

Forward and Backward Classical Conditioning of the
Aversively Motivated Jaw Movement Response in the Rabbit
(*Oryctolagus cuniculus*)

by

William Nelson Ten Have

A thesis
presented to the University of Manitoba
in partial fulfillment of the
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Doctor of Philosophy
in
Department of Psychology

Winnipeg, Manitoba

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A thesis submitted to the Faculty of Graduate Studies of
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ABSTRACT

Prior research has indicated that with identical associative parameters (i.e., US-CS interval, ITI, CS type, CS duration) the backward conditioning of the rabbit's nictitating membrane response (NMR) and jaw-movement response (JMR) produce opposite outcomes when assessed with the classical-classical transfer paradigm. The only variables that have not been equated between the experiments were the motivational systems activated by the US (aversive-NMR:appetitive-JMR) and the response system monitored. To assess if the excitatory or inhibitory backward conditioning outcomes were related to either motivational factors or response system characteristics two experiments were conducted.

Experiment 1 established the forward conditioning of the rabbit's JMR with an aversive US. Conditioning of the aversive JMR with a 500 msec tone CS, a 100 msec 1.5 mA electric shock US, and a 500 msec interval revealed reliable CR acquisition effects for a paired group relative to groups which received either CS alone presentations, US alone presentations, or unpaired presentations of the CS and US. Moreover, acquisition effects were found to be consonant with prior reports of forward conditioning of the rabbit's

aversive NMR and appetitive JMR for the topographical measures of CR onset latency, CR peak latency, CR amplitude and CR area.

Experiment 2 matched the associative parameters used with the appetitive JMR for the backward conditioning of the aversive JMR within a classical-classical transfer design assessment procedure. During the phase one treatments, rabbits received either 5, 25, 125, or 300 backward pairings of the US and CS, matched numbers of unpairings of the CS and US, or no presentations of the stimuli but matched for duration in the experimental chambers. The effects of the treatments were assessed during the phase two forward pairings of the CS and US. The results revealed that the backward pairings retarded forward acquisition and therefore produced inhibitory effects. In addition, the backward inhibitory effect was a direct function of the number of backward pairings administered during phase one. The results thus indicated that the motivational consequences of the US, rather than response characteristics, are a determinant of the associative effects produced in backward conditioning.

The finding that motivational asymmetry determined the backward conditioning outcome was examined in the context of current conditioning theories. The results of the two experiments were found to most closely support Konorski's

drive account of the associative and conditioning properties of appetitive and aversive stimuli.

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FORWARD AND BACKWARD CLASSICAL CONDITIONING OF
THE AVERSIVELY MOTIVATED JAW MOVEMENT RESPONSE
IN THE RABBIT (ORYCTOLAGUS CUNICULUS)

Operationally, the term classical conditioning refers to the delivery to a subject of a conditioned stimulus (CS) and an unconditioned stimulus (US) in some specified temporal arrangement, with the administration of these stimuli occurring independent of the subject's behavior (Pavlov, 1927; Skinner, 1935). Nested within this definition are the dual requirements that the presentation of the US reliably elicits a measureable unconditioned response (UR) and that the presentation of the CS does not, initially, produce a response resembling the UR (Gormezano & Kehoe, 1975; Kimble, 1961). As the result of repeated presentation of the CS and US in close temporal proximity, a response in the same effector system as the UR, occurring to the CS prior to US onset, develops and is labelled the conditioned response (CR). The processes that control the development of a CR are thought to be fundamental associative processes (Guthrie, 1935; Hull, 1943; Konorski, 1967; Pavlov, 1927, 1928; Spence, 1956).

Although a number of CS and US properties have been implicated in CR development, the most potent factor underlying CR development has been identified as the

temporal arrangement of the CS and US (e.g., Hall, 1976; Hilgard & Marquis, 1940; Smith, 1966, 1968; Smith, Coleman, & Gormezano, 1969). The temporal relationships of the CS and US have been categorized into four sets of experimental operations describing the primacy and recency of stimulus occurrences (Pavlov, 1927). Each category is defined by unique experimental operations. The first category, in which CS onset precedes US onset and CS offset coincides with US onset or offset, is termed delayed conditioning. A second category, in which CS onset and offset occur prior to US onset, has been identified as trace conditioning. The third category involves the coincidence of CS and US onsets and has been termed simultaneous conditioning. And the final category has been denoted as backward conditioning and involves the occurrence of US onset prior to CS onset.

The empirics arising from the applications of delayed and trace conditioning procedures have been unequivocal. Both the delayed and trace conditioning procedures have been reported to reliably produce CR development (e.g., Schneiderman, 1966; Schneiderman & Gormezano, 1964). When the temporal interval between CS onset and US onset (labelled the interstimulus interval or ISI) is brief, there appears to be little difference between delayed and trace conditioning effects. However, as the ISI increases the efficacy of the trace conditioning procedure declines relative to the delayed conditioning procedure (c.f., Hall,

1976; Kimble, 1961; Schneiderman & Gormezano, 1964). Although the results of short trace and delayed conditioning experiments suggest that as the time interval between the CS onset and US onset increase, conditioning decreases, the converse also appears true (Smith, Coleman, & Gormezano, 1969). That is, as the ISI declines from some optimal interval to simultaneity, conditioned performance also decreases until, for simultaneous conditioning procedures, there is little direct evidence of CR development (c.f., Gormezano & Moore, 1969; Hall, 1976).

In contrast to the results of simultaneous, trace, and delayed conditioning, there has been little agreement as to the effects produced with the application of backward conditioning procedures. In fact, backward pairings of the CS and US have been variously reported to result in: (1) the development of a CR, or excitatory conditioning (e.g., Burkhardt, 1980; Heth, 1976; Heth & Rescorla, 1973; Wagner & Terry, 1975); (2) the development of a response antagonistic to the CR, or inhibitory conditioning (e.g., Barlow, 1956; Moscovitch & LoLordo, 1968; Siegel & Domjan, 1971, 1974); and (3) effects which have been ascribed to nonassociative factors (e.g., Cason, 1922, 1935; Grether, 1938; Kimble, 1961; Smith, Coleman, & Gormezano, 1969; Spooner & Kellogg, 1947). (For a comprehensive review of the effects of backward conditioning see Appendix A).

While the inconsistent outcomes have led to the questioning of backward conditioning as a valid associative phenomenon (e.g., Holmes & Davis, 1979), Tait (1974), Tait, Quesnel, and Ten Have (in press), and Tait, Saladin, Williams, and Quesnel (1984) have suggested that the disparate observations may have a procedural basis. Since the backward conditioning paradigm necessitates US, and hence UR, occurrence prior to CS onset, the residual presence of the UR does not allow the unconfounded assessment of CR development during the US-CS presentations. To circumvent the problem of assessment two research strategies have been employed to measure backward conditioning effects: test trials, and transfer of training designs. The two procedures, however, each invoke assumptions limiting their applicability in the assessment of backward conditioning effects (c.f., Appendix A).

The test trial methodology involves the presentation of CS alone trials interspersed amongst the US-CS trials. Central to this research strategy is the assumption that while CR occurrence on test trials reflects excitatory conditioning, the absence of the CR on test trials is indicative of a nonassociative outcome. Although the assumption may be appropriate for instances of forward conditioning, where only excitatory outcomes are expected, in the backward conditioning paradigm the possibility of an inhibitory outcome cannot be ignored. Since an inhibitory

backward conditioning outcome would also be manifest in the absence of the test trial CR, it is clear that the test trial procedure may not differentiate between nonassociative and inhibitory outcomes.

