with escape. Also, Theios, *et al.* (1966) observed a deterioration in shuttleavoidance at shock levels which did not affect escape.

According to Theios, *et al.* (1966), rats show a strong tendency not to re-enter the compartment of the shuttlebox where they had been shocked on the previous trial. The strength of this so-called "staying" response, which interrupts shuttling, is assumed to vary directly with the intensity of shock.

Unfortunately, staying responses are simply described, rather than explained; for example, the reason for the recurrence of these responses, which are continually punished, is not delineated (McAllister, *et al.*, 1971).

Cicala, *et al.* (1971a, b) argued that the operant level of shuttleavoidance is lower with strong, compared to weak, shock and so shuttling is less likely to be reinforced, and to recur in the former case than in the latter case. Indeed, spontaneous responses were shown to be less numerous under conditions of strong, random shocks than under conditions of weak, random shocks.

To say that the operant level of shuttleavoidance depends on the intensity of shock is to say that the probability of shuttling depends on the intensity of shock. Without some explanation of why operant levels differ, Cicala, *et al.* are simply re-stating what needs to be explained.

Intense shocks have been hypothesized to elicit freezing, either as an innate response (Weiss, *et al.*, 1968; Anisman and Waller, 1972) or as a learned response (Blanchard and Blanchard, 1969a,b; Wahlsten and Sharp, 1969).

Weiss, *et al.* (1968) postulated:

(a) competing responses are produced by fear, which elicits the unconditioned response of freezing, and,

(b) the strength of fear, and hence the strength of freezing, varies directly with the intensity of shock.

These postulates were tested in the following way. Subjects were exposed to the CS plus inescapable shock (fear training) or to the CS alone or to inescapable shock alone, and then were required to learn shuttleavoidance. The fear-trained group showed fewer shuttling responses and less movement than the other groups. Also, the effect of a procedure designed to eliminate freezing was assessed. It was reasoned that, once shuttleavoidance has been learned, shuttling responses will be higher on the "behavioural hierarchy" than freezing; thus, shuttling responses should be enhanced by fear training compared to no-fear training. Subjects were given a number of trials in the shuttlebox, followed by fear training or by no-fear training, followed by shuttleavoidance. There were shorter latencies in the fear-trained group than in the other groups.

The essential idea of Weiss, *et al.*, that fear elicits the unconditioned response of freezing, was re-iterated by Anisman and Waller (1972). These authors spoke of the "species-specific defence reaction" of freezing.

If freezing were an innate, competing response, however, shuttling, or any other type of avoidance, would never be learned.

In contrast, in the view of Blanchard and Blanchard (1969a,b), fear elicits the conditioned response of freezing. Rats were given a single foot-shock and, subsequently, the magnitude of immobility was measured in either the shock situation or a non-shock situation. Immobility, or so-called "crouching", only occurred in the shock situation and so appeared to be conditioned to shock-associated stimuli.

Similarly, in the view of Wahlsten and Sharp (1969), fear sometimes elicits, and sometimes does not elicit, freezing. Specifically, freezing, and consequent declines in responding, may be observed in some situations, *viz.* those involving "conflict", e.g. shuttleavoidance, but not in other situations, e.g. one-way avoidance. Indeed, declines in responding occur in shuttleavoidance but not in one-way avoidance (Olton and Isaacson, 1968; Wahlsten and Sharp, 1969). However, there is no independent index of freezing other than declines in responding, since conflict is "defined" in terms of running in opposite directions; of course, running in opposite directions simply describes the requirements of shuttling.

If freezing were a learned, competing response then there should be more post-shuttling immobility at high, compared to low, values of shock. This prediction was not confirmed in the experiment described below.

McAllister, *et al.* (1971) postulated:

(a) competing responses are produced by fear, which is conditioned to situational cues in the shuttlebox, and,

(b) the degree of fear of situational cues varies directly with the intensity of shock.

These postulates were tested by giving rats the opportunity to learn shuttleavoidance, and then by allowing them to escape from the shuttlebox in the absence of shock. Subjects receiving strong shocks showed poorer shuttling but, subsequently, escaped with shorter latencies than subjects receiving weak shocks.

The data of McAllister, *et al.* may simply prove that some aspect of shuttleavoidance negatively transfers to the performance of the second, escape task (Bauer, 1972).

Nevertheless, situational cues are implicated in a number of findings of disruption in avoidance. For example, Theios, *et al.* (1966) and Wahlsten and Sharp (1969) demonstrated impaired shuttling with the non-handling, compared to the handling, of subjects in the inter-trial interval; handling may be interpreted as a means of lessening fear to stimuli in the shuttlebox. More conclusively, in an experiment by de Toledo and Black (1967) on one-way avoidance, rats were required to avoid shock by approaching a box in which they had been previously shocked. These rats showed poorer responding than controls.

6.2 RATIONALE FOR TESTING COMPETING-RESPONSE EXPLANATIONS OF SHUTTLEAVOIDANCE

It seems fruitful, then, to examine the role of situational cues in producing fear and competing responses.

In the present experiment, a cue is assumed to elicit fear and, thereby, competing responses, which interfere with shuttleavoidance, in two circumstances:

(i) the cue is paired with shock, and,
(ii) the cue is in the to-be-entered compartment.

On the basis of these assumptions, it is possible to eliminate the development of competing responses and hence to eliminate the postulated outcome of these responses, *viz.* inverted-U changes in shuttleavoidance. For example, consider a situation in which some subjects run from a shock-related stimulus towards a shock-related stimulus, and other subjects run from a shock-related stimulus to a shock-unrelated stimulus. In the former case, competing responses may develop and so inverted-U curves should occur; in the latter case, since running from a shock-related stimulus is not expected to induce competing responses and, indeed, since running from a certain type of shock-related stimulus (i.e. the CS) is often thought to work against the induction of competing responses (McAllister, *et al.*, 1971), inverted-U curves should not occur.

These predictions were tested in the following experiment.

6.2.1 METHOD

6.2.1.1 SUBJECTS

S̲s were 120 naive male albino rats obtained from the John Curtin School of Medical Research, Canberra, Australia. They were between 100 and 120 days old at the beginning of the experiment and were maintained on ad lib. food and water.

6.2.1.2 APPARATUS

The apparatus was the shuttlebox described in Chapter 3 with one exception. In the centre of each compartment at ceiling level, one 120-w. clear light bulb provided an increase in illumination of approximately 5,500 lux ca.

6.2.1.3 PROCEDURE

S̲s were randomly assigned to six groups. All S̲s were given a tone CS.

In three experimental groups, a visual cue came on at variable times in the occupied compartment before the onset of shock and, simultaneously, another visual cue came on in the to-be-entered compartment. Each of these groups received one of the following UCSs, .1 ma, .4 ma and 1.3 ma, and within each of them, half of the Ss, chosen randomly, were run with light in the occupied compartment and darkness in the to-be-entered compartment and the other Ss were run with darkness in the occupied compartment and light in the to-be-entered compartment. In three control groups, light was continuously presented in one compartment and, simultaneously, darkness was continuously presented in the other compartment. Each of these groups received one of the following UCSs, .1 ma, .4 ma and 1.3 ma, and within each of them, half of the Ss, chosen randomly, were run with light in the right compartment and darkness in the left compartment and the other Ss were run with darkness in the right compartment and light in the left compartment.

For the experimental groups, light or darkness came on in the occupied compartment 12.5 seconds after the end of a trial and remained on until S ran into the other compartment, where darkness or light was located. 12.5 seconds later, the cues reversed, ensuring that the experimental Ss, like the control Ss, had approximately equal exposure to light and to darkness.

Following pre-test trials to the tone CS (see Chapter 3), Ss were placed into one of the compartments of the shuttlebox, chosen at random. One hundred trials, with a CS-UCS interval of five seconds and an average inter-trial interval of 20 seconds (exact times were 10, 15, 20, 25 and 30 seconds in random order), were given.

Ss were run in batches of 12 every two days, with two Ss being from each group. The order of running Ss within each batch was randomized.

6.2.2 RESULTS

Means and standard deviations of the percentage and of the latency of avoidance responses in the experimental groups are presented in Table 6.21. An initial analysis of variance indicated that there was no interaction between light/dark and shock factors either for percent avoidance ($F_{2,54} = 2.7$, $p = .08$) or for latency ($F_{2,54} = 1.8$, $p > .1$); therefore, data from Ss run in light and those run in dark were combined. A subsequent analysis of variance revealed that there were no differences between groups either for percent avoidance ($F_{2,57} < 1$) or for latency ($F_{2,57} < 1$). These results are summarized in Table 6.22.

Means and standard deviations of percent avoidance and of latency in the control groups are presented in Table 6.23. An initial analysis of variance indicated that there was no interaction between light/dark and shock factors either for percent avoidance ($F_{1,54} = 1.1$, $p > .1$) or for latency ($F_{2,54} < 1$); therefore, data from Ss run in light and those run in dark were combined. A subsequent analysis of variance revealed that there were significant differences between groups in percent avoidance ($F_{2,57} = 10.6$, $p < .01$) and in latency ($F_{2,57} = 4.2$, $p < .05$). These results are summarized in Table 6.24.

Newman-Keuls comparisons (Winer, 1962) were used to further examine differences between groups in percent avoidance. The .4 ma group made more responses than either the .1 ma group ($W = 15.6$, $p < .01$) or the 1.3 ma group ($W = 17.8$, $p < .01$) and these latter groups did not differ ($W = 11.7$).

Also, Newman-Keuls comparisons were used to further examine the differences between groups in latency. The 1.3 ma group showed longer latencies than either the .1 ma group ($W = .4$, $p < .05$) or the .4 ma group ($W = .4$, $p < .05$) and these latter groups did not differ ($W = .4$).

Finally, the experimental groups and the control groups were compared at each shock level by means of *t*-tests. At .1 ma, the experimental group made more responses ($t_{38} = 2.7$, $p < .01$), and showed the same latencies ($t_{38} = 1.1$, $p > .1$), compared to the control group; at .4 ma, there was no difference between the experimental group and the control group either for the number of responses ($t_{38} = < 1$) or for latency ($t_{38} = 1.1$, $p > .1$); at 1.3 ma, the experimental group made more responses ($t_{38} = 3.2$, $p < .01$), and showed shorter latencies ($t_{38} = 4.3$, $p < .01$), than the control group.

Figure 6.21 and Figure 6.22 describe mean percent avoidance and mean latency, respectively, in all groups.

TABLE 6.21

Means and standard deviations of percent avoidance and of latency in the experimental groups (N = 20 per group).

		.1 ma	.4 ma	1.3 ma
1.	Percent avoidance			
	Means	48.65	57.25	51.95
	Standard deviations	26.93	20.93	20.60
2.	Latency			
	Means	2.68	2.64	2.53
	Standard deviations	.54	.71	.58

TABLE 6.22

Analysis of variance of percent avoidance and of latency in the experimental groups.

1. Percent avoidance

Source	SS	df	MS	F	p
Between groups	752.93	2	376.47	$F < 1$	ns
Within groups	30,173.25	57	529.36		
Total	30,926.18	59			

2. Latency

Source	SS	df	MS	F	p
Between groups	.26	2	.13	$F < 1$	ns
Within groups	21.72	57	.38		
Total	21.98	59			

TABLE 6.23

Means and standard deviations of percent avoidance and of latency in the control groups (N = 20 per group).

	.1 ma	.4 ma	1.3 ma
1. Percent avoidance			
Means	29.10	53.50	31.50
Standard deviations	17.64	17.43	20.18
2. Latency			
Means	2.88	2.95	3.35
Standard deviations	.57	.47	.62

TABLE 6.24

Analysis of variance of percent avoidance and of latency in the control groups.

1. Percent avoidance

Source	SS	df	MS	F	p
Between groups	7,234.13	2	3,617.07	10.62	< .01
Within groups	19,417.80	57	340.66		
Total	26,651.93	59			

2. Latency

Source	SS	df	MS	F	p
Between groups	2.59	2	1.30	4.16	< .05
Within groups	17.77	57	.31		
Total	20.36	59			

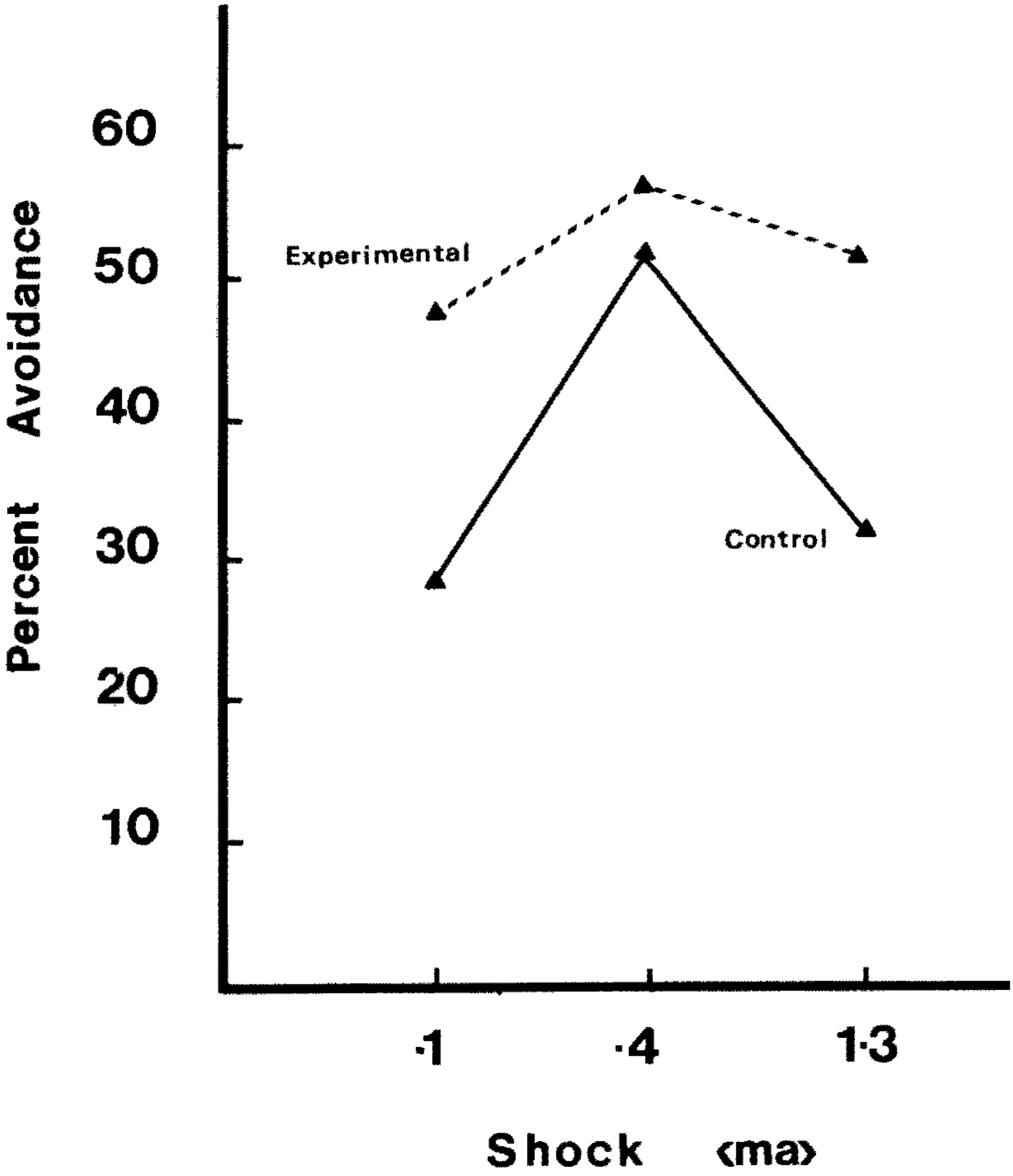


Figure 6.21 Mean percent avoidance in experimental and control groups (N = 20 per data point).

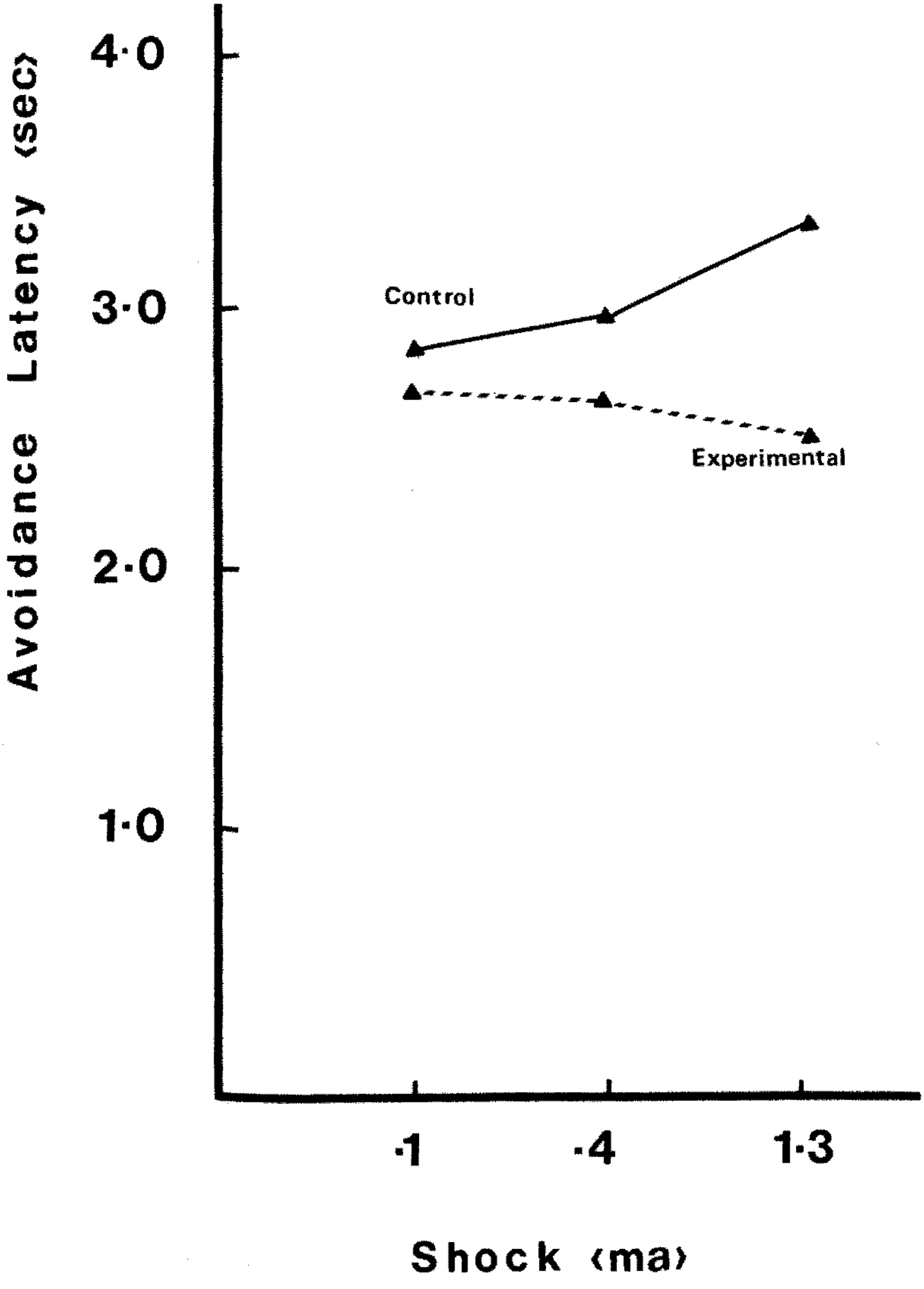


Figure 6.22 Mean latency in experimental and control groups (N = 20 per data point).

6.2.3 DISCUSSION

With respect to percent avoidance, inverted-U changes in responding as a function of the intensity of shock were found in the control groups, but were not found in the experimental groups where subjects were allowed to approach a visual cue which was not paired with shock. Presumably, this cue did not give rise to fear and, in turn, to competing responses. Thus, the control group made fewer responses than the experimental group at .1 ma and at 1.3 ma, and made the same number of responses as the experimental group at .4 ma.

As far as latency is concerned, improvements did not precede impairments in responding with the heightening of shock in the control groups. This finding is consistent with the demonstration that .7 ma produces optimal latencies (see Chapter 3). Nevertheless, in support of the postulation of competing responses, the control group had longer latencies than the experimental group at 1.3 ma.

The outcome of the present experiment is similar to that of Dyer (1971), whose manipulation of blinding subjects can be viewed as another way of precluding the association between visual cues and shock. Blinded guinea pigs were better shuttlers than non-blinded guinea pigs.

