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SEPARATE-PHASE DIFFERENTIAL CLASSICAL APPETITIVE CONDITIONING OF THE RABBIT'S JAW-MOVEMENT RESPONSE: EFFECTS OF CUE SIMILARITY AND US MAGNITUDE

by

Constantine X. Poulos

A thesis submitted in partial fulfillment of the
requirements for the degree of Doctor of Philosophy
in the Department of Psychology
in the Graduate College of
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May, 1974

Thesis Supervisor: Professor I. Gormezano

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CERTIFICATE OF APPROVAL

PH.D. THESIS

This is to certify that the Ph.D. thesis of

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INTRODUCTION

The purpose of the present studies is to determine the effects of stimulus similarity (Experiment 1) and US magnitude (Experiment 2) on differential classical appetitive conditioning of the rabbit's jaw-movement response.

Pavlov (1927), in his investigations of the conditioned reflex, postulated that: (a) the antagonistic and cortically-based factors of excitation and inhibition result from acquisition and extinction manipulations, respectively; (b) acquisition or extinction trials with a specific CS result in excitatory or inhibitory impulses that "irradiate" or spread over the cortex with decreasing magnitude from the cortical locus of the CS to adjacent cortical points; and (c) there is an isomorphic correspondence between cortical tissue and the physical characteristics of stimuli. Pavlov identified excitatory irradiation (generalization) from the observation that following acquisition training, historically neutral stimuli elicited conditioned responding which was proportional to their physical similarity to the acquisition stimulus. Similarly, he identified inhibitory irradiation (generalization) from the observation that following repeated extinction trials to a specific CS, ordered response decrements occurred to previously employed CSs as a function of their physical similarity to the extinction CS.

In addition to Pavlov's operational specification of excitation-inhibition, and stimulus generalization, he posited a number of temporally labile factors such as positive and negative induction (i.e., the mutual intensification of excitation and inhibition under certain trial sequential conditions) and excitatory and inhibitory aftereffects (i.e., behaviorally diffuse inertia-like factors following reinforcement and nonreinforcement). Pavlov noted that the differential conditioning paradigm involves stimulus correlated acquisition and extinction procedures and presumed that excitatory and inhibitory tendencies and their irradiation (generalization) were factors operating to govern differentiation (p. 125). Yet, in his theoretical and experimental treatment of differential conditioning he assigned a central role to the temporal course of induction and aftereffects.

Contemporaneous American theorists (e.g., Guthrie, 1930, 1935; Hull, 1929, 1939), quickly incorporated a number of Pavlovian concepts (and terminology) while specifically rejecting Pavlov's cortical theory. The thrust of American theorizing was to select and systematize Pavlovian concepts congruent with a framework emphasizing such stable, response specific learning factors as excitatory-inhibitory response tendencies and stimulus generalization. Within this framework, Spence (1936, 1937) subsequently crystalized and elaborated an S-R analysis of discrimination learning which provided a significant counter-force to views invoking cognitive and perceptual explanatory concepts (e.g., Kohler, 1929; Krechevsky, 1932). Basic to Spence's formulation were the following assumptions:

(a) reinforcement and nonreinforcement result in the formation of excitatory and inhibitory response tendencies, respectively; (b) excitatory and inhibitory tendencies generalize to other stimuli as a function of physical similarity; and (c) response strength is determined by algebraic summation of the magnitudes of excitatory and inhibitory tendencies.

The initial experimental evaluation of Spence's theory, which was pitted against cognitive-perceptual accounts, involved investigations of presolution learning and transposition behavior. Subsequently, empirical evaluations of Spence's fundamental assumptions involved systematic assessment of two primary factors: (a) amount of generalization between discriminanda as affected by stimulus similarity; and (b) strength of conditioned excitatory tendencies as affected by magnitude of reinforcement. Yet, in contrast to the case for classical aversive and instrumental appetitive conditioning (Beecroft, 1966; Kimble, 1961), systematic data on the effects of stimulus similarity and US magnitude for differential classical appetitive conditioning is lacking.

Excitation-Inhibition Theories of Differential Conditioning

An appreciation of how American theorists modified the Pavlovian concepts of excitation-inhibition and stimulus generalization entails consideration of Pavlov's cortical theory (1927). In Pavlov's writing we can distinguish two general kinds of constructs: (a) historically determined CS-US cortical connections which are stable and response specific (the conditioned-reflex arc) and; (b) cortical states of excitation and inhibition which could be temporally labile and have diffuse behavioral effects. While the concepts of conditioned-reflex arc and cortical states were interrelated in Pavlov's theory, explanatory primacy often shifted from one concept to the other. Generally, as Pavlov's investigations progressed from simple to more complex behavioral phenomena, the conditioned-reflex arc, as a conceptual tool, occupied a diminishing theoretical role in contrast to the increasing explanatory burden assigned to excitatory and inhibitory processes (cf. Konorski, 1948).

For Pavlov, a conditioned reflex was presumed to reflect the drainage of excitatory impulses from CS to US cortical centers via historically determined and permanent connections. The formation of these cortical connections involved the close sequential activation of CS and US centers, such that impulses are attracted from the first aroused and weaker (CS) to the secondly aroused and more activated (US) cortical center. Furthermore, Pavlov specified that nonreinforcement of a CS in a number of experimental paradigms (e.g., experimental extinction, differential conditioning) results in the activation of inhibitory rather than excitatory impulses in the CS cortical center. Central to Pavlov's formulation was the notion that excitatory and inhibitory cortical states were actively antagonistic. Thus, because of the permanence of previously established CS-US cortical connections, such nonreinforcement results in the transformation of an excitatory conditioned reflex into an inhibitory reflex. In emphasizing his view that conditioned response decrements were due to the mediation of an active process of inhibition rather than merely diminished excitatory factors, Pavlov cited supportive documentation from an extensive series of studies which involved a summation procedure. This procedure involved the simultaneous presentation of a stimulus of known response eliciting capacity with a CS which had been repeatedly nonreinforced, hence permitting an assessment of the active response-decrementing capacity of the latter by the assumption of algebraic summation. Accordingly, in Pavlov's analysis of acquisition and extinction effects, historical factors govern behavior via two distinct cortical mechanisms: (a) the establishment of permanent CS-US cortical connections, and (b) the transformation of CS cortical centers from excitatory to inhibitory.

Early in his investigations, Pavlov (1927, p. 113) observed that when a conditioned reflex is established to a specific CS, historically neutral stimuli "spontaneously" acquire response-eliciting properties in proportion to their physical similarity to the acquisition CS. He denoted the empirical phenomenon as "stimulus generalization" and postulated cortical irradiation as the underlying mechanism. Pavlov cited support for the notion of cortical irradiation from the observation that longer CS-US intervals (which presumably permitted a wider spread of cortical irradiation) resulted in generalized responding to a wider range of stimulus values (p. 187). He further specified that generalized responding reflected the formation of the corresponding cortical connections during acquisition training. He suggested that during acquisition cortical points corresponding to the generalization stimuli are activated by excitatory irradiation, and like the acquisition CS, become permanently connected to the US center.

Pavlov's theoretical analysis of the acquisition and extinction of conditioned reflexes, and stimulus generalization, focused on relatively stable behavioral modifications and emphasized the notion of permanent CS-US cortical connections. In contrast, his analysis of spontaneous recovery, generalization of aftereffects, and induction, which were time-dependent, labile phenomena, assigned a central role to the "dynamics" of cortical excitation and inhibition. Spontaneous recovery, in Pavlov's view, resulted from the dissipation of cortical inhibition which had accumulated during the previous extinction training. Pavlov dismissed "fatigue" as an explanatory notion on the basis of his observations that response decrements did not occur during acquisition sessions and that a single US presentation could reinstate an extinguished conditioned reflex (p. 60). Thus, while a CS could acquire relatively permanent inhibitory attributes by extended training, the immediate effect of a nonreinforced trial was a cortical inhibition that dissipated over time.

Pavlov's general concern with cortical processes, coupled with his analysis of spontaneous recovery, presaged a shift toward his subsequent emphasis on time-dependent phenomena. Pavlov believed that investigations involving the stimulus generalization of inhibitory aftereffects provided an optimal technique for assessing the time course of inhibitory cortical irradiation. The general design of these studies involved differential conditioning; a number of stimulus values were reinforced while a single, intermediate stimulus value was consistently nonreinforced until complete differentiation was established. Subsequently, the negative (inhibitory) stimulus was presented and generalized response decrements were assessed after various time intervals. It was found that the degree of response decrement was proportional to the similarity between the inhibitory stimulus and the test stimuli. However, of particular importance to Pavlov was the finding that response decrements initially increased over time then subsequently decreased and disappeared (i.e., inhibitory aftereffects). Pavlov interpreted the initial increase of inhibitory effects as reflecting the time-course of the cortical irradiation of inhibition, while the subsequent decrease was posited to reflect the time-dependent recession (concentration) of inhibition. To study the time course of excitatory cortical irradiation, Pavlov used an analogous design (though far less extensively) for studying stimulus generalization of excitatory aftereffects. A single CS value was reinforced while similar stimulus values were consistently nonreinforced until differentiation was established. Then, following a nonreinforced presentation of the positive CS, generalized response increments to the previously nonreinforced stimuli were assessed after various time intervals. The findings were analogous: generalized responding varied with stimulus similarity and initially increased over time then subsequently disappeared (i.e., excitatory aftereffects). Again Pavlov emphasized the temporal findings and interpreted them as reflecting time-dependent irradiation and subsequent concentration of cortical excitation.

Pavlov's subsequent studies of temporal factors in differential conditioning revealed that if a positive CS was applied almost immediately following a negative stimulus, it evoked augmented responding. The effect is opposite to that expected from irradiation and accordingly, Pavlov posited an additional dynamic cortical factor. He suggested that inhibitory cortical activation immediately causes increased excitability in adjacent cortical points, which occurs before inhibitory irradiation commences. The empirical finding, as well as the theoretical mechanism, was denoted as "positive induction." The finding that the prior presentation of a positive CS retarded the re-establishment of a conditioned reflex to an extinguished CS was denoted as "negative induction" and interpreted in a parallel fashion to positive induction.

While Pavlov tended to identify stable behavioral modifications with CS-US cortical connections and temporally labile ones with dynamic cortical states, he failed to clearly separate these constructs both conceptually and operationally. For example, he often viewed the generalization of inhibitory aftereffects as a parallel to simple stimulus generalization, thus blurring the distinction between temporary and stable behavioral modifications. Accordingly, the absence of distinct operational specifications rendered Pavlov's theorizing more a collection of general concepts than a systematic theory.

Early American learning theorists (e.g., Guthrie, 1930; Hull, 1929) quickly incorporated a number of Pavlov's general principles while concomitantly dismissing Pavlov's cortical theorizing. The rejection of Pavlov's cortical model stemmed primarily from the S-R behavioristic climate which discouraged the invoking of "dynamic" constructs. The general American response was to select those aspects of Pavlov's work which could be most easily severed from dynamic cortical mechanisms and re-anchored within an S-R associative framework. Specifically, while the notion that reinforcement and nonreinforcement give rise to antagonistic behavioral factors was incorporated (along with the "excitation-inhibition" terminology), the American concepts of excitation and inhibition were primarily restricted to encompass stable, S-R connections without temporal aftereffects. Similarly, while much of Pavlov's work on stimulus generalization centered on the temporal fluctuations of generalized responding, the derivative American concept of generalization involved the immediate and direct establishment of excitatory and inhibitory connections to similar stimuli without invoking temporally-labile learning factors.

The connectionistic modification of Pavlovian concepts was exemplified in the reaction to Loucks' (1933) challenge of Pavlov's documentation of both stimulus generalization gradients *per se*, and, in particular, the temporal fluctuation of generalized responding. American investigators in reacting to Loucks' criticism of Pavlovian "irradiation," focused their attention on stimulus generalization gradients, rather than on temporal fluctuations of generalized responding. For example, Bass and Hull (1934) and Hovland (1937), working with the human GSR, concluded that both excitatory and inhibitory stimulus generalization gradients were viable behavioral phenomena, thus meeting the brunt of Loucks' criticism. However, Bass and Hull, and Hovland carefully dissociated themselves from the Pavlovian notions of cortical irradiation and concentration and their attendant implications of temporal fluctuation.

It was originally Spence (1936, 1937) who systematically integrated the concepts of excitatory-inhibitory response tendencies and stimulus generalization and detailed their implications for analyzing discrimination learning. Spence's (1937) basic postulates were Spartan: (a) reinforcements and nonreinforcements increment excitatory and inhibitory tendencies, respectively; (b) excitatory and inhibitory tendencies generalize as a function of physical similarity; and (c) effective response strength to a stimulus is the algebraic summation of excitatory and inhibitory tendencies. Inhibitory as well as excitatory tendencies were viewed as stable, associative factors; and while Spence (1936) parenthetically suggested that some spontaneous recovery of differentially extinguished responses occurs, he failed to incorporate such a factor into his theory. In contrast to views (e.g., Krechevsky, 1933; Kohler, 1929) which advocated that cognitive or perceptual concepts were necessary to explain selective-learning phenomena, Spence (1937) presented an analytic tour-de-force by deriving transposition phenomena from his basic discrimination postulates. Thus, an historically pivotal aspect of Spence's (1936, 1937) writings was that he provided a conceptual and analytic base for an S-R position which held that discriminative performance, although more complex, reflects only basic acquisition and extinction processes.

Spence (1936, 1937) explicitly refrained from tying his behavioral postulates for differential conditioning to a specific reinforcement mechanism of learning. In addition, by addressing his formulation to instrumental appetitive situations, Spence did not develop its generality to other learning paradigms. Subsequently, Hull (1943) subsumed Spence's analysis of discrimination learning within his more general behavior theory. Hull's synthesis tied the Spencian postulates to a monistic reinforcement mechanism (drive-reduction) which systematically extended the scope of the discrimination theory to appetitive and aversive instrumental and classical conditioning paradigms, and provided operational specifications for the determinants of excitatory strength (e.g., amount of reinforcement, delay of reward). While Hull's two-factor theory of inhibition entailed a _formal_ modification of Spence's original postulates, divergent implications were not elaborated. In Hull's formulation both associative ($_{S}I_{R}$) and nonassociative aspects of inhibition (I_R) depended on mere response evocation and hence, inhibition was not operationally tied solely to nonreinforcement as in the Spencian postulates. However, the analytic application of Hullian theory on gradients underlying discrimination generally involved consideration of associative inhibitory tendencies occurring on nonreinforced trials and therefore, functionally reflected Spence's original postulates. The Hulliam framework also provided a systematic theoretical context for an analysis of the effects of motivational variables on discriminative performance. While Hull's integration of Spence's postulates with his afferent physiological model for stimulus generalization provided little additional scope to the discrimination theory, it clearly anchored Spence's formulation to Hull's earlier notion (1929) that stimulus generalization is a fundamental behavioral process inextricably tied to learning.

The discrimination theory embodied in Hull's (1943) formulation is often referred to as the "Hull-Spence" discrimination theory. However, subsequently Hull and Spence separately revised their positions on basic learning factors, which logically entailed modification of their positions on differential conditioning. Hull (1952), while retaining a reinforcement position, added the incentive-motivational construct (K) for instrumental appetitive conditioning. Since K was directly tied to an associative factor (r_g) and hence subject to stimulus generalization, the incentive factor should have been incorporated into his theory of differential conditioning. In a more radical departure, Spence (1956) proposed that S-R contiguity determined the learning of instrumental "habits," while a reinforcement mechanism governed incentive-motivation. Inhibition was restricted to the contiguity factor and was presumed to result from the learning of competing instrumental responses on nonreinforced trials. While instrumental responding and incentive motivation were both tied to associative factors and subject to the laws of generalization, Spence failed to delineate the theoretical implications for differential conditioning. Spence later (1960) proposed a frustration-based view of inhibition which he noted was quite similar to Amsel's (1958) formulation. According to this view, nonreward in a context associated with reward, leads to the conditioning of a frustration factor ($\underline{r_f}$) which mediates motivational consequences in addition to competing instrumenal responses. While Spence never elaborated the implications of frustrative-inhibition for differential conditioning, Amsel (1958, 1962) operating within the Hulliam framework, has noted some implications of frustration theory for differential conditioning.

More recently, findings opposite to those expected from simple generalization (i.e., behavioral contrast) have focused attention on the inadequacy of Hull-Spence discrimination theory (cf. Reynolds, 1961; Terrace, 1966). A typical procedure employed by operant investigators (cf. Dunham, 1968) involves a within-subject methodology where initially each of two successively presented stimuli is independently associated with a specific schedule of reinforcement. Following the establishment of stable response rates, the rate of reinforcement for one of the stimuli is varied while the other remains unchanged. If the rate of responding for the unchanged stimulus condition changes in a direction opposite to that engendered by the shifted reinforcement condition, the phenomena is denoted behavioral contrast. Increments or decrements in responding during the unchanged stimulus condition are further specified as positive or negative behavioral contrast, respectively, (however, positive behavioral contrast has been much more extensively investigated, cf. Dunham, 1968). According to Hull-Spence theory, a change in reinforcement which increments (or decrements) responding to a specific stimulus, will lead, via generalization, to a like increment (or decrement) in responding to a similar stimulus rather than an opposite effect as found in behavioral contrast. Terrace (1966) in questioning Hull-Spence theory, has suggested that positive behavioral contrast reflects the generalization of a frustration-based motivational factor while leaving negative behavioral contrast unexplained. On the other hand, Nevin and Shettleworth (1966) have suggested that aspects of behavioral contrast effects are mediated by induction-like interactions between excitatory and inhibitory factors. While frustration and inductive interaction formulations (instigated by behavioral contrast) indicate general theoretical orientations, they have not been systematically developed into clear alternatives to the Hull-Spence discrimination theory.

Theories of Stimulus Generalization

Pavlov's Cortical Theory. Pavlov (1927) regarded generalized responding as reflecting a fundamental aspect of an organism's ability to adapt to its environment. As such he proposed that stimulus generalization was a basic behavioral process. Central to his stimulus generalization theory were the following assumptions: (a) cortical points, corresponding to physical characteristics of stimuli, are spatially distributed to mirror, in a point-to-point fashion, physical characteristics of stimuli; and (b) over time, excitatory or inhibitory impulses spread over the cortex with decreasing magnitude from the point of initiation corresponding to the training CS. Inherent in Pavlov's formulation is the notion that physical similarity is a primary determinant of the degree of generalized responding which obtains "spontaneously" along all dimensions of a stimulus.

Pavlov's assumption regarding cortical correspondence and time-dependent cortical irradiation provided a basis for experimental evaluation of the theory. According to his formulation, an independent set of operations for identifying cortical spatial contiguity provides a basis for predictions on generalized responding. An often-cited article by Grant and Dittmer (1940) employed this strategy. They concluded that the known facts concerning the projection of the skin surface on the primary somatic sensory cortex did not yield isomorphic generalized responding along the surface of the skin. Grant and Dittmer also pointed out that a similar lack of correspondence between maps of the somatic cortex and generalized responding was reflected in the Bass and Hull (1934) findings on skin-surface generalization. Subsequently, Mednick and Freedman (1960) argued that in view of the nature and organization of the auditory cortex, findings of intensity generalization contradict Pavlov's assumption on cortical spatial contiguity.

Pavlov's notion of time-dependent cortical irradiation has received little experimental evaluation. Nevertheless, an article by Loucks (1933) which questioned Pavlov's behavioral evidence of "sluggish" fluctuations in generalized responding is often cited as challenging Pavlov's notion of a time-dependent irradiation. However, American investigators have apparently not investigated the empirical basis for Pavlov's suggestion that longer CS-US intervals permit wider cortical irradiation and hence produce generalized responding to a wider range of stimuli.

Hull's Afferent Theory. Hull's (1939, 1943) theory of primary stimulus generalization can be viewed as a modification of Pavlov's conceptualization which is stripped of its attendant cortical speculations. Hull (1943), within an associationistic framework, posited that ". . . the reaction involved in original conditioning becomes connected with a considerable zone of stimuli other than, but adjacent to, the stimulus conventionally involved in the original learning (p. 183)." For Hull, then, as with Pavlov, the establishment of generalized response tendencies occurs inextricably and concurrently with conditioning to the training stimulus. However, for Hull, generalized response tendencies, like conditioned response tendencies, involved only stable behavioral modifications. Furthermore, in the Hullian framework, those variables postulated to affect conditioned responding were assumed to similarly affect generalized responding.

Basically, Hull treated stimulus generalization as a behavioral axiom while his interest in why generalization comes about was secondary at best. Nevertheless, Hull suggested, in a notion quite similar to Pavlov's cortical correspondence, that "afferent neural continua" mirror the physical dimensions of exteroceptive stimuli. Then, in very general terms, Hull shifted the presumed locus for "habit spread" away from Pavlov's specification of the cortex, to a seemingly more perpheralistic locus involving afferent continua.

Hull assumed that generalization gradients were influenced by the differential sensitivity of the receptor mechanism which was presumed to be a given, biological constant. He suggested that psychophysical proximity (in jnd units) may be used to assess differential receptor sensitivity and thus to predict the form of generalization gradients.. However, clearly, to have explanatory value, the operations for assessing receptor sensitivity must be independent of those for assessing generalization. Yet, as Brown (1965) has emphasized, there is no clear demarcation between the methods of psychophysics and of generalization. Both methods involve training (or its functional equivalent in instructions) and testing and both yield evidence of how well subjects react differentially. Accordingly, in the absence of independent operations for assessing receptor sensitivity and "afferent continua," Hull's *mechanism* of generalization would appear to reduce to the more primitive assumption that physical similarity governs stimulus generalization.

Common Elements Theory. The notion that generalized responding reflects associative connections formed during conditioning to elements which are common to both the training and test stimuli has appealed to a variety of theorists (e.g., Guthrie, 1930, 1935; Hull, 1920; Thorndike, 1913; Dollard & Miller, 1950; Osgood, 1953; Brown, 1965). Historically, the notion has been perhaps most closely associated with the views of Guthrie and more recently with mathematical models of learning (Estes, 1950, 1959; Bush & Mosteller, 1951). Essentially, the notion involves conceptualizing the stimulus as an aggregate of separate stimulus elements or components to which associative connections may be individually established. The observation of a generalized response is taken to indicate the test stimulus contains elements common to the training stimulus. Thus, as in the Pavlovian-Hullian framework, the establishment of generalized associative tendencies occurs concurrently and inextricably with conditioning to the training stimulus. The number of common elements between training and test stimuli is presumed to vary directly with stimulus similarity and to govern response strength. However, a general set of operations for specifying the number of common elements solely in terms of the physical characteristics of stimuli has eluded theorists. Accordingly, the common elements notion, while exerting wide appeal, can be viewed as a suggestive pre-theoretical model for a mechanism of generalization.

Lashley-Wade. A questioning of the Pavlovian assumption that stimulus generalization represents a primary behavioral process has provided the basis of an alternative explanation of stimulus generalization. Lashley and Wade (1946) indicated the general trends of their influential theoretical analysis of stimulus generalization by critically contrasting their position with Hull's "neo-Pavlovian" approach. Lashley and Wade held ". . . there is no 'irradiation' or spread of effects of training during primary conditioning"; and that an ordered generalization gradient ". . . is a product of variable stimulus thresholds not of spread of associative process (p. 74)." For Lashley and Wade then, following training to a particular stimulus, an organism will respond to an historically neutral stimulus only if the organism "perceives" the test stimulus as being identical to the training stimulus. Stimulus generalization testing is viewed as a psychophysical procedure for assessing whether the organism is "perceiving" the test stimuli as "same as" or "different from" the training stimulus. In a phrase, for Lashley and Wade, stimulus generalization is merely a psychophysical measure of perceptual processes.

The Lashley-Wade "psychophysical" argument (also recently articulated by Prokasy and Hall, 1963) may be constructed as follows: (1) a necessary condition for invoking a concept of "associative spread" or transfer-of-training effect is to independently demonstrate responding to the generalization stimulus while the organism is "perceiving" the test stimulus as different from the training stimulus; (2) procedures for assessing such perceptual processing are by psychophysical methods; (3) stimulus generalization testing is merely a variant of such psychophysical procedures and therefore; (4) a generalized response is merely the identification of stimulus equivalence and notions involving "associative spread" are superfluous. However, as Brown, Bilodeau, and Baron (1951) have articulated, the notion that generalized responding is an index of "perceptual identification" which in turn is used to explain generalized responding is clearly circular in the absence of specification of the determinants of "perceptual identification." Such testable specifications are still wanting. Alternatively, because Hull's stimulus generalization postulate is embedded within a theory which operationally specifies the determinants of associative and motivational factors, it clearly does not involve circularity. Thus, in contrast to the Lashley-Wade "explanation" of stimulus generalization, Hull (1939) explicitly developed twenty-nine testable implications of his stimulus generalization theory.