Congruent with the limitations outlined above, applications of the test trial technique have produced evidence that backward conditioning effects are either excitatory or nonassociative (e.g., Champion, 1962; Grether, 1938; Smith, Coleman, & Gormezano, 1969; Trapold, Homzie, & Rutledge, 1964). Specifically, the backward conditioning test trial procedure has provided limited evidence of excitatory effects with the human GSR (Champion, 1962; Champion & Jones, 1961) and pervasive interpretations of nonassociative outcomes with such responses as the human finger flexion (e.g., Fitzwater & Reisman, 1952), the human eyelid (e.g., Trapold et al., 1964), the human patellar (e.g., Switzer, 1930), the monkey's fear (Grether, 1938), and the rabbit's nictitating membrane (Smith, Coleman, & Gormezano, 1969). North American studies of backward conditioning have primarily been restricted to the above aversive conditioning paradigms. Limited reviews of the Russian conditioning literature suggest that the test trial procedures may identify excitatory backward conditioning when employed with appetitive responses (e.g., Razran, 1956, 1971). With only incomplete experimental protocols available, the objective assessment of this literature is

not possible. However, test trial procedures used with the backward conditioning of the rabbit's appetitive jaw movement response (Quesnel, Moser, Ten Have & Tait, in press; Tait, Quesnel & Ten Have, 1979), have confirmed Razran's reports from the Russian literature. None of the studies that have used the test trial procedure exclusively to address the possibility that backward conditioning could result in inhibitory effects.

The second methodology for the assessment of backward conditioning effects, the transfer of training design, is an indirect measurement technique that has been employed in two distinct forms of backward conditioning transfer: the classical-instrumental transfer designs (e.g., Heth, 1976), and the classical-classical transfer designs (e.g., Plotkin & Oatley, 1975). Of the two forms, the classical-instrumental transfer has been employed more frequently to assess backward conditioning effects. For the classical-instrumental transfer a three-phase experimental procedure is implemented. In phase one an instrumental response (IR) is established and monitored. During phase two, US-CS pairings are administered. The effectiveness of the US-CS pairings are assessed in phase three, the test phase, in which the CS is superimposed on the IR rates. The CS produced changes in the IR rate are inferred to represent the presence of a CS-elicited CR. The central assumptions of the classical-instrumental transfer paradigm (c.f., Tait,

et al., in press) are that: (a) the conditioning of responses in phases one and two are independent processes that do not affect one another until juxtaposed in the test phase; and (b) the motivational factors underlying the conditioning in phase one and two are expressed in phase three as a function of simple combination rules.

The use of the classical-instrumental transfer design has met with mixed success in the assessment of backward conditioning effects. While studies which have employed the same stimulus (i.e., electric shock) as both the phase one reinforcer and the phase two US have reported evidence of inhibitory backward conditioning effects (c.f., Maier, Rapaport, & Wheatley, 1976; Moscovitch & LoLordo, 1968; Nagaty, 1951), experiments using motivationally dissimilar stimuli in the two phases (e.g., a food reinforcer and a shock US) have yielded evidence of both excitatory (e.g., Burkhardt, 1980; Heth, 1976; Heth & Rescorla, 1973; Mahoney & Ayres, 1976; Matsumiya, 1960; Nishizawa, 1962; Nishizawa & Umeoka, 1973) and inhibitory (e.g., Ayres, Mahoney, Proulx, & Benedict, 1976; Siegel & Domjan, 1971, 1974) effects.

Recent analyses of the classical-instrumental assessment strategy have indicated that uncontrolled response interactions may contribute to the outcomes observed in the test phase of the design (e.g., Dickinson & Pearce, 1977; Overmier & Lawry, 1979; Scavio, 1972, 1974;

Trapold & Overmier, 1972). According to the theoretical analyses, the classical-instrumental transfer design allows for the possible development of: a situational CR (i.e., CR₁) in phase one controlling the acquisition and maintenance of the instrumental response (i.e., IR₁; c.f., Scavio, 1972, 1974, 1975); and, an instrumental response (i.e., IR₂) in phase two that act to modulate the effectiveness of the US and occurrence of the CR (i.e., CR₂; Trapold & Overmier, 1972). As the result of the production of uncontrolled response components (i.e., CR₁ and IR₂), the change in the phase three response rate would be controlled by more than the simple CR₂-IR₁ interaction that is presumed to occur in the classical-instrumental transfer design (c.f., Rescorla & Solomon, 1967). The phase three behavioral outcome would be determined by the number and order of the interacting response components (ie.; CR₁-CR₂; IR₁-IR₂; IR₁-CR₂-IR₁; etc.), thus allowing for a multiplicity of possible effects to be observed in the paradigm (i.e., excitation or inhibition). Since the methodology to identify all possible sources of interacting responses has not been developed, it is not possible to interpret clearly the outcome of a classical-instrumental transfer assessment test of the effects of backward conditioning (c.f., Dickinson & Dearing, 1979).

Given the multiple response interaction problem which may occur in the classical-instrumental transfer

design, several authors (c.f., Holmes, 1971; Plotkin & Oatley, 1975; Quesnel, et. al., in press) have suggested that a better strategy might be to employ the classical-classical transfer design since such a procedure eliminates the confounding sources of instrumental interaction and allows a direct assessment of CR_1 - CR_2 interaction. The classical-classical transfer procedure has also been labelled the retardation of learning test, retardation test, and reacquisition test and usually involves a two phase experimental procedure. In phase one, the treatment phase, subjects are presented with US-CS pairings during which the characteristics of responding are monitored. The assessment of the phase one treatment occurs in phase two, the reacquisition test, where the subjects are presented with forward pairings of the stimuli and CR development is monitored. If CR acquisition is more rapid than acquisition in control groups then it is inferred that the phase one backward pairings produced excitatory conditioning effects. On the other hand, if CR acquisition is slower than acquisition in control groups then it is inferred that the backward pairings produced an inhibitory effect. Thus, the use of the classical-classical transfer permits the identification of excitatory, inhibitory, and nonassociative effects (i.e., no difference from control groups).

The assessment of backward pairings with the classical-classical transfer procedure has exacerbated the divergence of inhibitory and excitatory backward conditioning outcomes (c.f., Holmes, 1971; Quesnel et al., in press; Plotkin & Oatley, 1975; Siegel & Domjan, 1971, 1974; Tait, et al., in press) and revealed possible causal factors for the different outcomes. The majority of the studies have employed the aversive conditioning the nictitating membrane response (NMR) or the eyelid response (ER) of the rabbit (c.f., Holmes, 1971; Quesnel, et al., in press; Plotkin & Oatley, 1975; Siegel & Domjan, 1971, 1974; Tait, et al., in press). Across the studies, which sampled backward ISI's ranging from 50 to 10000 msec and number of backward pairings ranging from 5 to 700, the backward conditioning effects observed were uniformly inhibitory.