One aspect of the present results is somewhat puzzling. Approach to shock-unrelated stimuli facilitated percent avoidance at .1 ma compared with approach to shock-related stimuli. However, the facilitation cannot be due to the removal of competing responses; low intensities of shock, like .1 ma, are not assumed to be associated with these responses and, furthermore, .1 ma is not associated with the supposed effects of these responses, *viz.* declines in shuttleavoidance (see Chapter 3). In order to ensure the reliability of the .1 ma result, an additional experimental group ($N = 10$) and an additional control group ($N = 10$) were run with another low value of shock, i.e. .2 ma, as UCS. Means and standard deviations in the experimental group were 68.7 and 20.7, respectively, for percent avoidance, and, 2.1 and .4, respectively, for latency; those in the control group were 43.7 and 22.2, respectively, for percent avoidance, and, 2.8 and .5, respectively, for latency. The experimental group showed more responses ($t_{18} = 2.6$, $p < .05$) and shorter latencies ($t_{18} = 4.0$, $p < .01$) compared to the control group.

In general, then, competing-response explanations of the inverted-U relation between shuttleavoidance and shock predict the differences between the control group and the experimental group at the high intensity of shock, i.e. 1.3 ma, but do not predict the differences between these groups at the low intensities of shock, i.e. .1 ma and .2 ma.

6.3 SUMMARY

If subjects are required to approach shock-related stimuli, it is argued that competing responses may develop to impair performance at high levels of stimulation; conversely, if subjects are allowed to approach shock-unrelated stimuli, it is argued that competing responses may not develop and so there should be no impairments in performance at high levels of stimulation. Consistent with expectations, approach to a shock-related cue depressed the percentage of shuttleavoidance at the high shock intensity of 1.3 ma. Contrary to expectations, however, the same pattern of results was obtained at the low shock intensities of .1 ma and of .2 ma.

CHAPTER 7

THE INVERTED-U CURVE: NUMBER AND TYPE OF CSs

In the previous chapter, the experimental subjects made more shuttling responses at .1 ma and at 1.3 ma than the control subjects.

Experimental subjects received an auditory CS, signalling shock onset within 5 seconds, and a visual CS which consisted of one cue in the occupied compartment together with another cue in the to-be-entered compartment and which signalled shock onset within 12.5 seconds on the average. In contrast, control subjects received only the auditory CS. Thus, experimental subjects received two CSs whereas control subjects received one; also, experimental subjects received two types of CS whereas control subjects received one type.

In order to account for the differences between these subjects in shuttleavoidance, it was decided to isolate the effects of the number and the type of CSs at the shock intensities used in the previous chapter and, on the basis of pilot work, at another high shock intensity, i.e. 3.0 ma.

In the first experiment, a tone CS and a visual CS were examined where the visual CS consisted of one cue signalling shock in the occupied compartment together with another cue in the to-be-entered compartment. In the second experiment, a tone CS and a visual CS were examined where the visual CS consisted of one cue signalling shock in both compartments. In the third experiment, a tone CS and a visual CS were examined where the visual CS consisted of one cue signalling shock in the to-be-entered compartment together with another cue in the occupied compartment.

7.1 A TONE CS AND A VISUAL CS IN THE OCCUPIED COMPARTMENT

7.1.1 METHOD

7.1.1.1 SUBJECTS

Ss were 168 naive male albino rats from the John Curtin School of Medical Research, Canberra, Australia. They were between 100 and 120 days old at the beginning of the experiment and were maintained on ad lib. food and water.

7.1.1.2 APPARATUS

The apparatus was the shuttlebox described in Chapter 6.

7.1.1.3 PROCEDURE

Ss were randomly assigned to 12 groups. Four groups received a tone CS at one of four UCS intensities, i.e. .1 ma, .4 ma, 1.3 ma and 3.0 ma. Within each group, half of the Ss were randomly chosen to be run in two lighted compartments and the other Ss were run in two dark compartments. Another four groups received a visual CS at one of the four UCS intensities. Within each group, half of the Ss were randomly chosen to be run in darkness with light in the occupied compartment serving as CS and the other Ss were run in light with darkness in the occupied compartment serving as CS. A final four groups received the simultaneous presentation of the tone CS and of the visual CS at one of the four UCS intensities. Within each group, half of the Ss were randomly chosen to be run in darkness with light in the occupied compartment serving as CS and the other Ss were run in light with darkness in the occupied compartment serving as CS.

Following pre-test trials consisting of the simultaneous presentation of the tone CS and the light CS (see Chapter 3), Ss were placed into one of the compartments of the shuttlebox, chosen at random. One hundred trials, with a CS-UCS interval of five seconds and an average inter-trial interval of 20 seconds (exact times were 10, 15, 20, 25 and 30 seconds in random order), were given.

Ss were run in batches of 12 every two days, with one S being from each group. The order of running Ss within each batch was randomized. During the course of the experiment, data from five Ss were discarded owing to various equipment failures. Whenever this occurred, an extra S was run in the next batch.

7.1.2 RESULTS

Means and standard deviations of percent avoidance for each CS at each shock intensity are presented in Table 7.11. An initial analysis of variance indicated that there was no interaction between light/dark and shock factors in the tone CS groups ($F_{3,48} = 2.4$, $p > .1$), in the visual CS groups ($F_{3,48} = 1.7$, $p > .1$) or in tone plus visual CSs groups ($F_{3,48} < 1$); hence, data from Ss run in light and those run in dark were combined. A subsequent analysis of variance revealed that the type of CS was significant ($F_{2,156} = 3.3$, $p < .05$), that the intensity of shock was not significant ($F_{3,156} = 1.6$, $p > .1$) and that the interaction between the type of CS and the intensity of shock was significant ($F_{6,156} = 5.3$, $p < .01$). These results are summarized in Table 7.12.

CSs were compared at each shock intensity using Newman-Keuls comparisons (Winer, 1962), with the mean square within groups (i.e. 593.2) for the 12 groups as the error unit. At .1 ma, tone plus visual CSs produced more responses than either the visual CS ($W = 21.8$, $p < .05$) or the tone CS ($W = 24.1$, $p < .01$), and there was no difference between the latter CSs. At .4 ma, none of the CSs differed. At 1.3 ma, tone plus visual CSs ($W = 27.3$, $p < .01$) and the visual CS ($W = 18.2$, $p < .05$) produced more responses than the tone CS, and there was no difference between the former CSs. Finally, at 3.0 ma, tone plus visual CSs produced more responses than either the visual CS ($W = 18.2$, $p < .05$) or the tone CS ($W = 17.3$, $p < .01$), and there was no difference between the latter CSs.

Figure 7.11 shows mean percent avoidance to each CS at each shock intensity. Also, Figure 7.13 shows these means for the light CS and for tone plus light CSs and Figure 7.14 shows them for the dark CS and for tone plus dark CSs.

While the latency of avoidance responses was recorded, the differences between CSs at the four UCS intensities of this experiment proved to be small and mostly unreliable. Therefore, these data are not presented (see Appendix 2).

TABLE 7.11a

Means and standard deviations of percent avoidance in tone CS groups, in visual CS groups and in tone plus visual CSs groups: the visual CS in the occupied compartment.

Combined light and dark conditions (N = 14 per group).

		.1 ma	.4 ma	1.3 ma	3.0 ma
TONE CS	Means	30.43	47.28	24.07	28.43
	Standard deviations	26.02	16.56	16.39	20.66
VISUAL CS	Means	29.50	56.14	47.71	41.07
	Standard deviations	27.82	28.51	30.80	30.82
TONE PLUS VISUAL CSs	Means	56.50	55.21	59.14	60.35
	Standard deviations	26.04	23.54	13.16	24.12

TABLE 7.11b

Separate light and dark conditions (N = 7 per group).

LIGHT

		.1 ma	.4 ma	1.3 ma	3.0 ma
TONE CS IN TWO LIGHT COMPARTMENTS	Means	30.00	42.28	27.14	31.00
	Standard deviations	22.60	14.17	21.69	24.70
LIGHT CS	Means	35.85	54.71	45.28	60.28
	Standard deviations	31.80	34.98	34.70	21.12
TONE PLUS LIGHT CSs	Means	62.85	54.57	59.14	65.28
	Standard deviations	27.81	28.37	15.10	23.13

DARK

		.1 ma	.4 ma	1.3 ma	3.0 ma
TONE CS IN TWO DARK COMPARTMENTS	Means	30.90	52.29	21.00	25.85
	Standard deviations	21.48	18.31	9.45	17.30
DARK CS	Means	23.14	57.57	50.14	21.86
	Standard deviations	23.90	23.08	28.90	27.40
TONE PLUS DARK CSs	Means	50.14	55.86	59.14	55.42
	Standard deviations	24.53	19.87	12.13	25.86

TABLE 7.12

Analysis of variance of percent avoidance in tone CS groups, visual CS groups and tone plus visual CSs groups: the visual CS in the occupied compartment.

Source	SS	df	MS	F	p
Type of CS	3913.82	2	1956.91	3.30	< .05
Intensity of shock	2847.47	3	949.16	1.60	ns
Type of CS x Intensity of shock	18863.81	6	3143.96	5.30	< .01
Within groups	92538.40	156	593.19		
Total	118163.50	167			

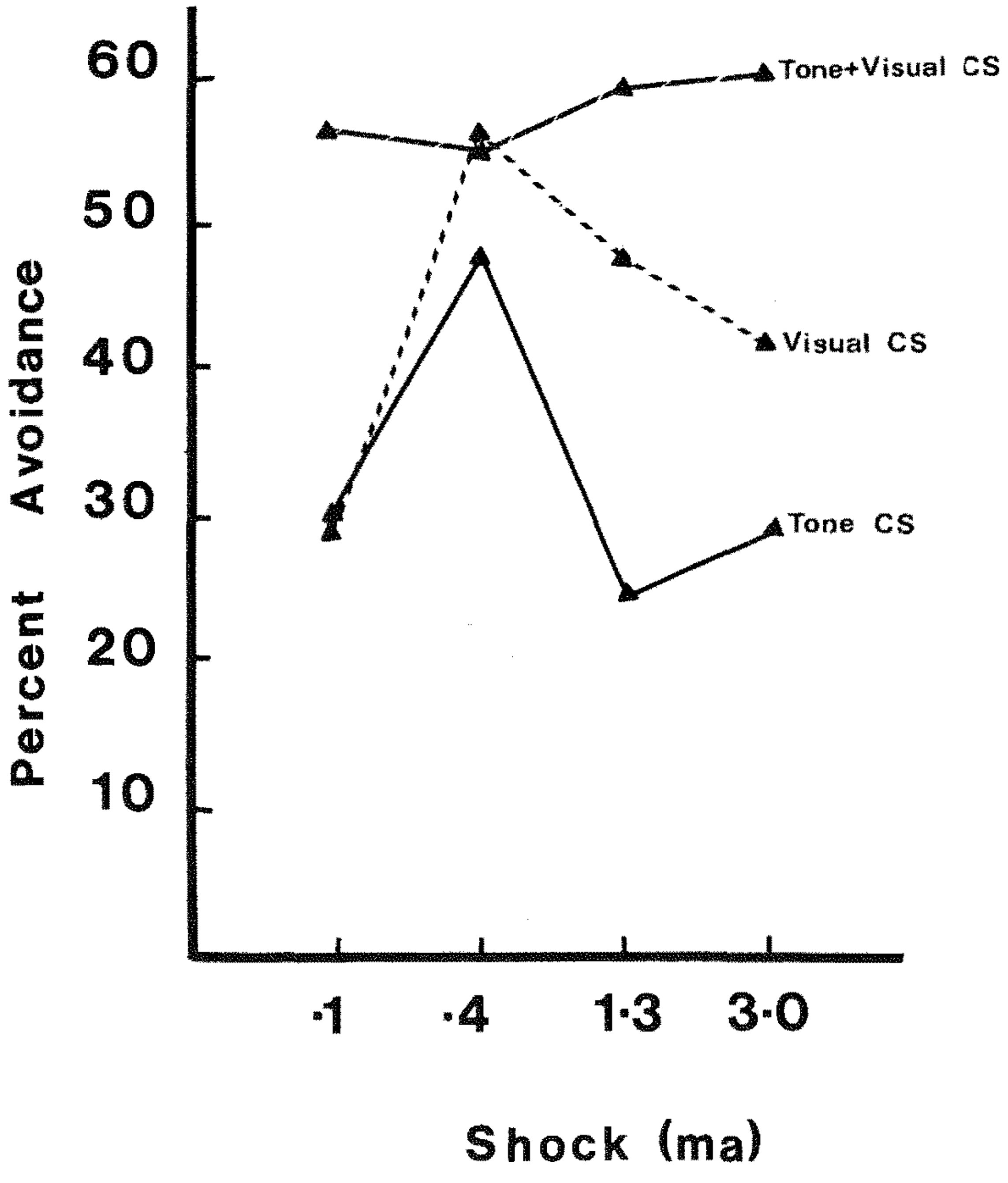
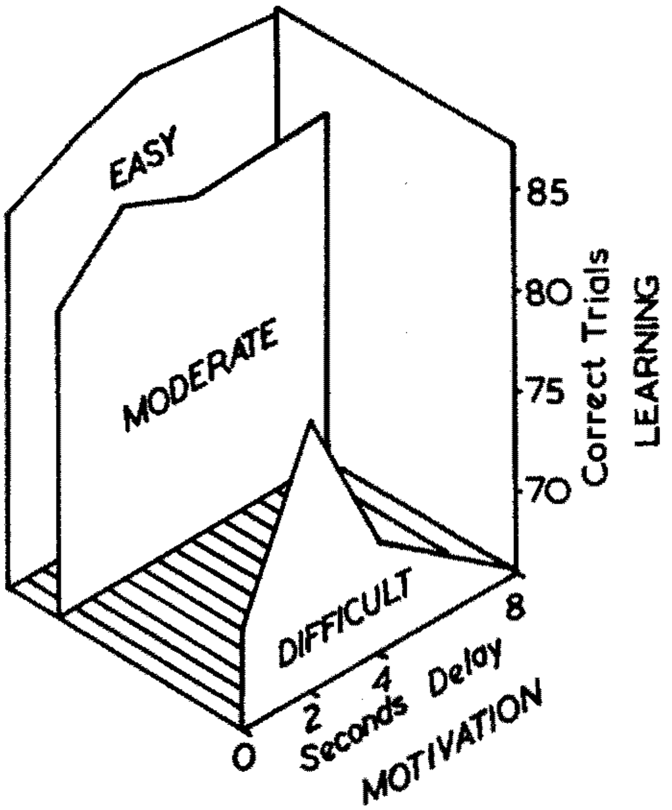


Figure 7.11 Mean percent avoidance to three types of CS, ie. tone, visual and tone + visual (N = 14 per data point).



A three-dimensional surface showing the relationship between learning scores in a discrimination task and (*a*) the intensity of the imposed motivation (air deprivation) measured by the number of seconds' delay underwater before release and (*b*) the level of difficulty of the task.

Figure 7.12 Summary of Broadhurst's (1957) results.

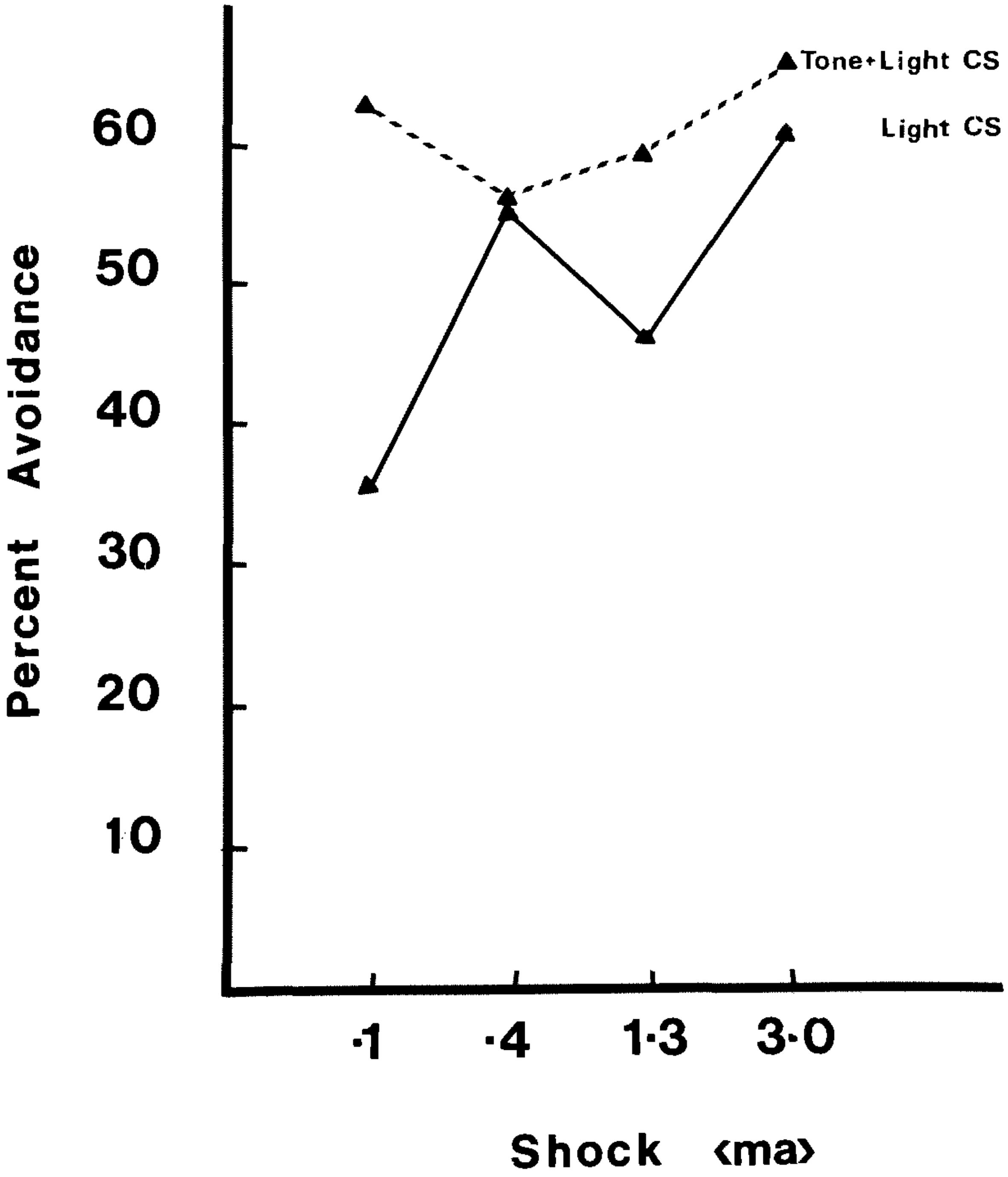


Figure 7.13 Mean percent avoidance to light and tone + light CSs. Light was presented in the occupied compartment (N = 7 per data point).

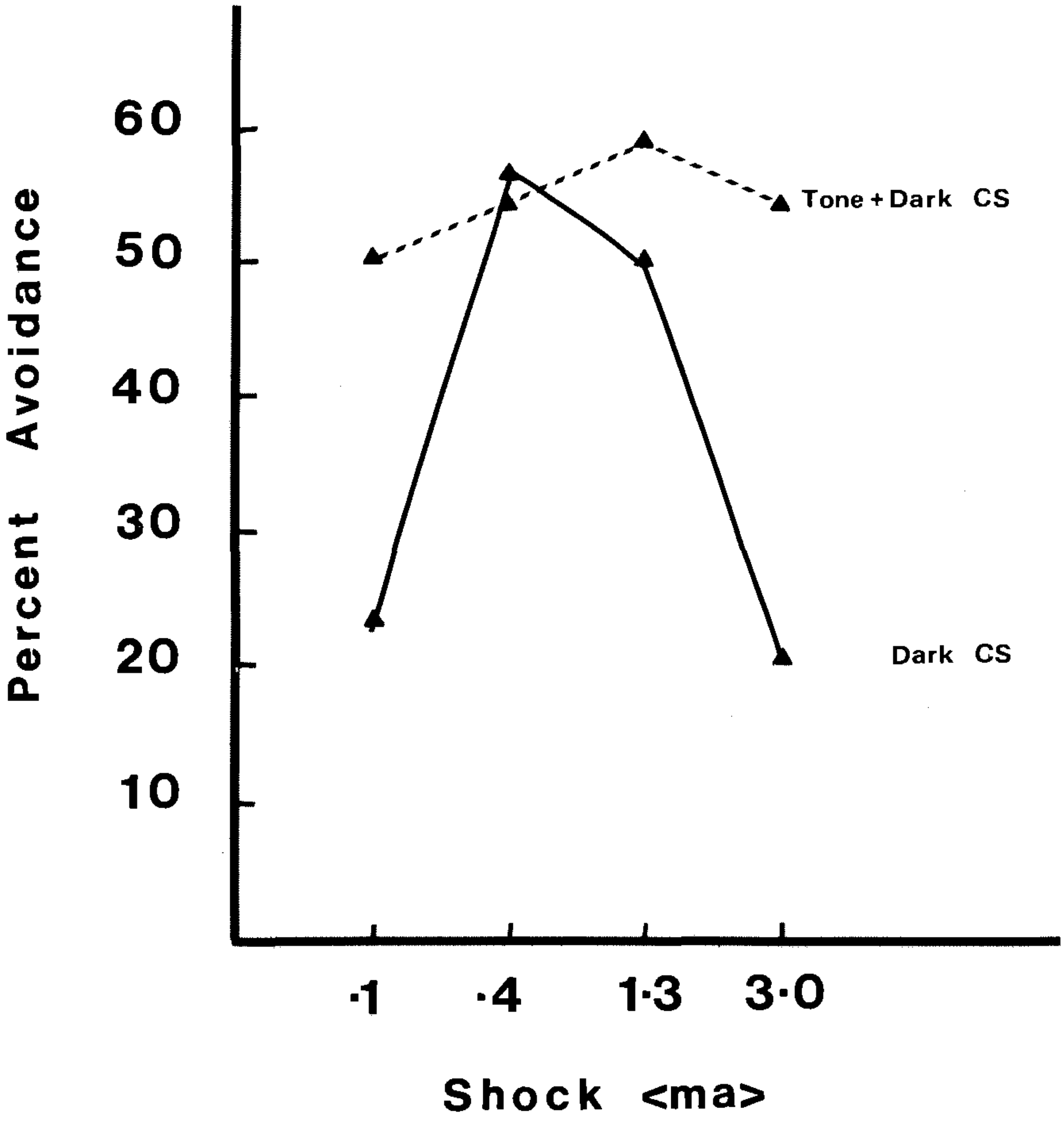


Figure 7.14 Mean percent avoidance to dark and tone + dark CSs. Dark was presented in the occupied compartment (N = 7 per data point).