A conceptually independent position elaborated by Lashley and Wade (1946) involved the notion that "attention" to the stimulus dimension, which is determined by differential conditioning, is necessary to obtain ordered generalization gradients. They held that ". . . the fundamental assumption of neo-Pavlovian theory, that in conditioning, all aspects of the stimulus are associated with the reaction, is demonstrably false . . . (p. 81)," rather ". . . a definite attribute of the stimulus is 'abstracted' and forms the basis of the reaction . . . (p. 81)." For Lashley and Wade, an organism must somehow perceive specific stimuli as points along a dimension before an ordered generalization gradient will emerge. They state that such establishment of a stimulus dimension for the organism ". . . does not occur in conditioning to a single stimulus value but is somehow a function of differential training with two or more stimuli on the same dimension (p. 81)." The latter statement would appear clearly testable: ordered generalization gradients will not obtain following single stimulus training. However, Lashley subsequently qualified his position and apparently suggested that single-stimulus training may produce ordered gradients through the "comparison" of memory traces (see Lashley's quoted communications, in Hull, 1947). Lashley's failure to specify the determinants of "memory traces" and "comparisons" renders his elaboration of the concept of "psychological dimensions" unanchored and untestable.

At this point, it is useful to note the historical mingling of the Lashley-Wade position that attention underlies ordered generalization gradients and Skinner's (1953) formulation of "stimulus control." Similar to Lashley and Wade, Skinner suggested that an organism may "attend to" only a portion of the stimulus. For Skinner, a stimulus is said to be "attended to" or to control behavior when variations in the stimulus produce ordered variations in behavior (i.e., an ordered generalization gradient). In contrast to Lashley and Wade, Skinner tended to treat attentional factors simply as responses which can be "shaped." Skinner posited that "*differential reinforcement*" is a determinant of stimulus control. However, in operant terminology, "differential reinforcement" includes (in addition to explicit differential conditioning) the paradigm where reinforcement is available in the presence of the experimental stimulus and is unavailable during its absence. That is, "differential reinforcement" involving stimulus presence and absence corresponds to the Lashley-Wade and Hullian specification, in "discrete-trial" terminology, of *single-stimulus training* (cf. Hull, 1947). Accordingly, whatever the similarities to Lashley and Wade, Skinner's formulation would converge with Hull's to the extent of positing that (discrete-trial) single-stimulus training can produce ordered generalization gradients.

Whether *operant* single-stimulus training, where the stimulus is continuously present during the experimental session, can produce ordered gradients involves a related but separate theoretical issue than that raised by Lashley and Wade. However, the confusion between operant and discrete-trial terminology has blurred the issue. For example, Jenkins and Harrison (1960), in attempting to evaluate the Hullian and Lashley-Wade position, contrasted operant and discrete-trial single-stimulus training which they referred to as "nondifferential" and "differential" training, respectively. They found that "nondifferential" training produced relatively flat generalization gradients in contrast to those produced by "differential" training. If one associates the Lashley-Wade position with the operant term "differential" training, then the study appears to support the Lashley-Wade position in contrast to the Hullian one. However, clearly, the differential training paradigm of Jenkins and Harrison is functionally equivalent to Hull's specification of (discrete-trial) single-stimulus training for which Hull of course predicts ordered generalization gradients. Alternatively, while Hull never explicitly addressed himself to operant single-stimulus training, Brown (1965), a Hullian-oriented theorist, has suggested that the operant procedure would not produce "effective" associative strength to the "experimental" stimulus and would thus be expected to yield flat generalization gradients. In a similar vein, a Hullian theorist could suggest that in the operant procedure, the total stimulus complex becomes associated with the response, and the variation of a minute portion of it (i.e., the "experimental" stimulus) would hardly be expected to produce an effective generalization decrement.

General Accounts of Associative Strength

Pavlov's Cortical Theory. In Pavlovian theory (1927), as previously indicated, historically determined CS-US cortical connections underlie the conditioned reflex. The capacity of these connections to mediate cortical drainage from CS to US centers determines the strength of the conditioned reflex. The formation and capacity of CS-US connections is governed by the degree of activation of the US center which Pavlov operationally tied to measures of UR strength. Thus, according to Pavlov, variations in the intensity or duration of the US which augment UR activity, directly govern the strength of appetitive and aversive conditioned reflexes.

Pavlov stipulated that mere repeated presentations of the CS will eventually result in it activating inhibitory rather than excitatory impulses in the CS center, while reinforcements in this respect, operate primarily to counteract this development. However, mere CS presentation is not sufficient to establish an inhibitory reflex which entails the drainage of inhibitory impulses from the CS to the US cortical center. Implicit in this formulation is that establishment of an inhibitory reflex entails some prior acquisition training for the formation of the necessary CS-US cortical connections. In line with this, Pavlov suggested that the "intensity" of inhibition is proportional to the strength of the US on which it is based (1927, pp. 100-101). The general notion that the conditioning of inhibitory factors entails, and is a direct function of, acquisition training has subsequently been associated with a variety of theorists (e.g., Amsel, 1958; Konorski, 1948; Rescorla, 1969; Spence, 1936).

Guthrie's Contiguity Theory. Guthrie (1930, 1935) questioned the necessity of Pavlov's cortical explanation of the conditioned reflex and asserted that the associationist's principle of contiguity was sufficient. The underlying principle was that stimuli which are active at the time of a response, tend, on being repeated to elicit that response. Associative connections are thus formed when the CS (via the attendant response produced stimuli) is concurrently active with the UR. While the conditioning of any specific element of the functional CS is presumed to occur in an all-or-none fashion, the effect of repeated trials is a cumulative increase in the number of elements conditioned which is reflected in an increase of conditioned responding. In this view, the US is effective for conditioning solely because it assures, or "forces" the occurrence of the UR. Accordingly, qualitative or quantitative variations in the US which potentiate UR activity (for example, amplitude, duration) will augment conditioning.

Guthrie proposed what is essentially an interference notion of inhibition. Nonreinforcement is presumed to result in the conditioning of a response to the stimulus elements which will interfere with the UR-based conditioned response. According to this view, the number of stimulus elements conditioned to an interfering response is directly governed by the number of trials the CS is presented without the US. Thus, in contrast to the Pavlovian notion that inhibition varies directly with underlying excitatory strength, contiguity theory entails that inhibitory strength is solely a function of the number of nonreinforced trials. It may be noted that the latter operational specification for inhibition was also postulated by Spence (1960, p. 110) while taking a general reinforcement position for classical aversive conditioning. Contiguity theory, on the other hand, explicitly postulates parallel relationships for both classical appetitive and classical aversive conditioning.

Hull's Effect Theory. Hull (1943), in postulating a monistic reinforcement mechanism held that there are drive-reducing (reinforcing) events tied to US presentations which establish and strengthen an associative bond between the CS and the UR. The theoretically necessary drive-reducing event was specifically tied to US offset for classical aversive conditioning, and more generally, to US onset or occurrence for classical appetitive conditioning. Hull further postulated that habit (H) strength was a positive function of the amount and number of reinforcements. Hull's subsequent (1952) revision of his theory by the introduction of an incentive construct (K), apparently did not alter his previous position on classical appetitive conditioning. Thus K, which was directly tied to classically-conditioned consummatory responses, was posited to vary as a function of the amount, as well as the number of reinforcements.

Hull postulated that mere response evocation resulted in a negative drive (reactive inhibition I_r) which depressed performance on the response which produced it and spontaneously dissipated with inactivity. For Hull, the conditioning of inhibitory tendencies (conditioned inhibition ${}_sI_r$) was a derived factor which resulted from a reduction in I_r attendant upon response cessation. While Hull's formulation for the conditioning of inhibitory tendencies formally involved responsivity, its application has generally been restricted to assuming that inhibition varies with the number of nonreinforced trials.

Empirical Review

Cue Similarity

The effects of variations of cue similarity on discriminative performance are central to an empirical evaluation of Hull-Spence theory. The theoretical predictions are straightforward: (a) CS+ performance will be positively related to the physical difference between the discriminanda due to decreased generalization of inhibition from CS-; and (b) CS- performance will decrease with increasing cue dissimilarity (due to diminished excitatory generalization). Moreover, in line with the theory, simple and differential conditioning paradigms can be analyzed and contrasted within the common context of the discrimination postulates.

The effects of cue similarity have been most extensively investigated in classical aversive conditioning. Consonant with Hullian theory, investigators using the human- (Gynther, 1957; Moore, 1964) and rabbit- (Frey, 1969) eyelid response have found that: (a) less similar CSs resulted in increased CS+ and decreased CS- performance; (b) differential conditioning depressed CS+ responding compared with simple conditioning involving continuous reinforcement; and

(c) responding in a partial reinforcement control group was intermediate between CS+ and CS- performance of a condition which received discriminable stimuli. This pattern of results has also been found (Homzie, 1968) when differential conditioning is preceeded by acquisition training to the positive CS (i.e., separate-phase differential conditioning). In brief, the results from classical aversive conditioning clearly support the Hull-Spence theory of differential conditioning.

However, in instrumental appetitive conditioning, the cue similarity variable appears to produce different effects on S+ performance while mediating effects comparable to classical aversive conditioning on CS- performance (cf. Hanson, 1959). Hanson (1959), working with operant procedures, found that when S+ and S- are similar, response rates to S+ are enhanced relative to single-cue continuous reinforcement. (The finding has subsequently been well-documented and constitutes a variant of positive behavioral contrast (cf. Dunham, 1968). Runway investigations contrasting partial- and continuous-reinforcement reveal another disconfirmatory finding. Goodrich (1959) and other investigators (cf. Spence, 1960) have found that 50 per cent partial reinforcement results in faster asymptotic start and run speeds than 100 per cent continuous reinforcement in spite of the latter receiving twice as many reinforcements. Partial reinforcement can of course be viewed as differential conditioning with highly similar (identical) discriminanda. In contrast, runway investigations involving black-white discriminative stimuli (e.g., Friedes, 1957; MacKinnon, 1967) have found S+

performance inferior to that of a continuous reinforcement condition. Nevertheless, positive behavioral contrast and the "Goodrich effect" are clearly not in accord with a generalization-of-inhibition analysis of differential conditioning. Explanations of positive behavioral contrast (Terrace, 1966) and the "Goodrich effect" (Spence, 1960; Amsel, 1967) have involved the assumption that non-reward in appetitive situations results in frustration-based motivational effects which elevate instrumental response rate or speed.

Whether the effects of cue similarity in classical appetitive conditioning mirror the case for classical-aversive or instrumental-appetitive conditioning has not been systematically assessed.

Reinforcement Magnitude

US Duration in Classical Aversive Conditioning. While extending the duration of an aversive and an appetitive US is an experimentally analogous manipulation, there is a marked theoretical divergence on the role of noxious US-duration in the learning process. Effect theories (e.g., Hull, 1943; Miller, 1951; Miller & Dollard, 1941) hold that US offset is a drive-reducing (reinforcing) event which mediates learning and thus maintain that increased US duration will retard learning due to delayed reinforcement. On the other hand, some contiguity formulations (e.g., Maier & Schneirla, 1942; Mowrer, 1947) posit that learning is primarily dependent upon events connected with US onset and hence that the duration of the US will have little effect on learning. While the majority of studies on US duration have been explicitly concerned with contrasting the latter positions, it should be noted that both Pavlovian and Guthrian formulations entail that extending an aversive as well as an appetitive US will augment conditioning. For Pavlov, this augmentation follows from increased cortical arousal of the US centers, while for Guthrie, it results from increased UR activity which facilitates the conditioning of an increased number of elements.

While differential predictions for the effects of aversive US duration would appear straightforward, a number of complicating factors have been elaborated. Miller (1951), speaking to a delay-of-reinforcement analysis, has pointed out that with increased US duration, the presumed reinforcing event may still immediately follow the response (UR), thus seeming to be more analogous to operations which affect the much less sensitive gradient of within-chain delay. In addition, Miller (1951) postulated two factors which may obscure the decremental effects of delayed US termination from a drive-reduction viewpoint. He speculated that temporal summation may operate to augment the noxiousness of the US and hence increase the amount of drive reduction at US offset, or alternatively, that rapid intra-trial adaptation to the US may occur, resulting in some degree of pre-offset drive reduction. In a similar vein, Runquist and Spence (1959) emphasized that increased US duration may augment motivational level and offset the decremental effects of retarded learning due to delayed reinforcement. On the other side of the coin, inter-trial adaptation or habituation may well occur with aversive stimuli and be tied to their duration, hence a factor which would lower the conditioning efficacy of long-duration USs.

At the empirical level, the effects of US duration on simple classical aversive conditioning are inconsistent (see Appendix A). For shock USs, increased US duration appears to have little effect on the conditioning of cardiac responses or the GSR. On the other hand, increased duration of air-puff USs appears to produce a slight decrement for human eyelid conditioning. Theoretical interpretations *vis a vis* effect and contiguity theories have often involved post-experimental invocation of a number of potential confounding factors (e.g., temporal summation, motivation level) which may have attenuated the decremental effects of delay of reinforcement. Clearly, to have scientific value, such post-experimental interpretations require independent empirical support.

The apparently single reported investigation of US duration in a differential conditioning paradigm (Ashton, Bitgood, & Moore, 1969) employed the nictitating membrane response of the rabbit in a factorial design involving shock duration (50- and 350 msec.) and intensity (.5-, 2-, and 4-ma.). The investigators reported that performance to both discriminative stimuli varied directly with increases in US duration as well as with intensity while the degree of differential responding was augmented only by the latter. However, from the graphical presentation of the data, it appears that performance was far from stabilized when training was terminated. Interpretation is further complicated by the fact that the duration of the discriminative stimuli was confounded with US duration.

US Intensity in Classical Aversive Conditioning. Although they differ for US duration, effect (e.g., Hull, 1943), contiguity (e.g., Guthrie, 1935; Mowrer, 1947), and cortical (Pavlov, 1927) theories concur in positing that increased US intensity will augment conditioning and a facilitative effect of US intensity has been a well-documented finding (see Appendix A). However, theorists operating within a Hullian framework must concern themselves with separating motivational and associative effects of US intensity. To this end, Spence (1958a) postulated that aversive USs elicit a hypothetical emotional response ($\underline{r_e}$) which bridges typical inter-trial intervals and directly governs drive ($\underline{D}$) level. Studies by Spence and his associates (see Appendix A) have provided support for the formulation that US intensity augments CR-associative strength ($\underline{H}$) above and beyond its effect on $\underline{D}$.

As in the case for simple conditioning, Hullian oriented theorists must also concern themselves with motivational as well as associative effects of US intensity on differential conditioning. Spence (1958a) addressed himself to this concern and detailed implications of his theorizing on US intensity for differential conditioning. Thus $\underline{H}$, and via the $\underline{r_e}$ mechanism, $\underline{D}$, were presumed to be a direct function of US intensity and to combine multiplicatively, while inhibition was presumed to vary solely with the number of nonreinforced trials. According to Spence's formulation, an increase in either $\underline{H}$ or $\underline{D}$ yields three interrelated predictions: augmented CS+ and CS- responding and an increased degree of differential responding.

Spence and Tandler (1963) evaluated these predictions in an investigation of two-air puff intensities with the human-eyelid response in a differential conditioning paradigm. They attempted to equate D while varying H by presenting the alternative US intensity on CS- trials after an interval (2500 msec.) presumed to be ineffective for conditioning. All three predictions were realized; increased US intensity with the positive stimulus facilitated CS+ and CS- performance, and in addition, augmented the degree of differential responding. In a similar and related study (Runquist, Spence, & Stubbs, 1958), Ss received the same intensity US on CS- as on CS+ trials but at a delayed interval, hence, in terms of Spence's theory, Ss differed on both H and D. Again, increased US intensity augmented performance to both discriminative stimuli, however, in contrast to the expectation of greater differentiation, there was no significant effect on the degree of differential responding.

While Spence's theory received some support, at variance with the Spence et al. findings, are the results from a subsequent human-eyelid study (Suboski & Khosla, 1969) which investigated the effects of comparable puff intensities but employed US omission on CS- trials. While increased US intensity resulted in superior differentiation, the investigators suggested that the superiority was largely determined by the fact that the high US intensity group displayed lower levels of CS- performance than the low intensity group.
The primary procedural variation may have been the use of US-omission on CS- trials. Support for this suggestion comes from human-eyelid investigations of US intensity with partial reinforcement (PR) schedules; Ross and Spence (1960) employed a US delay procedure of nonreinforcement and observed a facilitative effect of US

intensity while investigations which used a US-omission procedure with PR schedules (e.g., Boice & Boice, 1966; Runquist, 1963) have reported that increased US intensity decremented performance. Consequently, while a facilitative effect of US intensity in simple classical aversive conditioning has been well-documented, conclusions on the effects of this variable in differential conditioning differ.

Reward Magnitude in Instrumental Appetitive Conditioning. For simple instrumental conditioning, a positive relationship between performance and reward magnitude is expected by effect (e.g., Hull, 1943), contiguity (e.g., Guthrie, 1935) and incentive (e.g., Spence, 1956) formulations and has been a well-documented finding (e.g., Crespi, 1944; cf. Pubols, 1960). Initial investigations of reward magnitude in differential conditioning were primarily concerned with the implications of frustration-based notions of inhibition. Spence (1958b), in noting some implications of his r_g theory for differential conditioning, suggested that the finding of an inverse relationship between S- performance and S+ reward magnitude would provide strong support for a frustration account of inhibition. Subsequently, two studies (Hunter, 1959; Trapold, 1961) from the Iowa laboratories using rats in a straight alley setting found that while the degree of differential responding was augmented by increased food reward, this augmentation primarily reflected facilitated S+ performance. Hunter found S- performance was unaffected by S+ reward magnitude and Trapold observed no effect on S- goal speeds but some facilitation on start and run measures. In a similar investigation, Bower and Trapold (1959) also found that reward magnitude facilitated S+ but not S- performance and similar findings have been obtained with variations of sucrose concentration and the rat's differential bar-press response (Stebbins, 1959).

At the empirical level the results appear relatively consistent: increased reward magnitude facilitates S+ performance but has relatively little effect on S- responding. The failure to observe an inverse relationship between S- performance and S+ reward magnitude was viewed (cf. Hunter, 1959) as providing little direct support for a frustration notion of inhibition in differential conditioning. However, it should be noted that if inhibition is governed solely by the number of S- presentations, performance on S- would presumably reflect facilitative effects of S+ reward magnitude via stimulus generalization.

An investigation by Bower (1961) subsequently focused experimental attention on relative differential conditioning paradigms (i.e., both discriminanda are reinforced but with differential amounts of reward). Bower observed that rats which received differential amounts of food reward separately associated with two distinctive runways ran slower in the small-reward runway than control Ss who had received only the smaller magnitude. This phenomena, denoted as a negative-contrast effect, has been well-documented (cf. Black, 1968; Dunham, 1968; McHose, 1970) and is presumably related to the finding of depressed performance following a shift from large to small rewards relative to unshifted, small-reward conditions. Bower (1961) suggested that negative contrast effects in differential conditioning can be explained by an extension of Amsel's (1958) frustration theory to situations involving relative reductions in reward. According to this formulation, each reward magnitude results in the conditioning of a particular value of r_g, and primary frustration R_F is elicited when a small reward occurs in the presence of a large-value r_g.

As applied to Bower's study, the large-value r_g is presumed to generalize from the large-magnitude (S+) runway to the small-magnitude (S-) runway; thus leading to the occurrence of R_F in the S- goal chamber. Repeated elicitation of R_F results in the conditioning of a fractional frustration response (r_f) which, via stimulus generalization and higher-order conditioning, is elicited by stimuli which antedate the goal. The r_f is presumed to mediate the negative contrast effect because its stimulus consequence s_f leads to behavior which interferes with the instrumental response. According to this formulation, r_f and hence competing responses should be maximal nearest the goal box. However, negative contrast effects appear to be most pronounced in earlier sections of the runway where the *S* is first exposed to the negative cues (cf. Ludvigson & Gay, 1966, 1967; Platt & Gay, 1968). Ludvigson and Gay (1967) proposed that primary frustration (and the attendent competing behavior) occurs shortly after presentation of the negative cue and then dissipates, so that performance later in the runway is less disrupted. It should be noted that both formulations focus on the response-interfering aspects of frustration while the implications of increased motivational aspects are not systematically considered.

In a parametric runway investigation, MacKinnon (1967) equated rats on "S+" reward magnitude (500 mg.) while independently varying "S-" magnitude at values of 0-, 37-, 90-, 350-, and 500-mg. of food. He found that S- performance was positively related to reward magnitude on S- as was S+ performance, with the surprising exception of the condition which received nonrewarded S- presentations. In comparison to the condition which received small reward (37 mg.) on S-, 0 reward, while leading to dramatically slower S- performance, produced faster S+ performance in contrast to predictions based on the generalization of inhibitory factors. The results are perplexing and suggest an apparent discontinuity between the affects of 0 reward and comparative small reward in differential conditioning.

The employment of a constant, small-magnitude reward on S- while independently varying S+ reward magnitude parallels the design of investigations of reward magnitude employing nonreinforced S- trials (i.e., absolute differential conditioning). Investigations employing this procedure (e.g., Ludvigson & Gay, 1966; Matsumoto, 1969; cf. McHose, 1970) have found an inverse relationship between S- performance and S+ magnitude, while S+ performance is relatively insensitive to variations in reward magnitude. In terms of frustration theory, the decremental effects on S- responding reflects ordered amounts of disruptive $\underline{r_f}$ which, via stimulus generalization, is also presumed to account for the invariance of S+ performance (cf. Ludvigson & Gay, 1966). However, nonreward is presumably merely an extension of reduced reward to a zero value. Yet, in absolute differential conditioning (e.g., Bower & Trapold, 1959; Trapold, 1961) increased S+ reward magnitude facilitates S+ performance while S- responding is relatively unaffected. The seeming dichotomy between the effects of S+ reward magnitude in absolute and relative differential condition apparently awaits systematic theoretical resolution.

It should be noted that the r_g mechanism is presumed to affect instrumental responding via its response strength, rather than its underlying habit or associative strength; and as a response it should reflect the effects of acquisition and extinction. According to Amsel's (1958, 1967) formulation, while repeated nonreinforcement of r_g results in the conditioning of r_f, it also involves some extinction of r_g itself. As previously indicated, the explanatory burden of the decremental effects of nonreward on instrumental responding is primarily placed on the interfering responses elicited by the r_f-s_f mechanism while the presumed effects of decreased r_g are generally unemphasized. It is specifically postulated (cf. Amsel, 1967, p. 5) that no response competition occurs between r_f and r_g but only between the responses elicited by their respective interoceptive cues. While the paradigmatic requirements for the elicitation and hence conditioning of frustration can presumably obtain within-classical appetitive conditioning situations, the implications are that frustration generated competing responses are not operative factors affecting appetitive CRs.

In view of the above comments, the implications are that the effects of US magnitude on CS+ and CS- performance in classical appetitive conditioning will reflect the functional relationships governing the effects of reward magnitude on the differential conditioning of $\underline{r_g}$. In addition, it should be noted that in instrumental conditioning, an inverse relationship between S- performance and S+ reward magnitude has been viewed as presumptive evidence for frustration effects. Such an interpretation assumes that the performance decrements in $\underline{r_g}$ resulting from S- presentations are governed solely by the number of nonreinforced trials (also cf. Birch, 1961 for a similar analysis of extinction). Presumably the assumptions regarding the determinants of $\underline{r_g}$ can be evaluation in classical appetitive conditioning paradigms.