For example, Quesnel, et al. (in press, Experiment 1) examined the effects of 5, 15, 25, 45, and 65 backward pairings of a 50 msec electric shock US and 500 msec tone CS in phase one on the phase two forward acquisition of the rabbit's NMR. Groups that received either no stimulation (no treatment) or explicitly unpaired CS and US presentations in phase one were included as control groups. In both phase one and two of the experiment the ISI's were 500 msec. The results of the experiment revealed that at all values of the number of phase one trials, the unpaired controls were inhibited relative to the no treatment

controls. Furthermore, the results indicated that while the 5 and 15 backward pairing groups approximated the levels of the corresponding no treatment controls, the 45 and 65 backward pairings groups were inhibitory relative to both the no treatment and unpaired controls. Siegel and Domjan's (1974) study reports similar effects of the number of US-CS pairings on the rabbit's ER. Thus, both studies documented the development of inhibition as a function of the number of US-CS pairings.

Although reports of backward pairing effects for the rabbit's NMR and ER suggest a unitary inhibitory effect, contrary evidence has been obtained in classical-classical transfer of the rabbit's appetitive jaw-movement response (c.f., Quesnel, et al., in press: Experiment 1, Tait, et al., 1979). Tait, Quesnel, and Ten Have (1979) examined the appetitive jaw-movement response (JMR) with a backward pairing paradigm. Employing a 500 msec tone CS and 500 msec, one cc water injected into the oral cavity as the US, 22 backward pairings, unpairings, or no treatments were administered during phase one treatments. Following the phase one treatments, all rabbits received 250 forward pairings of the CS and US. Since the rate of reacquisition was greatest for the backward group, the results clearly indicated that US-CS pairings produced excitatory effects.

To explore the excitatory backward pairing effects observed with the appetitively motivated JMR, Quesnel, Ten Have, and Tait (in press: Experiment 2) presented rabbits with either 25, 175, or 325 backward pairings, unpairings, or no treatments of the same CS and US parameters as employed by Tait, Quesnel, and Ten Have (in press). Following the phase one treatments, all subjects received 250 forward pairings of the CS and US in a reacquisition test of the effects of the phase one treatments. The results of this experiment were unequivocal. At all values of the number of phase one trials, the phase two reacquisition test revealed that the backward groups were excitatory relative to both the unpaired and no treatment controls.

Thus, the application of the classical-classical transfer design to the assessment of backward conditioning effects documents a functional divergence of outcomes. Backward conditioning with an aversive US yields inhibitory effects whereas backward conditioning with an appetitive US yields excitatory effects. The disparate outcomes are not readily explained. Our studies were carefully matched on all major associative variables: US-CS interval, intertrial intervals, CS type, CS parameters, and for some groups in both sets of experiments, the number of trials per experimental session. The only variables that were not equated in the experiments were the motivational systems

activated by the US (aversive for the NMR and appetitive for the JMR), and the response system that was monitored.

Both variables are viable candidates for yielding the discrepant data. In North America, just two studies (Quesnel, et al., in press; Tait et al., 1979, in press) have examined appetitive backward conditioning, all the remaining experiments have employed aversive USs. The appetitive studies are consistent with each other and with the fragmentary results reported for Russian appetitive backward conditioning results (Razran, 1956, 1971). Since several theorists (Bindra, 1978; Konorski, 1967; Scavio, 1974) have suggested a basic asymmetry between central appetitive and aversive motivational states, and others (e.g., Rescorla, 1978, 1979, 1980) have posited the conditioning of qualitative components of motivational states, it is possible that the asymmetrical motivational variables might produce asymmetrical backward conditioning effects.

Differences in response systems being monitored is also a possible factor in producing the functional divergent results. Several theorists (e.g., Gormezano, 1972; Guthrie, 1935; Hull, 1943; Solomon, 1980) state conditions under which excitatory backward conditioning will be determined by UR characteristics. The previously noted excitatory backward conditioning of the long latency GSR is consistent

with all of these theoretical formulations. While both the NMR and JMR have short latencies (20-50 msec for the NMR; 140-210 for the JMR) the responses do differ, significantly, in topographical features. The unconditioned NMR is a closure that begins shortly after US onset and ceases shortly after US offset. However, the appetitive JMR is a sequence of jaw openings and closings that are initiated at with a much longer latency and continues long after the US offset (Sheafor, 1975). The long duration (Guthrie, 1935; Solomon, 1980) and sinusoidal topography (Guthrie, 1935) could be used to predict excitatory JMR backward conditioning. (For a detailing of theoretical expectations for backward conditioning see Appendix B).

The present investigation was designed to determine whether the observations of excitatory and inhibitory backward conditioning effects in the rabbit resulted from the motivational consequences of the US employed, or from the response system examined. The research strategy adopted was to employ the JM response system but change the US to an aversive stimulus. If backward pairings still produced excitatory effects, then response system characteristics would be implicated as the determining variable of the functionally divergent backward conditioning outcomes. However, if inhibitory effects were identified, then the motivational consequence of the US would be implicated.

To implement the research strategy, it was necessary to obtain first an aversive US that would support the conditioning of the rabbit's jaw movement response (Experiment 1). Secondly, it was necessary to reach agreement with the backward conditioning parameters and assessment procedures employed by Quesnel et al. (in press), to allow direct comparisons of experimental outcomes (Experiment 2).

EXPERIMENT 1

The purpose of Experiment 1 was to identify the response characteristics of the rabbit's aversively motivated JMR. Since aversive JMR conditioning has not been previously undertaken, it was necessary to establish effective forward conditioning parameters so that when the effects of backward pairings were assessed in Experiment 2 with a retardation of learning test, expected performance levels would be known. In addition, nested within Experiment 1 was a validity check on the use of the test trial procedure with the aversive JMR. If the changes in conditioning indices on test trials parallel the changes observed on paired trials, then the subsequent use of the test trial procedure to assess backward pairing effects would be unlikely to interact with the effects being measured (c.f., Appendix A). On the other hand, if parallel effects are not found in forward conditioning, then use of test trials with backward conditioning would be suspect.

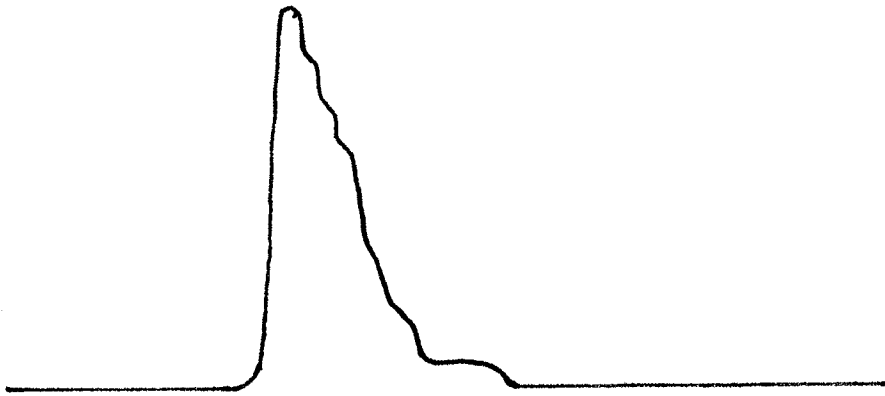
For the present study the stimuli and parameters were chosen according to the following rationale. The CS was a 500 msec, 1000 Hz tone since that has been shown to: (1) reduce nonassociative contributions to responding in rabbits (Gormezano, 1966); and (2) support reliable levels of

conditioning in other aversively (NMR & ER) and appetitively (JMR) motivated response systems in the rabbit (Gormezano, 1966, 1972). The US was a 100 msec, 1.5 mA electric shock applied to the rabbits lower mandible since pilot work had indicated that the reliability of aversive JMR elicitation was significantly enhanced with US intensities above 1.0 mA. Moreover, with a US intensity of 1.5 mA, response elicitation was found to approximate 100% (i.e., 98.7%) over as many as 750 trials. And finally, a CS-US interval of 500 msec was selected since this value has been shown to be effective for the conditioning of both the aversive NMR and appetitive JMR systems (Gormezano, 1972).