7.1.3 DISCUSSION

In the previous chapter, experimental subjects, which received a tone CS and a visual CS together, made more shuttling responses at .1 ma and at 1.3 ma than control subjects receiving a tone CS alone.

The results of the present experiment indicate that two CSs facilitate shuttleavoidance at .1 ma compared to one CS and that a visual CS, either together with a tone CS or separately, facilitates shuttleavoidance at 1.3 ma compared to a tone CS.

The functions relating shuttleavoidance and shock with variations in the number and the type of CSs are very similar to functions reported by Yerkes and Dodson (1908) and by Broadhurst (1957), describing the relation between the efficiency of discrimination and shock, or suffocation, with variations in the difficulty of the discrimination. It seems fruitful to compare the present data to Broadhurst's data (see Figure 7.12), where statistical analyses are reported. On the basis of this comparison, it may be concluded post-hoc that the CS varies the difficulty of shuttleavoidance. Further, it seems possible that difficulty has different parameters at different shock intensities.

Broadhurst required subjects to choose the correct alley of a Y-maze to escape from water. There were three conditions of difficulty (easy, medium, difficult) i.e. three differences in illumination between the correct and incorrect alleys, and four intervals of detention underwater before release i.e. 0-, 2-, 4- and 8- seconds. A significant interaction between difficulty and the interval of detention was found. Over all intervals of detention, the easy condition was associated with better learning than the medium condition, which was superior to the difficult condition. Although Broadhurst did not evaluate the effect of the interval of detention within each condition of difficulty, Brown (1965) re-analysed his data. According to Brown, there were no differences between intervals of detention in either the easy or the medium condition, while the 2-second interval was superior to the 0-, 4- and 8-second intervals in the difficult condition.

It should be noted that the findings of Broadhurst, and the earlier findings of Yerkes and Dodson, have been generally misreported. For example, Bolles (1967) summarized these findings with the following statements: performance was found to improve up to a point and, then, to deteriorate as the length of underwater detention increased; and, this point of optimal performance was at long intervals of underwater detention for easy tasks and at shorter intervals of underwater detention for more difficult tasks. This summary is not accurate. Instead, a sequence of improvement-deterioration occurred in the difficult tasks only. Also, the difference between easy tasks and difficult tasks was in the range, not the point, of optimal performance. Easy tasks maintained optimal performance, and difficult tasks showed deteriorations from optimal performance, as the length of underwater detention was heightened.

On the assumption that the CS varies the difficulty of shuttleavoidance and that shock intensity is comparable to the length of underwater detention, the present data was analysed in the same way as Broadhurst analysed his data. There proved to be a significant interaction between type of CS and shock intensity ($F_{6,156} = 5.3$, $p < .01$). Over all shock intensities, tone plus visual CSs were associated with better learning than the visual CS ($t_{110} = 2.8$, $p < .01$), which was superior to the tone CS ($t_{110} = 2.2$, $p < .05$). Finally, there were no differences between shock intensities for either tone plus visual CSs ($F_{3,52} < 1$) or for the visual CS ($F_{3,52} = 2.0$, $p > .1$), while there were differences for the tone CS ($F_{3,52} = 3.5$, $p < .05$); in particular, Newman-Keuls comparisons indicated that .4 ma was superior to .1 ma ($W = 16.9$, $p < .05$), 1.3 ma ($W = 23.3$, $p < .05$) and 3.0 ma ($W = 19.2$, $p < .05$).

Thus, there is some post-hoc evidence suggesting that tone plus visual CSs, the visual CS and the tone CS systematically increase the difficulty of shuttleavoidance. Also, difficulty would appear to have two parameters, i.e. the number of CSs at low shock intensities and the type of CS at higher shock intensities.

7.1.4 A FURTHER CONSIDERATION OF THE SHOCK INTENSITY OF .1 ma

The number of CSs seems to determine whether the function relating shuttleavoidance to shock rises to its optimal value. Thus, tone plus visual CSs show maximum shuttling at .1 ma, whereas the visual CS alone and the tone CS alone do not.

In order to explain this finding, it was decided to investigate operant responses in the shuttlebox to different numbers of cues in the absence of shock.

7.1.4.1 METHOD

Thirty Ss were randomly assigned to six groups and were run in random order. Two groups received a tone cue, either in two lighted compartments or in two dark compartments. Two groups received a visual cue, one being run in darkness with light in the occupied compartment serving as cue and another being run in light with darkness in the occupied compartment serving as cue. Two groups received the simultaneous presentation of the tone cue and of the visual cue, one being run in darkness with light in the occupied compartment serving as cue and another being run in light with darkness in the occupied compartment serving as cue.

Ss were placed into one of the compartments of the shuttlebox, chosen at random. One hundred trials, with an average inter-trial interval of 20 seconds (exact times were 10, 15, 20, 25 and 30 seconds in random order), were given. A trial consisted of presenting the cue and opening the door. Irrespective of whether S ran from the occupied compartment or failed to respond within 30 seconds, the cue was terminated and the door was lowered.

7.1.4.2 RESULTS

Means and standard deviations of the number of trials on which S ran from the occupied compartment within five seconds of cue onset are presented in Table 7.13. A non-statistical comparison between cues is sufficient for the present purposes.

TABLE 7.13

Means and standard deviations of the number of responses within five seconds of cue onset in tone cue groups, in visual cue groups and in tone plus visual cues groups.

Separate light and dark conditions (N = 5 per group).

LIGHT

	Tone cue in two light compartments	Light cue	Tone plus Light cues
Means	4.40	33.00	50.80
Standard deviations	6.12	32.08	25.85

DARK

	Tone cue in two dark compartments	Dark cue	Tone plus Dark cues
Means	2.40	4.40	2.80
Standard deviations	2.30	3.29	3.63

Tone plus light cues elicited more responses than either cue alone. In contrast, tone plus dark cues elicited a similar, small number of responses compared to either cue alone.

It was expected that this pattern of results would occur when tone plus light and tone plus dark were used as CSs at .1 ma, since a weak shock intensity might simply induce a constant facilitation of responses (see Table 7.11). Consistent with expectations, tone plus light CSs produced better shuttleavoidance than either CS alone. Contrary to expectations, however, tone plus dark CSs produced better shuttleavoidance than either CS alone and, indeed, the difference between tone plus dark CSs and the dark CS approached significance ($t = 2.1$, $p = .06$).

Accordingly, it was decided to check the reliability of this last finding with a larger sample of subjects. Two additional groups of rats ($N = 10$ per group) were run at .1 ma, one receiving tone plus dark CSs and another receiving the dark CS.

Means and standard deviations of percent avoidance for tone plus dark CSs were 20.8 and 19.3, respectively; those of percent avoidance for the dark CS were 16.3 and 14.1, respectively. There was no difference between these CSs ($t_{18} < 1$).

These findings suggest that tone plus dark CSs probably show the same, poor performance at low shock intensities as the dark CS.

7.1.4.3 DISCUSSION

In general, then, combinations of CSs seem to be facilitatory where one of the CSs involves a change from dark to light.

This facilitation might be thought to result from increases in "stimulus-intensity dynamism" (Hull, 1949) or increases in the amount of sensory change which reinforces responses (Bower, *et al.*, 1965).

Increases in stimulus intensity have been reported to improve conditioning in a variety of tasks (Hilgard and Marquis, 1940; Hull, 1949). According to Hull (1949), increases in stimulus intensity heighten stimulus-intensity dynamism, which reflects neural activity. Hull's idea has been questioned (e.g. Perkins, 1953) but, nevertheless, has a certain degree of plausibility. For example, it is possible that two CSs induce more neural activity and, thereby, enhance shuttle-avoidance compared to one CS. Contrary to this possibility, however, a tone CS and a dark CS together do not index more neural activity by enhancing shuttleavoidance compared to either CS alone.

Increases in the amount of sensory change, which is produced by termination of the CS, have been found to improve shuttling when the intensity of the CS is varied and when the time locus of the termination of the CS is varied, e.g. immediate termination of the CS following shuttling and delayed termination of the CS following shuttling (Bower, *et al.*, 1965). According to Bower, *et al.* (1965), increases in the amount of sensory change associated with the offset of a shock signal, i.e. the CS, heighten the ability of the shock signal to "reinforce" a response, i.e. to alter the probability of a response followed by offset of the shock signal. Thus, it is possible that the termination of two CSs is more reinforcing and, thereby, responsible for more shuttle-avoidance than the termination of one CS. Contrary to this possibility, however, a tone CS and a dark CS together do not index more reinforcement by enhancing shuttleavoidance compared to either CS alone.

In the present work, only some CSs, i.e. those which involve a dark-to-light change, combine to facilitate shuttling, either in the presence or in the absence of UCSs. These changes are particularly relevant to albino rats, where they may elicit a salient "orienting" or alerting reaction (Sokolov, 1963). Since one stimulus is known to be capable of increasing, or "sensitizing", physiological changes to stimulation of another modality (Duffy, 1972; Hinde, 1966, 1970), it seems reasonable to suppose, post-hoc, that a stimulus of particular relevance in a given species may selectively sensitize other types of stimulation; thus, a dark-to-light change in albino rats may selectively sensitize a tone.

The effect of sensitization may be to increment the probability of responses, in general. Since behavioural options are somewhat limited in shuttleboxes, responding is likely to take the form of shuttleavoidance.

In the foregoing analysis, then, variables which precede, rather than follow, shuttling are responsible for changes in shuttling. Accordingly, this analysis is quite distinct from statements about reinforcement: e.g. "tone plus light CSs are more reinforcing than either CS alone and tone plus dark CSs are as reinforcing as either CS alone". While light (Berlyne and Koenig, 1965; McCall, 1965; Morrison, 1965; Tapp and Sampson, 1966) and dark (Berlyne and Koenig, 1965; McCall, 1965) are known to be reinforcing, statements about reinforcement in relation to the different effects of tone plus light CSs compared with tone plus dark CSs are simply descriptive, not explanatory.

7.1.5 A FURTHER CONSIDERATION OF THE SHOCK INTENSITY OF 3.0 ma

The type of CS seems to determine whether the function relating shuttleavoidance to shock falls from its optimal level. Thus, a tone CS shows impaired shuttling at 3.0 ma, whereas tone plus visual CSs and the visual CS do not. These latter CSs consist of light or darkness signalling shock in the occupied compartment together with darkness or light in the to-be-entered compartment, and may eliminate competing responses by allowing approach to a cue which is not associated with shock (see Chapter 6).

Although there was no interaction between light/dark and shock factors for any CS, indicating that a separate consideration of light and dark is not required (Furedy, 1966), Table 7.11 points to a rather curious difference between light and dark. When S ran from a light CS to dark, tone plus light CSs and the light CS were not associated with impairments. In contrast, when S ran from a dark CS to light, tone plus dark CSs were not associated with impairments, but the dark CS evidenced declines in the number of responses from .4 ma to 3.0 ma ($t_{12} = 2.6$, $p < .05$).

These declines may be understood, post-hoc, in terms of the idea of species-specific constraints on learning (Hinde and Stevenson-Hinde, 1973). It may be suggested that light is inherently "unsafe" to albino rats since they avoid a lighted place in a choice situation; thus, they might have difficulty associating light with "safety", i.e. with the absence of shock in the to-be-entered compartment.

This suggestion is not consistent with the findings in relation to tone plus dark CSs, where there was no evidence of difficulty associating light with "safety", i.e. there were no declines in the number of responses at 3.0 ma.

Since there appeared to be an inconsistency between the findings with the dark CS and tone plus dark CSs, it was decided to check the reliability of these findings with a larger sample of subjects. Two additional groups of rats ($N = 10$ per group) were run at 3.0 ma, one receiving tone plus dark CSs and another receiving the dark CS.

Means and standard deviations of percent avoidance for tone plus dark CSs were 38.0 and 22.0, respectively; those for the dark CS were 33.4 and 22.0, respectively. There was no difference between these CSs ($t_{18} < 1$).

The foregoing data may be cautiously compared with the original data at the other shock intensities. Tone plus dark CSs at 3.0 ma ($N = 10$) showed less responses than tone plus dark CSs at 1.3 ma ($t_{15} = 3.3$, $p < .01$); the dark CS at 3.0 ma ($N = 10$) showed less responses than the dark CS at .4 ma ($t_{15} = 2.4$, $p < .05$).

Although comparisons between different subjects run at different times should be made cautiously, it seems that tone plus dark CSs, as well as the dark CS, are associated with impairments at 3.0 ma.

In more general terms, then, allowing subjects to run from a dark CS towards light may explicitly eliminate competing responses by allowing approach to a cue which is not associated with shock, but may implicitly introduce these responses by requiring species-inappropriate behaviour.

7.2 A TONE CS AND A VISUAL CS IN BOTH COMPARTMENTS

Since the previous experiment contained some unreliable data points, it seemed necessary to further examine its two main findings, *viz:*

(i) that only a CS involving a dark-to-light change combines with a tone CS to facilitate shuttleavoidance at .1 ma, and,

(ii) that approach to shock-related cues introduces competing responses and, thereby, impairs shuttleavoidance at high shock intensities.

These findings were investigated by using a visual CS and tone plus visual CSs, where the visual CS consisted of one cue signalling shock in both compartments. Species-specific effects were not expected since one cue in both compartments does not involve the choice between a lighted place and a dark place.

7.2.1 METHOD

7.2.1.1 SUBJECTS

Ss were 112 naive male albino rats obtained from the John Curtin School of Medical Research, Canberra, Australia. They were between 100 and 120 days old at the beginning of the experiment and were maintained on ad lib. food and water.

7.2.1.2 APPARATUS

The apparatus was the shuttlebox described in the previous experiment.

7.2.1.3 PROCEDURE

Ss were randomly assigned to eight groups. Four groups received a visual CS at one of four UCS intensities, i.e. .1 ma, .4 ma, 1.3 ma and 3.0 ma. Within each group, half of the Ss were randomly chosen to be run in darkness with light in both compartments serving as CS and the other Ss were run in light with darkness in both compartments serving as CS. Four groups received a tone CS together with the foregoing visual CS at one of the four UCS intensities.

The pre-test trials, test trials and the order of running subjects are described in the previous experiment. Data from three Ss were discarded owing to various equipment failures and extra Ss were used as replacements.

7.2.2 RESULTS

Means and standard deviations of percent avoidance for the tone plus light CSs, for tone plus dark CSs, for the light CS and for the dark CS at all shock intensities are presented in Table 7.21.

The functions relating percent avoidance to shock were analysed using Ferguson's (1965) non-parametric analysis of trend, which provides tests of monotonic (one-branched) trend, of bitonic (two-branched) trend and so on. Ferguson's analysis is normally used when the independent variable or the dependent variable is ordinal, rather than ratio or interval. This analysis may also be used when, as in the present case, the independent variable is interval but has unequally-spaced values. The complete results, for monotonic trends and for bitonic trends, and a description of Ferguson's technique, are included in Appendix 2.

The function of tone plus light CSs was monotonic ($p < .01$); in contrast, that of tone plus dark CSs was bitonic ($p < .05$). The function of the light CS did not show reliable bitonicity ($p > .1$). [Nevertheless, owing to the small numbers at each shock intensity ($N = 7$), the light CS was further examined with t-tests between adjacent shock intensities. It was found that .4 ma produced more responses than .1 ma ($t_{12} = 2.5$, $p < .05$) and 1.3 ma ($t_{12} = 2.5$, $p < .05$) and that 1.3 ma and 3.0 ma did not differ. Thus, with more subjects, the function of the light CS would probably show reliable bitonicity.] Finally, the function of the dark CS was bitonic ($p < .01$).

Also, two-CS functions were compared to one-CS functions at each shock intensity in the light and in the dark conditions. Tone plus light CSs produced more responses at .1 ma ($t = 2.9$, $p < .05$) than the light CS; tone plus dark CSs and the dark CS did not differ at any of the shock intensities.

Figure 7.21 and Figure 7.22 show mean percent avoidance, respectively, in the light and in the dark conditions.

TABLE 7.21

Means and standard deviations of percent avoidance in visual CS groups and in tone plus visual CS groups: the visual CS in both compartments. Separate light and dark conditions (N = 7 per group).

LIGHT

		.1 ma	.4 ma	1.3 ma	3.0 ma
LIGHT CS	Means	39.86	70.00	38.57	42.86
	Standard deviations	27.01	17.93	28.92	31.98
TONE PLUS LIGHT CSs	Means	72.14	63.14	51.00	43.43
	Standard deviations	11.11	18.11	17.05	25.87

DARK

		.1 ma	.4 ma	1.3 ma	3.0 ma
DARK CS	Means	24.85	63.43	40.29	35.14
	Standard deviations	21.68	13.57	18.47	21.97
TONE PLUS DARK CSs	Means	33.00	47.71	59.57	28.29
	Standard deviations	23.82	18.06	24.32	21.94

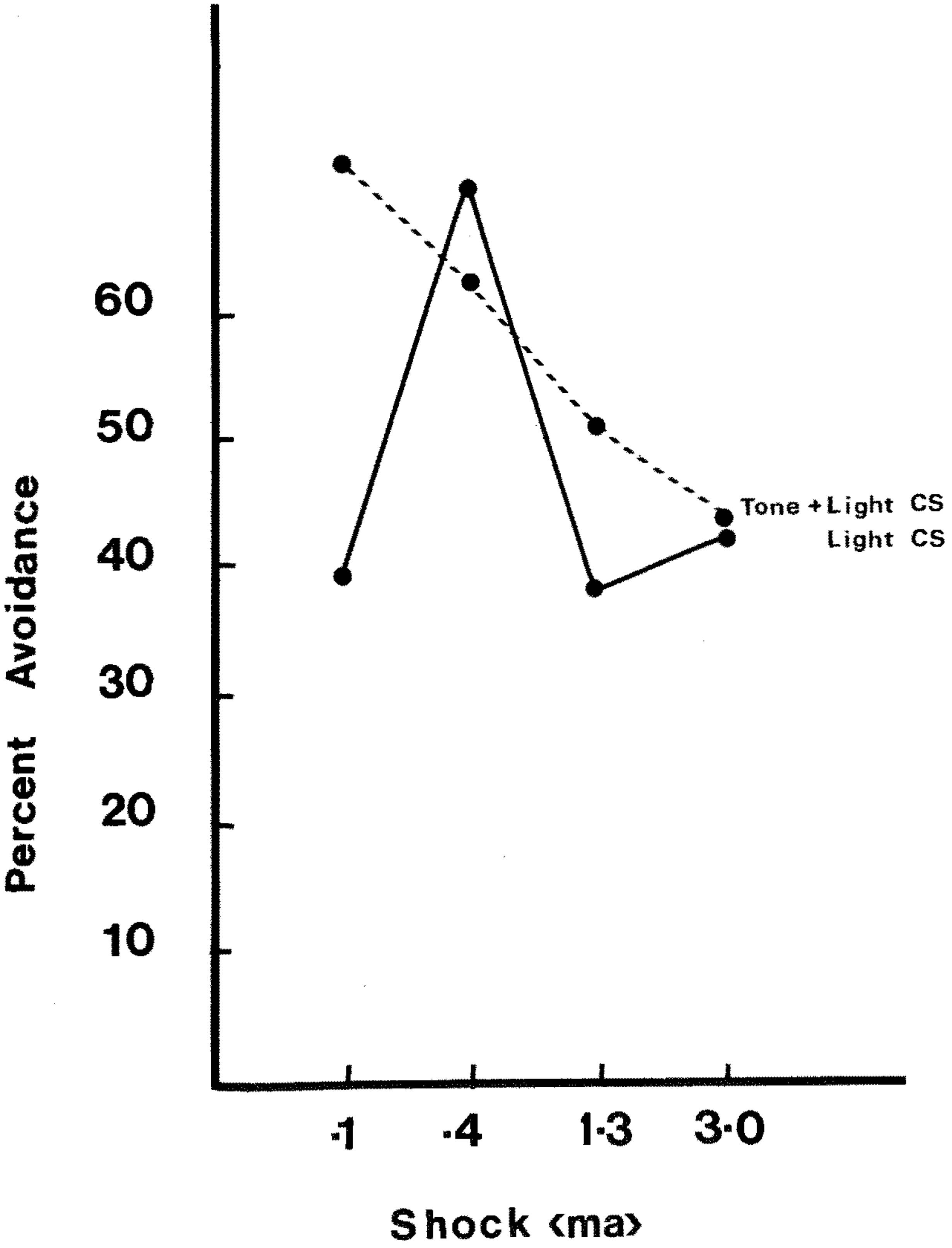


Figure 7.21 Mean percent avoidance to light and tone + light CSs. Light was presented in both compartments (N = 7 per data point).