US Magnitude in Classical Appetitive Conditioning. Most studies of US magnitude (e.g., Gantt, 1938; Kleschov, 1936; Wagner, Siegel, Thomas, & Ellison, 1964) have investigated the dog's salivary response to food and have reported a positive relationship between salivary responding and amount of food. However, appetitive investigations of the dog's salivary response have commonly employed a procedure of US presentation which has subsequently been questioned on the methodological grounds that the operations of reinforcement are contingent on an ancilliary but prerequisite instrumental response, thus introducing a potentially obscuring factor into the classical conditioning paradigm (cf. Kierylowicz, Soltysik, & Divaç, 1968; Gormezano, 1969). Specifically, in these studies the receipt of the US on the receptor surfaces of the oral cavity, and hence UR elicitation, was contingent upon responses of approaching and seizing the food from a hopper. The speed of this prerequisite instrumental response may well have been positively related to food magnitude, thus providing for shorter, and possibly facilitory functional ISIs for the larger magnitude conditions. However, more recently, Sheafor (1970) investigated US magnitude employing the jaw-movement response of the rabbit to intraoral water presentations. Employing three levels of US magnitude (1-, 5-, and 20-cc), Shaefor observed that percentage responding was positively related to US magnitude. The finding is congruent with virtually every major position on conditioning (e.g., Guthrie, 1930; Hull, 1943; Pavlov, 1927).

As the incorporation of Spence's (1937) model within Hull's (1943) behavior theory indicates, an excitation-inhibition analysis of differential conditioning can be integrated with alternative mechanisms of generalization and associative strength. Yet, central to any excitation-inhibition analysis is the amount of generalization between discriminanda. Furthermore, as the preceding development indicates, major theories of generalization (e.g., Guthrie, 1935; Hull, 1943; Pavlov, 1927) converge in operationally specifying stimulus similarity as a primary determinant of generalization. Similarly continuity, effect, and cortical theories of associative strength converge in identifying US magnitude as a basic determinant of excitatory associative strength. Despite the operational convergence and the theoretically fundamental status of classical appetitive conditioning, systematic data on the effects of cue similarity and US magnitude for differential classical appetitive conditioning are lacking.

EXPERIMENT I

The purpose of the present study was to assess the effects of cue similarity on separate-phase differential classical appetitive conditioning of the rabbit's jaw-movement response. A contrast control involving single-cue continuous reinforcement was also incorporated within the design.

For an excitation-inhibition analysis of differential conditioning (Hull, 1943; Spence, 1937), the predicted effects of cue similarity on discriminative performance are straightforward: (a) CS- performance will be positively related to cue similarity due to increased excitatory generalization; and (b) CS+ performance will be negatively related to cue similarity due to increased inhibitory generalization. Moreover, according to the theory, simple and differential conditioning paradigms are analyzed and contrasted within the common context of the discrimination postulates. For example, since simple conditioning with continuous reinforcement involves no inhibition to CS-, it can be analyzed as a case functionally equivalent to complete cue dissimilarity (i.e., no generalization of inhibition).

In classical aversive conditioning, the results are consonant with the theory. Investigators using the human (Gynther, 1957; Moore, 1964) and rabbit (Frey, 1967) eyelid response have found that: (a) less similar CSs resulted in decreased CS- performance and increased CS+ performance; and (b) differential conditioning depressed CS+ performance compared to continuous reinforcement. The same pattern of results has been found (Homzie, 1968) when differential conditioning is preceeded by acquisition training to the positive CS (i.e., separate-phase differential conditioning). In brief, the results from classical aversive conditioning clearly support Hull-Spence theory.

However, the case for instrumental appetitive conditioning with regard to the positive cue may be different. Operant investigators (e.g., Hanson, 1959; cf. Terrace, 1966) have reported that differential conditioning involving similarly colored keys produces substantially higher rates of responding to S+ than does continuous reinforcement (i.e., a variant of positive behavioral contrast). Runway investigations contrasting partial and continuous reinforcement reveal another disconfirmatory finding. Goodrich (1959) and others (cf., Spence, 1960) have found that partial (50%) reinforcement leads to faster asymptotic performance than continuous reinforcement. Partial reinforcementcan of course be viewed as the limiting case of differential conditioning with highly similar (identical) cues. In contrast, runway studies involving relatively highly discriminable stimuli (black vs. white goal boxes) have found S+ performance inferior to that of a continuous reinforcement condition (e.g., Friedes, 1957; MacKinnon, 1967). Nevertheless, positive behavioral contrast and the "Goodrich effect" are clearly not in accord with a simple generalization-of-inhibition analysis. Explanations of positive behavioral contrast (Terrace, 1966) and the

"Goodrich effect" (Amsel, 1962) have invoked formulations which assume that nonreward in appetitive situations produce frustration-based motivational effects which elevate responding.

The above noted discrepancy between the results from classical-aversive and instrumental-appetitive conditioning further emphasizes the importance of determining the effects for classical appetitive conditioning. Specifically, does the traditional account of simple excitatory and inhibitory generalization adequately integrate the findings in classical appetitive conditioning or are notions involving motivational effects of nonreinforcement indicated? Accordingly, to assess the effects of cue similarity on classical appetitive conditioning, the present study used the separate-phase differential conditioning procedure of asymptotic acquisition training to a 600-Hz tone followed by four independent manipulations of cue similarity: CS- tone frequency values of 600, 1000, and 2100 Hz, and a condition with no CS- presentations (i.e., a continuous-reinforcement group). The separate-phase design was chosen over the single-phase differential conditioning paradigm because it permits, in terms of Hull-Spence theory, a more analytic evaluation of the generalization of excitation and the effects of the subsequent build-up and generalization of inhibition. Additionally, the seprate-phase design is more similar to some operant procedures which have produced behavioral contrast in that they involve stabilizing responding to the positive cue before the negative cue is introduced (e.g., Hanson, 1959).

Method

Subjects

The Ss were 48 albino rabbits (oryctolagus cuniculus) weighing about 2 kg each and were 80-100 days old when purchased form Morrison's Rabbitry, West Liberty, Iowa. Upon arrival, the animals were individually caged and given free access to food and water.

Apparatus

The apparatus and recording technique were the same as that described by Mitchell and Gormezano (1970) who detail departures from earlier procedures (Smith, DiLollo, & Gormezano, 1966). Twelve ventilated conditioning chambers were provided by the modification of four 3-drawer legal-sized, fire-proof filing cabinets. The front inside panel of each chamber contained a 6.35-cm. speaker located midway between two 230-V, 10-W incandescant lamps. The latter were mounted behind diffusion glass and produced 4.3 foot-candles of interior illumination.

A Plexiglas box, designed to restrain rabbits, was equipped with a headstock and back plate which were adjustable, and a foam-padded pinnea clamp (cf. Fig. 1 of Mitchell & Gormezano, 1970). The restrained S was fitted with headmount supporting a transducer for recording jaw movements and a Luer-Lock coupler for water delivery to S's oral cavity. The Plexiglas box, containing the restrained S, was placed in the conditioning chamber such that S's head was about 20.32 cm from the stimulus panel.

The jaw-movement transducer consisted of an opaque rectangular flag mounted on a wire axis which was interposed between a small light source and a phototransistor. A length of angled piano wire, connected to the axle, was inserted into a permanent wound-clip applied to the tip of the S's lower jaw. Jaw movements resulted in flag rotation which produced a variation in the amount of light transmitted to the phototransistor. An electrical signal produced by the resulting conductance changes in the phototransistor was amplified and recorded in an adjoining room on an Offner six-channel, ink-writing oscillograph.

Distilled water, which served as the US, was contained in 12 stainless steel reservoirs pressurized at 10 psi above atmospheric pressure. The US delivery system consisted of tubing running from the output of the reservoirs, through sound-proofed solenoid valve junctions, into the conditioning chambers where it was attached to the Luer-Lock junction on the S's headmount. A 15.24 cm length of .3175-cm diameter Tygon tubing connected to the Luer-Lock junction, terminated in a blunted (No. 16) hypodermic needle which was inserted into a permanently implanted fistula in the S's cheek. The US was a pulsed delivery of 3 cc of water into the S's oral cavity, with each individual pulse consisting of a 1-cc squirt delivered over a .3-sec interval. The interval between each successive 1-cc squirt was .45 sec, and provided an almost uninterrupted stream of water. Thus the total duration of the US was 1.8 sec.

Tones of 600, 660, 1000, and 2100 Hz, employed as CSs, had durations of 500 msec and were delivered through the speaker at the front of each conditioning chamber. The tones yielded a sound pressure level, as measured by the B scale of a General Radio sound level meter, of 62 dB (re .0002 dynes/cm^2) which was 6 dB above the background sound level produced by a white noise generator.

The twelve conditioning chambers were divided into two equal squads, each squad received its trials during the intertrial intervals of the other. A punched paper tape fed through a Western Union transmitter programmed intertrial intervals and receipt of the stimuli whose durations were controlled by an Iconix timebase (Model 6255), preset controller (Model 6010), and storage/relay unit (Model 6087).

Procedure

On the fifth day following arrival, the Ss were anesthetized by an intraperitoneal injection of sodium pentabarbitol (50 mg/ml). A small hole length was punched in the S's depilated left cheek. A short length of polyethelene tubing (PE 240), which had been heat flared on one end and a polyethelene washer attached, was passed through the punched hole of the cheek from the inside such that the flared end and washer were flush against the inside cheek. An additional polyethelene washer (.794-cm OD) was attached to the protruding tubing which was then heat flared to permanently secure the cannula. A 9-mm stainless steel wound-clip was then applied to the tip of S's lower jaw.

After a 48-h recovery period, the rabbits were restricted to

90 cc of water per day for the duration of the experiment. Prior to the availability of water on the fourth day, the rabbits were adapted to the apparatus and their base rate of jaw movements recorded at times corresponding to the observation intervals of subsequent acquisition sessions. Acquisition training began on the following day.

Design

Twelve _S_s were randomly assigned to each of four groups. In Phase I (acquisition phase), all groups received identical acquisition training with a 600-Hz CS. The acquisition phase involved eight reinforced (i.e., CS-US) trials per daily session for fourteen consecutive days.

During the subsequent 24 days of Phase II (differential-conditioning phase), all groups continued to receive eight reinforced trials per session with the 600-Hz tone (i.e., CS_1). The between _S_ manipulation of cue similarity involved eight nonreinforced presentations of a different tonal frequency (i.e., CS_2) of 660, 1000, and 2100 Hz, for three differential-conditioning groups (Groups 660, 1000, 2100) while the fourth group (Group N) received no nonreinforced stimuli and thus merely involved a continuation of its (eight CS_1-US trials per daily session) acquisition training procedure. The order of CS_1 and CS_2 presentations was randomly varied with the restriction that not more than three trials of one type could occur consecutively and involved intertrial intervals of 2.0, 2.5, and 3.0 min with a mean of 2.5 min. Group N in Phase II, as well as all groups in Phase I, received the eight reinforced trials per session at intertrial intervals which mirrored the intervals between CS_1 trials during Phase II. Thus, the intervals between reinforced trials were equated across both phases as well as across the four treatment conditions.

Throughout the experiment, the CS-US interval was 500 msec which was also the duration of the CS on both reinforced and non-reinforced trials. Deflections of the recording pens of at least 1 mm from baseline (corresponding to .3 mm of jaw movement) occurring during the 500 msec interval following CS onset were recorded as CRs.

Results

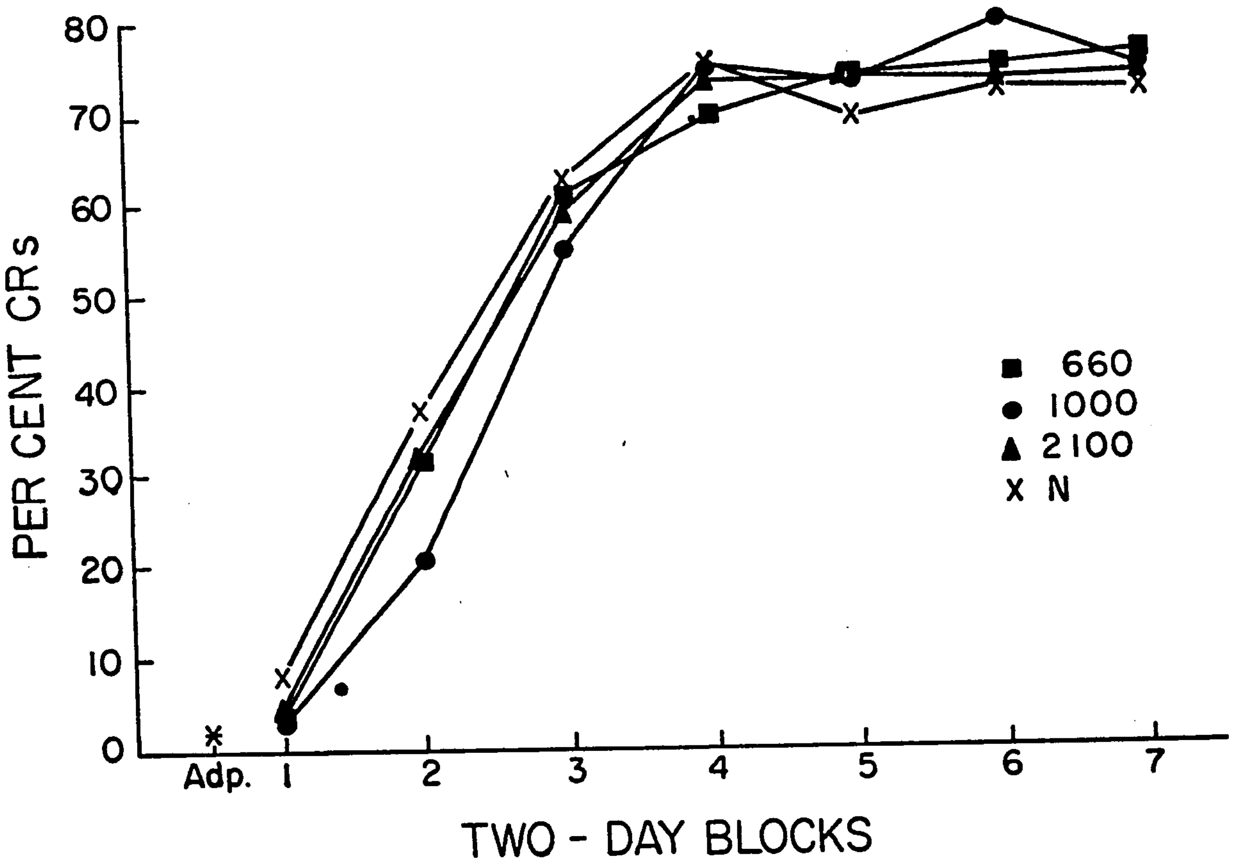
Phase I

CR Frequency. Figure 1 portrays, for each group, base-rate responding on the adaptation day and the percentage CRs during acquisition training over seven, two-day blocks. The figure reveals that adaptation-day responding did not exceed 2% and that the groups exhibited quite similar acquisition functions. For all groups, responding increased quickly and uniformly over the early portion of acquisition and response levels of about 74% were attained by the fourth block and maintained during the remaining acquisition phase. On the last day-block, nearly identical CR levels of 76.7%, 75.0%, 74.8%, and 72.7% were exhibited by Groups 660, 1000, 2100, and N, respectively. Moreover, in terms of mean overall levels of responding during acquisition, the largest difference between groups was 2.3% (54.5% vs. 56.7% for Groups 1000, and N, respectively).

An analysis of variance of the percentage CR data with Groups as a "dummy" variable supported the observation of comparable acquisition performance. Thus, while Days was a significant source of variance, neither the Groups nor the Groups X Days effect was significant (see Table 1). To assess whether asymptotic (i.e., stable) and comparable response levels had been attained, an additional analysis of variance was performed on the percentage CR data of the last four, two-day blocks of acquisition. The analysis revealed that neither the Days, Groups, nor the Day X Groups effect was significant ($\underline{F}$s $<$ 1) and thus, supports the observation that asymptotic performances as well as comparable performance among groups had obtained.

Figure 2 presents, for each group, mean percentage CRs over four within-session blocks during acquisition. The figure reveals that each group displayed relatively stable within-session responding; yet, a pattern can be discerned which involved an initial slight increment followed by a more pronounced, but still slight, within-session decrement. The analysis of variance presented in Table 1 supports the observation of comparable within-session performance in that the Group X Blocks effect was not significant. However, as Table 1 reveals, overall within-session variation (Blocks) was significant. Subsequent trend analyses of these overall mean within-session percentages yielded a significant downward linear component ($\underline{F} = 5.64$; $\underline{df} = 1, 132$; $\underline{p} < .05$) and revealed that the quadratic and the cubic components were not significant.

Figure 1. Mean percentage CRs for each group on adaptation day and as a function of two-day blocks during the first phase: Exp. I.


80
70
60
50
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0
PER CENT CRs
Adp.
1
2
3
4
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6
7
TWO - DAY BLOCKS
■ 660
● 1000
▲ 2100
X N

Figure 1

Table 1

Analysis of Variance of Percentage CRs in Phase I
With Groups, Day-Blocks, and Within-Session
Blocks as Factors: Exp. I

Source	df	MS	F
Between:			
Groups (G)	3	.03195	.994
Error (b)	44	1.24642	
Within:			
Days (D)	6	14.76043	131.51**
D X G	18	.06560	.58
Error (w_1)	264	.11224	
Blocks (B)	3	.22814	3.75*
B X G	9	.03637	.60
Error (w_2)	132	.06083	
B X D	18	.09194	2.64**
B X D X G	54	.03094	.89
Error (w_3)	792	.03476	

** $p < .01$

* $p < .05$

Figure 2. Mean overall percentage CRs for each group as a function of four within-session blocks during the first phase: Exp. I.

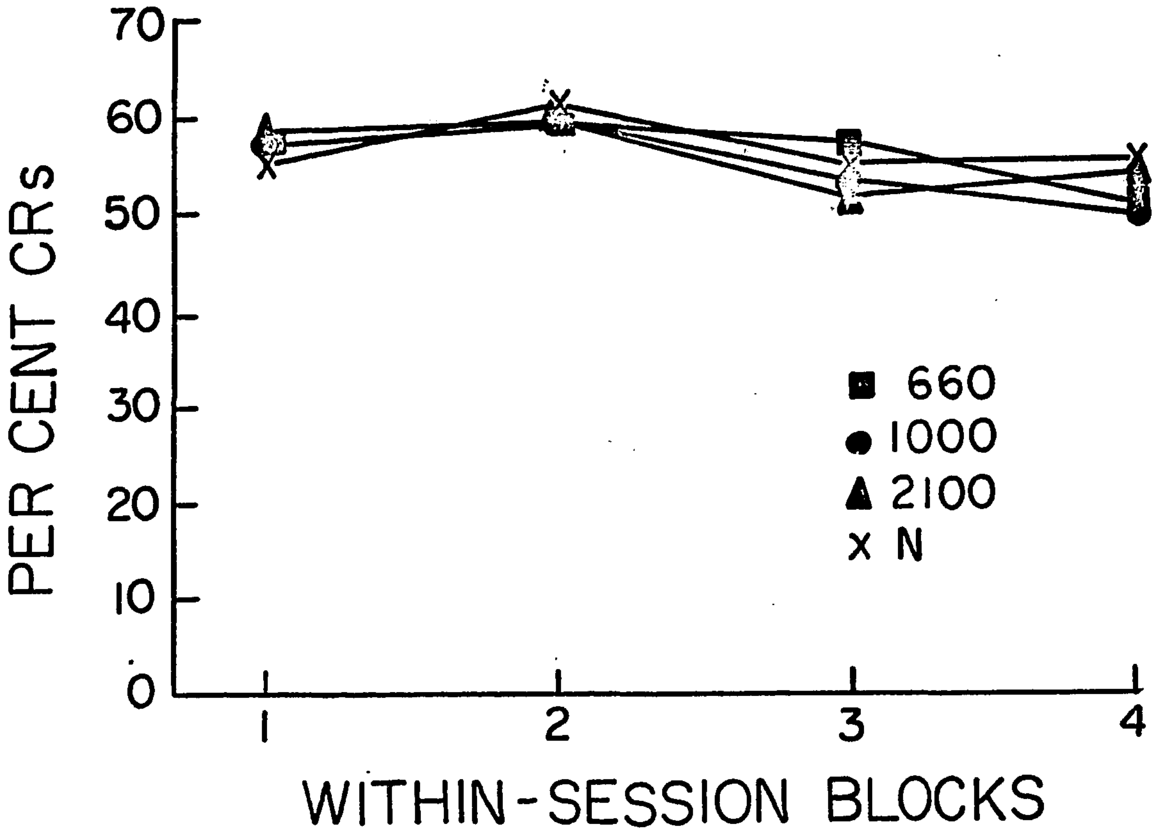
70
60
50
40
30
20
10
0
PER CENT CRs
1
2
3
4
WITHIN-SESSION BLOCKS
■ 660
● 1000
▲ 2100
x N

Figure 2

CR Onset Latency. The mean CR onset latencies of each group as a function of the last three, four-day blocks of acquisition are presented in Figure 3 (the first two days are omitted due to the very low levels of responding). The figure reveals nearly identical CR latency decreases over training for all groups. The same features are revealed in Figure 4 which presents the group frequency distributions of CR latencies for the last three, four-day blocks. An analysis of variance, with Groups as a "dummy" variable (see Table 2) supported the observation of a comparable decrease in CR latency over training in that the Days effect was significant while the Groups and Groups X Days effects were not. The finding that CR latency decreased over training is consistent with previous observations with the jaw-movement response (e.g., Mitchell & Gormezano, 1970; Smith, DiLollo, & Gormezano, 1966).

Phase II

CR Frequency. Figure 5 presents mean overall percentage CRs to the reinforced (CS_1) and nonreinforced (CS_2) stimuli as a function of CS_2 tonal frequency during the second phase. In addition, the mean overall percentage CRs for Group N is presented. Looking first at responding to the reinforced stimulus, the figure indicates that overall levels of responding to CS_1 were not substantially, nor systematically, affected by the CS_2 manipulation. Overall response levels for Groups 660, 1000, and 2100 were 78.7%, 70.1%, and 75.6%, respectively. An analysis of variance of CS_1 percentage CR data revealed that overall responding was not reliably different among

Figure 3. For each group, mean CR latency as a function of the last three, four-day blocks during Phase I: Exp. I.

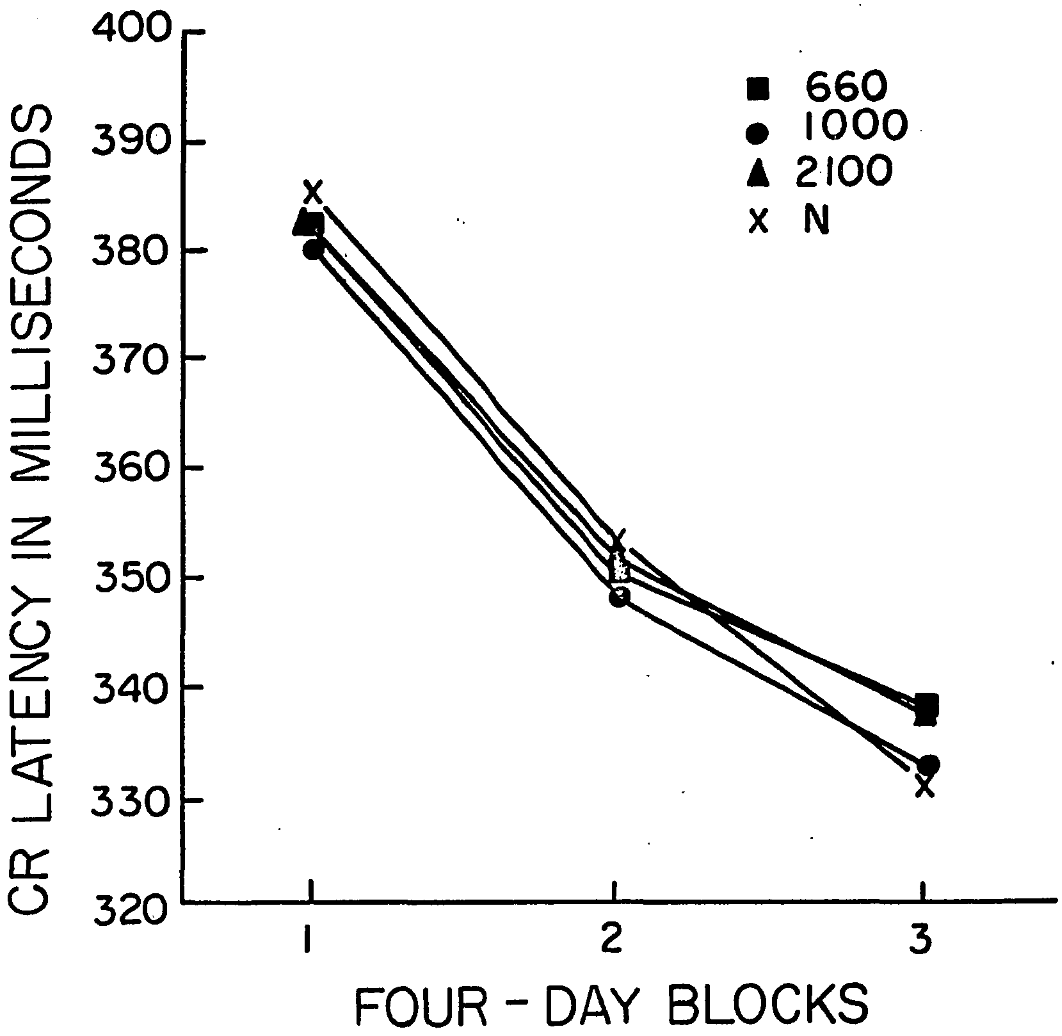
400
390
380
370
360
350
340
330
320
CR LATENCY IN MILLISECONDS
1
2
3
FOUR - DAY BLOCKS
■ 660
● 1000
▲ 2100
x N

Figure 3

Figure 4. Groups frequency distributions of CR latencies for the last three, four-day blocks of the first phase: Exp. I.