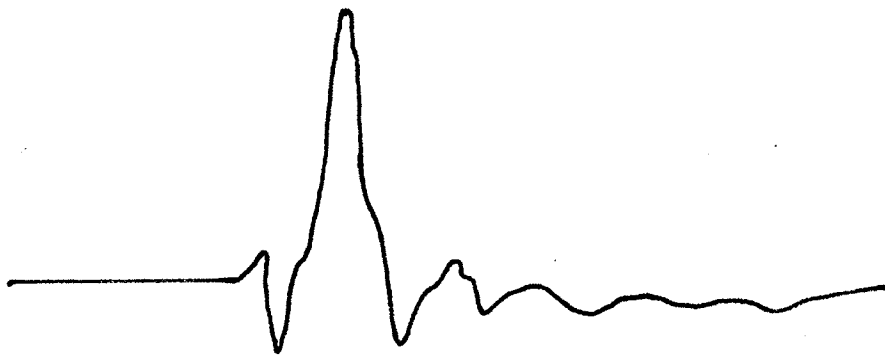
Figure 1 presents the topographical representation of the rabbit's aversively motivated JMR and NMR and appetitively motivated JMR. For the aversively motivated NMR and JMR the US was a 100 msec, 1.5 mA electric shock applied to the paraorbital region (NMR) or lower mandible (JMR). For the appetitive JMR the US was a 300 msec, 1.0 cc intraoral injection of water. From these topographies it is clear that while the NMR is a discrete response which sharply elevates from baseline at US onset and then rapidly declines back to near baseline levels following US offset, the appetitive JMR demonstrates a smoothly increasing and decreasing sinusoidal topography which deviates from baseline in both directions and continues well beyond US offset. In contrast to the NMR and appetitive JMR, the

aversive JMR appears to share topographical features with both of the other response systems. That is, while the aversive JMR manifests a peak response analogous in shape to the NMR, it also demonstrates rapid and sharply defined sinusoidal topographical characteristics analogous to the response characteristics of the appetitive JMR. From the topographical analysis of the elicited responses it appears that the aversive JMR manifests response characteristics midway between the NMR and appetitive JMR characteristics. Given that the aversive JMR appears to differ marginally in form from the other response systems, topographical measures of CR development were collected to validate the aversive JMR system with reference to prior reports of the CR characteristics manifest by the NMR and appetitive JMR. The response measures collected were CR frequency (percent CRs), CR onset latency, CR peak latency, CR amplitude, and CR area.

Figure 1: The topographical portrayal of the elicited aversively motivated (a) NMR and (b) JMR and the appetitively motivated (c) JMR. Downward deflections of the pen reflect US onset and upward deflections indicate US offset. For the NMR the US was a 100 msec, 1.5 mA paraorbital shock. For the aversive JMR the US was a 100 msec, 1.5 mA shock to the inferior labia oris. And for the appetitive JMR the US was a 1.0 cc, 300 msec intraoral injection of water. (The aversive NMR and aversive JMR topographies were taken from Ten Have & Tait (1981) and represent response amplitudes of 6 and 4 mm for the NMR and JMR, respectively. The appetitive JMR topography was derived from Gormezano & Coleman (1973) and is assumed to represent a response amplitude of approximately 4 mm).



AV NMR



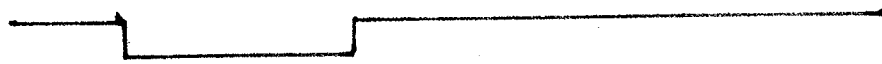
AV JMR



AV US



AP JMR



AP US

Method

Subjects

The subjects were 32 male and female albino rabbits (Oryctolagus cuniculus) about 90 days of age and weighing approximately 2.0 kg. The rabbits were obtained from the Kleefeld Rabbitry of Tourond, Manitoba.

Apparatus

The apparatus and recording procedures for the conditioning of the rabbit's JMR were similar to those described by Gormezano (1972). Briefly, each drawer of two four-drawer, fire-proof, filing cabinets served as an experimental chamber. The filing cabinets were situated in a room separated from the recording and programming equipment and were acoustically isolated by a continuous white masking noise (65 dB, sound pressure level, C scale). Each of the eight experimental chambers (66.3 x 32.5 x 27.5 cm) contained a glossy white stimulus panel (32.5 x 27.5 cm) transversely positioned five cm from the front of the chamber. In each stimulus panel were recessed and mounted two 24 V, six watt incandescent bulbs, which provided illumination to the chambers, and an 8.75 cm, eight ohm, Jana speaker, through which tones could be presented. In addition, an exhaust fan, at the back of each chamber, provided ventilation.

Plexiglas boxes, detailed by Gormezano (1966), were employed to restrain the rabbits in each experiment. The restraining box was positioned centrally in the chamber such that the animal's face was positioned approximately 7.5 cm from the stimulus panel. The positioning of the restraining box was maintained by spring clamps mounted in the floor of a white porcelain painted tray which was fitted to the base of each experimental chamber. The 22.5 x 10.0 x 20.0 cm restraining device served to restrict the animal's gross body movements while head movements were minimized by an adjustable yoke collar and pinnae clamp. In addition, both the yoke collar and pinnae clamp were covered with layers of polyurethane foam to prevent injury to the rabbit's ears.

Jaw movement responses were monitored and recorded by means of microtorque rotary potentiometers (Giannini type 20 & Conrac model 85111 type 2). A single potentiometer was attached to the center bolt of a muzzle-like head mount and positioned on the left side of the animal's head. Monitoring of the JMR was accomplished by means of an insulated-bent pianowire, one end of which was mechanically coupled to the potentiometer shaft and the other end inserted through a stainless steel Autoclip (Clay-Adams, 9 mm) located on the subject's mandible. Subsequently, JMRs displaced the pianowire which rotated the potentiometer shaft to cause a change in voltage that was transduced by the analog-to-digital (A/D) input channels of a Raytheon 703

computer. During trials, each specified A/D channel was sampled every 10 msec for 2000 msec and in this observation interval the stimulus events were delivered and the dependent measures were extracted from the digital representations of the analog response signals.

The DISTRAC-1 software control (Tait & Gormezano, 1974), modified for service with an 8K Raytheon computer system, regulated the delivery and timing of all stimulus events, as well as collected and measured the dependent variables. Moreover, DISTRAC-1, between trials, printed the trial by trial response onset latencies on the ASR33 teletype and plotted the digital representations of the changes in the potentiometer voltage levels on a Tektronix (model 602) oscilloscope. To implement the software package the following peripheral devices of the Raytheon 703 computer were employed: (1) 16 multiplexed channels of 10 bit A/D; (2) a real time clock; (3) a high-speed paper tape reader; (4) a magnetic tape unit; and (5) a 16 bit digital input/output (I/O) buffer optically coupled to each of the stimulus devices. The stimulus devices consisted of a Heath (model IG-18) sine-square wave tone generator and an alternating current (AC) shock source.

For all phases of the experiment, the CS was a 500 msec, 80 dB (sound pressure level, C scale), 1000 Hz tone delivered through the speakers mounted on the stimulus

panels of the chambers. The US was a 1.5 mA, 100 msec, 60 Hz, AC steel Autoclips placed five mm on either side of the midline of the rabbit's inferior labia oris.