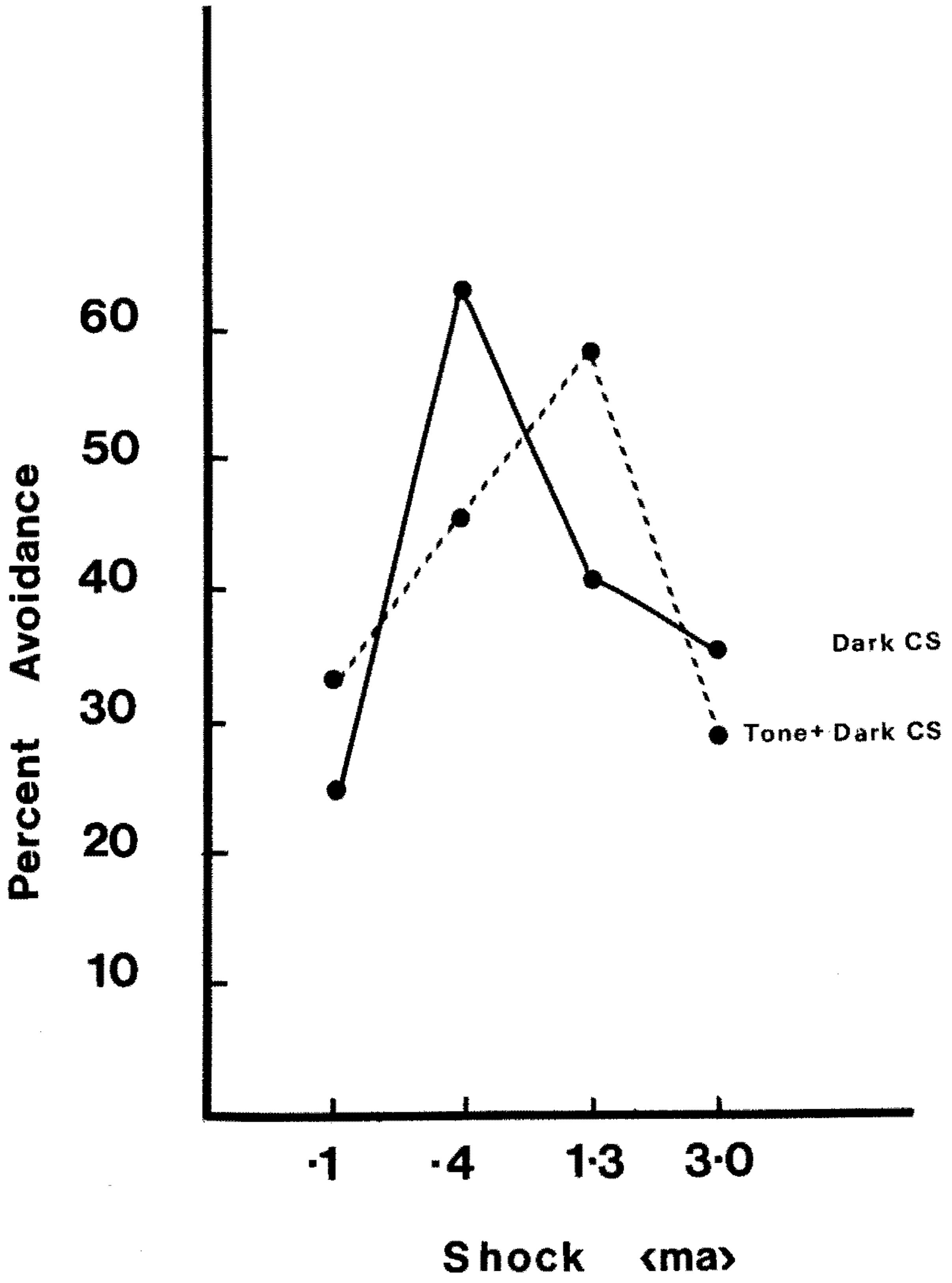


Figure 7.22 Mean percent avoidance to dark and tone + dark CSs. Dark was presented in both compartments (N = 7 per data point).

7.2.3 DISCUSSION

The findings are consistent with those of the previous experiment.

In particular, a CS involving a dark-to-light change combined with a tone CS to facilitate shuttleavoidance at .1 ma whereas a CS involving the reverse change did not. Also, approach to shock-related cues seems to have introduced competing responses, as indexed by impairments in shuttleavoidance with all of the CSs, at high shock intensities.

7.3 A TONE CS AND A VISUAL CS IN THE TO-BE-ENTERED COMPARTMENT

These findings were further examined using a visual CS and tone plus visual CSs, where the visual CS consisted of one cue signalling shock in the to-be-entered compartment together with another cue in the occupied compartment.

Species-specific effects were expected since different cues in the two compartments involve the choice between a lighted place and a dark place. In particular, approaching a light CS should be less appropriate than approaching a dark CS and so the former CS should give rise to poorer shuttleavoidance than the latter CS.

7.3.1 METHOD

7.3.1.1 SUBJECTS

_S_s were 112 naive male albino rats obtained from the John Curtin School of Medical Research, Canberra, Australia. They were between 100 and 120 days old at the beginning of the experiment and were maintained on ad lib. food and water.

7.3.1.2 APPARATUS

The apparatus was the shuttlebox described in the previous experiment.

7.3.1.3 PROCEDURE

Ss were randomly assigned to eight groups. Four groups were presented with a visual CS at one of four UCS intensities, i.e. .1 ma, .4 ma, 1.3 ma and 3.0 ma. Within each group, half of the Ss were randomly chosen to be run in darkness with light in the to-be-entered compartment serving as CS and the other Ss were run in light with darkness in the to-be-entered compartment serving as CS. Four groups received a tone CS together with the foregoing visual CS at one of the four UCS intensities.

The pre-test trials, test trials and the order of running subjects are described in the previous experiment. Data from six Ss were discarded owing to various equipment failures and extra Ss were used as replacements.

7.3.2 RESULTS

Means and standard deviations of percent avoidance for tone plus light CSs, for tone plus dark CSs, for the light CS and for the dark CS at all shock intensities are presented in Table 7.31.

The functions relating percent avoidance to shock were again analysed using Ferguson's (1965) non-parametric analysis of trend. The complete results, for monotonic trends and for bitonic trends, are included in Appendix 2.

The function of tone plus light CSs was monotonic at a marginal level ($p = .08$); in contrast, the function of tone plus dark

CSs was bitonic ($p < .05$). The function of the light CS showed monotonicity ($p < .01$). Finally, the function of the dark CS showed no trends. [Nevertheless, t-tests between adjacent shock intensities indicated that there was some decline in the number of responses from .4 ma to 1.3 ma ($t_{12} = 2.4$, $p < .05$.]

Also, two-CS functions were compared to one-CS functions at each shock intensity in the light and in the dark conditions. Tone plus light CSs produced more responses at .1 ma ($t_{12} = 2.2$, $p < .05$) and at 1.3 ma ($t_{12} = 3.6$, $p < .01$) than the light CS; tone plus dark CSs produced more responses at 1.3 ma ($t_{12} = 5.4$, $p < .01$) than the dark CS.

Figure 7.31 and Figure 7.32 show mean percent avoidance, respectively, in the light and in the dark conditions.

TABLE 7.31

Means and standard deviations of percent avoidance in visual CS groups and in tone plus visual CSs groups: the visual CS in the to-be-entered compartment.

Separate light and dark conditions (N = 7 per group).

LIGHT

		.1 ma	.4 ma	1.3 ma	3.0 ma
LIGHT CS	Means	26.86	39.29	8.57	5.43
	Standard deviations	23.46	22.68	10.63	8.75
TONE PLUS LIGHT CSs	Means	46.57	45.86	48.43	25.29
	Standard deviations	20.42	28.30	27.27	26.66

DARK

		.1 ma	.4 ma	1.3 ma	3.0 ma
DARK CS	Means	25.14	21.42	5.71	21.29
	Standard deviations	21.66	17.22	3.86	21.04
TONE PLUS DARK CSs	Means	23.71	37.43	44.71	27.00
	Standard deviations	17.95	20.77	18.73	19.15

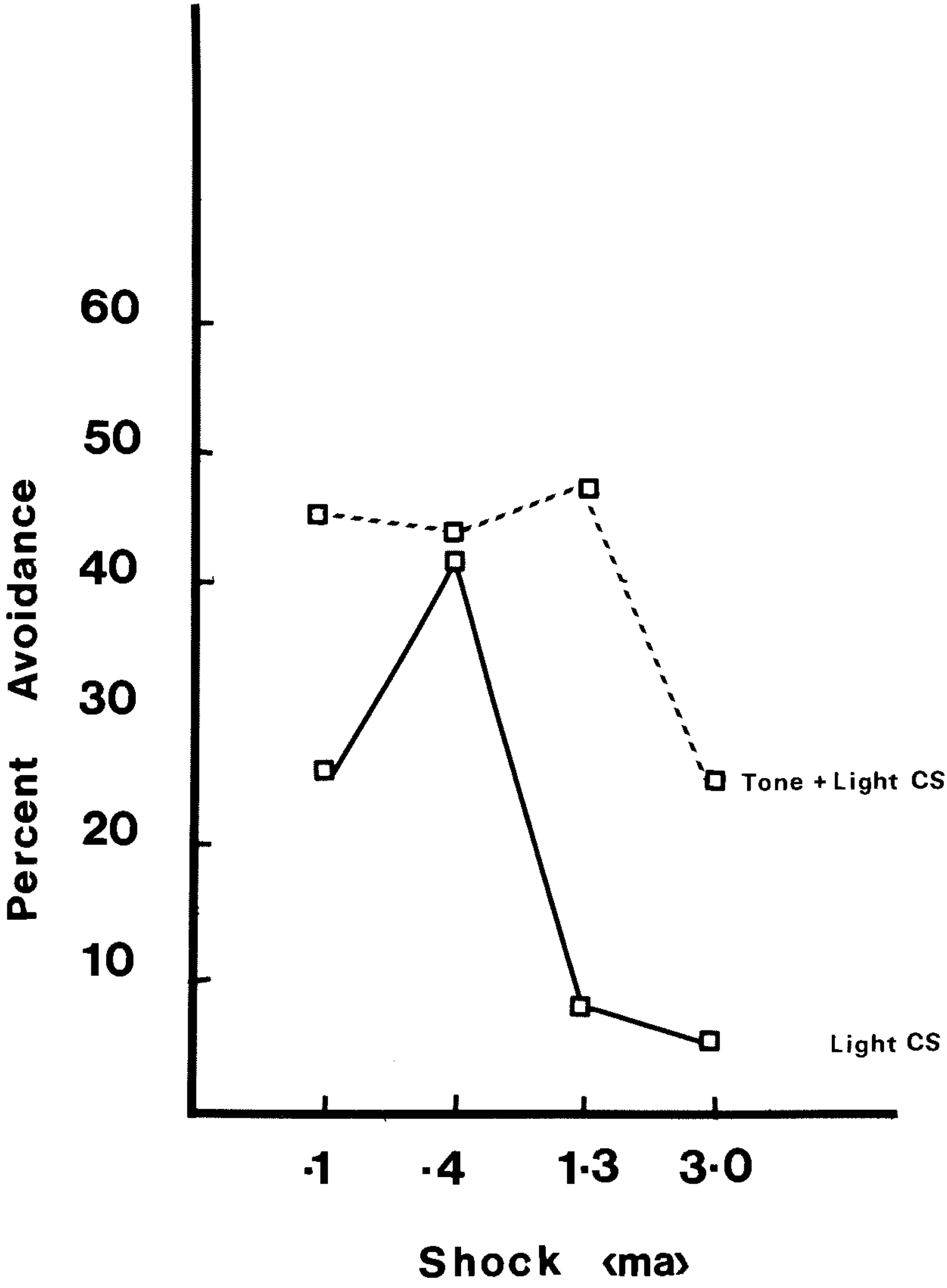


Figure 7.31 Mean percent avoidance to light and tone + light CSs. Light was presented in the to-be-entered compartment (N = 7 per data point).

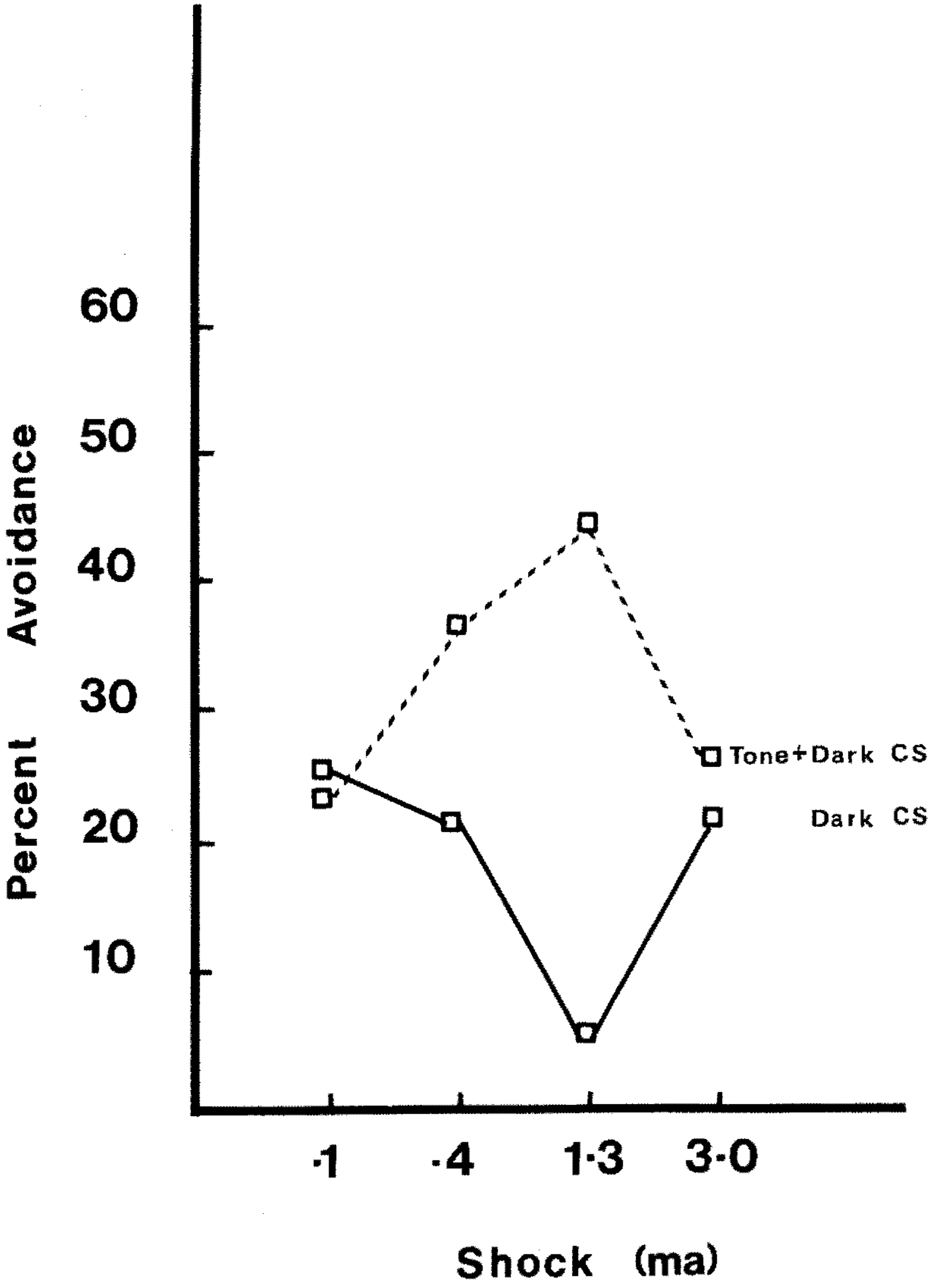


Figure 7.32 Mean percent avoidance to dark and tone + dark CSs. Dark was presented in the to-be-entered compartment N = 7 per data point).

7.3.3 DISCUSSION

The findings are mostly consistent with those of the previous experiments.

In particular, a CS involving a dark-to-light change combined with a tone CS to facilitate shuttleavoidance at .1 ma whereas a CS involving the reverse change did not. Also, approach to shock-related cues seems to have introduced competing responses, as indexed by impairments in shuttleavoidance with all of the CSs at high shock intensities.

Contrary to expectations, however, species-specific effects, noted in the first experiment at 3.0 ma, did not appear to have markedly altered shuttling at 3.0 ma. While approaching a light CS should have been less appropriate for albino rats than approaching a dark CS, the poorer shuttling with the former CS, either together with a tone CS or alone, was very slight.

7.4 SUMMARY

It would seem, then, that different situational cues may manipulate the efficiency of shuttleavoidance depending on the intensity of shock.

At low intensities of shock, a visual change from dark to light combines with a tone stimulus to elicit, apparently, a pronounced orienting or alerting reaction in albino rats. Accordingly, some kind of response is likely from these animals. Since behavioural options are somewhat limited in shuttleboxes, responding is likely to take the form of shuttling.

At high intensities of shock, stimuli which eliminate competing responses facilitate, and stimuli which fail to eliminate competing responses impair, shuttleavoidance. While the development of competing responses can be experimentally induced, these responses may sometimes result from requiring species-inappropriate behaviour.

While different situational cues may manipulate the efficiency of shuttleavoidance depending on the intensity of shock, the present data suggest that common behavioural processes have inverted-U effects on efficiency throughout the continuum of shock values. These processes are outlined in detail in the next chapter.

CHAPTER 8

MODEL OF THE INVERTED-U CURVE

On the basis of the experiments of the previous chapter, an explanation of inverted-U changes in the efficiency of behaviour as a function of level of stimulation will be attempted.

The type of situation in which these changes may be expected has not been adequately specified by other theorists, notably Berlyne (1967), Hull-Spence proponents, e.g. Broen and Storms (1961), and Broadbent (1965).

8.1 EXISTING MODELS

8.1.1 BERLYNE

According to Berlyne (1967), inverted-U curves are the product of two antagonistic "systems", i.e. reward and aversion. The systems are stimulated by changes in activation, or arousal, that are induced by psychophysical, "ecological" and "collative" stimuli; reward is mobilized by moderate increases in arousal and aversion is mobilized by intense increases in arousal. The systems sum to improve and, then, to impair behaviour with the heightening of arousal since reward operates in a facilitatory, negatively-accelerated manner and aversion operates in a detrimental, positively-accelerated manner.

In Berlyne's model, there are two important hypotheses about reward-aversion influences; *viz.* that they are always initiated by stimuli and that they have "anatomical distributions".

In order to justify the first hypothesis, Berlyne cited authors who found opposite changes in behaviour at different intensities of stimulation (e.g. Grastyan, *et al.*, 1965, 1966; Schneirla, 1959; Sokolov, 1963). For example, Grastyan, *et al.* (1965, 1966) examined the rate of lever-pressing, which terminated electrical impulses to the brain, in cats. The lever was initially avoided and subsequently monopolized by the animals as the intensity of the impulses increased. This kind of reward-punishment sequence, which is consistent with the idea of reward-aversion systems, is not always found. For example, when the brain is stimulated, some electrode placements successively produce reward and punishment, but others only show reward (Bower and Miller, 1958).