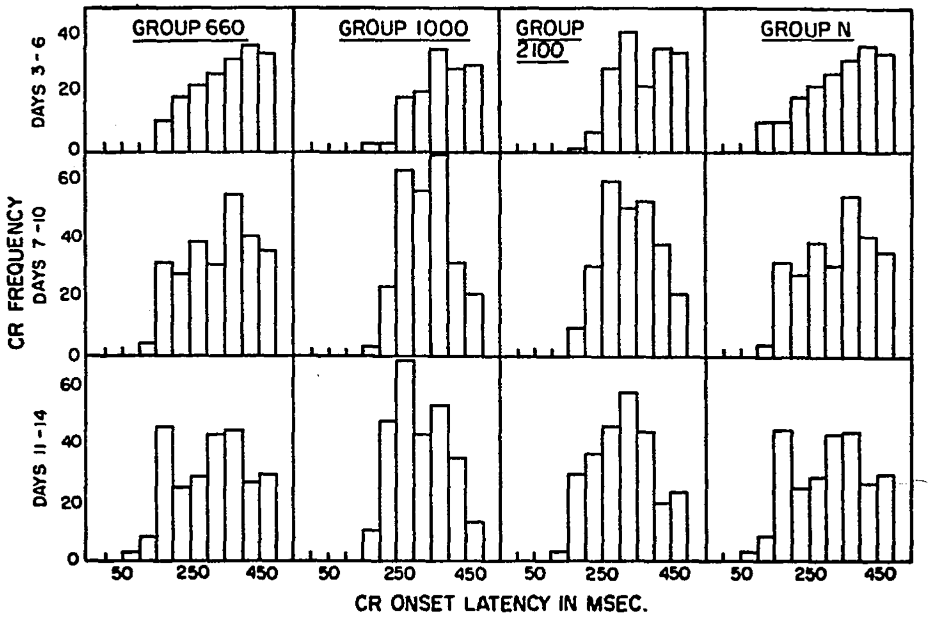
GROUP 660
GROUP 1000
GROUP 2100
GROUP N
CR FREQUENCY
DAYS 3 - 6
DAYS 7 - 10
DAYS 11 - 14
0
20
40
60
50
250
450
CR ONSET LATENCY IN MSEC.

Figure 4

Table 2

Analysis of Variance of CR Onset Latency in Phase I With Groups and Day-Blocks as Factors: Exp. I

SOURCE	df	MS	F
Between:			
Groups (G)	3	142.29140	.01
Error (b)	44	10760.82621	
Within:			
Days (D)	2	34286.49827	45.56**
D X G	6	160.41752	.21
Error (w)	88		

** $p < .01$

* $p < .05$

Figure 5. Mean overall percentage CRs to CS_1 and CS_2 as a function of CS_2 tonal frequency and the mean for Group N during Phase II: Exp. I.

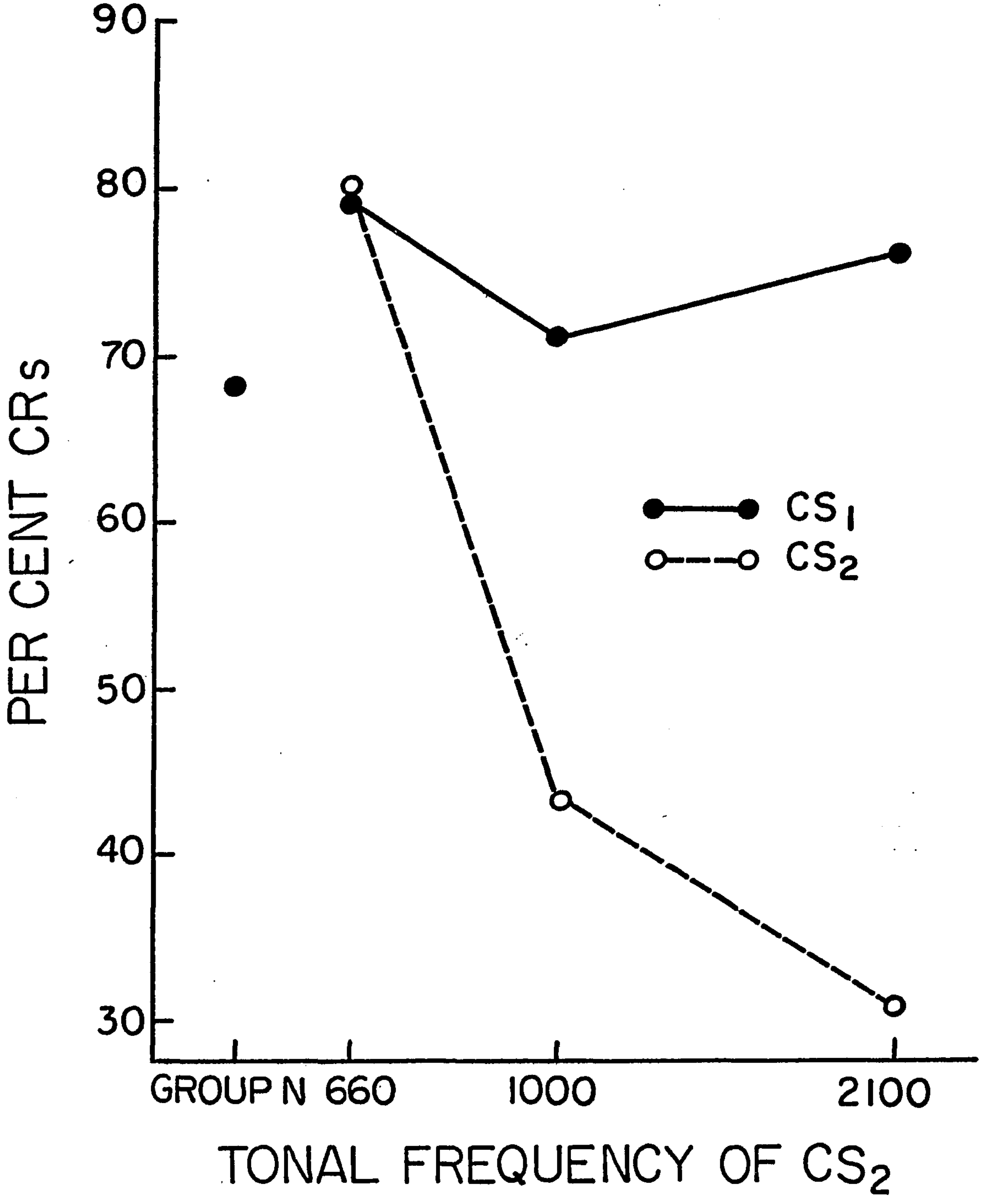
90
80
70
60
50
40
30
PER CENT CRs
GROUP N
660
1000
2100
TONAL FREQUENCY OF CS2
CS1
CS2

Figure 5

the three differential-conditioning groups (see Table 3). In addition, subsequent trend analyses (adjusted for the unequal frequency intervals) revealed that neither the linear nor quadratic components were significant ($Fs < 1$). It can also be noted from Figure 5 that the overall level of responding for Group N (67.8%) was somewhat lower than the CS_1 responding for the differential-conditioning groups. However, an analysis of variance of CS_1 percentage CR data which contrasted Group N with the differential-conditioning groups combined revealed no significant effect (see Table 4). Moreover, a Dunnett's test for multiple comparisons with a control revealed that the overall responding for Group N was not significantly different from the CS_1 responding for any of the three differential-conditioning groups ($ps > .10$).

Looking now at CS_2 performance, Figure 5 reveals that overall responding to CS_2 was directly ordered with stimulus similarity. Overall response levels for Groups 660, 1000, and 2100 were 80.3%, 43.0%, and 30.4%, respectively, and a separate analysis of variance of CS_2 percentage CR data revealed a significant Groups effect (see Table 5). A subsequent trend analysis corroborated the observation that CS_2 performance was directly related to stimulus similarity in revealing a highly significant downward linear component ($F = 17.87$; $df = 1, 33$; $p < .001$).

It is also apparent from Figure 5 that the degree of differentiation (i.e., CS_1 minus CS_2) was related to CS_2 dissimilarity. The mean overall percent differentiation for Group 660, 1000, and 2100

Table 3

Analysis of Variance of Percentage CRs to CS_1 in Phase II With Groups, Day-Blocks, and Within-Session Blocks as Factors: Exp. I

SOURCE	df	MS	F
Between:			
Groups (G)	2	1.08530	.26
Error (b)	33	4.11952	
Within:			
Days (D)	11	.10185	1.94*
D X G	22	.05013	.95
Error (w_1)	363	.05257	
Blocks (B)	3	.69493	11.17**
B X G	6	.05902	.95
Error (w_2)	99	.06220	
B X D	33	.05768	1.96**
B X D X G	66	.03225	1.10
Error (w_3)	1089	.02943	

Table 4

Analysis of Variance of Percentage CRs to CS_1 in Phase II with Group N vs. the Differential-Conditioning Subjects: Exp. I

Source	df	MS	F
Between:			
Groups (G)	1	.04073	.46
Error (b)	46	.08673	

** $p < .01$

* $p < .05$

was -1.6%, 27.1%, and 45.2%, respectively. An analysis of variance on percentage CR data, with CS_1 and CS_2 as a within factor, revealed that the CS_1/CS_2 X Groups effect was significant (see Table 6). Subsequent analyses of simple effects indicated that significant differentiation occurred in Groups 1000 and 2100 ($\underline{F}$s = 36.28 and 100.93, respectively; $\underline{df}$ = 1, 11; $\underline{p}$s $<$ .01), but not in Group 660 ($\underline{F} < 1$). A trend analysis on CS_1 minus CS_2 difference scores provided direct support that differentiation was ordered with CS_2 dissimilarity by revealing a highly significant upward linear component ($\underline{F}$ = 44.98; $\underline{df}$ = 1, 33; $\underline{p} < .001$).

Figure 6 presents mean percentage CRs, for each group, for the last, two-day block of acquisition, and to CS_1 and CS_2 as a function of twelve, two-day blocks during the second phase. Looking first at CS_1 responding, examination of the left portion of the figure reveals that there was a slight, between-phase decrement (i.e., between the last Phase-I block and the initial Phase-II block) for the differential conditioning groups. Groups 660, 1000 and 2100 exhibited between-phase decrements of 9.3%, 8.8%, and 1.2%, respectively. An analysis of variance of these percentage CR data for the differential-conditioning groups indicated that the between-phase decrement was significant (i.e., a significant Days effect, see Table 7). Figure 6 suggests that the degree of between-phase decrement was related to CS_2 similarity. However, a trend analysis based on the between-phase difference scores revealed that the linear component was not significant ($\underline{F}$ = 1.73; $\underline{df}$ = 1, 33; $\underline{p} < .05$). As can be noted from Figure 6, the differential-conditioning groups showed a between-phase decrement while Group N's responding

Table 5

Analysis of Variance of Percentage CRs to CS_2 in Phase II With Groups, Day-Blocks, and Within-Session Blocks as Factors: Exp. I

Source	df	MS	F
Between:			
Groups (G)	2	38.73341	12.66**
Error (b)	33	3.05980	
Within:			
Days (D)	11	0.32060	4.62*
D X G	22	0.19311	2.78**
Error (w_1)	363	0.06938	
Blocks (B)	3	1.21456	23.08**
B X G	6	0.02486	0.47
Error (w_2)	99	0.05263	
B X G	33	0.05349	1.48*
B X D X G	66	3.21812	1.35*
Error (w_3)	1089	0.03624	

** $\underline{p} < .01$

* $\underline{p} < .05$

Table 6

Analysis of Variance of Percentage CRs in Phase II With Groups, CS_1/CS_2, Day-Blocks, and Within-Session Blocks as Factors: Exp. I

Source	df	MS	F
Between:			
Groups (G)	2	23.82379	3.61*
Error (b)	33	6.59639	
Within:			
CS_1/CS_2 (C)	1	48.02903	82.39**
C X G	2	15.99493	27.44**
Error (w_1)	33	.58293	
Days (D)	11	.13460	1.92*
D X G	22	.15717	2.24**
Error (w_2)	363	.07012	
Blocks	3	1.87224	28.81**
B X G	6	.03327	.51
Error (w_3)	99	.06499	
C X D	11	.28785	5.55**
C X D X G	22	.08608	1.66*
Error (w_4)	363	.05183	
C X B	3	.03725	.75
C X B X G	6	.05061	1.02
Error (w_5)	99	.04983	

Table 6 continued

Source	df	MS	F
D X B	33	.06047	1.78**
D X B X G	66	.04511	1.33*
Error (w_6)	1089	.03398	
C X D X B	33	.05070	1.60*
C X D X B X G	66	.03590	1.13
Error (w_7)	1089	.03168	

** $p < .01$

* $p < .05$

increased slightly (1.8%). However, an analysis of variance on the between-phase difference score which contrasted Group N with the differential-conditioning groups combined indicated no significant effect (see Table 8). In addition, a Dunnett's test for multiple comparisons with a control indicated that the between-phase performance for Group N did not significantly differ from the performance of any of the differential-conditioning groups ($ps > .10$).

An examination of Figure 6 also suggests that subsequent to the initial Phase-II block, CS_1 responding remained relatively stable over the second phase of training. An analysis of variance of these CS_1 percentage CR data during the second phase for the differential-conditioning groups revealed, however, a significant Days effect (see Table 3). Subsequent linear trend analyses over all twelve day-blocks for each differential-conditioning group revealed a significant upward linear component for Group 660 ($F = 13.74$, $df = 1, 363$; $p < .01$), but indicated that the linear components for Groups 1000 and 2100 were not significant ($Fs = 2.42$ and 1.63, respectively; $df = 1, 363$; $ps > .05$).

Looking now at CS_2 responding, Figure 6 reveals that Groups 1000 and 2100 displayed an increase in CS_2 responding over the initial three day-blocks and then exhibited a general decrease over subsequent training sessions. In contrast, CS_2 responding for Group 660 involved a slight and gradual increase over training sessions. An analysis of variance of these CS_2 percentage CR data corroborated the

Figure 6. Mean percentage CRs, for each group, for the last, two-day block of acquisition, and to CS_1 and CS_2 as a function of two-day blocks during Phase II: Exp. I.

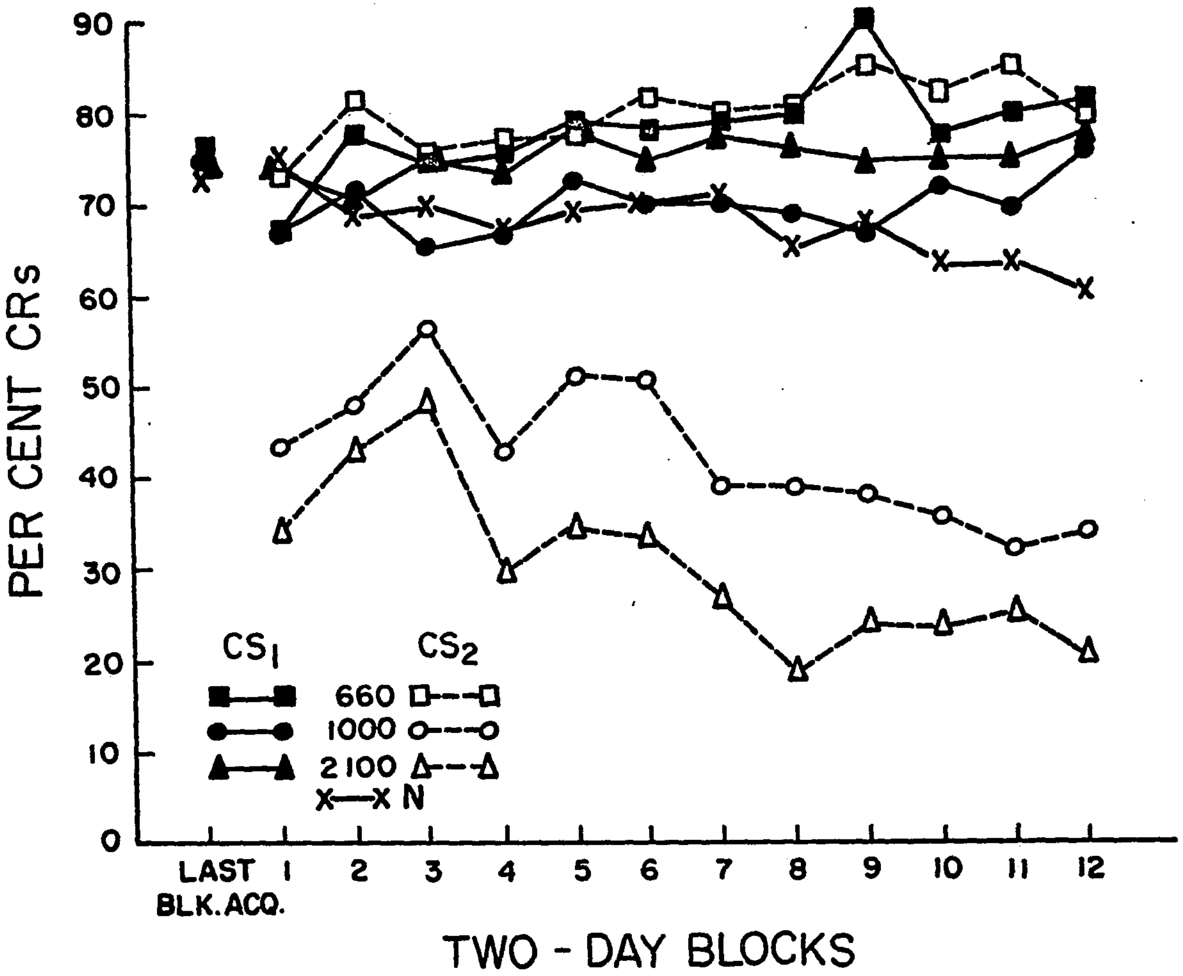
PER CENT CRs
90
80
70
60
50
40
30
20
10
0
LAST BLK.ACQ.
1
2
3
4
5
6
7
8
9
10
11
12
TWO - DAY BLOCKS
CS1
CS2
660
1000
2100
N

Figure 6

Table 7

Analysis of Variance of Percentage CRs to CS_1 on the Last Day-Block of Phase I and the First Day-Block of Phase II With Groups, Day-Blocks, and Within-Session Blocks as Factors: Exp.I

SOURCE	df	MS	F
Between:			
Groups (G)	2	.02462	.04
Error (b)	33	.63353	
Within:			
Days (D)	1	.27093	5.36*
D X G	2	.04502	.89
Error (w_1)	33	.05051	
Blocks (B)	3	.36703	6.79**
B X G	6	.01954	.36
Error (w_2)	99	.05409	
B X D	3	.07006	2.35
B X D X G	6	.04920	1.65
Error (w_3)	99	.02976	

** $\underline{p} < .01$

* $\underline{p} < .05$

Table 8

Analysis of Variance of Between-Phase Difference scores with Group N vs. the Differential-Conditioning Subjects: Exp. I

SOURCE	df	MS	F
Between:			
Groups	1	.10709	3.68
Error (b)	46	.02903	

** $\underline{p} < .01$

* $\underline{p} < .05$

observations of differential performance over training in that the Days X Groups effect was significant (see Table 5). Subsequent linear trend analyses over all twelve day-blocks revealed a highly significant downward linear component for Groups 1000 and 2100 (Fs = 24.89, and 37.71, respectively, dfs = 1, 363; $ps < .001$) and a significant upward linear component for Group 660 ($F = 5.11$; df = 1, 363; $p < .05$). Additional trend analyses over the twelve day-blocks revealed that the curvilinear component (i.e., deviation from linearity) was significant for Group 2100 ($F = 2.20$; df = 10, 363; $p < .01$) marginally significant for Group 1000 ($F = 1.72$; df = 10, 363; $p < .10$) and did not approach significance for Group 660 ($F < 1$).

As can be noted from Figure 6, the initial increase in CS_2 responding for Groups 1000 and 2100 was quite marked. On the first, second, and third two-day block, Group 1000 exhibited increasing response levels of 43.9%, 48.4%, and 56.6%, respectively. Group 2100 displayed response levels of 34.2%, 43.4%, and 48.3%, for the first, second, and third two-day block, respectively. This observation of an initial increase in CS_2 responding for Groups 1000 and 2100 was provocative in view of the corresponding stability of CS_1 performance and appeared to resemble a phenomemon frequently noted by Pavlov (1927). Accordingly, while realizing the interpretive cautions necessitated, linear trend analyses were performed on these CS_2 data over the initial three day-blocks of differential conditioning. These analyses revealed significant upward linear components for Groups 1000 and 2100

(Fs = 5.58 and 6.87, respectively; dfs = 1, 363; ps $< .025$) but none for Group 660 ($F < 1$). Parallel linear trend analyses were performed on the CS_1 data for the corresponding initial three day-blocks of Phase II and these analyses indicated that the linear components were not significant for any of the three groups (Fs = 2.50, .06, and .16, for Groups 660, 1000, and 2100, respectively; dfs = 1, 363; ps $> .05$).

Considering the effects of training on the degree of differentiation, it is apparent from Figure 6 that discrimination for Groups 1000 and 2100 generally increased over training via decreasing CS_2 performance which contrasts with the virtually complete absence of discrimination for Group 660. This observation was corroborated by analysis of variance in that the CS_1/CS_2 X Days X Groups effect was significant (see Table 6).

Figure 7 portrays within-session effects for each group, through the presenting of mean overall percentage CRs to CS_1 and CS_2, as a function of four within-session blocks during the second phase. It is apparent from the figure that each group function describes a uniformly consistent pattern of a slight within-session decrement. An analysis of variance of CS_1 percentage CR data revealed that the within-session decrement to CS_1 was reliable, but not differential among the three differential-conditioning groups as indexed by a significant Blocks effect and a nonsignificant Blocks X Groups effect, respectively (see Table 3). Similarly, an analysis of

Figure 7. Mean overall percentage CRs for each group to CS_1 and CS_2 as a function of four within-session blocks during Phase II: Exp. I.