Procedure

On arrival, and for the duration of the experiment, the animals were individually housed and maintained on food and water ad lib. Two days following their arrival the rabbits were randomly assigned to one of four groups (n = 8), placed in the restraining devices, and three Autoclips were implanted on each animal's mandible. Two Autoclips were employed as stimulation sites for the delivery of the US. The third Autoclip was implanted under the tip of the mandible to hold the insulated piano-wire armature of the rotary potentiometer.

Immediately following Autoclip placement, the subjects were fitted with head mounts and potentiometers and placed in the experimental chambers for an adaptation session equal in length to subsequent conditioning sessions. During the adaptation session neither the CS nor the US were delivered to the subject, however, jaw movements were monitored in periods corresponding to the observation intervals employed during the acquisition sessions. Twenty-four hours following the adaptation sessions, the first of ten daily acquisition sessions was administered.

For acquisition the four groups of rabbits were randomly assigned to one of four treatment conditions. Group CS-US experienced 22 paired presentations of the CS and US, arranged such that the onset of the CS preceded US onset by 500 msec, and three CS alone test trials during each acquisition session. Group CS experienced 25 presentations of the tone CS in each of the acquisition sessions, of which 22 CS alone trials were designated as paired trials and three CS alone trials were designated as test trials. For both of these groups, test trials were administered on trials 8, 16, and 24 during which topographical forms of the responding were collected. On the other hand, the subjects of group US received 22 presentations of the 1.5 mA US during each conditioning session but no stimuli were delivered during trials 8, 16, and 24. For groups CS-US, CS, and US, trials were presented at intertrial intervals (ITI's) of 100, 120, and 140 sec (mean ITI = 120 sec). Subjects assigned to Group CS/US, however, received 25 CS alone presentations, 22 US alone presentations, and three no stimulus trials, arranged in an explicitly unpaired fashion with the restriction that no more than three CSs or three USs could occur successively and that the mean interval between stimulus presentations was set at 60 sec (ITI values of 50, 60, and 70 sec) for each acquisition session. Moreover, for group CS/US, the eighth, sixteenth, and twenty-fourth CS alone presentations

were designated as test trials (i.e., trials 17, 32, and 46). Following the ten acquisition sessions, all rabbits experienced an extinction session consisting of 50 CS alone trials presented with ITI's of 50, 60 and 70 sec (mean ITI = 60 sec) of which trials 8, 16, and 24 of each 25 trial block was designated as a test trial.

Response specification

A 1.0 mm movement of the jaw, corresponding to a 0.6 V change in the A/D, was the criterion employed to define the occurrence of a response. The execution of CRs were defined as responses occurring in a scoring interval that corresponded to the 500 msec CS or, for groups US and CS/US, the 500 msec interval preceding US onset. For all groups, during extinction only responses occurring during the 500 msec CS were scored as CRs. In addition, for all groups, CR occurrence initiated the topographical measure of CR onset latency, CR peak latency, CR amplitude, and CR area. CR onset latency was defined as the interval, in msec, from CS or scoring interval onset to the initiation of the response prior to US onset. The measure CR peak latency was defined as the time representation (msec) of the peak response amplitude within the CR scoring interval. The CR amplitude refers to the deviation of the response (mm) from non response baseline levels. And CR area refers to the mathematically defined area enclosed by the baseline response level and the CR's deviations from this level.

Results

The results of Experiment 1 were organized and analyzed according to the following structure. The experiment was separated into three segments on the basis of the experimenter operations. The first segment was the adaptation session during which no stimuli were administered. The second segment consisted of the acquisition sessions in which the treatment stimuli were administered. The third segment comprised the extinction trial blocks in which only the CS was presented. In each segment, data were collected during time intervals designated as either "paired" or "test" trials which correspond to the CS-US and CS alone presentations received by the paired group during the acquisition sessions. For continuity of description the trial types will be denoted as "paired" or "test" trials for all segments of this experiment.

For each segment and each trial type of Experiment 1 a analysis-of-variance (ANOVA) was applied to the data for each dependent variable. Moreover, for each analysis, the occurrence of a significant ANOVA resulted in the further analysis of that dependent measure by the application of a Newman-Keuls multiple range test to confirm the contribution of the respective groups to the observations of significant differences.

CR Frequency

Figures 2 and 3 present the mean percent CR performance of all groups on paired (figure 2) and test (figure 3) trials during Experiment 1. As may be observed in both figures, while CR frequency was low for all groups in the adaptation session, during acquisition only Group CS-US demonstrated a substantial change in CR performance levels. For both paired and test trials Group CS-US manifest a negatively accelerated growth of percent CRs while the remaining groups (i.e., CS, US, & CS/US) maintained low levels of responding across the acquisition sessions. In extinction, levels of responding were again low for all control groups and Group CS-US demonstrated a decline in CR frequency across the paired trial blocks to control levels. However, over the extinction test trials, Group CS-US performed at a lower level than in acquisition but did not show a substantial decline in percent CR, and remained elevated relative to the other groups.

Figure 2: Mean Percent CRs occurring on paired trials of Experiment 1 for Groups CS-US, CS, US, and CS/US.