By way of substantiating the second hypothesis, Berlyne referred to the demonstrated correlations between increases and decreases in a response and the specific locus of electrical impulses to the brain (e.g. Olds and Milner, 1954; Roberts, 1958). This kind of localization of reward and punishment, which supports the idea of reward-aversion systems with anatomical distributions in the brain, is not always found. For example, the same site can generate rewarding and punishing effects (Grastyan, *et al.*, 1965, 1966).

In using labels such as "systems", Berlyne attempts to be too general. For example, rats with access to self-stimulation and to food for one hour daily prefer one type of reward over another, or both types equally, depending on the placement of electrodes (Routtenberg and Lindy, 1965). This specificity of reward raises the following question: in what sense is reward a "system", i.e. a diffuse process manipulated by any stimulus?

Indeed, the supposed behavioural index of reward and aversion "systems" i.e. inverted-U curves, is not generally reported. These curves are relatively uncommon (Bolles, 1967).

8.1.2 HULL-SPENCE PROPONENTS

Within the Hull-Spence tradition, inverted-U curves have been explained by the competition between incorrect and correct habits. For example, Broen and Storms (1961) discussed how high levels of stimulation could produce the dominance of incorrect habits under two circumstances: when the incorrect habits are, initially, equally probable, or more probable, than the correct habit, and when the incorrect habits are, initially, less probable than the correct habit. Of course, these circumstances apply to every possible situation.

Unlike Berlyne's approach, Hull-Spence explanations analyse inverted-U curves in specific situations. Unfortunately, this analysis tends to be post-hoc and, accordingly, to be circular. The occurrence of competing habits and, hence, impairments in behaviour is not predicted; instead, the occurrence of competing habits is inferred from impairments in behaviour.

8.1.3 BROADBENT

Broadbent (1965) illustrated his explanation of inverted-U curves by the example of a situation with two responses, R_1 and R_2, and two stimuli, s_1 and s_2. He supposed that: R_1 is correct in the presence of s_1 and is followed by gain or reward G and R_1 is incorrect to s_2, producing no gain; also, R_2 is correct and incorrect, respectively, to s_2 and to s_1, and elicits, respectively, gain G + B and gain B. In Broadbent's view, R_2 is an innate response bias, e.g. position preference. However, he does not explain why R_2 is invariably associated with gain B, or what gain B is.

When s_1 and s_2 are difficult to discriminate, subjects are likely to optimize gain and so to make R_2 rather than R_1. Since R_2 is sometimes correct and sometimes incorrect, subjects' preference for R_2 will impair the accuracy of their performance. This impairment is, supposedly, most evident with the heightening of stimulation, due to increases in the level of responding.

Thus, Broadbent's model is applicable to a particular type of situation where two responses may be correct and incorrect in the presence of two stimuli and where one of the responses is, innately, more probable than the other. In shuttleavoidance, however, only one response is correct in the presence of only one stimulus, i.e. the CS; and only one condition, *viz.* requiring subjects to run from a lighted to a dark compartment, could involve innate response biasses or "species-specific constraints", in the terminology of the previous chapter. This condition does not give rise to inverted-U changes in shuttleavoidance as a function of the intensity of shock (Chapter 7, Section 8.2.1).

Within the context of decision-making in humans, Broadbent (1971) later revised his ideas about the origin of impairment in the accuracy of performance with the heightening of stimulation. Instead of innate biasses, he talked about subjects' "suspending judgement" due to uncertainty about which response is correct. In shuttleavoidance, involving infra-human species, however, postulates of suspended judgements are circular. The only index of these judgements is the behaviour "explained" by them.

Generally, Broadbent analyses inverted-U curves in specific situations. However, this analysis does not encompass shuttleavoidance and, accordingly, appears to be too narrow.

8.2 THE PRESENT MODEL

Berlyne, Hull-Spence proponents and Broadbent have not adequately considered the relation of inverted-U curves to situations, and to the variables which operate in these situations.

8.2.1 THE TYPE OF SITUATION AND INVERTED-U CURVES

Since there are some difficulties in interpreting the findings with appetitive tasks (see Chapter 1), only aversively-motivated tasks will be examined.

Inverted-U curves were noted by Yerkes and Dodson (1908) when the visual contrast between a shocked, or "unsafe", box and an unshocked, or "safe", box was diminished. Similarly, these curves were noted by Broadhurst (1957) when the visual contrast between an unsuccessful, or "unsafe", escape route and a successful, or "safe", escape route was reduced.

In the present work on shuttleavoidance, inverted-U curves have been found where the visual demarcation between the shocked, or "unsafe", occupied compartment and the unshocked, or "safe", to-be-entered compartment is either weak or non-existent.

In the third chapter, the presentation of a weak light CS (8 lux ca) in the occupied compartment, together with darkness in the to-be-entered compartment, gave rise to non-monotonic trends in shuttle-avoidance as a function of the intensity of white noise, of shock and of white noise plus shock.

Again, in the previous chapter, a visual CS (light or darkness) in both compartments and a tone CS, together with light or darkness in both compartments, had non-monotonic effects across intensities of shock; Figure 8.01 summarizes these effects. For the visual CS (light or darkness) in both compartments, percent avoidance shows a bitonic trend ($p < .01$), using Ferguson's (1965) analysis. For the tone CS, together with light or darkness in both compartments, percent avoidance does not show a reliable bitonic trend ($p > .1$).(1) [Nevertheless, t-tests between adjacent shock groups suggest that bitonicity would probably achieve significance with more subjects; thus, the .1 ma group made fewer responses than the .4 ma group ($t_{26} = 2.1$, $p < .05$), which made more responses than the 1.3 ma group ($t_{26} = 3.7$, $p < .01$) and the 1.3 ma group and the 3.0 ma group did not differ ($t_{26} < 1$.]

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(1) Appendix 2, Section 2.2.2.3 and Section 2.2.2.4, presents the complete results.

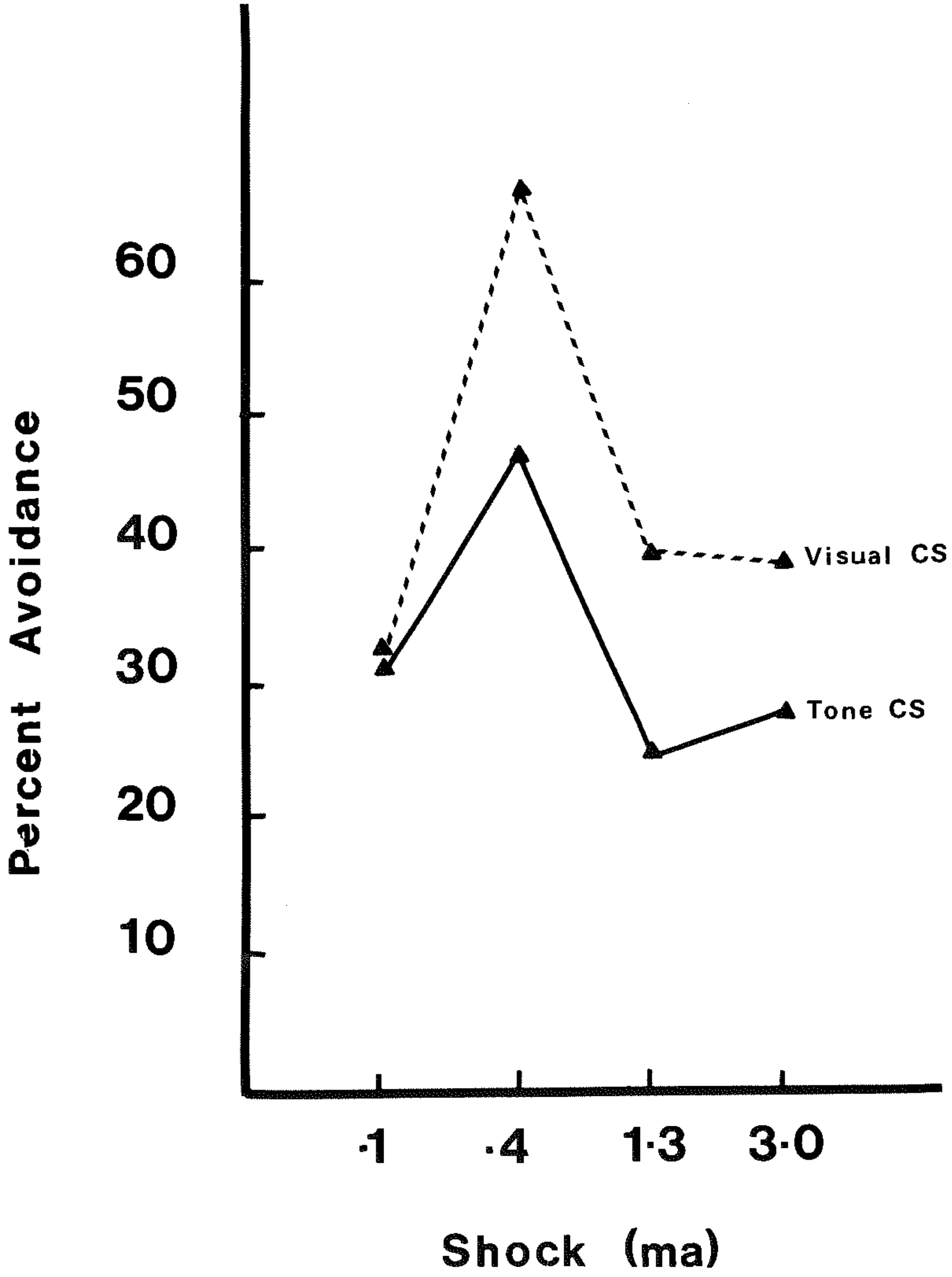

Figure 8.01 Mean percent avoidance to a tone CS and a visual CS consisting of either light or darkness in both compartments (N = 14 per data point). These CSs require Ss to choose between alternatives which are equally aversive.

Thus, the absence of criteria for discriminating between an "unsafe", e.g. shock-related, alternative and a "safe", e.g. shock-unrelated, alternative seems to be associated with inverted-U curves. In the absence of such criteria, subjects are required to approach unsafe cues.

In general, approach to shock-related cues is known to impair different kinds of behaviour. Using a shock box and a no-shock box, for example, Franchina, *et al.* (1973) and Knapp (1965) examined, respectively, escape and one-way avoidance. When the boxes were similar, and hence subjects ran towards shock-related cues, responding was poorer compared to when the boxes were dissimilar, and subjects ran towards shock-unrelated cues.

In particular, approach to a shock-related cue, i.e. the CS, impairs shuttleavoidance. Thus, cats showed impeded shuttling where they moved toward, rather than away from, the source of the CS (McAdam, 1964). Again, in the experiments of the previous chapter, subjects with a CS (light or dark) located in the to-be-entered compartment evidenced poorer shuttling than those with the same CS located in the occupied compartment, across all intensities of shock ($t_{110} = 3.6$, $p < .01$).

The difference between a CS in the to-be-entered compartment and a CS in the occupied compartment may be understood within the theoretical analysis of shuttleavoidance of McAllister, *et al.* (1971).

8.2.2 REINFORCEMENT AND INVERTED-U CURVES

According to McAllister, *et al.* (1971), two kinds of reinforcing events (which alter the probability of the shuttling response that they follow) have antagonistic influences on the shuttling response. These reinforcements, so-called "fear reduction from CS offset" and "fear of situational cues", combine to determine "effective reinforcement" and operate, respectively, to produce systematic increases and to produce systematic decreases in shuttleavoidance as a function of the intensity of the UCS. Fear of situational cues is thought to be the major component of effective reinforcement at high intensities of the UCS where shuttleavoidance is poor (Moyer and Korn, 1964).

This last assumption is entirely post-hoc. Nevertheless, the idea that incremental and decremental influences combine to have inverted-U effects on shuttleavoidance is testable. If, for example, the incremental influence is identified with the location of the CS in the occupied compartment and the decremental influence is identified with the location of the CS in the to-be-entered compartment, then two predictions might be made:

(i) incremental and decremental influences, in the same situation, combine to produce inverted-U trends, and,

(ii) incremental and decremental influences, in separate situations, combine to predict inverted-U trends.

8.2.3 A TEST OF THE INCREMENTAL-DECREMENTAL MODEL: VISUAL CSs ALONE

In support of the first prediction, incremental and decremental influences, in the same situation, combine to produce inverted-U trends. Thus, running from and towards a visual CS was associated with bitonic changes in percent avoidance with increases in the intensity of shock, in the case of either a light CS (Chapter 7) or a dark CS (Chapter 7).

According to the second prediction, incremental and decremental influences, in separate situations, combine to predict inverted-U trends. Following Berlyne (1967), "combine" is assumed to mean "add".

While the foregoing assumption, and any other assumption, is post-hoc, it should be noted that incremental and decremental influences represent differences in the shock value, or aversiveness, of stimuli in the to-be-entered compartment; the differences can be independently manipulated and so might have independent (i.e. additive; Broadbent, 1963) effects. Thus, the incremental influence is manipulated by requiring subjects to run from a CS, which signals shock, to a neutral cue (i.e. to run towards a less aversive stimulus); and, the decremental influence is manipulated by requiring subjects to run from a neutral cue to a CS (i.e. to run towards a more aversive stimulus). When these manipulations are added, subjects run from a CS to a CS (i.e. run towards an equally aversive stimulus).

Of course, percent avoidance, produced by different manipulations, cannot simply add; otherwise, percent avoidance could exceed one hundred percent. Therefore, this addition needs to be divided by a numerical constant, such as two. In fact, any constant can be arbitrarily chosen since divisions of added scores of percent avoidance at different intensities of shock do not alter the form of the function relating percent avoidance to shock.

According to the second prediction, then, the function of percent avoidance produced by requiring subjects to run towards an equally aversive stimulus is the mean of the function describing approach to a less aversive stimulus and the function describing approach to a more aversive stimulus. Figure 8.02 and Figure 8.03 present these functions for the light CS and for the dark CS, respectively.

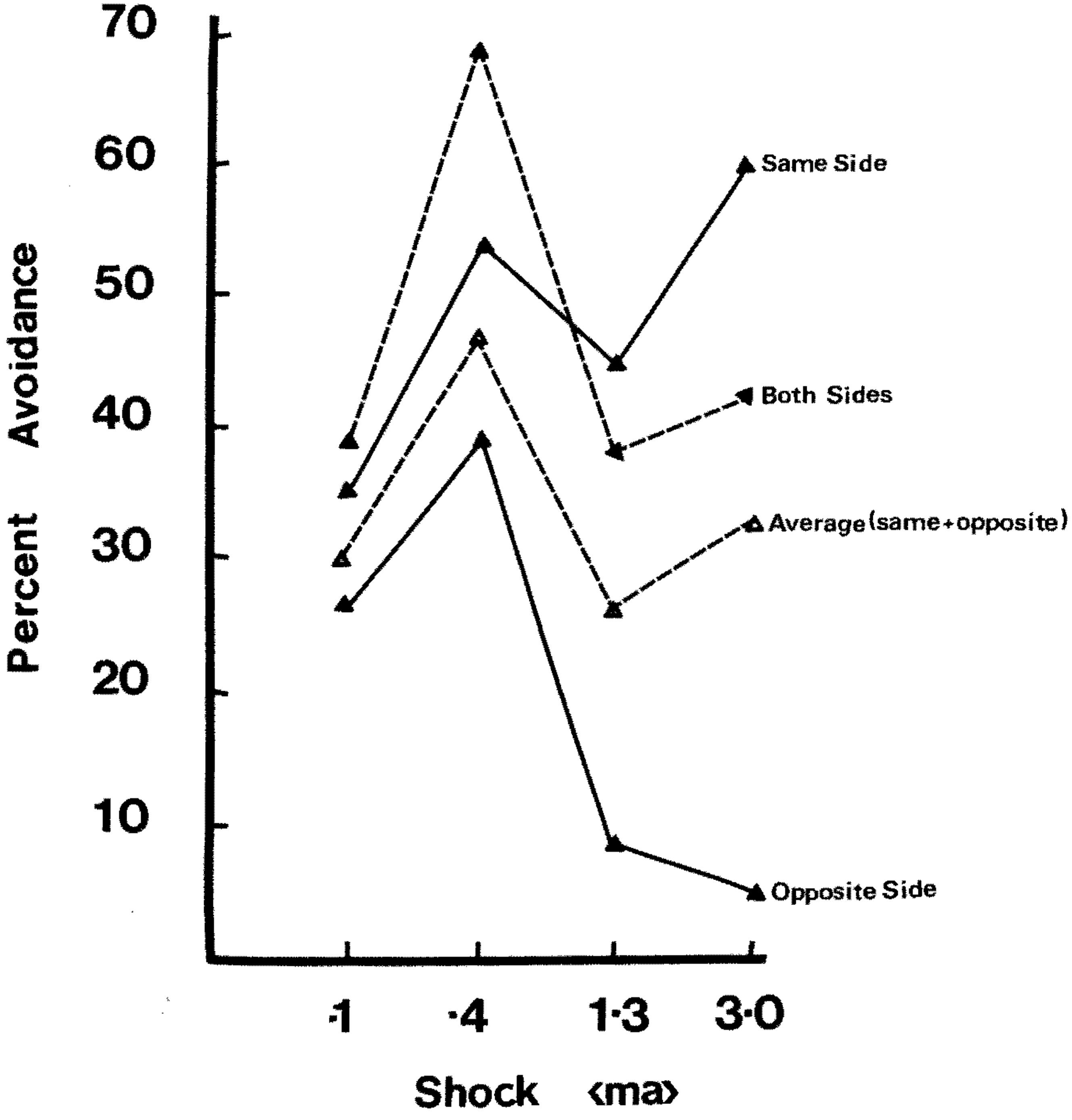

Figure 8.02 Mean percent avoidance to three light CSs. Light was presented in the occupied compartment (same-side) both compartments (both sides) or the to-be-entered compartment (opposite side), with N = 7 per data point. The average curve represents the mean of the same-side and opposite-side CSs at each shock level.

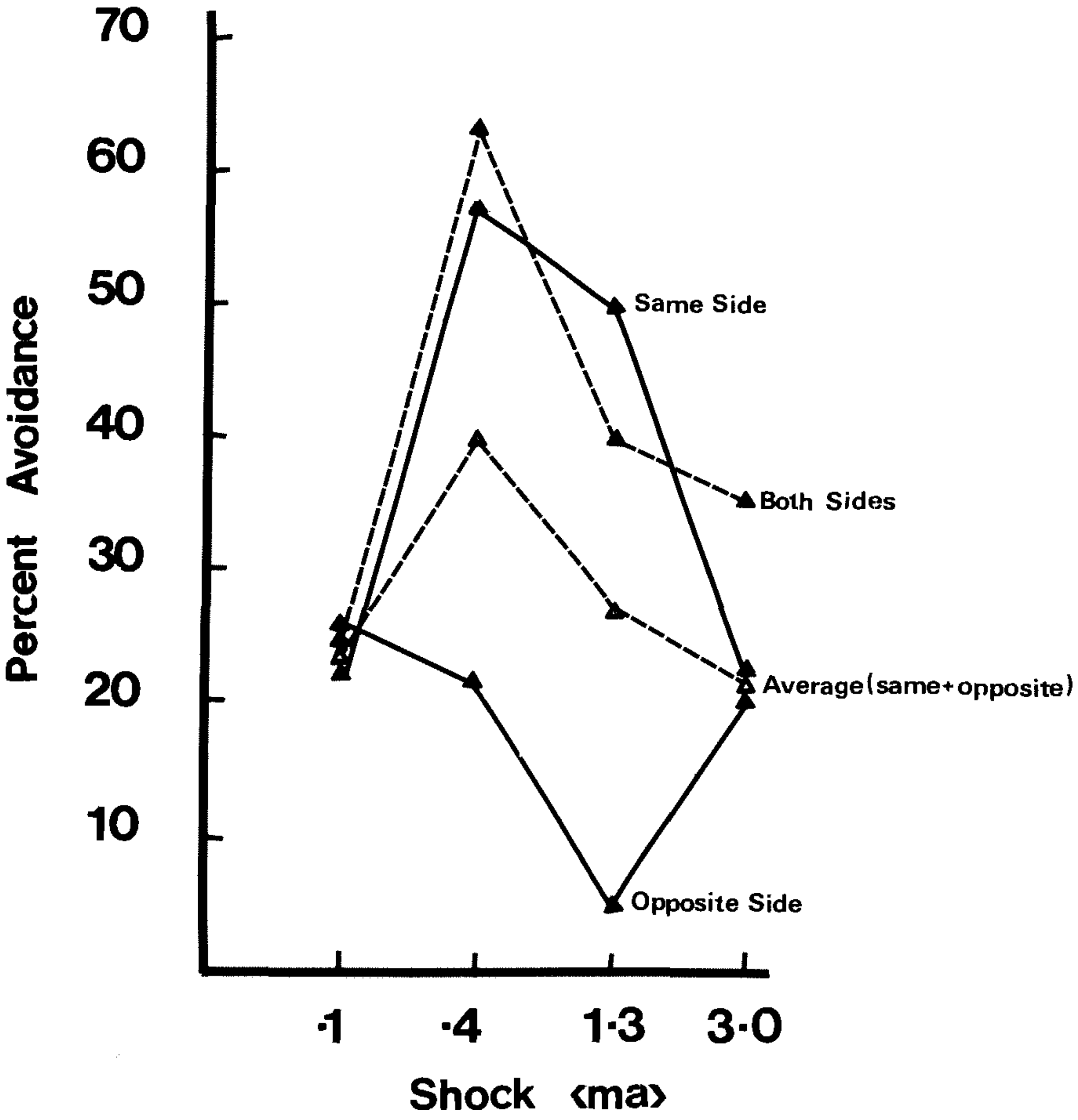

Figure 8.03 Mean percent avoidance to three dark CSs. Dark was presented in the occupied compartment (same-side), both compartments (both sides) or the to-be-entered compartment (opposite side), with N = 7 per data point. The average curve represents the mean of the same-side and opposite-side CSs at each shock level.