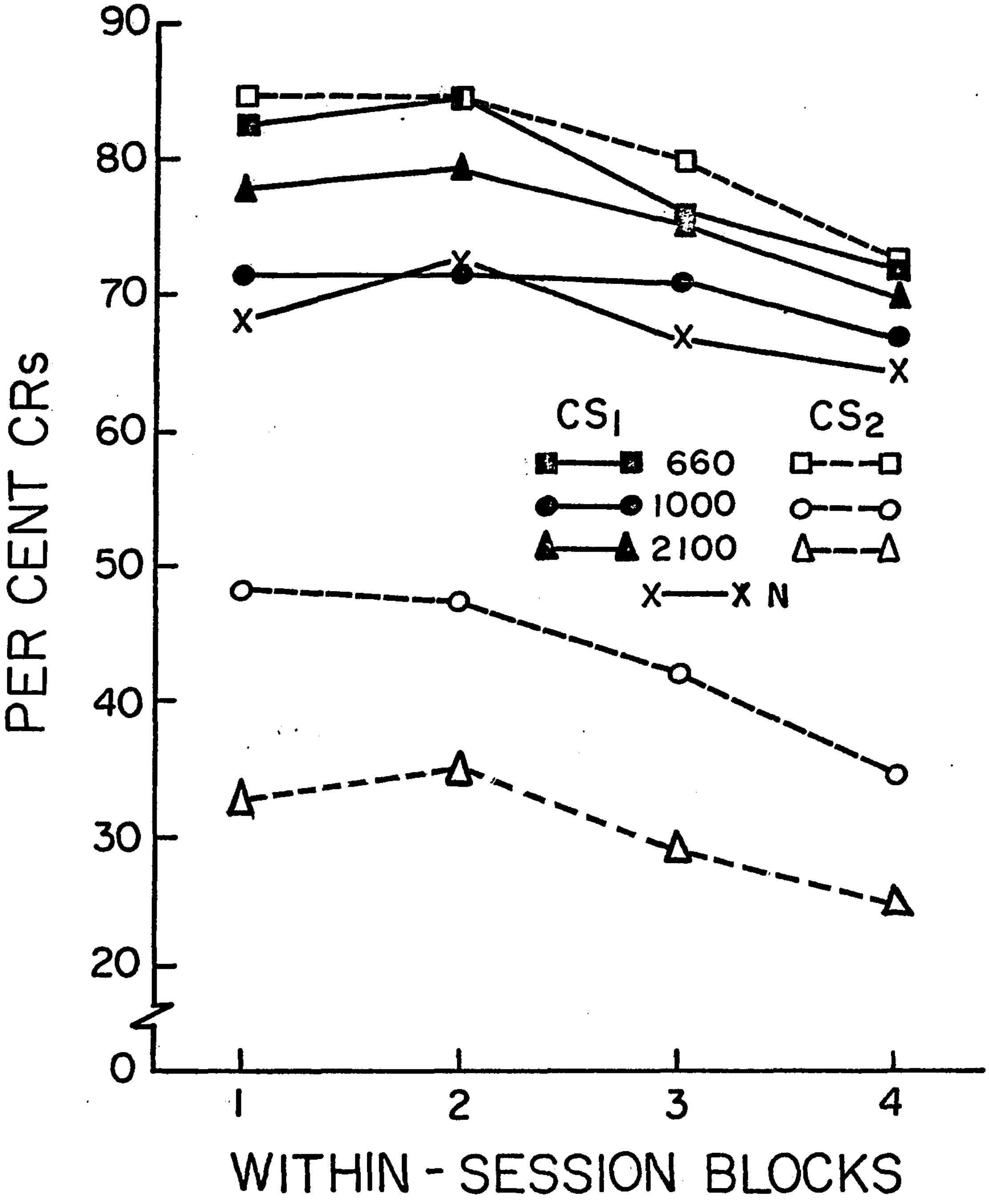
90
80
70
60
50
40
30
20
0
PER CENT CRs
1
2
3
4
WITHIN - SESSION BLOCKS
CS1
CS2
660
1000
2100
N

Figure 7

variance of CS_2 percentage CR data revealed a reliable within-session decrement to the nonreinforced stimulus which was not differential among the three groups (i.e., a significant Blocks effect and a nonsignificant Blocks X Groups effect: see Table 5). Finally, another analysis of variance indicated that CS_1 and CS_2 within-session performance involved a comparable decrement as indexed by a non-significant CS_1/CS_2 X Blocks effect and that this comparability obtained across differential conditioning groups (i.e., a nonsignificant CS_1/CS_2 X Blocks X Groups effect: see Table 6).

CR Onset Latency. Figure 8 presents overall mean CR onset latency to CS_1 and CS_2 as a function of CS_2 tonal frequency and overall mean CR onset latency for Group N. Considering first response latency to the reinforced stimulus, the figure indicates that Groups 660 and 1000 displayed identical mean latencies (294 msec) while Group 2100 exhibited a somewhat longer mean latency (321 msec) and Group N's was intermediate (307 msec). An analysis of variance of these mean CR latencies for the differential-conditioning groups revealed, however, that there were no reliable differences among the three groups (see Table 9). In addition, subsequent trend analysis on these CS_1 data over tonal frequency indicated that neither the linear nor quadratic components were significant (*F*s < 1). Figure 8 also reveals that overall mean latency to CS_2 was an increasing function of CS_2 tonal frequency with mean latencies of 277, 315, and 339 msec for Groups 660, 1000, and 2100, respectively. However, a separate

Figure 8. Overall mean CR latency to CS_1 and CS_2 as a function of CS_2-tonal frequency during Phase II: Exp. I.

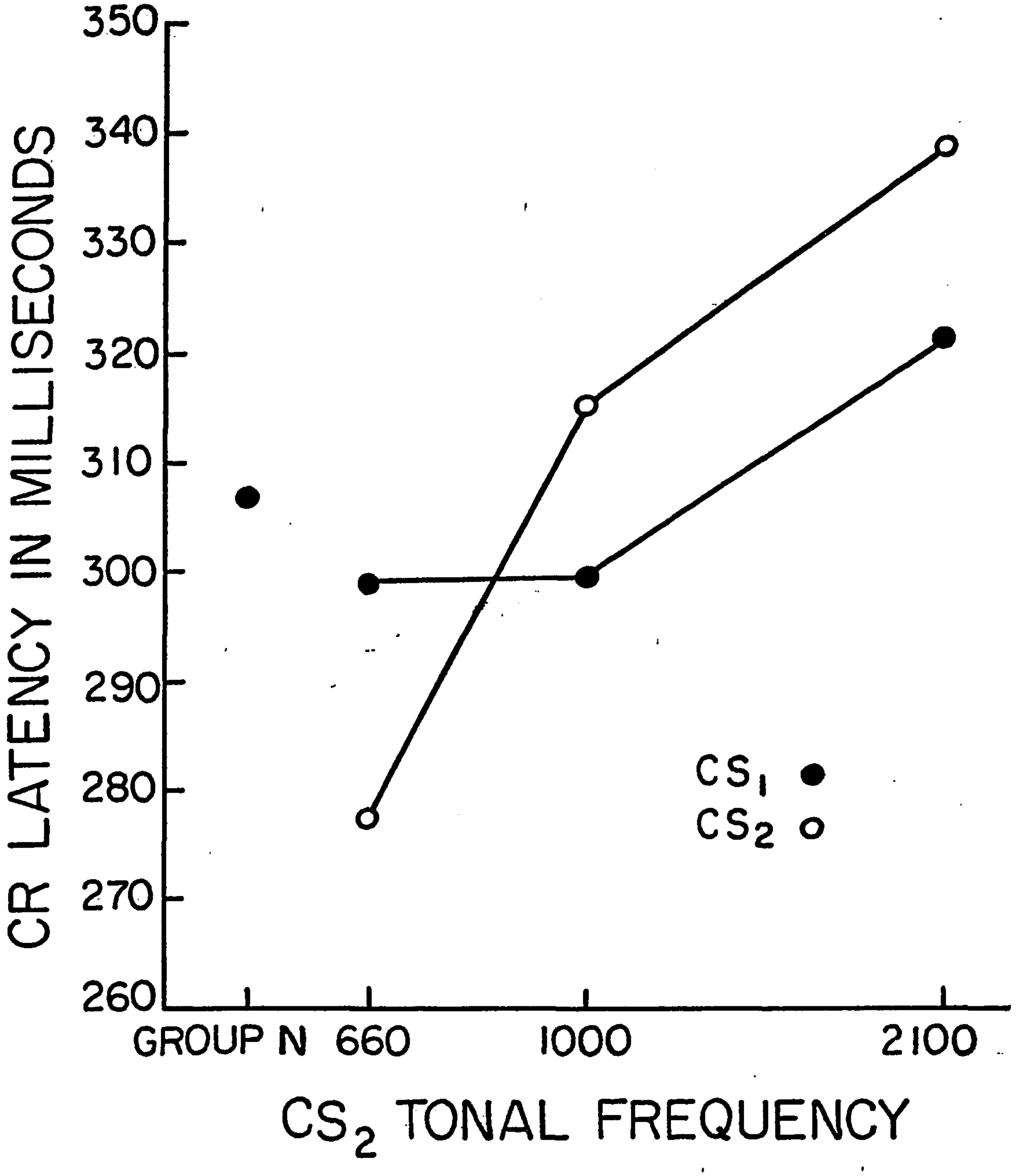
CR LATENCY IN MILLISECONDS
350
340
330
320
310
300
290
280
270
260
GROUP N
660
1000
2100
CS_2 TONAL FREQUENCY
CS_1 ●
CS_2 ○

Figure 8

analysis of variance of the data also revealed no reliable differences as indexed by a nonsignificant Groups effect (see Table 10). Subsequent trend analyses on these CS_2 data also indicated that neither the linear ($\underline{F} = 3.89$; $\underline{df} = 1, 33$; $\underline{p} > .05$) nor the quadratic ($\underline{F} < 1$) components were significant.

Now, turning to differential response latencies between CS_1 and CS_2, Figure 8 reveals that for Group 660, overall mean CR latency was somewhat shorter for CS_2 than CS_1 while the opposite relationship obtained for Groups 1000 and 2100. An analysis of variance which involved CS_1 and CS_2 as a within factor, corroborated the above observation as indexed by a significant Groups X CS_1/CS_2 effect (see Table 9). Subsequent analyses of simple effects revealed however, that differential CS_1 and CS_2 response latencies were not reliable in any of the three groups ($\underline{F}$s = 2.34, 3.70, and 2.69, for Groups 660, 1000, and 2100, respectively; $\underline{df} = 1, 11$; $\underline{p}$s $> .05$).

The top panel of Figure 9 presents, for each of the four groups, mean CR onset latency to the reinforced stimulus as a function of three, eight-day blocks during the second phase. (The data are also presented in Figure 10 in group-distribution form). It is apparent from Figure 9 that Groups N and 2100 showed a slight decrease in CR latency over training while Groups 660 and 1000 showed a more pronounced initial decrease followed by a slight increase. An analysis of variance of the data for the differential-conditioning groups indicated that the decrease in CR latency over training was reliable as indexed by a significant Days effect (see Table 9). However, the

Figure 9. For each group, mean CR latency to CS_1 (top panel) and to CS_2 (bottom panel) as a function of eight-day blocks during Phase II: Exp. I.

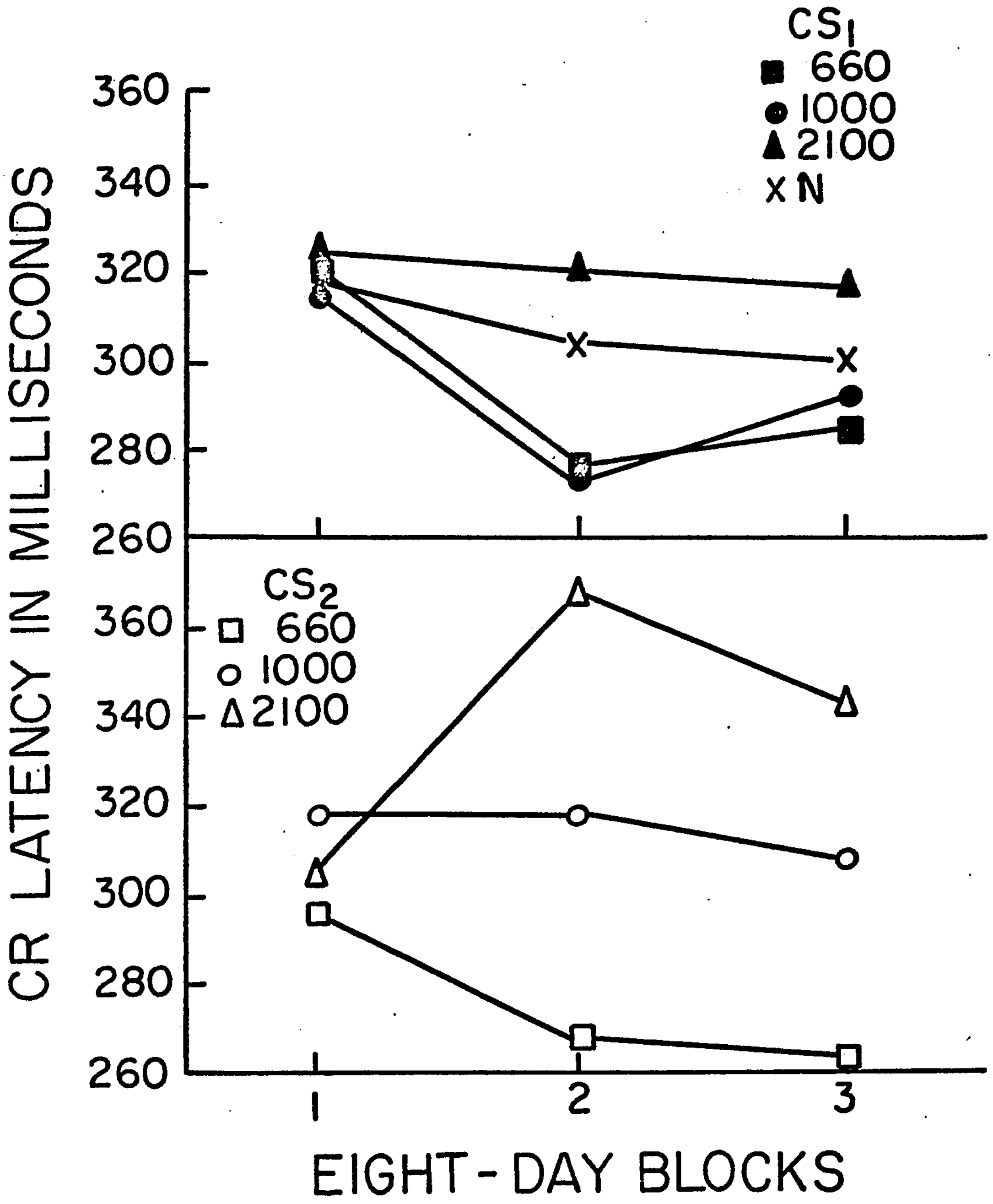
CS1
■ 660
● 1000
▲ 2100
x N
CS2
□ 660
○ 1000
Δ 2100
360
340
320
300
280
260
CR LATENCY IN MILLISECONDS
1
2
3
EIGHT-DAY BLOCKS

Figure 9

Figure 10. Group frequency distributions of CR latencies for eight-day blocks during Phase II: Exp. I.

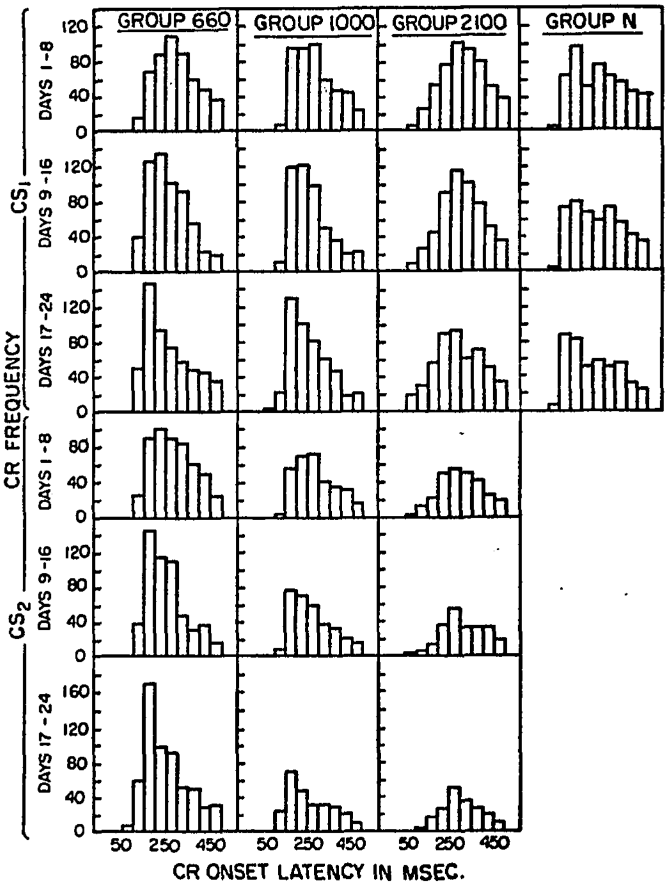
GROUP 660
GROUP 1000
GROUP 2100
GROUP N
CS1
CS2
CR FREQUENCY
DAYS 1-8
DAYS 9-16
DAYS 17-24
0
40
80
120
160
50
250
450
CR ONSET LATENCY IN MSEC.

Figure 10

Table 9

Analysis of Variance of CR Onset Latency to CS_1 in Phase II With Groups and Day-Blocks as Factors: Exp.I

SOURCE	df	MS	F
Between:			
Groups (G)	2	8703.52738	.45
Error (b)	33	19178.76898	
Within:			
Days (D)	2	7776.14780	6.30**
D X G	4	1487.61123	1.21
Error (w)	66	1233.74424	

** p <.01

* p <.05

Table 10

Analysis of Variance of CR Onset Latency to CS_2 in Phase II With Groups and Day-Blocks as Factors: Exp. I

Source	df	MS	F
Between:			
Groups (G)	2	34793.51861	2.36
Error (b)	33	14761.15675	
Within:			
Days (D)	2	1992.90218	.80
D X G	4	7359.22782	2.96*
Error (w)	66	2489.72732	

** $p < .01$

* $p < .05$

Table 11

Analysis of Variance of CR Onset Latency in Phase II With Groups, CS_1/CS_2, and Day-Blocks as Factors: Exp. I

Source	df	MS	F
Between:			
Groups (G)	2	35641.93956	1.12
Error (b)	33	31807.66357	
Within:			
CS_1/CS_2 (C)	1	2940.96926	1.38
C X G	2	7855.10643	3.68*
Error (w_1)	33	2132.26216	
Days (D)	2	2578.66550	1.21
D X G	4	7482.53485	3.51*
Error (w_2)	66	2130.34595	
C X D	2	7190.38448	4.51*
C X D X G	4	1364.30420	.86
Error (w_3)	66	1593.12561	

** $p < .01$

* $p < .05$

graphical suggestion of a differential decrease over training was not reliable as evidenced by a nonsignificant Days X Groups effect (see Table 9).

The bottom panel of Figure 9 presents, for each differential conditioning group, mean CR onset latency to CS_2 as a function of three, eight-day blocks. (This data is also presented in group-distribution form in Figure 10). Generally, Figure 9 indicates that CR latency decreased over training for Group 660, increased for Group 2100, and remained relatively stable for Group 1000. An analysis of variance of these CR onset data supported the above observation as indicated by a nonsignificant Days effect and a significant Groups X Days interaction (see Table 10). In addition, an analysis of variance of the CR onset data of the differential conditioning groups, which involved CS_1 and CS_2 as a within factor, revealed that the CS_1/CS_2 X Days effect was significant (see Table 11).

Discussion

The primary findings of the present experiment for separate-phase differential conditioning were: (a) responding to the reinforced cue was unaffected by the degree of cue similarity and was not depressed relative to a control condition which continue to receive single-cue continuous reinforcement; (b) responding to the nonreinforced cue was positively related to the degree of cue similarity which primarily accounted for the additional observation that the degree of differentiation was an inverse function of cue similarity;

(c) responding to the negative cue generally decreased over differential-conditioning training for Groups 1000 and 2100 while a corresponding decrease in responding to the positive cue did not obtain; and (d) responding to the negative cue for Groups 1000 and 2100 increased over initial differential-conditioning training despite prior asymptotic training to the positive cue, although this finding was supported by *a posteriori* analyses.

The present findings for CS_1 responding are not in accord with Hull-Spence discrimination theory (Hull, 1943; Spence, 1937). According to the theory, differential conditioning involves the development of inhibition to the negative cue which generalizes in proportion to stimulus similarity to the positive cue and results in a proportional reduction in CS_1 net response strength. The generalization-of-inhibition axiom also requires that differential conditioning will result in decremented CS+ responding, relative to CS+ responding under continuous reinforcement. Thus, for the present experimental parameters, Hull-Spence theory predicts the following relative ordering on CS_1 responding: $N > 2100 > 1000 > 660$. The present experiment found no significant differences between CS_1 performance among the four conditions and even the ordering on overall CS_1 response levels were not in the predicted direction: 660 (78.7%), 2100 (75.6%), 1000 (70.1%), and N (67.8%). Similarly, there were no significant differences on CS_1 onset latencies and their relative ordering were also not in the predicted direction: 660 (293.8 msec), 1000 (294.1 msec), N (306.7 msec) and 2100 (320.9 msec). In light of this absence of support for Hull-Spence theory, the theoretical boundary conditions for adequately assessing generalization-of-inhibition effects merit brief discussion. An obvious requirement is that the amount of differential-conditioning training be sufficient to ensure the build-up of inhibition to the negative cue. The present finding of a general decrease in CS_2 responding during the 24 days of differential conditioning for Groups 1000 and 2100 (statistically confirmed by significant linear downward trend components over day-blocks) is presumptive evidence, in terms of Hull-Spence theory, that inhibitory conditioning to the negative cue had occurred. Peak CS_2 responding (on the third day block) for Groups 1000 and 2100 was 56.5% and 48.3%, respectively, which decreased respectively, to 34.5% and 20.5% on the last day block. In spite of this evidence of inhibitory conditioning to CS_2, there was no indication of decrementing CS_1 performance over differential-conditioning training. An additional requirement for detecting a decremental effect of generalized inhibition is that the cues are sufficiently similar to ensure that inhibitory generalization does, in fact, obtain. The present range of differences between the cues (60-, 400-, and 1500 Hz) were comparable to those used in classical aversive conditioning investigations whose results clearly support Hull-Spence theory (e.g., Frey, 1967; Homzie, 1968). In short, the present failure to detect the predicted generalization-of-inhibition effects apparently cannot be attributed to inappropriate parameters. As previously indicated, the present CS_1 findings are at variance with those from separate-phase differential classical aversive studies which have all involved human Ss (e.g., Gynther, 1957; Homzie, 1968) and clearly supported the generalization-of-inhibition axiom of Hull-Spence theory.

The present CS_1 findings also provide little basis for invoking a frustration-based motivational construct in differential classical appetitive conditioning. There was no significant indication of effects analagous to positive behavioral contrast in instrumental appetitive conditioning (i.e., substantially enhanced S+ responding following the introduction of differential conditioning). Conceivably, a frustration theorist could argue that response-enhancing motivational effects were equal to the decrementing effects of nonreinforcement, thus resulting in no significant performance variation among the conditions. However, given the range of cue similarity in the present study, such a suggestion is not persuasive.

As previously noted, classical appetitive conditioning has been a neglected experimental area. Consequently, considerations of why increased cue similarity decrements CS_1 responding in classical aversive conditioning, but does not affect CS_1 responding in classical appetitive conditioning are necessarily highly speculative. Nevertheless, a finding from a previous study with the rabbit's jaw-movement response (Holmes & Gormezano, 1971) which involved a contrast between partial and continuous reinforcement is suggestive. The Holmes and Gormezano (1971) study found that 50% partial reinforcement produces lower asymptotic responding than does continuous reinforcement. This finding is consonant with Hull-Spence discrimination theory since partial reinforcement is analyzed as the limiting case of cue similarity (i.e. , identity). However, Group 660 in the present experiment, which did not show discrimination and can thus be viewed at one level as functionally equivalent to a 50% partial reinforcement condition, exhibited no indication of depressed asymptotic performance relative to the continuous reinforcement contrast control. A salient procedural difference was the present use of prior acquisition training with continuous reinforcement. The general implication for differential classical appetitive conditioning is that perhaps extensive prior acquisition training with the positive cue serves to protect its response strength from the decrementing effects of subsequent differential conditioning. An implication of this speculation is that the separate-phase procedures used in classical aversive conditioning investigations did not involve the degree of first phase post-asymptotic training to the positive cue comparable to that employed in the present study. In this regard, it may be noted that separate-phase human classical aversive investigations (e.g., Gynther, 1959; Homzie 1968) have used a single acquisition session and little, if any, post-asymptotic training. This contrasts with the fourteen daily acquisition training sessions and extended post-asymptotic training of the present experiment. What underlying mechanism could account for such potential response-protective aspects of extended acquisition training is unclear. The above speculation is only in terms of procedural differences.