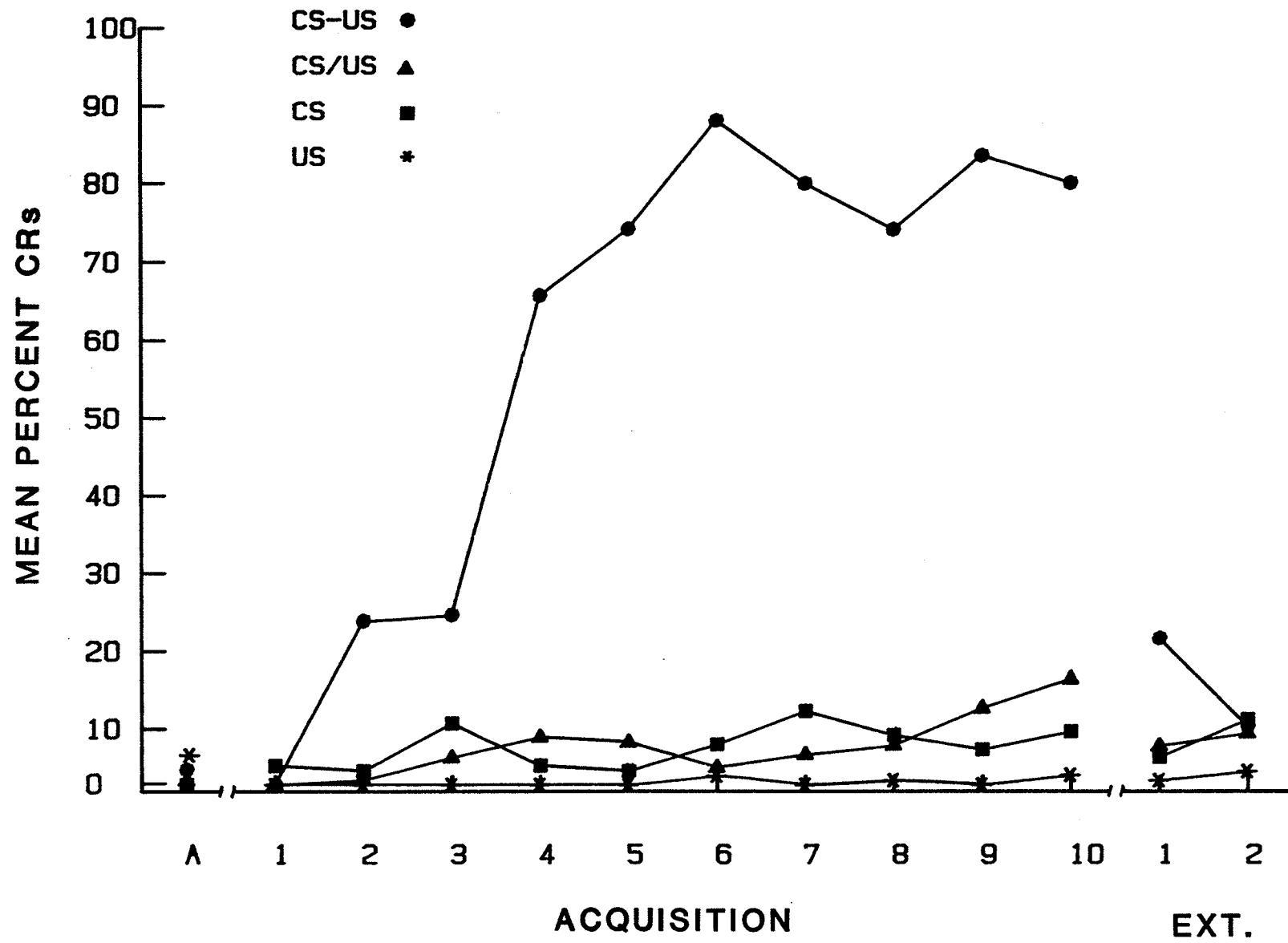
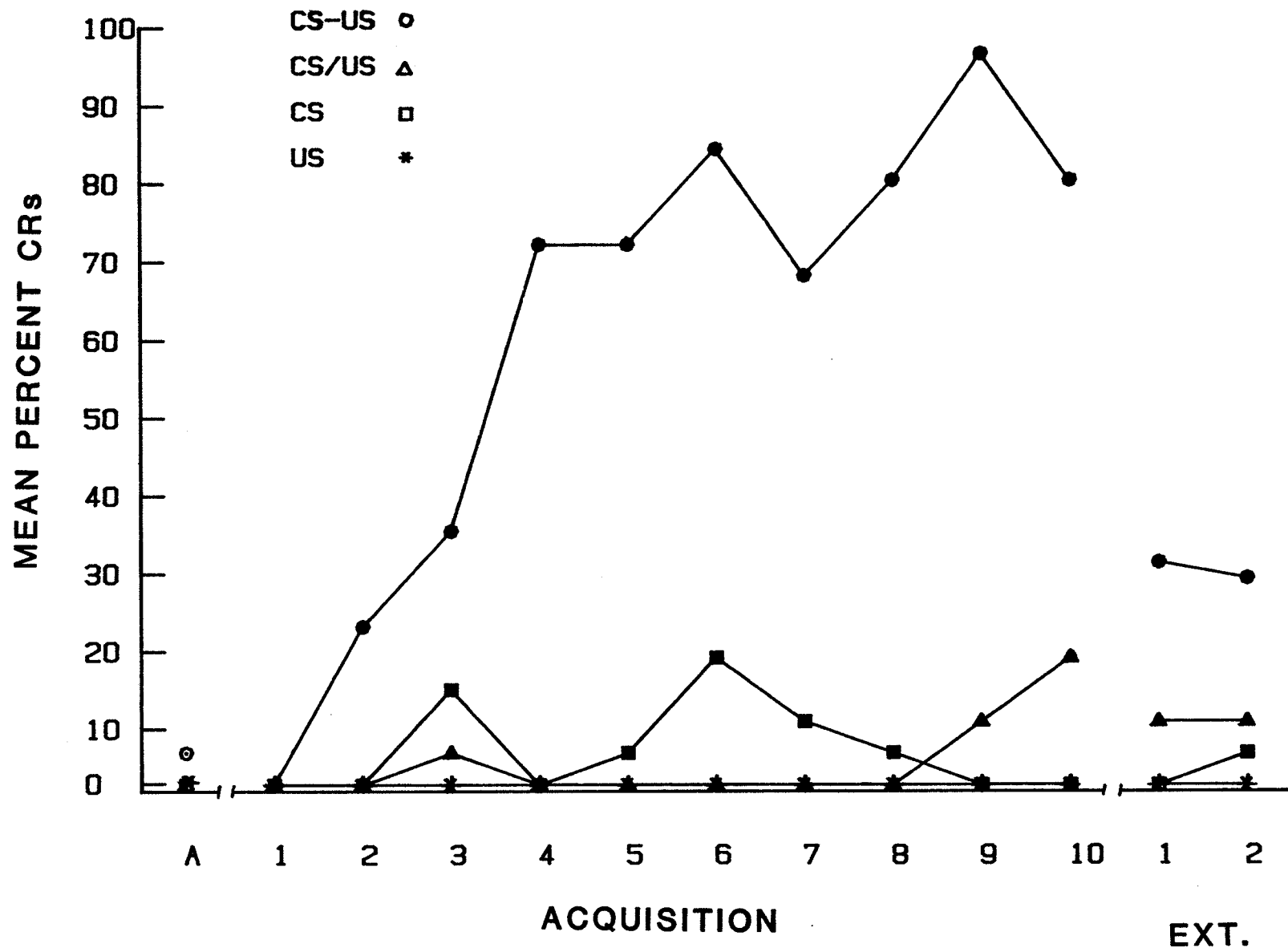


Figure 3: Mean percent CRs occurring on test trials of Experiment 1 for Groups CS-US, CS, US, and CS/US.



The application of Between Groups ANOVA to the CR frequency data confirmed the graphic interpretation. For the adaptation session the ANOVAs revealed no statistically significant group differences during either paired ($F(3,28)=1.04, p<.40$) or test ($F(3,28)=1.00, p<.41$) trials. For the acquisition phase, the analysis of the paired trial data with a mixed effects ANOVA yielded a significant Group effect ($F(3,28)=55.05, p<.0001$) which the Newman-Keuls test ($\alpha=.05$) confirmed resulted from the differences in responding of Group CS-US relative to the CS, US, and CS/US groups, which did not differ from one another. Moreover, the paired trial ANOVA indicated the presence of significant Days ($F(9,252)=15.48, p<.001$) and Group by Days interaction ($F(27,252)=11.44, p<.001$) effects. Significant linear ($F(3,28)=43.15, p<.001$), quadratic ($F(3,28)=23.89, p<.0001$), and quartic ($F(3,28)=7.23, p<.01$) trend components to the interactions strengthened the interpretation of the effect accruing only as the result of Group CS-US performance since this group accounted for 94.2% of the Group by Days effect.

Similar outcomes were obtained for the test trials during acquisition. The test trial mixed effects ANOVA yielded a significant Group effect ($F(3,28)=90.61, p<.0001$) which the Newman Keuls test ($\alpha=.05$) revealed was due to the difference in percent CRs of Group CS-US relative to the control groups which did not differ from each other. The ANOVA also revealed significant Days ($F(9,252)=9.03, p<.01$)

and Group by Days interaction ($F(27,252)=7.53$, $p<.01$) effects. Again Group CS-US test trial performance accounted for 89.2% of the Group by Days interaction effect confirming the reliable changes in the performance of Group CS-US across the conditioning sessions.