The equally aversive function of the light CS is, apparently, non-monotonic (Chapter 7) and its form is strikingly similar to the mean of the less aversive function and the more aversive function. However, this mean is not reliably non-monotonic across intensities of shock, using Ferguson's (1965) non-parametric analysis of trend or using parametric comparisons. Considering the dark CS, the equally aversive function is significantly bitonic (Chapter 7) and, again, its form is similar to the mean of the less aversive function and the more aversive function. Again, however, this mean is not reliably non-monotonic across intensities of shock.

At the very least, the foregoing data provide some support, albeit statistically insignificant support, for the hypothesis that the equally aversive function may be described by the mean of the less aversive function and the more aversive function. Indeed, this hypothesis was substantiated in the case of the light CS and of the dark CS, where the less aversive functions and the more aversive functions were notably different.

Also, recent work on shuttleavoidance in goldfish partially suggests that the effects of an equally aversive manipulation are intermediate between those of a less aversive manipulation and of a more aversive manipulation. Gallon (1974) used a light CS in both compartments of a shuttlebox, in the same compartment as the fish or in the opposite compartment as the fish. The both-compartments CS gave worse responding than the same-compartment CS, but better responding than the opposite-compartment CS. However, a dark CS did not result in a similar ordering of the three CSs.

8.2.4 A TEST OF THE INCREMENTAL-DECREMENTAL MODEL: VISUAL CSs TOGETHER WITH A TONE CS

The foregoing predictions, *viz.* that incremental and decremental influences, in the same situation, combine to produce inverted-U trends and that these influences, in separate situations, add to predict inverted-U trends, may be tested by the two-CS functions of the previous chapter. Unfortunately, such a test cannot be satisfactory since combinations of a light CS and a tone CS manipulated irrelevant variables and those of a dark CS and a tone CS resulted in some data points of doubtful reliability.

In the case of light, predictions about incremental and decremental influences cannot be examined. Combinations of light and tone were associated with optimal levels of percent avoidance, with a low intensity of the shock UCS and with no shock UCS. These combinations seemed to represent a species-specific sensitization of the tone stimulus by the sensory change from dark-to-light, and, accordingly, do not allow an isolation of the effects of incremental and decremental influences, which are assumed to be determined by external stimuli, e.g. the UCS (McAllister, *et al.*, 1971).

In the case of dark, only one prediction about incremental and decremental influences can be investigated. In the same situation, these influences did, indeed, give rise to inverted-U trends; thus, when a tone CS, as well as a dark CS in both compartments, was presented, percent avoidance showed significant bitonicity (Chapter 7). In separate situations, however, these influences contained unreliable data points (where subjects received a tone CS together with a dark CS in the occupied compartment) and cannot be meaningfully related to inverted-U, or any other, trends.

8.2.5 SUMMARY

On the basis of the one-CS and the two-CS functions of the previous chapter, it would seem that incremental and decremental influences are responsible for inverted-U changes in shuttleavoidance with the heightening of stimulation. In particular, these influences, in the same situation, combine to produce inverted-U changes and, in separate situations, add to predict inverted-U changes.

Incremental and decremental influences may result from an interaction between the same two variables, i.e. the classical conditioning of aversive properties to the CS and the location of the CS.

8.3 NATURE OF INCREMENTAL-DECREMENTAL INFLUENCES

8.3.1 THE INCREMENTAL INFLUENCE

McAllister, *et al.* (1971) identified the incremental influence as fear reduction from the termination of the CS. This identification may be interpreted in two ways.

In one sense, the hypothesis that increases in the probability, i.e. positive reinforcement, of shuttling responses result from the offset of a feared CS is somewhat trivial. By definition, a feared CS is one which has been paired with a UCS, has acquired aversive properties and, accordingly, tends to be avoided. When this CS is presented in the occupied compartment, its avoidance will produce shuttling, i.e. the to-be-learned response.

In another sense, the hypothesis that increases in the probability of shuttling responses result from the offset of the CS is not trivial. According to Bower, *et al.* (1965) and Bolles and Grossen (1970), the amount of change in a stimulus following a response (e.g. termination of the CS, or, response-produced "safety signals"), determines the degree of increase in the probability of the response. The experiments of Chapter 7 do not support this view. Thus, light or dark CSs in the occupied compartment produced the same amount of change in post-shuttling stimuli, but significantly better percent avoidance across all intensities of the UCS, compared to light or dark CSs in the to-be-entered compartment ($t_{110} = 3.6$, $p < .01$).

In general, the identification of the incremental influence as fear reduction from the termination of the CS seems to be true in the trivial sense. That is, the incremental influence is explicable in terms of only two variables, *viz.* the classical conditioning of aversive properties to the CS and the location of the CS.

8.3.2 THE DECREMENTAL INFLUENCE

Contrary to some suggestions, impairments in shuttleavoidance at high intensities of the UCS cannot be the result of innate responses (Anisman and Waller, 1972; Weiss, *et al.* 1968) or non-specific responses (Berlyne, 1967; Duffy, 1972; Malmo, 1959). Instead, these impairments appear to be conditioned changes. While McAllister, *et al.* (1971) hypothesized a conditioned reduction in "effective" reinforcement, the experiments of Chapter 7 suggest that a conditioned response interferes with shuttleavoidance.

The decremental influence cannot be determined by innate freezing to the UCS. Deteriorations in shuttleavoidance were found to vary with CS location, which could not affect the elicitation of innate patterns of behaviour.

Similarly, the decremental influence cannot be manipulated by physiological changes, e.g. "excessive" activation (Hebb, 1955). For example, with a light CS in the occupied compartment compared to a light CS in the to-be-entered compartment at 3.0 ma, non-specific physiological responding to light and to shock would be the same. However, in the former case, shuttleavoidance was optimal and, in the latter case, it was impaired.

Instead, the decremental influence seems to be a conditioned change.

According to McAllister, *et al.* (1971) the process of impairment may be understood as a conditioned reduction in "effective" reinforcement. In particular, more fear of situational cues will be conditioned with strong, compared to weak, UCSs. The fear of these cues, that remains after shuttling, produces less "effective" reinforcement by strong UCSs than by weak UCSs. However, the fear of post-shuttling situational cues should be constant, regardless of pre-shuttling events, such as location of the CS. Yet, deteriorations in shuttleavoidance depended on variations in these events.

The process of impairment appears to represent a conditioned avoidance of a shock-associated stimulus, e.g. a CS in the to-be-entered compartment. Before the animals learn the shuttling response, they are likely to avoid this CS, particularly with strong, as opposed to weak, UCSs and, consequently, to "stay" (Theios, *et al.*, 1966) in the occupied compartment. In the situation of shuttleavoidance, staying has been inappropriately interpreted as "freezing".

In general, the decremental influence seems to be explicable in terms of only two variables, i.e. the classical conditioning of aversive properties to the CS and the location of the CS.

8.3.3 CONCLUSION

The classical conditioning of aversive properties to the CS interacts with the positioning of the CS to alter shuttleavoidance in opposite directions. When the CS is presented in the occupied compartment, subjects will avoid this aversive stimulus and so shuttling responses will be facilitated and when the CS is presented in the to-be-entered compartment, subjects will avoid this aversive stimulus and so shuttling responses will be impaired.

In other words, incremental-decremental influences result from the variation of the aversiveness of stimuli in the two compartments of the shuttlebox. In the previous chapter, this variation was achieved by changes in the location of an aversive stimulus, i.e. the CS.

A recent study by Freedman, *et al.* (1974) varied the aversiveness of the two compartments of the shuttlebox in a different way. In the presence of a tone CS, subjects were required to shuttle between compartments with different, but fixed, shock values, designated either "high" (H), "medium" (M) or "low" (L). With a constant level of shock in the to-be-entered compartment, increasing the shock intensity, and so the aversiveness, of the occupied compartment should have the same effect as the previous manipulation of incrementing the aversiveness of a CS in the occupied compartment by means of pairing the CS with progressively stronger UCSs. That is, shuttleavoidance should be systematically facilitated. Conversely, with a constant level of shock in the occupied compartment, increasing the shock intensity, and hence the aversiveness, of the to-be-entered compartment should have the same effect as the previous manipulation of incrementing the aversiveness of a CS in the to-be-entered compartment by means of pairing the CS with progressively stronger UCSs. That is, shuttleavoidance should be systematically impaired.

Freedman, *et al.* ran six groups of rats, defined by the shock level in the two compartments, i.e. H - H, M - M, L - L, H - L, H - M and M - L. Thus, there were nine different relations between the shock values in the two compartments, i.e. H - H, M - M, L - L, H - L and L - H, H - M and M - H, as well as M - L and L - M.

With the level of shock held constant in the to-be-entered compartment and shock intensity varied in the occupied compartment, the following means (N = 10) of the number of avoidance responses in 200 trials were obtained. Running from H to L, M to L and L to L gave, respectively, 96.1, 61.4 and 80.7; running from H to M, M to M and L to M gave, respectively, 32.9, 46.1 and 30.5; finally, running from H to H, M to H and L to H gave, respectively, 24.4, 14.4 and 46.5. Within each of these three groupings of means, there were no significant differences between any of the conditions. Contrary to expectations, then, increasing the shock intensity, and so the aversiveness, of the occupied compartment does not systematically increment the efficiency of shuttleavoidance.

With the level of shock held constant in the occupied compartment and shock intensity varied in the to-be-entered compartment, the following means of the number of avoidance responses in 200 trials were reported. Running from L to H, L to M and L to L elicited, respectively, 46.5, 30.5 and 80.7; running from M to H, M to M and M to L elicited, respectively, 14.4, 46.1 and 61.4; finally, running from H to H, H to M and H to L elicited, respectively, 24.4, 32.9 and 96.1. Within the first and last of these three groupings of means, there were significant differences between conditions. Consistent with expectations, then, increasing the shock intensity, and hence the aversiveness, of the to-be-entered compartment systematically impairs the efficiency of shuttleavoidance. The only exception to this trend is the L to H mean, which the authors regarded as an artefact.

In summary, the data of Freedman, *et al.* partially supports the possibility that an avoidance of shock-associated stimuli precedes the learning of the shuttling response. Contrary to this idea, there was no increment in responses as a function of the intensity of shock in, and so the shock-association value of, the occupied compartment. Consistent with this idea, there was a decrement in responding as a function of the intensity of shock in, and hence the shock-association value of, the to-be-entered compartment.

A number of variables could account for the former finding. For example, Freedman, *et al.* did not prevent shuttling during the inter-trial interval. Any "spontaneous cross-overs" were punished by shock. Therefore, the failure to observe a facilitation of responses could be due to punishment, which is known to increase immobility (Randall and Riccio, 1969). Also, Freedman, *et al.* chose .33 ma as their lowest value of shock. In the previous chapter, .4 ma consistently produced optimal shuttleavoidance. Thus, the failure to observe a facilitation of responses could result from the selective use of moderate to high values of shock.

While Freedman, *et al.* have provided evidence for impairment, but not for improvement, in shuttleavoidance with changes in the aversiveness of the two compartments of the shuttlebox, other types of avoidance commonly show facilitation and deterioration depending on the location of aversive stimuli. In the literature on pre-exposure to shock (e.g. Anisman, 1973), for example, rats were exposed to situational cues paired with one intensity of shock (de Toledo and Black, 1967). Subsequently, when subjects were required to learn one-way avoidance by either running from or running towards these cues, the efficiency of responding, respectively, increased and decreased.

8.4 GENERAL SUMMARY

Inverted-U changes in the efficiency of behaviour as a function of the level of stimulation have been found in a particular type of situation, where there is no clear demarcation between "safe" and "unsafe" alternatives (Yerkes and Dodson, 1908; Broadhurst, 1957). These changes have been hypothesized to result from the antagonistic operation of incremental and decremental influences or reinforcements (McAllister, *et al.*, 1971). Indeed, in the one-CS functions of the previous chapter, incremental and decremental influences, in the same situation, combined to produce inverted-U curves and, in separate situations, added to predict inverted-U curves. The source of these influences was interpreted as the classical conditioning of aversive properties to the CS interacting with the location of the CS to alter shuttleavoidance in opposite directions.

CHAPTER 9

EVALUATION OF ACTIVATION THEORY - 2

9.1 A RE-EXAMINATION OF THE BEHAVIOURAL ADDITIVITY OF STIMULI

The conclusions of the previous chapter about the inverted-U curve may suggest an inadequacy in the experiments of Chapter 3 where, contrary to the expectations of activation theory, white noise and shock together did not substantially alter shuttleavoidance compared to the mean of white noise alone and shock alone.

It has just been argued that a CS, located in both compartments, induces antagonistically-operating influences, or reinforcements, and thereby gives rise to inverted-U changes in shuttling with the heightening of stimulation.

Analogously, a weak light CS in the occupied compartment, together with darkness in the to-be-entered compartment, probably manipulates the incremental influence (by requiring subjects to run from light) as well as the decremental influence (by requiring subjects to run towards a stimulus which is not clearly distinguishable from light); in Chapter 3, this CS was associated with quadratic trends in shuttle-avoidance as a function of the intensity of white noise or of shock. In accord with activation theory, the following prediction was made: *viz.* an augmentation in activation would be evidenced by a decreasing monotonic trend in shuttleavoidance as a function of the intensity of white noise plus shock.

However, if it is assumed that variations in activation vary antagonistic influences, then an alternative prediction is possible: *viz.* an augmentation in activation facilitates the incremental influence and hence improves shuttling, but simultaneously facilitates the decremental influence, producing impairments in shuttling. These opposite effects of the incremental influence and of the decremental influence may cancel out.

Consequently, the failure of white noise and shock together to alter shuttleavoidance substantially, compared to the mean of white noise alone and shock alone, may not necessarily falsify activation theory.

The present chapter is designed to isolate the effects of the incremental influence and of the decremental influence and, then, to re-examine shuttling in the presence of combined UCSs and of separate UCSs. On the basis of the foregoing interpretation of the findings of Chapter 3, two hypotheses were considered:

(i) that white noise plus shock yield better shuttling than shock with the maximization of the incremental influence by locating the CS in the occupied compartment, and,

(ii) that white noise plus shock yield poorer shuttling than shock with the optimization of the decremental influence through the presentation of the CS in the to-be-entered compartment.

9.1.1 METHOD

9.1.1.1 SUBJECTS

<u>Ss</u> were 28 naive male albino rats obtained from the John Curtin School of Medical Research, Canberra, Australia. They were between 80 and 90 days old at the beginning of the experiment and were

maintained on ad lib. food and water.

While Ss came from the same Wistar strain as all other rats used in the present thesis, these Ss had not been handled by their distributors, unlike all other rats. Consequently, modifications were made to the usual pre-test trials. In addition, the intensity of shock chosen for the test trials was intended to reduce the incidence of freezing in the apparatus.

9.1.1.2 APPARATUS

The apparatus was the shuttlebox described in Chapter 7, with one exception. Scrambled electric shock was delivered by a Grason-Staedler 700 Constant Current Stimulator.

9.1.1.3 PROCEDURE

Ss were randomly assigned to four groups. Two groups were run in darkness with light in the occupied compartment serving as CS. These groups received either 115 dB plus .6 ma or .6 ma as UCS. Another two groups were run in darkness with light in the to-be-entered compartment serving as CS. These groups received either 115 dB plus .6 ma or .6 ma as UCS. Since there was limited time available to conduct the experiment, the usual counter-balancing of visual cues, so that half of the Ss were run in light with a dark CS, did not occur.

On the first day, 30 pre-test trials, with an average inter-trial interval of 20 seconds (exact times were 10, 15, 20, 25 and 30 seconds in random order), were given. On each trial, the door was opened, the light CS was presented in both compartments for 11.5 seconds and, finally, the door was lowered.

On the next day, 100 test trials, with a CS-UCS interval of five seconds and an average inter-trial interval of 20 seconds (exact times were 10, 15, 20, 25 and 30 seconds in random order), were given.

Ss were run in batches of 12 every two days, with three Ss being from each group. The order of running Ss within each batch was randomized. During the course of the experiment, data from two Ss were discarded due to experimenter error. Whenever this occurred, an extra S was run in the next batch.

9.1.2 RESULTS

Means and standard deviations of the percentage of avoidance responses and of the latency of these responses are presented in Table 9.1. When the light CS was located in the occupied compartment, the 115 dB plus .6 ma group made fewer responses than the .6 ma group, but the difference between these groups was not reliable (t_{12} 1.4, $p > .1$); also, the 115 dB plus .6 ma group showed the same latencies as the .6 ma group ($t_{12} < 1$). When the light CS was located in the to-be-entered compartment, the 115 dB plus .6 ma group made the same number of responses ($t_{12} < 1$), and showed the same latencies ($t_{12} < 1$), as the .6 ma group.

Figure 9.11 and Figure 9.12 describe mean percent avoidance and mean latency, respectively, in all groups.

TABLE 9.1

Means and standard deviations of percent avoidance and of latency in groups with a visual CS in the occupied compartment and with either white noise plus shock or shock as UCS and in groups with a visual CS in the to-be-entered compartment and with either white noise plus shock or shock as UCS (N = 7 per group).

		Light CS in occupied compartment		Light CS in to-be-entered compartment	
		.6 ma	115 dB plus .6 ma	.6 ma	115 dB plus .6 ma
1. Percent avoidance	Means	46.10	27.86	20.14	16.29
	Standard deviations	16.23	30.80	18.60	9.14
2. Latency	Means	3.24	3.53	3.40	3.63
	Standard deviations	0.50	1.06	1.02	1.28

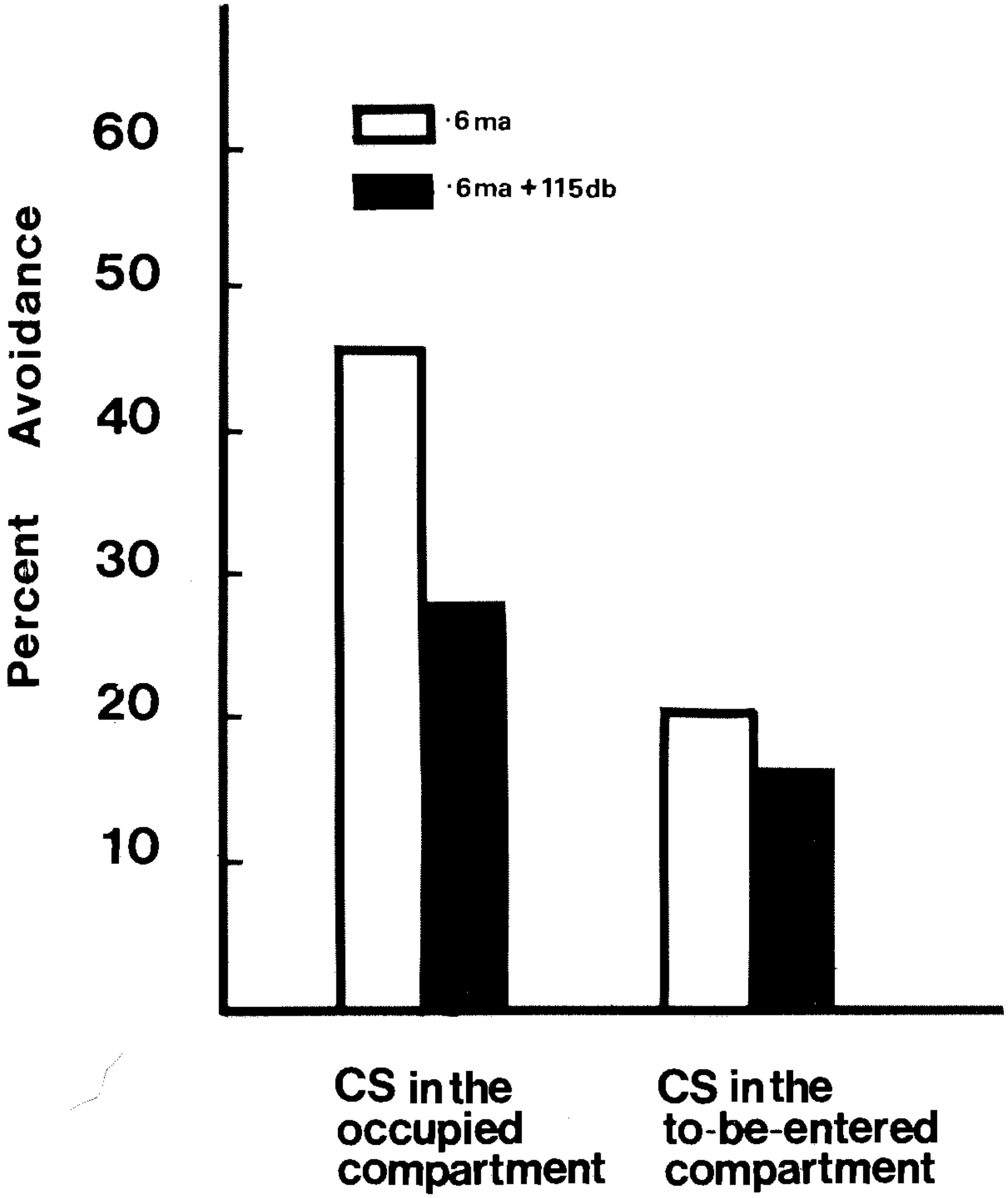

Figure 9.11 Mean percent avoidance with different CS locations and either shock or shock + white noise UCSs (N = 7 per data point).