On the other hand, the present finding that CS_2 performance was positively related to cue similarity follows directly from the generalization-of-excitation axiom of Hull-Spence theory and is consistent with the findings from both classical aversive (e.g., Frey, 1967; Homzie, 1968) and instrumental appetitive (e.g., Friedes, 1957; Hanson, 1959) conditioning. However, because of prior asymptotic training to the positive cue, excitatory generalization alone, cannot account for the additional finding that responding to the nonreinforced cue increased over initial differential-conditioning training for Groups 1000 and 2100. Strikingly similar findings were frequently noted by Pavlov (1927, pp. 118-122) and he analyzed them in terms of "external inhibition". The latter phenomenon involves the temporary suppression or inhibition of conditioned reflexes by novel stimuli which, following repeated presentations, lose their response-suppressive capacity. With regard to separate-phase differential conditioning, Pavlov hypothesized that the negative cue can be conceptualized as involved two components. One component involves commonality with the elements of the positive cue, thus providing the basis for excitatory generalization, while the other component involves "new" elements or novelty which provides the basis for response suppression (i.e., external inhibition). On initial presentations of the negative cue, the novel component would then operate to suppress CRs and mask the full assessment of excitatory generalization. Over repeated presentations of the negative cue, the novel aspects of the cue will habituate and hence lose their response-suppressive capacity. Following habituation, excitatory generalization would then be reflected in increased responding. Such an analysis would appear to account for the present findings of an initial increase in CS_2 performance for Groups 1000 and 2100. The finding that Group 660 (which never achieved discrimination) did not exhibit a significant initial increase in CS_2 performance is readily understood in terms of the negative cue being so similar to the positive one (60 Hz difference) that its novel and hence, suppressive component was negligible. However, there is a seeming inconsistency between the present findings and the phenomenon Pavlov (1927) described. Pavlov (1927) reported that the increase in responding to the negative cue involved about the first five trials on which the negative cue was presented. In the present study, increments in CS_2 responding occurred over the first forty-eight CS_2 presentations. However, Pavlov's data were based on stimulus durations of 30-sec while the present study involved CS_2 durations of .5 sec. Clearly, it is reasonable to suggest that stimulus duration determines the rate of habituation of the novel and hence, response-suppressive aspects of a stimulus.

EXPERIMENT II

The purpose of the present study was to investigate the effects of US magnitude on separate-phase differential classical appetitive conditioning of the rabbit's jaw-movement response.

As previously indicated, the excitation-inhibition model of discrimination learning (Hull, 1943; Spence, 1936, 1937) essentially involves the algebraic interaction of excitatory and inhibitory generalization gradients of response tendencies along a physical dimension. Thus, the first experiment sought to assess the model by affecting the amount of generalization via the manipulation of stimulus similarity. The aim of the present experiment is to assess the implication of the traditional excitation-inhibition model by affecting the strength of generalized response tendencies via the manipulation of US magnitude. Major excitation-inhibition theorists (e.g., Hull, 1943; Pavlov, 1927; Spence, 1960) concur in positing that US magnitude is a primary determinant of excitatory strength for classical appetitive conditioning. Predictions from an excitation-inhibition analysis of discrimination for the effects of US magnitude on differential conditioning performance hinge, however, on the factors assumed to affect inhibitory conditioning. The simplest assumption is that the conditioning of inhibition to CS- is simply determined by the number of nonreinforced presentations. This was

Hull's (1943) working assumption for both classical appetitive and classical aversive conditioning and Spence's later position (1958a), at least with regard to the classical aversive case. The predictions for this position are straightforward: increased US magnitude will produce augmented CS+ performance and, via excitatory generalization, augmented performance on CS-. Another prediction, that the degree of differentiation will be directly tied to US magnitude follows from the assumed multiplicative relationship between "habit" (H) strength and underlying motivational level (D). An alternative position (e.g., Pavlov, 1927; Spence, 1936) involves the added assumption that the amount of inhibition conditioned to the negative cue is a direct function of the amount of excitatory strength associated with that stimulus. In this case, unique predictions for the effects of US magnitude on the relative ordering of CS+ performance and CS- performance are precluded in the absence of specification of the relative contributions of the excitatory and inhibitory factors. However, the observation of an inverse relationship between US magnitude and CS- performance would provide seemingly strong support for this "excitatory-based" notion of inhibition.

Method

Subjects

The Ss were 72 New Zealand albino rabbits. The animals were about 100 days old and each weighed approximately

2 kg when they were obtained from Morrison's Rabbitry, West Liberty, Iowa. Upon arrival, the animals were individually caged with free access to food and water.

Apparatus

The apparatus was the same as described in Experiment I. The 1-,3-, and 9-cc US magnitude values of the present study involved durations of .3, 1.8, and 6.3 sec respectively, while the duration of the CS was .5 sec.

Procedures

The surgical preparation of the Ss, the initiation of the water deprivation regime, and adaptation training were the same as those described in Experiment I.

Design

Twelve Ss were randomly assigned to each of three groups described by the level of US magnitude (1, 3, and 9 cc) used on reinforced trials (Groups 1-, 3- and 9-cc). In Phase I (i.e., acquisition phase) each group received acquisition training with its respective US magnitude which involved four reinforced trials per daily session for fifteen consecutive days. Half the Ss received their training with a 600-Hz CS while the other half received theirs with a 2100-Hz CS. In Phase II (i.e., differential-conditioning phase) each group continued to receive four reinforced trials per session with its acquisition CS (i.e., CS_1) except that now, four nonreinforced presentations of a different tonal frequency (i.e., CS_2)

were introduced into each session during the 24 days of training. The tonal frequency of CS_2 (600 or 2100 Hz) was counterbalanced with respect to tonal frequency for CS_1. The order of CS_1 and CS_2 presentations was randomly varied with the restriction that not more than three trials of one type could occur consecutively and involved intertrial intervals of 2.0, 2.5, 3.0 min with a mean of 2.5 min. The intervals between CS_1 trials during differential conditioning mirrored the intertrial intervals during the acquisition phase of training. Thus, the intervals between reinforced trials was equated across acquisition and differential-conditioning training. Throughout the experiment the CS-US interval was 500 msec which was also the duration of both CS_1 and CS_2. Deflections of the recording pens of at least 1 mm from baseline (corresponding to .3 mm of jaw movement) occurring during the 500 msec following CS onset were recorded as CRs.

During the course of the experiment three animals (one per group) died, apparently due to respiratory infections. In addition, one _S_ in Group 1-cc was discarded for failing to give a single CR during acquisition training and accordingly, one randomly designated _S_ from each of the other groups was discarded to provide an equal number (10) of _Ss_ per treatment condition.

Results

Phase I

CR Frequency. Figure 11 presents, for each group, base-rate responding on adaptation day and percentage CRs during acquisition training over three-day blocks. The figure reveals that adaptation-day responding was less than 2% and that acquisition performance was nominally ordered with US magnitude with the 9- and 3-cc conditions exhibiting quite similar acquisition performance which was substantially and consistently superior to that of the 1-cc condition. An analysis of variance on these percentage CR data revealed that the overall Groups effect was significant (see Table 12) and a linear trend analysis corroborated the observation that performance was ordered with US magnitude in revealing a significant upward linear component ($\underline{F} = 7.45$; $\underline{df} = 1, 27$; $\underline{p} < .05$). A subsequent Newman-Keuls comparison test indicated that the overall mean percentage CRs for the 1-cc condition (29.9%) was significantly lower ($\underline{p}$s $< .01$) than the means for the 3-cc (57.6%) and 9-cc (60.3%) conditions and that the latter two means were not significantly different from each other.

Figure 11 also suggests that each group approached its respective performance asymptote by the third day-blockand that this performance was maintained over subsequent acquisition training. Response levels on the last day block were 45.5%, 69.2%, and 76.5% for Groups 1-, 3-, and 9-cc, respectively. To assess whether stable asymptotic response levels had been attained, an additional analysis of variance was performed on the percentage CR data of the last three, three-day blocks of acquisition. The analysis revealed that while the Groups effect was significant ($\underline{F} = 6.28$; $\underline{df} = 2, 27$; $\underline{p} < .01$)

Figure 11. For each group, mean percentage CRs on adaptation day and as a function of three-day blocks during Phase I: Exp. II

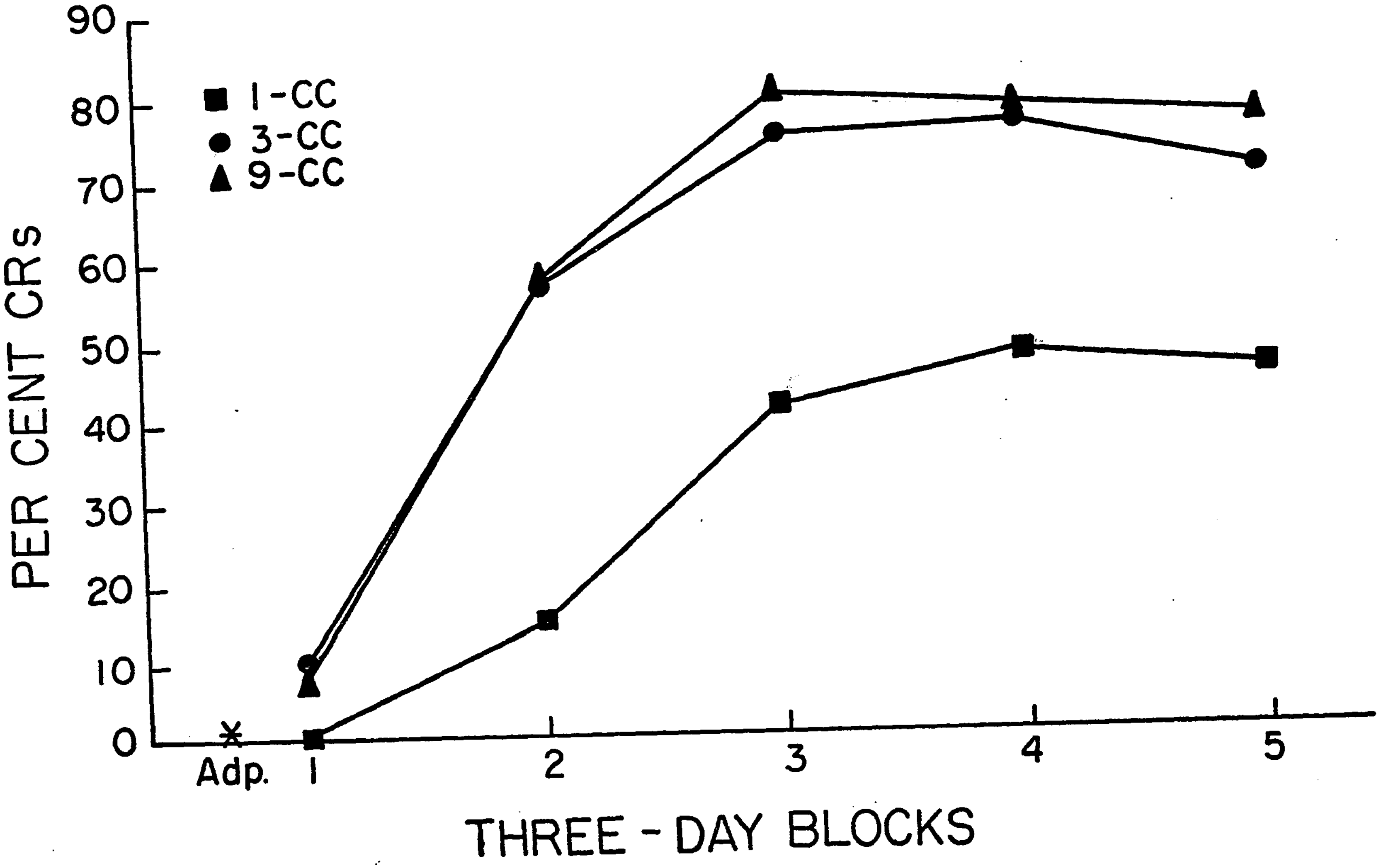
90
80
70
60
50
40
30
20
10
0
PER CENT CRs
■ 1-CC
● 3-CC
▲ 9-CC
*
Adp.
1
2
3
4
5
THREE - DAY BLOCKS

Figure 11

Table 12

Analysis of Variance of Percentage CRs in Phase I
With Groups, Day-Blocks, and Within-Session
Blocks as Factors: Exp. II

Source	df	MS	F
Between:			
Groups (G)	2	2.83676	6.66**
Error (b)	27	.42640	
Within:			
Days (D)	4	4.02366	50.95**
D X G	8	1.0778	1.36
Error (w_1)	108	.07897	
Blocks (B)	1	.07002	2.16
B X G	2	.03014	.93
Error (w_2)	27	.03237	
B X G	4	.02848	1.65
B X D X G	8	.00966	.56
Error (w_3)	108	.01727	

** $p < .01$

* $p < .05$

neither the Days nor the Days X Groups effect approached significance (*F*s < 1) thus supporting the experimental objective of producing stable and differential response strength among groups. It may also be noted here that the counter-balanced factor of tonal frequency (600 and 2100 Hz) produced comparable overall performance (46% and 53%, respectively) and the difference did not approach statistical significance (*F* < 1).

Figure 12 portrays for each group, the mean percentage CRs over two within-session blocks during acquisition. The figure indicates stable within-session performance for each group with only a slight within-session decrement for the 3- and 9-cc conditions. An analysis of variance revealed that the graphical indication of a within session decrement for the larger US magnitudes was not reliable in that neither the Blocks, nor the Blocks X Groups effect was significant (see Table 12).

CR Onset Latency. The panels of Figure 13, present the group frequency distributions of CR latencies for five, three-day blocks. The indication of the frequently-observed phenomenon of a decrease in CR latency over acquisition training can be noted from the figure. (The relatively low CR frequency level of the 1-cc condition precluded a uniform statistical assessment of the effects of training on CR latencies for the three conditions). In addition, as suggested by the figure, the mean overall CR onset latencies during acquisition generally corresponded with the frequency measure in that the 1-cc condition exhibited a substantially longer mean

Figure 12. For each group, mean percentage CRs as a function of two within-session blocks during Phase I: Exp. II.

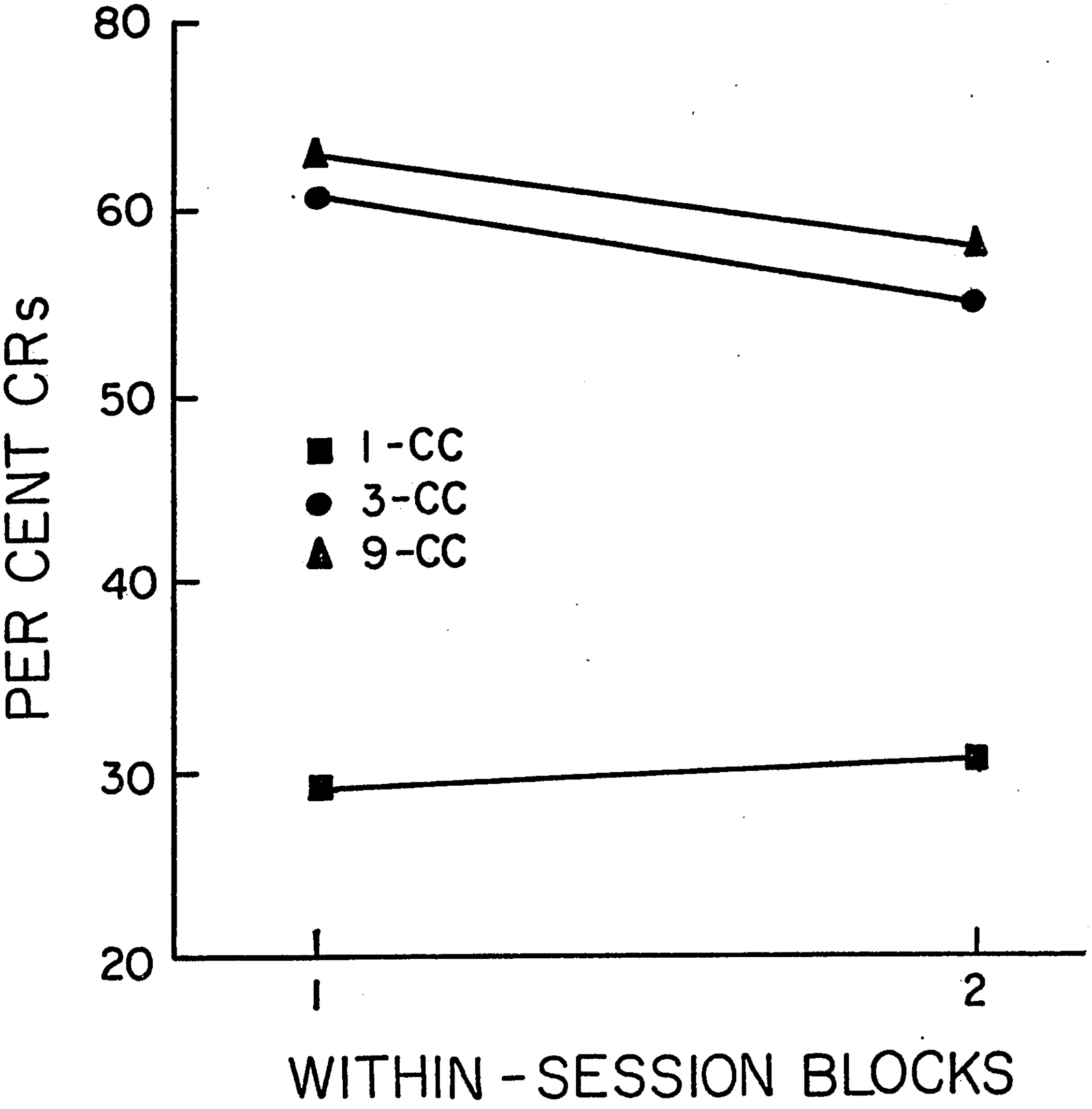
80
60
50
40
30
20
PER CENT CRs
■ 1-CC
● 3-CC
▲ 9-CC
1
2
WITHIN-SESSION BLOCKS

Figure 12

Figure 13. Group frequency distribution of CR latencies in five-day blocks for Phase I: Exp. II.

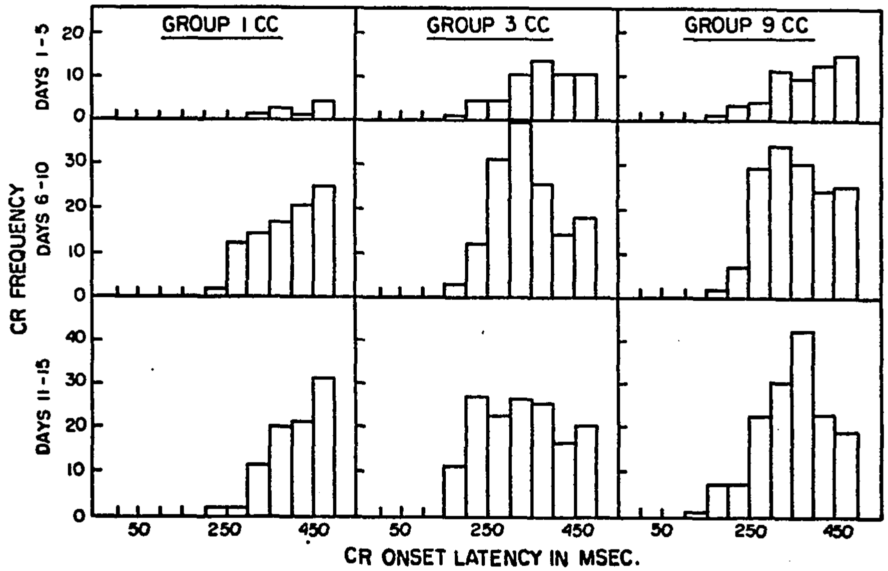
GROUP 1 CC
GROUP 3 CC
GROUP 9 CC
CR FREQUENCY
DAYS 1-5
DAYS 6-10
DAYS 11-15
20
10
0
30
20
10
0
40
30
20
10
0
50
250
450
CR ONSET LATENCY IN MSEC.

Figure 13

Table 13

Analysis of Variance of Mean Overall CR Onset Latency in Phase I: Exp.II

Source	df	MS	F
Between:			
Groups	2	14039.85108	6.54**
Error	27	2156.28861	

** $p < .01$

* $p < .05$

latency (420 msec) than did the 3- and 9-cc conditions whose means were quite similar (353 and 357 msec, respectively). An analysis of variance of these overall mean CR latencies revealed a significant Groups effect (see Table 13) and a trend analysis over US-magnitude values indicated a significant downward linear component ($\underline{F} = 7.45$; $\underline{df} = 1, 27$; $\underline{p} < .05$). A subsequent Newman-Keuls comparison test revealed that the mean latency for the 1-cc condition was significantly ($\underline{ps} < .01$) longer than that of the 3- and 9-cc conditions and that the latter two means did not significantly differ from each other.

Phase II

<u>CR Frequency</u>. Figure 14 presents mean overall percentage CRs to the reinforced (CS_1) and nonreinforced (CS_2) stimuli as a function of US magnitude. Considering first responding to the reinforced stimulus, the figure indicates that CS_1 responding during differential conditioning was ordered with US magnitude with the most pronounced effect obtaining between the performance of the 1-cc and that of the larger US-magnitude conditions. An analysis of variance of the CS_1 percentage CR data revealed a significant Groups effect (see Table 14) and a linear trend analysis over US-magnitude values indicated a significant upward linear component ($\underline{F} = 5.26$; $\underline{df} = 1, 27$; $\underline{p} < .05$). A follow-up Newman-Keuls comparison test revealed that the CS_1 performance of the 1-cc condition (39.0%) was significantly ($\underline{p} < .05$) lower than that of the 9-cc condition (68.3%) but that the performance

Table 14

Analysis of Variance of Percentage CRs to CS_1 in Phase II With Groups, Day-Blocks, and Within-Session Blocks as Factors: Exp. II

Source	df	MS	F
Between:			
Groups (G)	2	3.71070	3.65*
Error (b)	27	1.00918	
Within:			
Days (D)	7	.02344	.40
D X G	14	.04523	.77
Error (w_1)	189	.05882	
Blocks (B)	1	.00001	.00
B X G	2	.19651	4.77*
Error (w_2)	27	.04123	
B X D	7	.04836	2.09*
B X D X G	14	.02486	1.07
Error (w_3)	189	.02316	

** $\underline{p} < .01$

* $\underline{p} < .05$

of the 3-cc condition (61.0%) was not reliably different from that of the other two groups.

With regard to overall CS_2 responding, the figure indicates a slight non-monotonicity with response levels of 15.6%, 27.9%, and 26.7% from Groups 1-, 3-. and 9-cc, respectively. A separate analysis of variance on these CS_2 percentage CR data indicated the Groups effect was nonsignificant (see Table 15) and trend analyses over US-magnitude values revealed that neither the linear nor quadratic components were significant (F = 1.30, and 2.00, respectively; dfs = 1, 27; $ps > .10$).

Figure 14 also indicates that the overall degree of differentiation (i.e., CS_1 minus CS_2) was ordered with US magnitude; the overall percentage differentiation for the 1-, 3-, and 9-cc condition was 23.4%, 33.1%, and 41.6%, respectively. An analysis of variance with CS_1 and CS_2 as a within factor indicated that overall differentiation was highly reliable (see Table 16). A linear trend analysis over US-magnitude levels based on overall CS_1 minus CS_2 difference scores revealed a significant upward linear component ($F = 4.24$; df = 1, 27; $p < .05$).