During extinction the levels of CR occurrence were low for all groups, however, on paired trials Group CS-US demonstrated the greatest decline in responding from 19.2% on trial block 1 to 7.7% on trial block 2. Moreover, within the first extinction trial block the subjects of Group CS-US responded reliably (48.6%) during the first five trials but demonstrated little CR exhibition during the remaining paired trials of the trial block (i.e., 8%, 13%, 23%, and 10% in the remaining five trial segments). The application of a mixed effects ANOVA to the paired trial extinction data confirmed the interpretation of the extinction effects by revealing a nonsignificant Group ($F(3,28)=1.72$, $p<.20$) and Group by Trial Block interaction ($F(3,28)=0.23$, $p<.70$) effects, but did yield a significant Trial Block effect ($F(1,28)=3.72$, $p<.05$).

On the other hand, in extinction test trial percent CRs demonstrate higher levels for Group CS-US (29%) than for Groups CS (2.5%), US (0%), and CS/US (9.9%). Moreover, across the extinction trial blocks there appears little decline in responding for all groups. The ANOVA confirmed

this interpretation by revealing a significant Group effect ($F(3,28)=3.65$, $p<.05$), which a Newman-Keuls ($\alpha=.05$) range test indicated was the result of Group CS-US manifesting elevated levels of performance relative to the controls, but no Trial Block ($F(1,28)=0.02$, $p<.1.0$) or Group by Trial Block interaction ($F(3,28)=0.11$, $p<.96$) effects.

The CR frequency data are consistent with reports of the conditioning of a variety of response systems in the rabbit. During the acquisition phase the negatively accelerated growth of CR occurrence in Group CS-US, while control group response levels remained low, yielding a result similar to the conditioning evidence reported for the rabbit's aversive NMR (Gormezano, 1966), Heart Rate (Schneiderman, Smith, Smith, & Gormezano, 1966), and the appetitive JMR (Smith, DiLollo, & Gormezano, 1966). Moreover, the rapid extinction of responding by Group CS-US yields evidence of extinction effects consistent with the observed results of heart rate conditioning (Schneiderman, Smith, Smith & Gormezano, 1966) extinction, which returns to baseline levels with as few as 15 extinction trials.

CR Topographies

To support and validate the CR frequency account of aversive JMR conditioning, a descriptive analysis of the CR topographical features is provided for Group CS-US on the

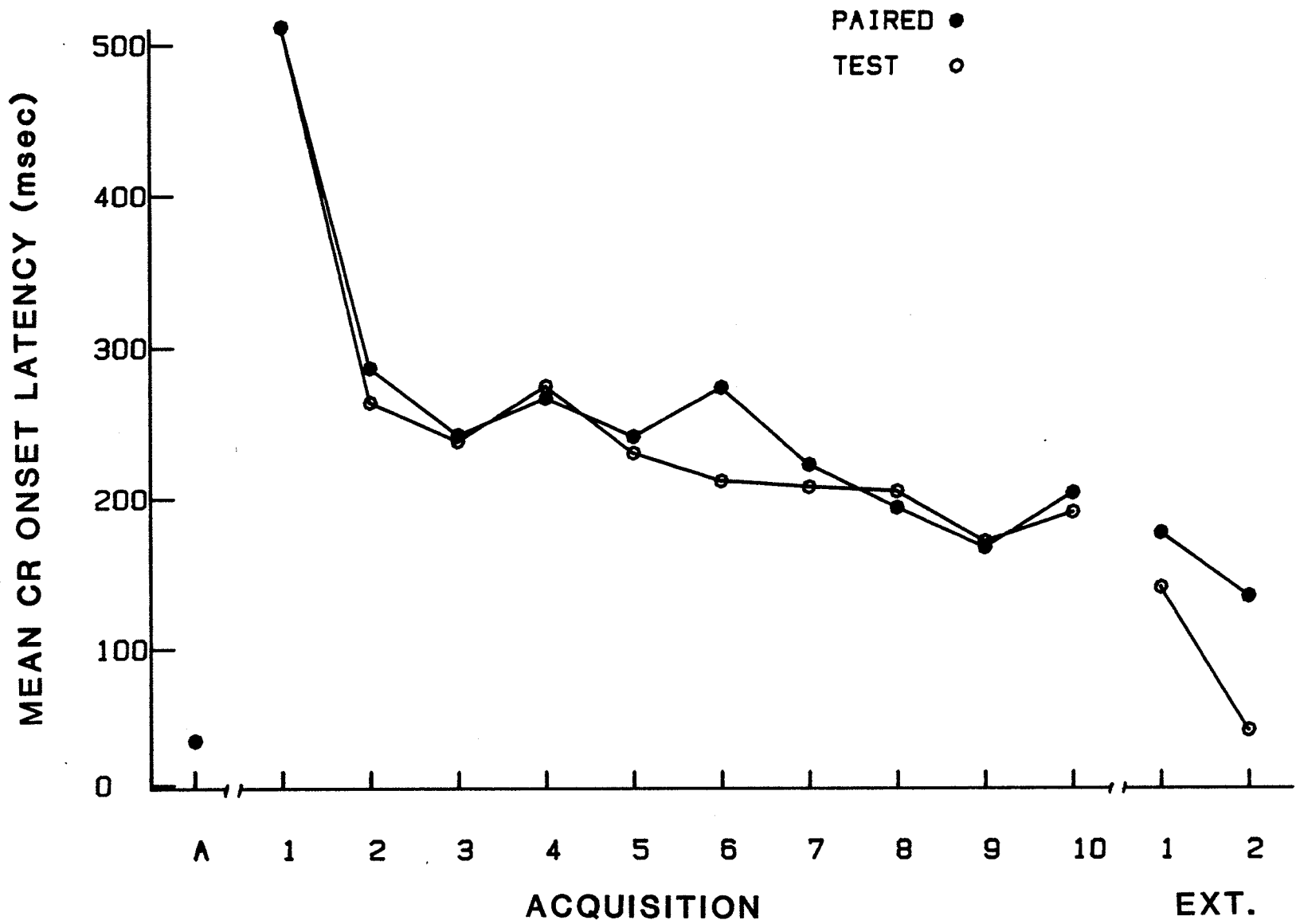
CRs occurring for each subject. The descriptive analysis was undertaken due to statistical complications arising from missing data. These complications, due to subjects that never initiated CRs in Groups CS, US, and CS/US, and also due to the differential acquisition rates of subjects in Group CS-US, precluded statistical analysis. Thus, given the limitations of the descriptive analysis the presentation of CR features focuses on Group CS-US since this group manifested the most frequent and orderly occurrence of CRs. Moreover, where appropriate, the data reported in this study are compared with prior reports of aversive NMR (Gormezano; 1972; Smith, 1966, 1968) and appetitive JMR (Gormezano, 1972, Smith, DiLollo, & Gormezano, 1966) measures. However, while limited reports of CR topographies are available for these responses in acquisition, reports of the adaptation and extinction CR characteristics are either missing (appetitive JMR) or very limited and unclear (NMR). As such, the cross response comparisons will be limited to acquisition effects.

CR onset latency. The CR onset measure is defined as the time interval from CS onset to CR initiation. Figure 4 presents the mean CR onset latency of subjects executing a CR, for Group CS-US on paired (filled circle) and test (open circle) trials. As may be seen from the paired trial data, while responding during the adaptation session demonstrates very short latencies (i.e., 30 msec), responding during the

acquisition sessions demonstrated substantially longer CR onset latencies. During the acquisition phase, the first CR appeared on acquisition day two and demonstrated an orderly decline in latency across the acquisition days. While the day two mean CR onset was 281 msec, by acquisition day 10 the mean onset was 197 msec. Furthermore, during extinction the decrease of CR onset latency continued to decline from 170 msec on trial block 1 to 127 msec on trial block 2.