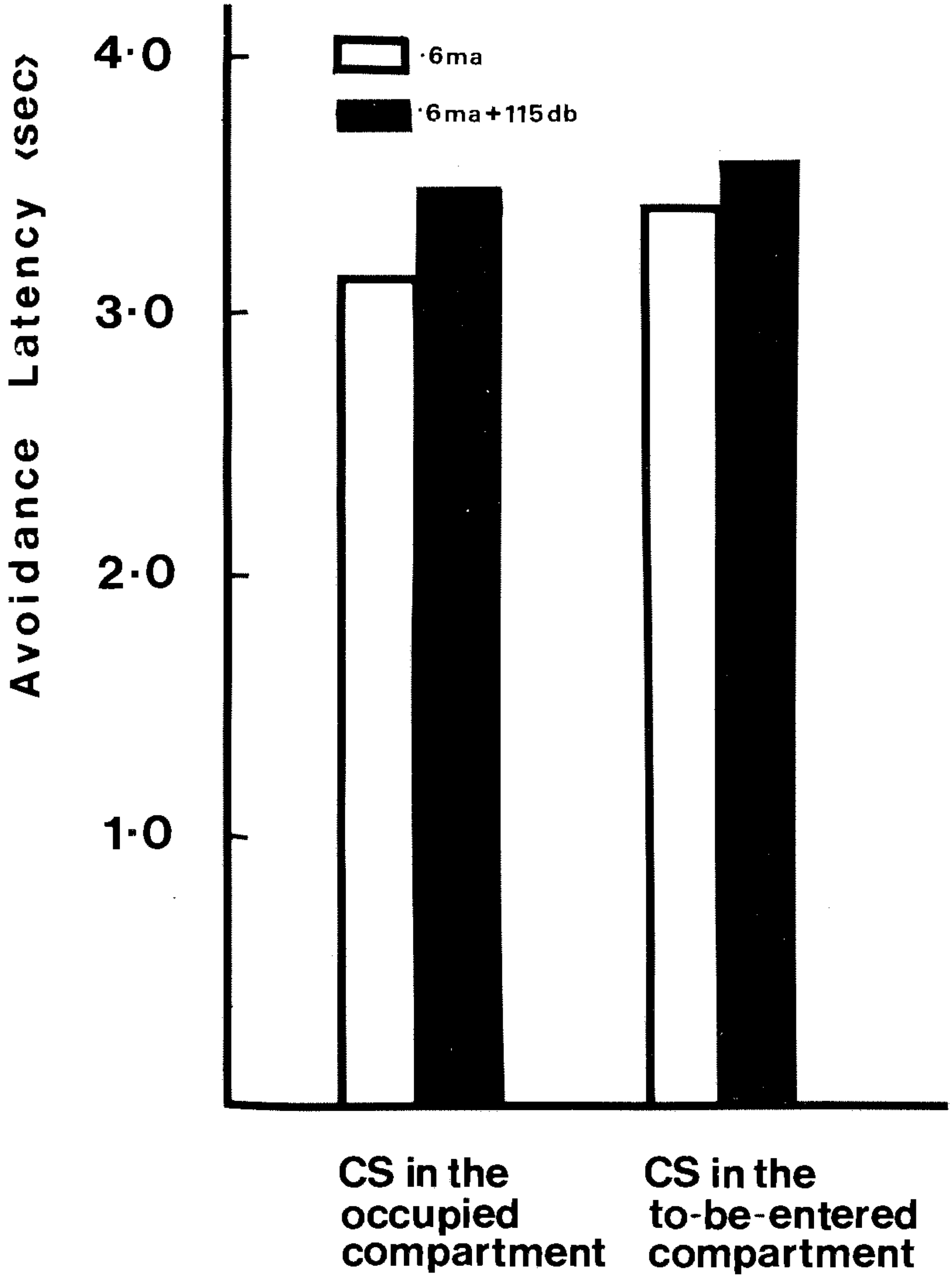

Figure 9.12 Mean latency with different CS locations and either shock or shock + white noise UCSs (N = 7 per data point).

9.1.3 DISCUSSION

White noise and shock were expected to induce greater levels of activation than shock and, accordingly,

(i) to facilitate shuttleavoidance where the incremental influence was maximized by locating the CS in the occupied compartment, and,

(ii) to suppress shuttleavoidance where the decremental influence was optimized through the presentation of the CS in the to-be-entered compartment. These expectations were not confirmed.

Instead, combining UCSs had the effect of impairing shuttling, particularly in the case of one measure, *viz.* percent avoidance. This impairment, which was pronounced and marginal, respectively, with the CS in the occupied compartment and with the CS in the to-be-entered compartment, did not achieve significance. Nevertheless, a similar result was noted in previous experiments. In Chapter 3, combinations of UCSs regularly depressed percent avoidance.

The consistency of the data on percent avoidance does not seem to accord with post-hoc rationalizations.

Potentially, different UCSs could create differences in percent avoidance by affecting two variables, *viz.* the efficiency of escape or, in terms of the ideas of the previous chapter about the source of incremental-decremental influences, the aversiveness of the CS. On the one hand, white nose, which elicits a startle response (Bolles and Warren, 1966), may combine with shock to enhance escape. However, the efficiency of escape is unrelated to the number of avoidance responses (Moyer and Korn, 1966; Theios, *et al.*, 1966). On the other hand, white noise may combine with shock to increase the aversiveness of, say, a CS presented in the occupied compartment. In consequence, subjects might be more likely to run from the occupied compartment and, thereby, to make a greater number of avoidance responses.

In the experiments of the present chapter and of the third chapter, however, combining UCSs did not increase percent avoidance, but had the opposite effect. Accordingly, it might be suggested that one UCS "inhibits" or "masks" or "over-shadows" another UCS (e.g. Mackintosh, 1974). Without a delineation of the inhibition mechanism, this suggestion is descriptive, rather than explanatory, and, furthermore, is difficult to reconcile with the work of Chapter 4, where two stimuli combined to heighten, not to lessen, skin conductance.

In short, the consistency of the data on percent avoidance does not accord with, apparently, reasonable post-hoc rationalizations which are not purely descriptive. Consequently, without the benefit of the wisdom provided by further experimentation, this consistency is assumed to be a chance, albeit an unlikely, event.

Contrary to the postulates of activation theory, then, the augmentation of activation *per se* is not associated with the inverted-U changes in shuttleavoidance predictable from incremental and decremental influences. Thus, the manipulation of combining white noise and shock increased the amplitude of one measure of activation, i.e. skin conductance (Chapter 4); this manipulation did not vary shuttling where the incremental and the decremental influence were constant and were operating together (Chapter 3) and did not vary shuttling where the incremental and the decremental influence were constant and were operating alone (the present chapter).

9.2 SUMMARY

On the basis of the conclusions about inverted-U curves in the previous chapter, it was argued that white noise and shock may have combined to increase the level of activation in the experiments of Chapter 3; however, increases in activation may have altered antangonistically-operating influences in opposite directions and, thereby, appeared to have no effect on shuttleavoidance. Contrary to this argument, white noise plus shock did not improve shuttling, compared to shock alone, where the incremental influence had been maximized; and, white noise plus shock did not impair shuttling, compared to shock alone, where the decremental influence had been maximized.

CHAPTER 10

CONCLUSION

As Berlyne (1967) notes, the concept of activation has had a widespread impact on the psychology of motivation, which many people, like Hebb (1955), regard as the study of the causes of behaviour. Hence, it seems appropriate to consider the findings of the present thesis within the framework of how activation theory can contribute to the explanation of behaviour.

10.1 ASSUMPTIONS OF ACTIVATION THEORY

According to activation theory, there is a continuum of activation, i.e. greater and lesser degrees of neural activity extending from the ascending reticular activating system to the cortex, to the spinal cord and to the periphery, e.g. the autonomic nervous system. With increasingly greater degrees of neural activity, there are inverted -U changes, i.e. sequences of improvements and impairments, in behaviour.

10.1.1 INCREASES IN PHYSIOLOGICAL MEASURES

At the physiological level, the present thesis tested activation theory using the paradigm of the interactions between "drives" (Bolles, 1967), or "stresses" (Wilkinson, 1969). In particular, it was expected that two stimuli together have more activating effects than either stimulus alone.

Consistent with this expectation, it was found that a loud burst of white noise and a moderate intensity of shock elicited greater increases in skin conductance than a weak burst of white noise and the moderate intensity of shock.

Similarly, in a study by Patton (1970), stresses combined to heighten autonomic activity in humans, until an asymptotic level of activity was reached. Again, using neural measures, rather than surface measures of the nervous system, Wayner (1974) demonstrated a correlation between sensory input to the brain stem motor control system and the rate of spinal reflex discharges.

10.1.2 INVERTED-U CHANGES IN BEHAVIOURAL MEASURES

At the behavioural level, the present thesis examined two explanations of inverted-U changes in the efficiency of a response with the heightening of stimulation:

(i) the hypothesis of activation theory that these changes result from over-activation, and,

(ii) the hypothesis that these changes result from the development of competing, or interfering, responses.

The first explanation was assessed using the paradigm of the interaction between "drives" (Bolles, 1967), or "stresses" (Wilkinson, 1969). In particular, it was expected that two stimuli together have more activating effects than either stimulus alone. For example, if white noise and shock separately give rise to inverted-U trends in shuttleavoidance, then they should combine to intensify activation, producing a decreasing monotonic trend.

Contrary to this expectation, there proved to be an inverted-U function with either white noise or shock, but not a decreasing monotonic function with white noise plus shock.

The second hypothesis was evaluated in terms of the following rationale. It was argued that competing responses do not develop when subjects are allowed to approach shock-unrelated cues and, conversely, that competing responses develop when subjects are required to approach shock-related cues. The supposed consequences of these responses, i.e. inverted-U trends in shuttleavoidance, should eventuate in the latter case, but not in the former case.

Shuttling from a shock-related cue, i.e. the CS, seemed to represent a facilitatory, incremental influence, with some species-specific differences between a light CS and a dark CS; and, shuttling towards a shock-related cue, i.e. the CS, seemed to represent an interfering, decremental influence.

In general, the sequence of improvement-impairment in shuttle-avoidance as a function of the intensity of stimulation was explicable by the operation of these influences which, in the same situation, combined to produce inverted-U functions and which, in separate situations, added to predict inverted-U functions.

10.1.3 RELATIONS BETWEEN PHYSIOLOGICAL MEASURES AND BEHAVIOURAL MEASURES

In the present studies, the continuum of activation *per se* was not related to the incremental-decremental influences which appeared to have inverted-U effects on shuttleavoidance. Specifically, in Chapter 4, the manipulation of combining white noise and shock increased one physiological index of activation, i.e. skin conductance. However, this manipulation did not alter shuttleavoidance in situations where the incremental and decremental influences operated either concurrently or independently.

Thus, in the experiments of Chapter 3, a weak light in the occupied compartment served as CS, together with darkness in the to-be-entered compartment, and so subjects were required to run from light and to run towards darkness, which was not clearly distinguishable from light. In other words, incremental and decremental influences were likely to have occurred concurrently. Under these conditions, either white noise or shock and white noise plus shock were all associated with the same, inverted-U trends in shuttling.

Again, in the experiment of Chapter 9, incremental and decremental influences were introduced independently. In the presence of each of these influences, white noise plus shock and shock were both associated with the same levels, statistically, of shuttling.

10.2 THE CONTINUUM OF ACTIVATION AND BEHAVIOUR

In the present studies, a continuum of activation may describe the functioning of the autonomic nervous systems of rats. However, this description does not allow predictions about responses in shuttleboxes.

Similarly, in Wayner's (1974) studies, a continuum of activation described the functioning of the brain stem motor control system of cats and rats. However, Wayner could not use this information to predict the form of stereotyping of "schedule-induced" responses in certain types of situations, i.e. those with intermittent presentations of food following bar-pressing and unlimited access to water.

It is not clear, then, how shuttling and schedule-induced responding, in particular, relate to the level of activation. Indeed, even the original activation theorists became increasingly vague in their statements on the manner in which behaviour, in general, relates

to the level of activation. Within this context, for example, Duffy (1972, p. 601) asserted:
"Whatever the findings, they are not crucial to activation theory, which does not demand the hypothesis of the (inverted-) U shaped curve".

10.3 THE CONTINUUM OF ACTIVATION AND THEORIES OF BEHAVIOUR

From a theoretical standpoint, it seems relevant to pose the following question. If, contrary to the present evidence, the continuum of activation were able to predict behaviour, what would the concept of "activation" add to that of "stimulation" in making predictions?

The continuum of activation is typically regarded as a physiological "intervening variable, produced by certain factors and resulting in certain effects upon various aspects of response" (Duffy, 1972, p. 579). However, there has been a continuing debate on the place of intervening variables, otherwise called "inner states", in the specification of the necessary and sufficient conditions of behaviour. For example, Skinner (1953) said:
"The objection to inner states is not that they do not exist, but that they are not relevant in a functional analysis. We cannot account for the behaviour of any system while staying wholly inside it; eventually we must turn to forces operating upon the organism from without. Unless there is a weak spot in our causal chain so that the second link is not lawfully determined by the first, or the third by the second, then the first and third links must be lawfully related. If we must always go back beyond the second link for prediction and control, we may avoid tiresome and exhausting digressions by examining the third link as a function of the first (p. 35)".

Within Skinner's framework, the concept of activation is a tiresome and exhausting digression. In the present experiments, for example, forces operating "from without", such as the intensity of shock, may manipulate the level of activation and, together with another variable, *viz.* the location of the CS, predict the efficiency of shuttleavoidance. Whether or not the intensity of shock manipulates the level of activation is quite irrelevant to predicting the efficiency of shuttleavoidance.

10.4 CONCLUSION

In the present work, the continuum of activation *per se* is not sufficient to predict the effects of the incremental and decremental influences which are, apparently, responsible for inverted-U changes in one response. Conceptually, this continuum cannot be necessary to generate predictions about changes in any response.

It would seem that an explanation, i.e. a delineation of the sufficient and necessary antecedents, of behaviour is capable of proceeding quite adequately without references to "activation", "arousal", "energy mobilization" or "excitation".

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APPENDIX 1

EXPERIMENTS OF CHAPTER 3

SECTION 1.1 BITONICITY IN THE FUNCTIONS OF WHITE NOISE, OF SHOCK AND OF WHITE NOISE PLUS SHOCK IN THE EXPERIMENTS OF CHAPTER 3

1.1.1 BITONICITY

It has been pointed out(1) that a significant quadratic trend in shuttleavoidance as a function of the level of stimulation does not necessarily imply a significant inverted-U trend in shuttleavoidance as a function of the level of stimulation.

Accordingly, the functions of white noise, of shock and of white noise plus shock were analysed for bitonicity, or bitonic trend, using Ferguson's (1965) non-parametric analysis of trend which is fully described in Appendix 2. Significant bitonicity in this analysis indicates a significant two-branched, or inverted-U, trend.

The results of Ferguson's analysis are presented below.

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(1) I wish to thank Dr. Michael Cook for this observation.

1.1.2 BITONICITY IN THE FUNCTIONS OF WHITE NOISE, OF SHOCK AND OF WHITE NOISE PLUS SHOCK

A. White Noise Function.

Percent avoidance $\underline{S} = -230$ $\sigma_s = 111.3$ $z = -2.1$ ($p < .05$)

Latency $\underline{S} = 150$ $\sigma_s = 110.7$ $z = 1.4$

B. Shock Function.

Percent avoidance $\underline{S} = -248$ $\sigma_s = 111.2$ $z = -2.2$ ($p < .05$)

Latency $\underline{S} = 436$ $\sigma_s = 111.1$ $z = 3.9$ ($p < .01$)

C. White Noise Plus Shock Function.

Percent avoidance $\underline{S} = -718$ $\sigma_s = 313.0$ $z = -2.3$ ($p < .05$)

Latency $\underline{S} = 814$ $\sigma_s = 313.0$ $z = 2.6$ ($p < .01$)

SECTION 1.2 COMPARISONS OF THE FUNCTIONS OF WHITE NOISE AND OF SHOCK WITH THE FUNCTION OF WHITE NOISE PLUS SHOCK

1.2.1 LINEAR AND QUADRATIC WEIGHTS

Linear and quadratic weights were derived from the sum of orthogonal polynomial weightings of the five means of each function. Linear weightings were -2 -1 0 1 2 and quadratic weightings were 2 -1 -2 -1 2.