Figure 15 presents mean percentage CRs, for each group, for the last three-day block of acquisition, and to CS_1 and CS_2 as a function of eight, three-day blocks during the second phase. Examination of the left portion of the figure suggests there was a slight CS_1 performance decrement between the last acquisition block and the initial Phase-II block. However, an analysis of variance

Table 15

Analysis of Variance of Percentage CRs to CS_2 in Phase II With Groups, Day-Blocks, and Within-Session Blocks as Factors: Exp. II

Source	df	MS	F
Between:			
Groups (G)	2	.73546	1.65
Error (b)	27	.44488	
Within:			
Days (D)	7	.24854	4.42**
D X G	14	.06110	1.09
Error (w_1)	189	.05620	
Blocks (B)	1	1.02521	20.69**
B X G	2	.11525	2.33
Error (w_2)	27	.04956	
B X D	7	.05646	2.73*
B X D X G	14	.01947	.94
Error (w_3)	189	.02066	

** $\underline{p} < .01$

* $\underline{p} < .05$

Figure 14. Mean overall percentage CRs to CS_1 and CS_2 as a function of US magnitude during Phase II: Exp. II.

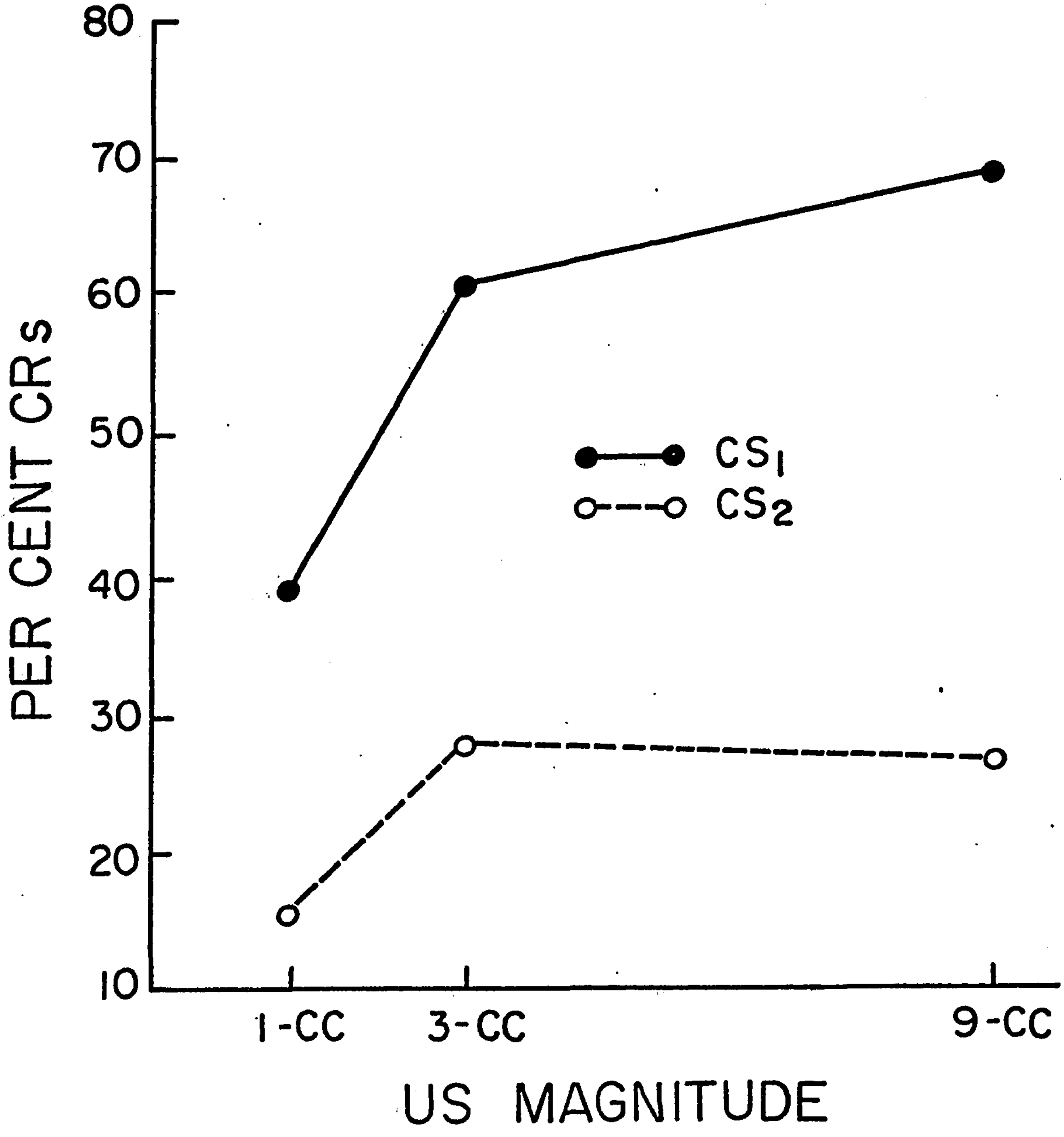
80
70
60
50
40
30
20
10
PER CENT CRs
CS₁
CS₂
1-CC
3-CC
9-CC
US MAGNITUDE

Figure 14

Table 16

Analysis of Variance of Percentage CRs in Phase II With Groups, CS_1/CS_2, Day-Blocks and Within-Session Blocks as Factors: Exp. II

Source	df	MS	F
Between:			
Groups (G)	2	3.78661	3.25
Error (b)	27	1.16531	
Within:			
CS_1/CS_2 (C)	1	25.60522	88.68**
C X G	2	.65955	2.28
Error (w_1)	27	.28875	
Days (D)	7	.16123	2.35*
D X G	14	.05264	.77
Error (w_2)	189	.06873	
Blocks	1	.51415	10.25**
B X G	2	.27669	5.51**
Error (w_3)	27	.05017	
C X D	7	.11074	2.39*
C X D X G	14	.05369	1.16
Error (w_4)	189	.04629	

Table 16 continued

Source	df	MS	F
D X B	7	.05963	2.33*
D X B X G	14	.03372	1.31
Error (w_5)	189	.02564	
C X D X B	7	.04519	2.49*
C X D X B X G	14	.01060	.58
Error (w_6)	189	.01818	

** $p < .01$

* $p < .05$

Figure 15. Mean percentage CRs, for each group, for the last three-day block of acquisition, and to CS_1 and CS_2 as a function of eight three-day blocks during Phase II: Exp. II.

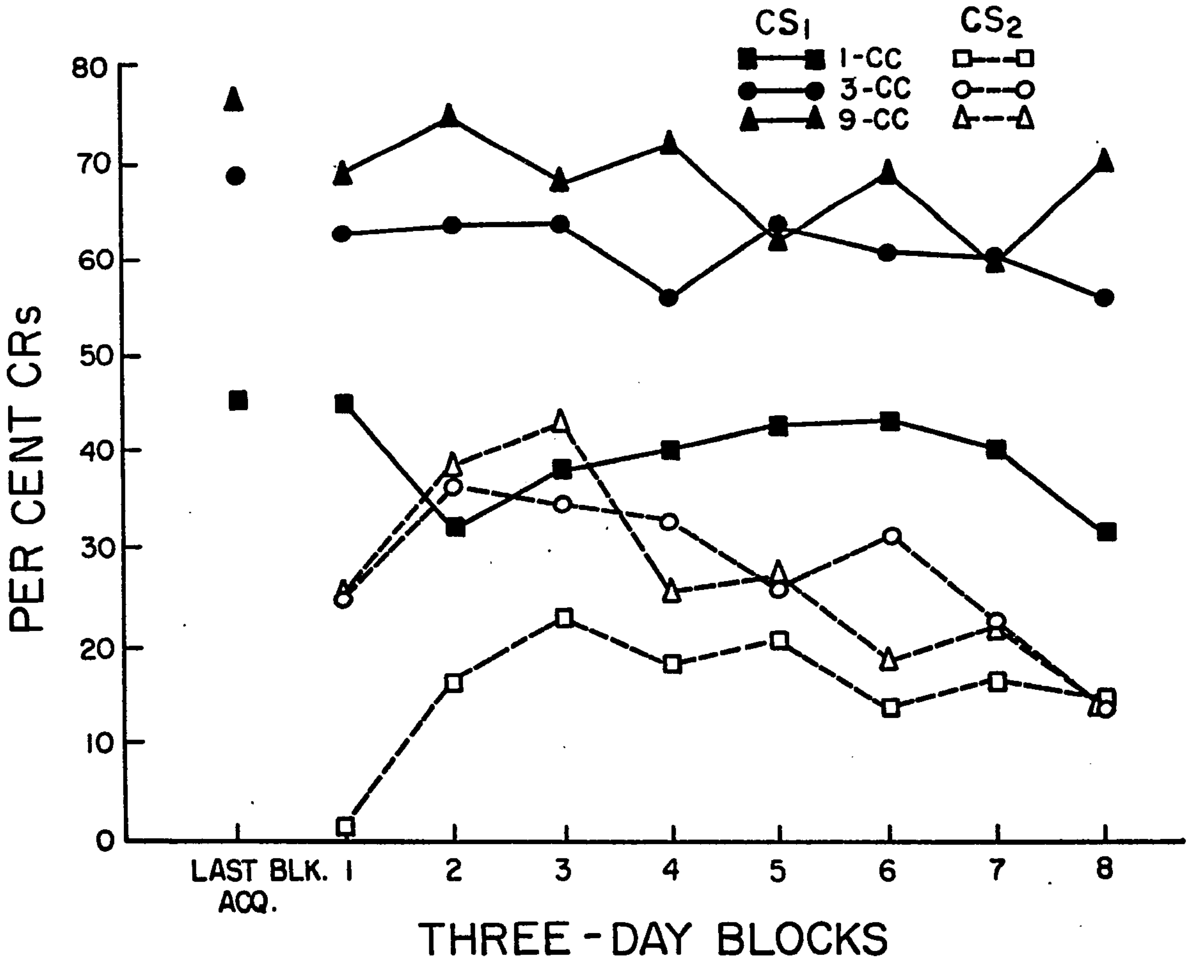
CS1
1-CC
3-CC
9-CC
CS2
80
70
60
50
40
30
20
10
0
PER CENT CRs
LAST BLK. ACQ.
1
2
3
4
5
6
7
8
THREE-DAY BLOCKS

Figure 15

of these percentage CR data revealed that the between-phase differences were not reliable in that neither the Days nor the Days X Groups effect was significant (see Table 17). The figure also suggests that CS_1 performance, for each group, did not vary substantially nor systematically over discrimination training. An analysis of variance on CS_1 data supported this observation in that both the Days and Days X Groups effects did not approach significance (see Table 14).

Examination of the CS_2 functions in Figure 15 reveals that each group exhibited an initial increase in CS_2 responding followed by a general systematic decrease over subsequent differential-conditioning sessions. The paradoxical nature of an initial increase in CS_2 responding in the context of stable CS_1 performance (which was also noted in the first experiment) is perhaps best illustrated by the 1-cc condition. For this condition, differentiation was virtually perfect during the first three-day block in that there was virtually no responding (2.5%) to the negative cue. CS_2 responding for this group then increased to 16.0% on the second day-block and to 23.2% on the third day-block from which it subsequently decreased over training to 14.5% on the last day-block. A similar pattern obtained for both the 9-cc condition (25.3%, 38.3%, 42.6%, and 13.8%, for the first, second, third, and last day-block, respectively) and the 3-cc condition (25.0%, 36.7%, 34.7%, and 13.9%, for the first, second, third, and last day-block, respectively.) .

Table 17

Analysis of Variance of Percentage CRs to CS_1 on the Last Day-Block of Phase I and the First Day-Block of Phase II With Groups, Day-Blocks, and Within-Session Blocks as Factors: Exp. II

Source	df	MS	F
Between:			
Groups (G)	2	.82118	2.80
Error (b)	27	.29298	
Within:			
Days (D)	1	.07089	1.59
D X G	2	.01499	.34
Error (w_1)	27	.04465	
Blocks (B)	1	.13222	5.49*
B X G	2	.00546	.23
Error (w_2)	27	.02407	
B X D	1	.02650	1.42
B X D X G	2	.00782	.42
Error (w_3)	27	.01864	

** $p < .01$

* $p < .05$

An analysis of variance of the CS_2 percentage CR data summarized in the figure supported the observation that CS_2 performance varied in a comparable manner over training as indexed by a significant Days effect and a nonsignificant Days X Groups effect (see Table 15). A linear trend analysis over the eight day-blocks for all groups indicated a significant downward linear component over training ($F = 7.92$; $df = 1, 189$; $p < .01$). An additional trend analysis over the eight day-blocks for all groups revealed that the curvelinear component (i.e., deviation from linearity) over training was significant ($F = 3.84$; $df = 6, 189$; $p < .01$). To more specifically assess the reliability of the initial increase in CS_2 responding, an additional linear trend analysis was performed on the groups data over the initial three day-blocks and this analysis revealed a highly reliable upward linear component ($F = 13.43$; $df = 1, 189$; $p < .01$).

Figure 16 presents, for each group, the overall mean percentage CRs to CS_1 and to CS_2 during Phase II as a function of two within-session blocks. Looking at CS_1 data only for the moment, it can be noted from the figure that there was a very slight within-session decrement for the 3- and 9-cc conditions while the 1-cc condition exhibited a slight within-session increment. An analysis of variance of CS_1 data revealed a significant Blocks X Groups effect (see Table 14) and subsequent analyses revealed that within-session variation was not significant for the 3- and 9-cc conditions (Fs = .76 and 2.62, respectively, dfs = 1, 27; $p > .10$) while the

Figure 16. For each group, mean overall percentage CRs to CS_1 and CS_2 as a function of two within-session blocks during Phase II: Exp. II.

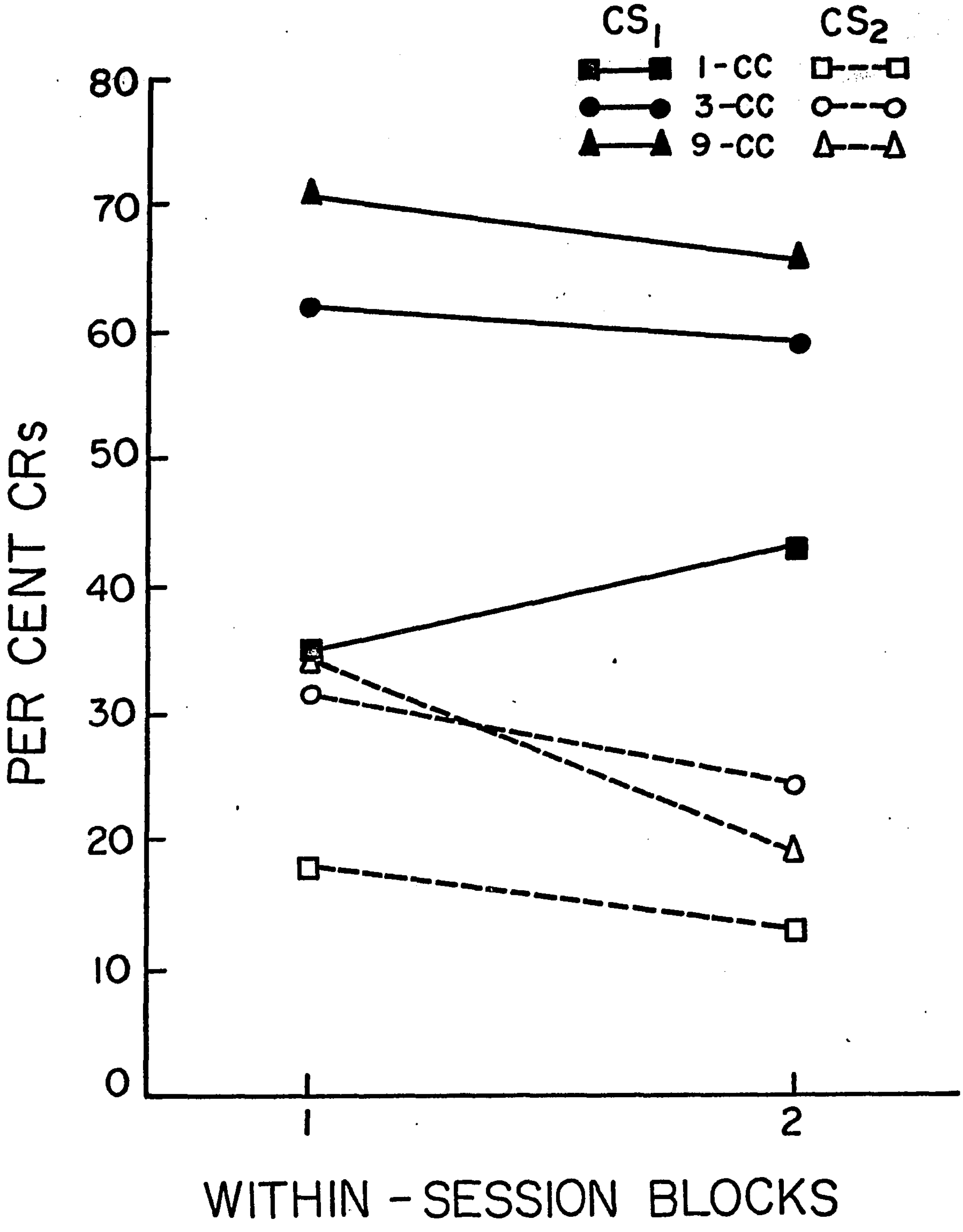
CS1
CS2
1-CC
3-CC
9-CC
80
70
60
50
40
30
20
10
0
PER CENT CRs
1
2
WITHIN - SESSION BLOCKS

Figure 16

within-session increase for the 1-cc group was reliable ($\underline{F} = 6.21$, $\underline{df} = 1, 27$, $\underline{p} < .05$). Turning now to CS_2 responding, the figure indicates within-session decrements for each group and an analysis of variance of CS_2 data revealed that while the within-session decrement was highly reliable, it was not significantly differential among groups (i.e., a significant Blocks effect and a nonsignificant Blocks X Groups effect: see Table 15). Finally, an analysis of variance which involved CS_1 and CS_2 as a within factor confirmed the observation of a greater within-session decrement on CS_2 than on CS_1 performance and revealed that this relationship was not differential among groups (i.e., a significant CS_1/CS_2 X Blocks effect and a nonsignificant CS_1/CS_2 X Blocks X Groups effect: see Table 16).

<u>CR Onset Latency</u>. Figure 17 presents overall mean CR onset latency during Phase II to CS_1 and CS_2 as a function of US magnitude. The figure reveals that the mean CR latencies were inversely ordered with US magnitude with the most pronounced effect between the 1- and 3-cc conditions for both CS_1 (389, 335, and 331 msec for the 1-, 3-, and 9-cc conditions, respectively) and CS_2 (379, 357, and 356 msec for the 1-, 3-, and 9-cc conditions, respectively). Separate analyses of variance on the CS_1 and CS_2 latency data revealed that there were no reliable differences among the groups for either CS_1 or CS_2 latencies (see Tables 18 and 19, respectively). A linear trend analysis over US-magnitude values for the CS_1 data indicated the linear component was nonsignificant ($\underline{F} = 3.15$; $\underline{df} = 1, 27$; $\underline{p} > .05$); a similar analysis for the CS_2 data also revealed a

Figure 17. Overall mean CR latency to CS_1 and CS_2 as a function of US magnitude during Phase II: Exp. II.

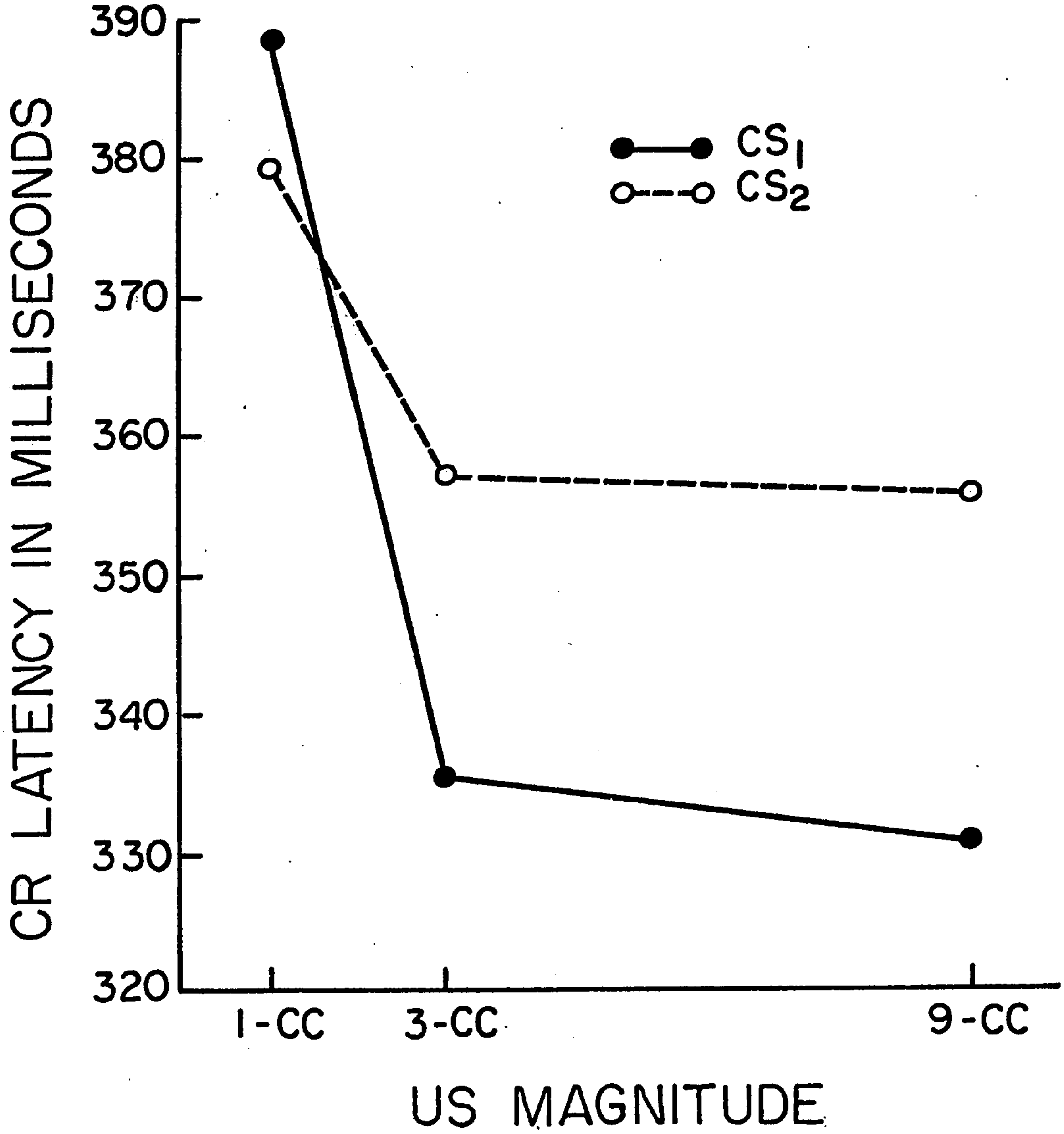
390
380
370
360
350
340
330
320
CR LATENCY IN MILLISECONDS
1-CC
3-CC
9-CC
US MAGNITUDE
●—● CS_1
○---○ CS_2

Figure 17

Table 18

Analysis of Variance of CR Onset Latency to CS_1 in Phase II With Groups and Day-Blocks as Factors: Exp. II

Source	df	MS	F
Between:			
Groups (G)	2	20803.43236	2.86
Error (b)	27	7263.24796	
Within:			
Days (D)	1	2149.60841	2.89
D X G	2	7.42914	.01
Error (w)	27	742.90769	

** $\underline{p} < .01$

* $\underline{p} < .05$

Table 19

Analysis of Variance of CR Onset Latency to CS_2 in Phase II With Groups and Day-Blocks as Factors: Exp. II

Source	df	MS	F
Between:			
Groups (G)	2	3562.78753	.44
Error (b)	27	8123.09366	
Within:			
Days (D)	1	8356.59518	2.35
D X G	2	18608.72030	5.23*
Error (w)	27	3561.11297	

** $p < .01$

* $p < .05$

non-significant linear component (F < 1). Examination of the figure also indicates that the mean latencies were somewhat longer to CS_2 than CS_1 for the3- and 9-cc conditions while this relationship was reversed for the 1-cc condition. A separate analysis of variance which involved CS_1 and CS_2 as a within factor revealed, however, that differential response latencies were not reliable (i.e., nonsignificant effects of CS_1/CS_2 and CS_1/CS_2 X Groups: see Table 20).

The top panel of Figure 18 presents, for each group, mean CR onset latency to CS_1 as a function of two, twelve-day blocks during the second phase (the data arepresented in group-distribution form in Figure 19). Figure 18 indicates that there was slight decrease over training of CS_1 latencies for each group but an analysis of variance on these data revealed there was no significant effect over day-blocks (see Table 18).

The corresponding latency data for CS_2 is presented in the bottom panel of Figure 18 (these data are also presented in Group-distribution form in Figure 19). It is apparent from the figure that there were no uniform effects of training on CS_2 latencies. Over training, the 1-cc condition exhibited a marked decrease in CS_2 latency and the 3-cc condition a slight decrease, while the 9-cc condition exhibited an increase. An analysis of variance of the CS_2 latency data reflected these observations in a significant Days X Groups effect (see Table 19).

Table 20

Analysis of Variance of CR Onset Latency in Phase II With Groups, CS_1/CS_2, and Day-Blocks as Factors: Exp. II

Source	df	MS	F
Between:			
Groups (G)	2	20792.01426	1.67
Error (b)	27	12450.58558	
Within:			
CS_1/CS_2 (C)	1	4546.05936	1.55
D X G	2	3574.20563	1.22
Error (w_1)		2935.75603	
Days (D)		9491.42779	4.23*
D X G		9248.92467	4.12*
Error (w_2)		2243.92396	
C X D		1014.77580	.49
C X D X G		9367.22476	4.55*
Error (w_3)		2060.09671	

** $p < .01$

* $p < .05$

Figure 18. For each group, mean CR latency to CS_1 (top panel) and to CS_2 (bottom panel) as a function of twelve-day blocks during Phase II: Exp. II.

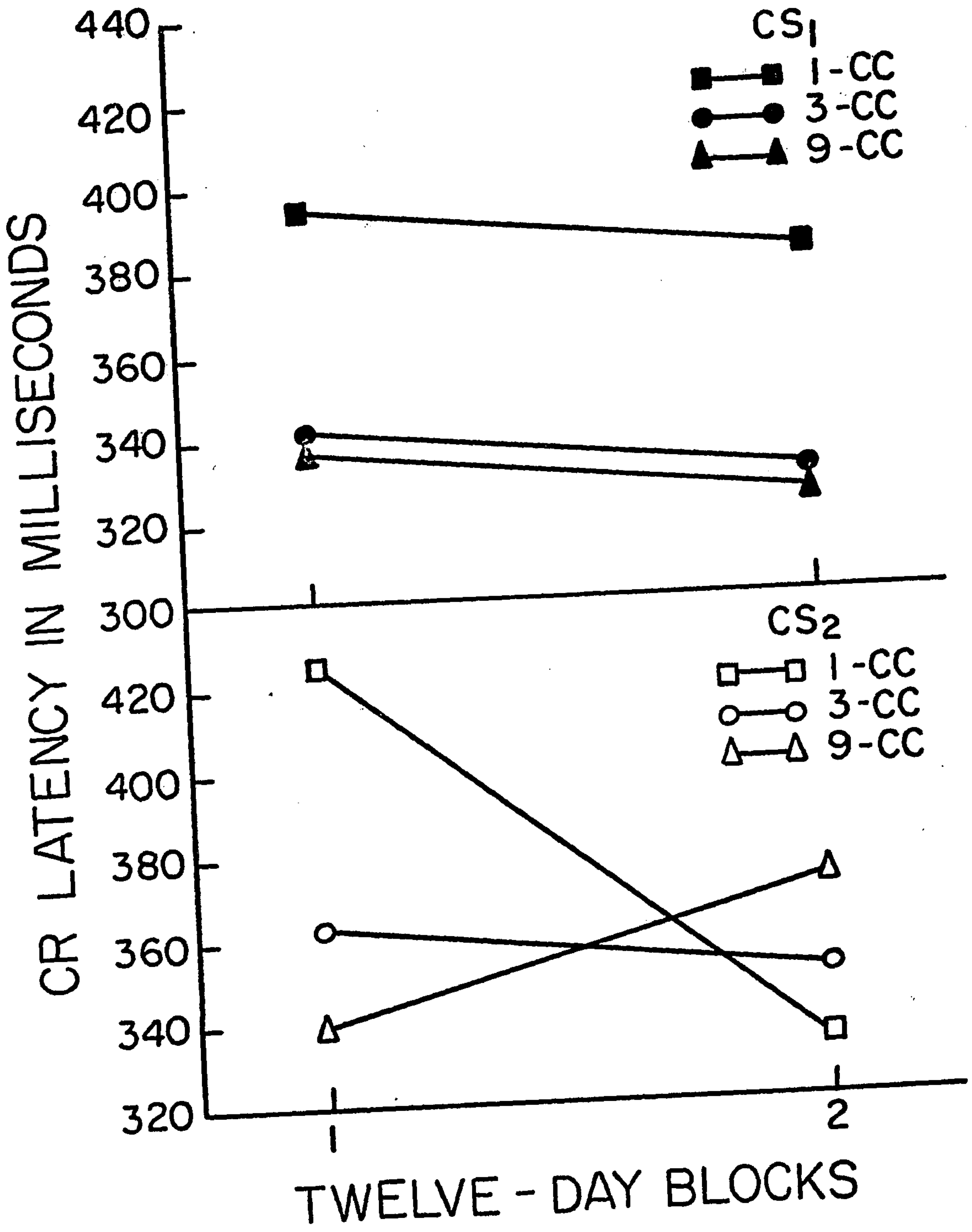
CS1
1-CC
3-CC
9-CC
CS2
1-CC
3-CC
9-CC
CR LATENCY IN MILLISECONDS
440
420
400
380
360
340
320
300
420
400
380
360
340
320
1
2
TWELVE - DAY BLOCKS

Figure 18

Figure 19. Group frequency distributions of CR latencies to CS_1 and CS_2 in twelve-day blocks for Phase II: Exp. II.

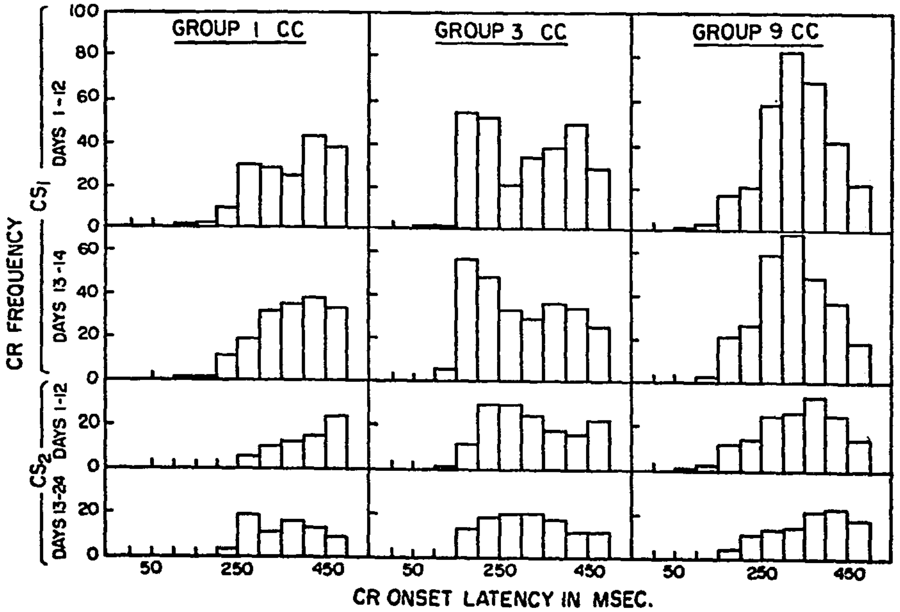
GROUP 1 CC
GROUP 3 CC
GROUP 9 CC
CR FREQUENCY
CS1
DAYS 1-12
DAYS 13-14
CS2
DAYS 1-12
DAYS 13-24
100
80
60
40
20
0
50
250
450
CR ONSET LATENCY IN MSEC.

Figure 19

Discussion

The primary findings of the present experiment were: (a) performance during single-cue acquisition training and responding to the positive cue during subsequent differential conditioning was positively related to US magnitude; (b) responding to the negative cue was generally ordered with but not significantly affected by US magnitude; (c) the degree of differentiation was positively related to US magnitude; (d) following asymptotic single-cue acquisition training, responding to the positive cue was not significantly affected by differential-conditioning training; and (e) negative-cue responding for all US-magnitude conditions increased over initial differential-conditioning training then decreased over the subsequent training sessions.

The finding that performance during single-cue acquisition training was a positive function of US magnitude is in agreement with virtually every major theory of classical appetitive conditioning (e.g., Guthrie, 1935; Hull, 1943; Pavlov, 1927). In addition, the finding is consistent with the results from a prior classical appetitive conditioning of the rabbit's jaw-movement response (Shaefor, 1970), as well as with the effects of US intensity in classical aversive conditioning (cf., Spence & Platt, 1966) and reward magnitude in instrumental appetitive conditioning (cf., Pubols, 1960).

However, specific predictions from excitation-inhibition theories for the effects of US magnitude on differential-conditioning performance depend on the factors assumed to influence inhibitory conditioning. Predictions from Hull's (1943) discrimination theory, which involves the working assumption that the conditioning of inhibition to the negative cue is simply determined by the number of nonreinforced presentations, are most direct. According to the theory, an increase in US magnitude yields three predictions: augmented CS_1 and CS_2 responding and an increased degree of differentiation. The present findings that percentage CRs to CS_1 and the degree of differentiation were ordered with US magnitude is clearly in accord with the theory. While the present investigation yielded no significant effects of US magnitude on CS_2 response levels, it should be noted that the ordering on CS_2 performance was similar to that of CS_1 performance (i.e., similar response levels for Groups 9- and 3-cc which were superior to that of Group 1-cc). Thus, with regard to the relative ordering on CS_1 and CS_2 performance and the degree of differentiation, the overall pattern of findings appears consistent with Hull's discrimination theory. It may also be noted that the general pattern of findings are in reasonable agreement with the results from investigations of US intensity in classical aversive conditioning (e.g., Ashton, Bitgood, & Moore, 1969; Spence & Tandler, 1963; Runquist, Spence & Stubbs, 1958) and of reward magnitude in instrumental appetitive conditioning (e.g., Bower & Trapold, 1959; Hunter, 1959).

An alternative position (e.g., Pavlov, 1927; Spence, 1936), involves the added assumption that the amount of inhibition conditioned to the negative cue is a direct function of the excitatory strength associated with that stimulus. For the present experiment, the prediction is that the degree of inhibitory conditioning to the negative cue will be a positive function of US magnitude since it is assumed that US magnitude determines the amount of generalized excitation associated with the negative cue. However, in terms of the relative ordering on CS_1 performance and CS_2 performance, unique predictions are precluded in the absence of specification of the relative contributions of excitatory and inhibitory factors. In apparent recognition of this predictive ambiguity, theorists (e.g., Spence, 1958b) have suggested that support for the "excitatory-based" inhibitory assumption would be provided by an inverse relationship between performance to the negative cue and reinforcement magnitude. Such a relationship was not obtained in the present experiment. The "excitatory-based" inhibitory assumption would also entail that CS_2 responding during differential-conditioning training would decrease more for the larger- than for the smaller-US magnitude conditions. There was no significant indication that CS_2 performance for the US- magnitude conditions decreased differentially over training in the present study. Thus, the present results provide little evidence for an "excitatory-based" inhibitory factor in classical appetitive conditioning.

According to either Hull's (1943) or Spence's (1936) variants of the excitation-inhibition model, the build-up of inhibition to the negative cue during differential-conditioning training will generalize to the positive cue and result in a decrement in CS_1 performance over training. The present finding of a general decrease in CS_2 performance over training (statistically confirmed by significant linear downward trend components over day-blocks) is, in terms of Hull-Spence theory, presumptive evidence that inhibitory conditioning had occurred. In spite of this indication of the conditioning of inhibition to CS_2 over training, there was no corresponding decrement in CS_1 performance over differential-conditioning training.

The increase in negative-cue responding over initial differential-conditioning training, which was also noted in the first experiment, cannot be accounted for in terms of simple excitatory generalization. The paradoxical nature of the phenomenon is perhaps best illustrated by the behavior of the 1-cc group. For this group, there was nearly perfect differentiation during the first three-day block in that responding to the negative cue was virtually absent (2.5%). Yet, despite prior asymptotic training to the positive cue, negative-cue responding increased to 23.2% by the third three-day block. A similar pattern of initqal increment in CS_2 responding also obtained for the 3- and 9-cc conditions. As previously suggested with respect to Experiment I, Pavlov's "external-inhibition" analysis that the negative cue initially involves "novel" aspects which suppress responding but which habituate over repeated presentations could integrate the present findings.

GENERAL DISCUSSION

At least part of the theoretical eminence of the traditional excitation-inhibition model of discrimination learning (Hull, 1943; Spence, 1936, 1937) derives from its testability and the small number of axioms involved. Excitatory and inhibitory generalization gradients of response tendencies are established along a physical dimension. In these terms, the cue similarity manipulation of Experiment I involved a "horizontal" displacement of the gradients, while the US-magnitude manipulation of Experiment II involved a "vertical" displacement.

The results from both experiments provide support for the generalization-of-excitation axiom of the Hull-Spence theory. Experiment I yielded clear support for the physical similarity dimension in that amount of responding to a particular negative cue was directly related to physical similarity to the positive cue. Negative-cue performance in Experiment II, where the degree of excitatory strength to the positive cue was manipulated via US magnitude, was also clearly in accord with the excitation axioms.

However, both experiments fail to support the generalization-of-inhibition axiom. Thus, despite the extensive variation in the degree of cue similarity in Experiment I, there was no confirmation of the predicted inverse relationship between CS_1 performance and CS_2

similarity. Moreover, the first experiment provided no evidence that differential conditioning in even the most similar cue condition depressed positive-cue performance relative to that of a single-cue continuous reinforcement contrast control. In addition, while a general decrease in negative-cue responding over differential-conditioning training was obtained in both experiments (evidence of the build-up of inhibition in terms of the theory), there was no indication in either experiment of a corresponding decrease in positive-cue responding as required by the generalization-of-inhibition axiom.

Due to the paucity of data for classical appetitive conditioning, it is not clear whether the present failure to find evidence for generalization-of-inhibition in the separate-phase paradigm is unique to the classical appetitive case, reflects extensive prior acquisition training to the positive cue, or reflects a human-infrahuman discontinuity. A theoretical integration of the present findings requires resolution of these issues.

The additional finding in both experiments that CS_2 responding increased over initial differential-conditioning sessions despite prior asymptotic training to the positive cue provides clear support for the reliability of the phenomenon. This phenomenon cannot be accounted for simply in terms of excitatory generalization whereas Pavlov's external-inhibition analysis could account for these findings. No North American investigator has previously reported a similar phenomenon with the separate-phase differential-conditioning paradigm. A critical procedural parameter may be extensive single-cue acquisition training. While speculative, this suggestion gains some force from Pavlov's apparently consistent use of extremely extensive training procedures.

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APPENDIX

REVIEW: US DURATION IN SIMPLE CLASSICAL AVERSIVE CONDITIONING

Apparently Sullivan (1950) conducted the first direct investigation of classical conditioning which employed variations in US duration in an attempt to evaluate the delay-of-reinforcement notions of effect theorists. Sullivan observed higher human GSR conditioning with a 750-msec than with a 4000-msec tone US. However, he found that the pre-training response level of the brief-US condition was somewhat higher, thus making conclusions tentative. Noting this potential sampling bias, Bitterman, Reed and Krauskopf (1952) employed a within-S design in which a .5-sec and a 3.0-sec shock US was separately paired with each of two randomly presented CSs, which were mounted lamps differentiated by their position. While these investigators observed no differential effects of US duration on human GSR conditioning or extinction, their design clearly admitted potentially obscuring effects of stimulus generalization. Coppock and Chambers (1959) used a between-groups strategy but also employed the human GSR and a shock US. While they used a wide range of US durations (.5-, 3.0-, and 15 sec) they reported no differential effect on the level of conditioning and concluded that delayed-US termination is not an important determinant of GSR conditioning. Wegner and Zeamen (1958) summarized the results from a number of their previous studies of human heart rate conditioning which had used various durations of shock USs (.1-, 2.0-, 6.0-, and 15-sec). They reported that US duration had little differential effect on either CR or UR magnitude. They argued that since UR magnitude was unaffected by US duration, there was no indication that temporal summation of noxiousness had obtained. They also reported that the topography of the UR (rapid acceleration followed by a slow return to baseline) was relatively invariant across US durations. They reasoned that if UR topography is a valid index of intratrial adaptation, they had not varied the duration of the functional US, hence precluding a contrast between contiguity and effect theories.

Runquist and Spence (1959) reported a series of four experiments investigating the effects of US duration on the conditioning of the human eyelid response. In the first experiment two groups were differentiated by the duration of the corneal-puff US (50 vs. 1000 msec) while receiving a 550 msec CS and a 500 msec ISI. The second experiment mirrored the first, except that the air-puff US was administered to the paraorbital region in order to preclude S's control of the effective duration of the US. The second pair of experiments were replications of the first pair, except that the CS overlapped and extended beyond US offset by 50 msec. Although the investigators did not specify the logic underlying the CS-overlap procedure, it may be noted that a drive reduction theory could predict that the contiguity of the CS with US termination would operate to minimize the decremental effects of US duration relative to the first experiments. A slight superiority in the performance of the brief-US

Ss was obtained in all four experiments. Although the difference in each case was statistically nonsignificant, the investigators argued that the consistency of the findings provided support for a drive-reduction position. They also suggested that the observed effect was relatively slight because increased US duration may have augmented motivational levels and offset the retarded learning from delayed reinforcement. On the other hand, it may be noted that intertrial habituation to the US (MacDonald, 1946) may be a function of puff-duration which would operate to depress the performance of the long-US Ss.

Noting Spence and Runquist's arguments, Dufort (1967), in a closely related study, attempted to equate motivational level by using interpolated US presentations. Two groups received an equal number of 50- and 1000-msec corneal puffs, but were differentiated by the US value which was paired with the CS. It may be noted that intertrial habituation to the air puff would also be presumably equated by this strategy. Dufort observed that the group which received the brief US on paired trials displayed significantly superior asymptotic performance. He concluded that the interpolated US procedure maximized performance differences relative to the Spence and Runquist study and hence his results provided clear support for a drive reduction theory.

Overmeir (1966) investigated US duration in a study concerned with comparing cardiac and instrumental-transfer indices of conditioning. Initially dogs received shuttle-box avoidance training in which a visual discriminative stimulus was used. After attaining criterion performance, the Ss were immobilized with curare and received classical conditioning with two tones, one of which was paired with a .5-sec and the other with a 50-sec shock. No differential effects of US duration on cardiac conditioning were observed. However, after recovering from the curare, the Ss were presented the tones in the shuttle box and faster avoidance responses were observed with the tone which had been previously paired with long USs. This inconsistency between cardiac and instrumental indices of conditioning apparently remains unresolved.

Review: US Intensity in Simple Classical Aversive Conditioning

Pavlov (1927) reported that the magnitude of a salivary CR was positively related to the UR eliciting properties of various acidic USs. However, the first systematic investigation of US intensity was conducted by Passey (1948) who reported that the frequency and magnitude of human eyeblink CRs were an increasing function of four air-puff intensities. Subsequently, a positive relationship between performance and US intensity has been consistently found with the human-eyelid response (e.g., Porter & Hug, 1968; Prokasy, 1967a; cf. Spence & Platt, 1966; cf. Prokasy, 1967b) as well as with the nictitating membrane response of the rabbit (e.g., Papsdorf, Gormezano, & Prokasy,,1964; Smith, 1966). The relatively few studies reporting discrepant findings used response-measures which involved baseline derived-difference scores. Thus, Fitzgerald and Teyler (1970), who used the rat's cardiac response to shock, and two studies (Feather, Delse, & Bryson, 1967; Warstler & Ost, 1965) which respectively used the human and dog salivary response to acidic USs, observed a non-monotonic relationship between performance and US intensity. Yet, the reasons for such discrepant findings are unclear.

At a theoretical level, Passey concluded that his results confirmed Hull's (1943) position that amount of reinforcment determines associative strength (H). Subsequently, Spence (1953) took issue with this interpretation by emphasizing that within Hullian theory, performance reflects a multiplicative relationship between H and motivational level (D). He suggested that D was positively related to US intensity and concluded that Passey's design may have confounded associative and motivational effects of US intensity. In an attempt to separately assess these factors in human-eyelid conditioning, Spence used a factorial transfer design. On the first thirty trials, half of the Ss received a weak air puff (.25 lb/sq.in.) and the others a strong one (5.0 lb/sq.in.), while on the second day of training, Ss continued either with the same intensity US or received the alternative US intensity. Consonant with Passey's study, Spence found pre- and postshift performance reflected the intensity of the corresponding US. Moreover, he observed postshift performance was positively ordered with preshift US intensity. Spence speculated that the historical effects of preshift US intensity may have reflected either differential CR habit strength or differential D based on fear conditioned to the situational cues.

In a subsequent theoretical paper (1958a) Spence's thinking oriented toward a nonassociative nexus between D and US intensity for classical aversive conditioning. He posited that aversive USs arouse a hypothetical emotional response (r_e), the strength of which is ordered with US intensity and directly governs the level of D. The assumption was made that the motivational effects of r_e persist over short intervals; hence, he proposed a theoretical schema by which US-induced D can bridge intertrial intervals without invoking learning. While Spence (1958a) acknowledged the possibility that the motivational effects of US intensity may be mediated by an emotional response which is conditioned to the situational cues, he placed the explanatory burden of US motivational effects in classical aversive conditioning on the nonassociative r_e mechanism.

Spence and his associates initiated a series of often-cited investigations (Spence, Haggard, & Ross, 1958a, 1958b; Spence & Tandler, 1963; Trapold & Spence, 1960; Ross & Hunter, 1959), designed to separately assess associative (H) and motivational (D) effects of US intensity in human-eyelid conditioning. The general tactic of these studies involved differentiating Ss on H by manipulating the intensity of the US used on paired trials, while presumably equating the general level of D by appropriate parameters of unpaired US presentations; or alternatively, equating paired US intensity (and H) and varying unpaired US intensity and presumable D (e.g., Spence, Haggard, & Ross, 1958a; Trapold & Spence, 1960). The results indicated that performance was positively related to the intensity of the US on paired trials, as well as on unpaired trials, findings which were presumed to reflect H and D, respectively. Spence and his associates interpreted a positive relationship between H and US intensity as supporting a "reinforcement-type theory" for classical aversive conditioning, while explicitly taking no position on the underlying mechanism.

While the facilitative effects of US intensity have been found to be relatively invariant across manipulations of CS intensity (e.g., Beck, 1963; Walker, 1960), ITI (Prokasy, Grant, & Myers, 1958) and ISI (Smith, 1966), the effects of US intensity for partial reinforcement (PR) schedules appear to depend on the procedure employed on nonreinforced trials. In an investigation of US intensity with a 50% PR schedule on the human eyelid response, Ross and Spence (1960) employed a delay procedure on nonreinforced trials in which the US was presented after an interval (2650 msec.) presumed to be ineffective for conditioning and thus functionally unpaired. With this delay procedure, a positive relationship was observed between performance and US intensity. In contrast, Runquist (1963), and Boice and Boice (1966), who employed US omission on nonreinforced trials in studies otherwise similar to the previous investigataion, observed that increased US intensity resulted in decremented performance. Noting this inconsistency, Minnigrade and O'Connel (1968) directly contrasted US omission and delay with 50% PR schedule under two levels of US intensity (1.0 and 2.0 lb/sq.in.). The US delay interval was, however, longer than ones previously employed (5000 msec). These investigators observed no effect of US intensity nor nonreinforcement procedure on performance and speculated that they may not have used a sufficiently large manipulation of US intensity. Finally, Holdstock and Schwartzbaum (1965) investigated the effect of shock intensity (.5 vs. 1.5 ma) with the rat's cardiac response employing a 50% PR omission procedure and found that performance was inversely related to US intensity. Thus, while the results are far from conclusive, they suggest that a facilitative effect of US intensity with PR schedules does not obtain with US-omission in contrast to US-delay procedures of nonreinforcement. While the reason for this discrepancy is unclear, the results suggest that the effects of US intensity in a differential conditioning paradigm may in turn depend on the nonreinforcement procedure employed.