	Linear weights	Quadratic weights
White noise function (N = 10 per mean)	$\hat{\beta}_{WN} = 11.0$	$\hat{\gamma}_{WN} = -52.5$
Shock function (N = 10 per mean)	$\hat{\beta}_{S} = 59.6$	$\hat{\gamma}_{S} = -63.6$
White noise plus shock function (N = 20 per mean)	$\hat{\beta}_{WN+S} = -4.1$	$\hat{\gamma}_{WN+S} = -50.0$

1.2.2 SUM OF SQUARES FOR THE LINEAR-QUADRATIC COMPARISON:

$$\left(\hat{\beta}_{WN} + \hat{\beta}_{S} - \hat{\beta}_{WN+S}\right) + \left(\hat{\gamma}_{WN} + \hat{\gamma}_{S} - \hat{\gamma}_{WN+S}\right) = 0$$

Linear component $L_1 = \hat{\beta}_{WN} + \hat{\beta}_{S} - \hat{\beta}_{WN+S} = [11.0 + 59.6 - (-4.1)]^2$

$= 74.7^2$

$= 5580.1$

Quadratic component $L_2 = \hat{\gamma}_{WN} + \hat{\gamma}_{S} - \hat{\gamma}_{WN+S} = [-52.5 - 63.6 - (-50.0)]^2$

$= 66.1^2$

$= 4369.2$

1.2.3 σ^2 (L_1) and σ^2 (L_2)

$$\sigma^2 (L_1) = \sigma^2 (\beta_{WN}) + \sigma^2 (\beta_S) + \sigma^2 (\beta_{WN+S})$$

$$\hat{\sigma}^2 (L_1) = \text{Mean square error } (L_1) \times \frac{\Sigma c^2_j}{n_j} \quad \text{(Hays, 1963)}$$

Since a pooled estimate of error was computed across all 15 groups in the white noise function, in the shock function and in the white noise plus shock function, then

$$\hat{\sigma}^2 (L_1) = \text{Mean square error} \times \left(\frac{\Sigma c^2_{WN}}{n_{WN}} + \frac{\Sigma c^2_s}{n_S} + \frac{\Sigma c^2_{WN+S}}{n_{WN+S}}\right)$$

$$= \text{Mean square error} \times \left(\frac{10}{10} + \frac{10}{10} + \frac{10}{20}\right)$$

$$= \text{Mean square error} \times \left(\frac{50}{20}\right)$$

$$\sigma^2 (L_2) = \sigma^2 (\gamma_{WN}) + \sigma^2 (\gamma_S) + \sigma^2 (\gamma_{WN+S})$$

$$\hat{\sigma}^2 (L_2) = \text{Mean square error } (L_2) \times \frac{\Sigma c^2_j}{n_j} \quad \text{(Hays, 1963)}$$

Again, since a pooled estimate of error was computed across all 15 groups in the white noise function, in the shock function and in the white noise plus shock function, then

$$\hat{\sigma}^2 (L_2) = \text{Mean square error} \times \left(\frac{\Sigma c^2_{WN}}{n_{WN}} + \frac{\Sigma c^2_S}{n_S} + \frac{\Sigma c^2_{WN+S}}{n_{WN+S}}\right)$$

$$= \text{Mean square error} \times \left(\frac{14}{10} + \frac{14}{10} + \frac{14}{20}\right)$$

$$= \text{Mean square error} \times \left(\frac{70}{20}\right)$$

1.2.4 F RATIO FOR THE LINEAR-QUADRATIC COMPARISON:

$$(\beta_{WN} + \beta_S - \beta_{WN+S}) + (\gamma_{WN} + \gamma_S - \gamma_{WN+S}) = 0 \text{ (Snedecor and Cochran, 1967)}$$

$$F_{2,188} = \text{Mean square } \left(\frac{L_1}{\sigma^2\ (L_1)} + \frac{L_2}{\sigma^2\ (L_2)}\right)$$

$$= \text{Mean square } \left(\frac{L_1}{[\text{Mean square error} \times \frac{50}{20}]} + \frac{L_2}{[\text{Mean square error} \times \frac{70}{20}]}\right)$$

$$= \frac{\text{Mean square}}{\text{Mean square error}} \left(L_1 \times \frac{20}{50} + L_2 \times \frac{20}{70}\right)$$

$$= \frac{\text{Mean square}}{\text{Mean square error}} \left(5580.1 \times \frac{20}{50} + 4369.2 \times \frac{20}{70}\right)$$

$$= \frac{\text{Mean square (3480.3)} *}{\text{Mean square (101403.3)}}$$

$$= \frac{1740.2}{539.4}$$

$$= 3.2 \ (p < .05)$$

---

* It should be noted that the sum of squares reported in Chapter 3 (i.e. 3464.0) was computed in a slightly different way, using an estimation of the linear and quadratic coefficients of each function. These coefficients are the linear and quadratic weights of each function divided by the appropriate sum of squared weights.

APPENDIX 2

EXPERIMENTS OF CHAPTER 7

SECTION 2.1 MEANS AND STANDARD DEVIATIONS OF THE LATENCY OF AVOIDANCE RESPONSES IN THE EXPERIMENTS OF CHAPTER 7

2.1.1 LATENCY IN TONE CS GROUPS, IN VISUAL CS GROUPS AND IN TONE PLUS VISUAL CSs GROUPS: THE VISUAL CS IN THE OCCUPIED COMPARTMENT

Combined light and dark conditions (N = 14 per group).

		.1 ma	.4 ma	1.3 ma	3.0 ma
TONE CS	Means	2.8	2.8	3.2	3.2
	Standard deviations	.4	.4	.8	.6
VISUAL CS	Means	2.9	2.8	3.0	2.6
	Standard deviations	.6	.5	1.0	.9
TONE PLUS VISUAL CSs	Means	2.9	2.8	3.0	2.3
	Standard deviations	.7	.5	.6	.7

Separate light and dark conditions (N = 7 per group).

LIGHT

		.1 ma	.4 ma	1.3 ma	3.0 ma
TONE CS IN TWO LIGHTED COMPARTMENTS	Means	2.8	3.1	3.1	3.3
	Standard deviations	.5	.2	.9	.5
LIGHT CS	Means	2.7	2.7	3.0	2.2
	Standard deviations	.7	.4	1.2	.7
TONE PLUS LIGHT CSs	Means	2.8	2.7	2.9	2.1
	Standard deviations	.9	.7	.8	.6

DARK

		.1 ma	.4 ma	1.3 ma	3.0 ma
TONE CS IN TWO DARKENED COMPARTMENTS	Means	2.8	2.6	3.3	3.1
	Standard deviations	.3	.4	.6	.7
DARK CS	Means	3.2	2.8	3.1	3.1
	Standard deviations	.5	.6	1.0	1.0
TONE PLUS DARK CSs	Means	3.0	2.9	3.0	2.6
	Standard deviations	.5	.4	.4	.7

2.1.1.1 A FURTHER CONSIDERATION OF THE SHOCK INTENSITY OF .1 ma

A. Latency of responses within five seconds of cue onset in tone cue groups, in visual cue groups and in tone plus visual cues groups. Separate light and dark conditions (N = 5 per group).

LIGHT

	Tone cue in two lighted compartments	Light cue	Tone plus Light cues
Means	3.5	3.3	2.6
Standard deviations	1.1	1.0	.4

DARK

	Tone cue in two darkened compartments	Dark cue	Tone plus Dark cues
Means	3.4	3.3	3.0
Standard deviations	.9	.8	1.3

B. Latency of avoidance responses in the replication study: dark CS group and tone plus dark CSs group at .1 ma (N = 10 per group).

	Dark CS	Tone plus Dark CSs
Means	3.0	2.6
Standard deviations	.9	1.1

2.1.1.2 A FURTHER CONSIDERATION OF THE SHOCK INTENSITY OF 3.0 ma.

Latency of avoidance responses in the replication study: dark CS group and tone plus dark CSs groups at 3.0 ma (N = 10 per group).

	Dark CS	Tone plus Dark CSs
Means	2.7	2.5
Standard deviations	.4	.3

2.1.2 LATENCY OF AVOIDANCE RESPONSES IN VISUAL GROUPS AND IN TONE PLUS VISUAL GROUPS: THE VISUAL CS IN BOTH COMPARTMENTS

Separate light and dark conditions (N = 7 per group).

LIGHT

		.1 ma	.4 ma	1.3 ma	3.0 ma
LIGHT CS	Means	3.0	2.7	2.7	2.6
	Standard deviations	.5	.6	.5	.8
TONE PLUS LIGHT CSs	Means	2.6	2.6	2.8	3.2
	Standard deviations	.4	.6	.7	.9

DARK

		.1 ma	.4 ma	1.3 ma	3.0 ma
DARK CS	Means	3.4	3.2	2.7	3.0
	Standard deviations	.5	.6	.7	.5
TONE PLUS DARK CSs	Means	3.1	2.9	2.8	3.6
	Standard deviations	.3	.5	.5	.3

2.1.3 LATENCY OF AVOIDANCE RESPONSES IN VISUAL CS GROUPS AND IN TONE PLUS VISUAL CSs GROUPS: THE VISUAL CS IN THE TO-BE-ENTERED COMPARTMENT

Separate light and dark conditions (N = 7 per group).

LIGHT

		.1 ma	.4 ma	1.3 ma	3.0 ma
LIGHT CS	Means	3.1	3.1	3.3	3.1
	Standard deviations	.6	1.0	1.1	1.1
TONE PLUS LIGHT CSs	Means	3.0	2.3	2.3	3.4
	Standard deviations	.5	.4	.7	1.0

DARK

		.1 ma	.4 ma	1.3 ma	3.0 ma
DARK CS	Means	3.0	3.0	2.7	3.0
	Standard deviations	.9	.5	.6	.8
TONE PLUS DARK CSs	Means	3.0	2.7	2.3	2.9
	Standard deviations	.6	.2	.4	.3

SECTION 2.2 FERGUSON'S NON-PARAMETRIC ANALYSIS OF TREND OF PERCENT AVOIDANCE IN THE EXPERIMENTS OF CHAPTER 7.

2.2.1 FERGUSON'S NON-PARAMETRIC ANALYSIS OF TREND(1)

Ferguson's (1965) non-parametric trend analysis provides a test of relationships between two variables X and Y. It is non-parametric in the sense that it is applied when one (or both) of the variables is (are) ordinal. It is capable of distinguishing between monotonic (one branch), bitonic (two branch), tritonic (three branch) - *etcetera* - functions, but gives no information about the specific forms of the functions.

The analysis is based on ranks and employs the sampling distribution of the statistic S, as used in the definition of Kendall's coefficient of rank correlation, tau (Kendall, 1948).

S describes disarray in a set of ranks paired on X, Y. To compute this statistic the values of the X variable are ranked from lowest to highest as are the values of the Y variable. Each pair of ranks is then compared with every other pair. For each comparison of pairs of ranks a weight of +1, -1, or 0 is assigned according to the following rule:

+1 if the order of the X ranks is the same as that of the corresponding Y ranks.

-1 if the order of the X ranks is opposite to that of the corresponding Y ranks.

0 if the X ranks and/or the corresponding Y ranks are equal.

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(1) I am deeply grateful to J.A. Slee for her kind permission to use this summary of Ferguson's analysis, which appeared in her doctoral thesis "The perceptual nature of visual imagery", Australian National University, 1976.

according to their natural order, but the values of the independent variable, X, are ranked according to their orthogonal polynomial weights for the number of different levels of X, and the desired trend. For monotonic trend these ranks for X in fact follow natural order, but for other trends they do not. For example, take the following values of Y. These have been sorted into three samples corresponding to increasing levels of X. (This example is taken from Ferguson, 1965.)

Sample I:	3	7	11	16	22	29	31	36	
Sample II:	3	4	7	18	19	32			
Sample III:	22	38	46	47	47	50	53	54	56

To test for monotonic trend we first consult the tables of orthogonal polynomials (Fisher and Yates, 1963, pp. 98-108), and discover that, for three levels of an independent variable and a test for a single branch function, the polynomial weights are -1, 0, +1. These are ranked 1, 2, 3. Thus, the data can be represented by a set of paired ranks, as follows:

Sample I:	X:	1	1	1	1	1	1	1	1	
	Y:	1.5	4.5	6	7	10.5	12	13	15	
Sample II:	X:	2	2	2	2	2	2			
	Y:	1.5	3	4.5	8	9	14			
Sample III:	X:	3	3	3	3	3	3	3	3	3
	Y:	10.5	16	17	18.5	18.5	20	21	22	23

Here the X ranks are ordered with respect to other X ranks; only comparisons of pairs of Y ranks are necessary. As the X ranks are in natural order, a weight of +1 is assigned if a pair of Y ranks is in natural order, a weight of -1 is assigned if a pair of Y ranks is in inverse order, and a weight of 0 is assigned if the ranks of a pair are

For example, for a comparison of the paired ranks X:3, Y:20 and X:7, Y:25, the weight assigned is +1; for a comparison of the paired ranks X:7 Y:20 and X:3, Y:25, or a comparison of the paired ranks X:3,Y:25 and X:7, Y:20, the weight is -1; and for a comparison of the paired ranks X:3, Y:25 and X:3, Y:25, or of the paired ranks X:3, :20 and X:3, Y:25, or of the paired ranks X:3, Y:20 and X:7, Y:20, the weight is 0. S is the sum of the weights over all comparisons of X, Y pairs.

Commonly (particularly where X is an experimentally manipulated variable) there are many ties on X and the data may be regarded as a set of samples of Y which are ordered in relation to X. Under these circumstances, there are tabular procedures for calculating S (see Ferguson, 1965).

The significance of the relation between X and Y can be calculated by referring S (or the corresponding tau) to special tables for $N < 10$, where N refers to the number of paired ranks (Kendall, 1948).

However, for $N \geq 10$, the sampling distribution of S (or tau) approximates the normal distribution (Kendall, 1948, pp. 38-39), and in these cases the significance of S can be tested by referring the ratio $z = S/\sigma_s$ to standard tables of the normal distribution (with a correction of S for continuity). The expressions for computing the standard error of S (with, and without ties on the ranks of the two variables) are given by Ferguson (1965, p. 11, p. 13).

Where samples of Y for different levels of X are independent (i.e. based on different subjects), as in the present research, Ferguson's trend analysis proceeds as described above, with one difference. The values of the dependent variable Y are ranked as before equal. The value of $\underline{S}$ is:

$$\underline{S} = 14 + 10 + 9 + 9 + 4 + 3 + 3 + 1 + 9 + 9 + 9 + 9 + 9 + 7 = 105$$

The value of 14 is obtained by comparing the first Y rank for Sample I, 1.5, with all Y ranks for Samples II and III. The rank 1.5 in Sample I is not compared with other Y ranks for that sample, because all such values in Sample I are tied on X (and so comparisons of them are assigned a weight of 0 - see above). The value of 10 is obtained by comparing the second Y rank for Sample I with all Y ranks for Samples II and III - and so on, until the final value of 7 is obtained by comparing the last Y rank in Sample II with each Y rank in Sample III.

To test for bitonic trend in the same data, we again consult the Fisher and Yates tables for orthogonal polynomials. For three levels of an independent variable, and a test for a two branch function, the values of the polynomial are 1, -2, 1, which are ranked 2.5, 1, 2.5. Again the values of the dependent variable are ranked according to their natural order. The data for bitonic trend are represented as follows:

Sample I:	X:	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	
	Y:	1.5	4.5	6	7	10.5	12	13	15	
Sample II:	X:	1	1	1	1	1	1			
	Y:	1.5	3	4.5	8	9	14			
Sample III:	X:	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
	Y:	10.5	16	17	18.5	18.5	20	21	22	23

Here the X ranks for Samples I and II are in inverse order, so a weight of -1 is assigned to a pair of Sample I and Sample II Y ranks which are in natural order, a value of +1 is assigned if the Y pair from these samples is also in inverse order, and a weight of 0 if the two Y ranks are equal. However, the X ranks for Samples II and III are in natural order, so weights for comparisons of Y ranks for Sample II with Y ranks for Sample III are assigned as for monotonic trend. The value of the S for bitonic trend is:

$$\underline{S} = -5 - 1 + 0 + 0 + 4 + 4 + 4 + 6 + 9 + 9 + 9 + 9 + 9 + 7$$
$$= 64$$

The value of -5 is obtained by comparing the first Y rank of 1.5 for Sample I with each Y rank for Sample II, and assigning weights as described above. No comparison of pairs is necessary for Samples I and III, because these samples are tied on X. The value of -1 in the equation is obtained by comparing the second Y rank for Sample I, with each Y rank for Sample II, and so on, until the final value of 7 is obtained by comparing the last Y rank for Sample II with each Y rank for Sample III.

For $N \geq 10$, the standard error of S is computed (Ferguson, 1965, p. 11, p. 13). The value of this error term depends on the number of ties on each variable, and so will differ between tests for monotonic and bitonic trend; there are more ties on the X variable in the test for the latter trend than in the test for the former. S is corrected for continuity and z obtained by dividing the corrected S by the standard error.

For complete details, see Ferguson.

2.2.2 PERCENT AVOIDANCE IN THE EXPERIMENTS OF CHAPTER 7

2.2.2.1 ONE- AND TWO-CS FUNCTIONS WITH A VISUAL CS IN BOTH COMPARTMENTS

In the experiment of Section 7.2.2 in Chapter 7, there were four levels of X (i.e. .1 ma, .4 ma, 1.3 ma and 3.0 ma) and 28 observations on Y (i.e. percent avoidance). The results of the tests for trend on each of the CSs are presented below. Each $\underline{S}$ value has been corrected for continuity.

TESTS FOR RELATIONSHIPS BETWEEN SHOCK AND PERCENT AVOIDANCE WITH THE DARK CS

(a) Monotonic trend: $\underline{S} = 3$ $\sigma_s = 48.7$ $z = .1$

(b) Bitonic trend: $\underline{S} = -110$ $\sigma_s = 43.5$ $z = -2.5^{**}$ $(p < .01)$

TESTS FOR RELATIONSHIPS BETWEEN SHOCK AND PERCENT AVOIDANCE WITH THE LIGHT CS

(a) Monotonic trend: $\underline{S} = -24$ $\sigma_s = 48.8$ $z = -.5$

(b) Bitonic trend: $\underline{S} = -53$ $\sigma_s = 43.5$ $z = -1.2$

TESTS FOR RELATIONSHIPS BETWEEN SHOCK AND PERCENT AVOIDANCE WITH TONE PLUS DARK CSs

(a) Monotonic trend: $\underline{S} = -1$ $\sigma_s = 48.8$ $z = -.1$

(b) Bitonic trend: $\underline{S} = -119$ $\sigma_s = 43.5$ $z = -2.7^{**}$ $(p < .01)$

TESTS FOR RELATIONSHIPS BETWEEN SHOCK AND PERCENT AVOIDANCE WITH TONE PLUS LIGHT CSs

(a) Monotonic trend: $\underline{S} = -141$ $\sigma_s = 48.8$ $z = -2.9^{**}$ $(p < .01)$

(b) Bitonic trend: $\underline{S} = 20$ $\sigma_s = 43.4$ $z = .5$

** Probabilities are for two-tailed tests.

2.2.2.2 ONE- AND TWO-CS FUNCTIONS WITH A VISUAL CS IN THE TO BE-ENTERED COMPARTMENT

In the experiment of Section 7.3.2 in Chapter 7, there were four levels of X (i.e. .1 ma, .4 ma, 1.3 ma and 3.0 ma) and 28 observations on Y (i.e. percent avoidance). The results of the tests for trend on each of the CSs are presented below. Each S value has been corrected for continuity.

TESTS FOR RELATIONSHIPS BETWEEN SHOCK AND PERCENT AVOIDANCE WITH THE DARK CS

(a) Monotonic trend: $S = -23$ $\sigma_s = 48.8$ $z = -.5$

(b) Bitonic trend: $S = 53$ $\sigma_s = 43.4$ $z = 1.2$

TESTS FOR RELATIONSHIPS BETWEEN SHOCK AND PERCENT AVOIDANCE WITH THE LIGHT CS

(a) Monotonic trend: $S = -133$ $\sigma_s = 48.7$ $z = -2.7$** $(p < .01)$

(b) Bitonic trend: $S = -30$ $\sigma_s = 43.5$ $z = -.7$

TESTS FOR RELATIONSHIPS BETWEEN SHOCK AND PERCENT AVOIDANCE WITH TONE PLUS DARK CSs

(a) Monotonic trend: $S = 29$ $\sigma_s = 48.8$ $z = .6$

(b) Bitonic trend: $S = -88$ $\sigma_s = 43.5$ $z = -2.0$* $(p < .05)$

TESTS FOR RELATIONSHIPS BETWEEN SHOCK AND PERCENT AVOIDANCE WITH TONE PLUS LIGHT CSs

(a) Monotonic trend: $S = -66$ $\sigma_s = 48.8$ $z = -1.4$* $(p = .08)$

(b) Bitonic trend: $S = -49$ $\sigma_s = 43.4$ $z = -1.1$

** Probabilities are for two-tailed tests.

* Probabilities are for one-tailed tests. Since the preceding experiments of Chapter 7 generated the expectations of bitonic trends with tone plus dark CSs, and of monotonic trends with tone plus light CSs, it seemed appropriate to use one-tailed tests of bitonicity and monotonicity, respectively, in the functions of tone plus dark CSs and of tone plus light CSs.

2.2.2.3 ONE-CS FUNCTIONS: A VISUAL CS IN BOTH COMPARTMENTS

In Section 8.2.1 of Chapter 8, a visual CS in both compartments was assumed to eliminate the demarcation between an unsafe, shocked compartment and a safe, unshocked compartment. Accordingly, data of subjects run in these conditions, with the dark CS groups and light CS groups combined at each intensity of shock, were tested for trend. Thus, there were 4 levels of X (i.e. .1 ma, .4 ma, 1.3 ma and 3.0 ma) and 56 observations on Y (i.e. percent avoidance). Each S value has been corrected for continuity.

The parameters of the monotonic trend were $S = -38$, $\sigma_s = 136.6$ and $z = -.3$; and those of the bitonic trend were $\underline{S} = -304$, $\sigma_s = 122.0$ and $z = -2.5$ ($p < .01$ for a two-tailed test).

2.2.2.4 ONE-CS FUNCTIONS: A TONE CS

In Section 8.2.1 of Chapter 8, a tone CS was assumed to eliminate the demarcation between an unsafe, shocked compartment and a safe, unshocked compartment. Accordingly, data of subjects run in these conditions, in either two dark compartments or two lighted compartments, were tested for trend. Thus, there were four levels of X (i.e. .1 ma, .4 ma, 1.3 ma and 3.0 ma) and 56 observations on Y (i.e. percent avoidance). Each S value has been corrected for continuity.

The parameters of the monotonic trend were $\underline{S} = -156$, $\sigma_s = 136.6$ and $z = -1.1$; and those of the bitonic trend were $\underline{S} = -156$, $\sigma_s = 122.0$ and $z = -1.3$.