A parallel response pattern is apparent for the test trial data. During the adaptation session mean CR onset latencies were short (28 msec) but during acquisition onset latencies were longer initially and declined across the sessions. Specifically, the mean onset latencies of CR on day two was 258 msec but by acquisition session 10 the mean CR onset latency had declined to 184 msec. Moreover, during the extinction trial blocks, mean CR latencies decreased from 133 msec in block 1 to 37 msec in trial block 2.

Figure 4: Mean CR onset latencies of Group CS-US on paired and test trials during Experiment 1.



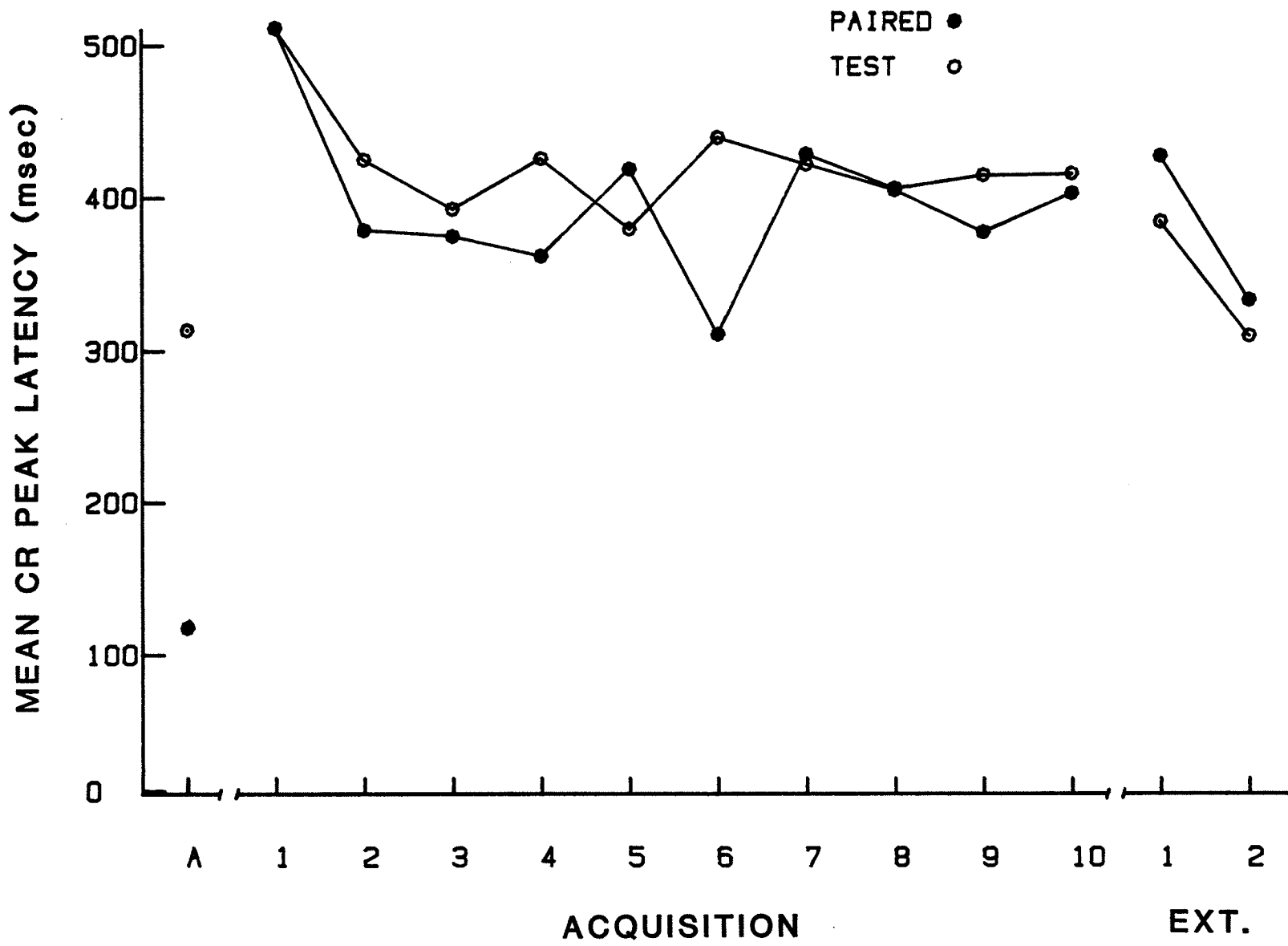
The observed effects of aversive JMR conditioning on CR onset latency are consonant with the reports of CR latency change in other response systems in the rabbit. For both the aversive NMR (Gormezano, 1972; Smith, 1969) and the appetitive JMR (Smith, DiLollo, & Gormezano, 1966) CR onset latency has been observed to move in the direction of CS onset as conditioning progresses. Thus, the aversive JMR and NMR, and the appetitive JMR all yielded similar observations for the role of CR onset latency during conditioning.

CR peak latency. The CR peak latency has been defined as the time from CS onset at which the CR reaches its maximal amplitude (Smith, 1968). Figure 5 presents the paired (filled circle) and test (open circle) trial mean CR peak latencies for subjects that exhibited CRs. During the adaptation session the mean CR peak latency on paired trials was relatively short (i.e., 110 msec) while the test trial mean peak latency was longer (309 msec). However, during the acquisition sessions mean CR peak latencies were similar for both paired and test trials. Moreover, across the acquisition sessions mean CR peak latencies did not appear to change substantially from their initial levels to move either closer to or further away from US onset (i.e., 500 msec following CS onset). During extinction, however substantial increases in CR peak are observed on both paired and test trials.

Although the response shaping formulations (c.f., Appendix B) have specified accounts of reinforcement in classical conditioning which require CR peak to approach and overlap US onset (c.f., Kimmel & Burns, 1975; Martin & Levey, 1969), for the aversive JMR substantial changes from initial mean CR peak latencies are not apparent. While there has been no investigation of CR peak latency changes for the rabbit's appetitive JMR, studies of the rabbit's aversive NMR (Gormezano, 1972; Smith, 1966) have indicated that early in training CR peak latency occurs relatively near US onset but over extended training (up to 1000 trials) CR peak latency may move closer to US onset. Thus, the failure to observe a substantial change of mean CR peak latencies toward US onset are not surprising given the comparatively limited acquisition training of the present experiment. Furthermore, Gormezano (1972) has suggested that while NMR CR peak latencies may demonstrate change with extended training, and Smith (1966, 1968) has indicated that the primary determinant of CR peak latency flexibility is the ISI. That is, with short ISI's there is not sufficient time available to initiate a complete CR prior to US onset, hence CR peak near US onset would represent the growth of the CR overlapping US onset. On the other hand, with longer ISI's, allowing the complete expression of the CR prior to US onset, CR peak may not necessarily overlap US onset. The CR peak latencies of the aversive JMR may thus represent

conditioned responding in a nonoptimal ISI which allows the complete CR occurrence to predate US onset, but with extended training the CR peak latencies might move toward US onset.

Figure 5: Mean CR peak latencies for paired and test trials in Experiment 1.

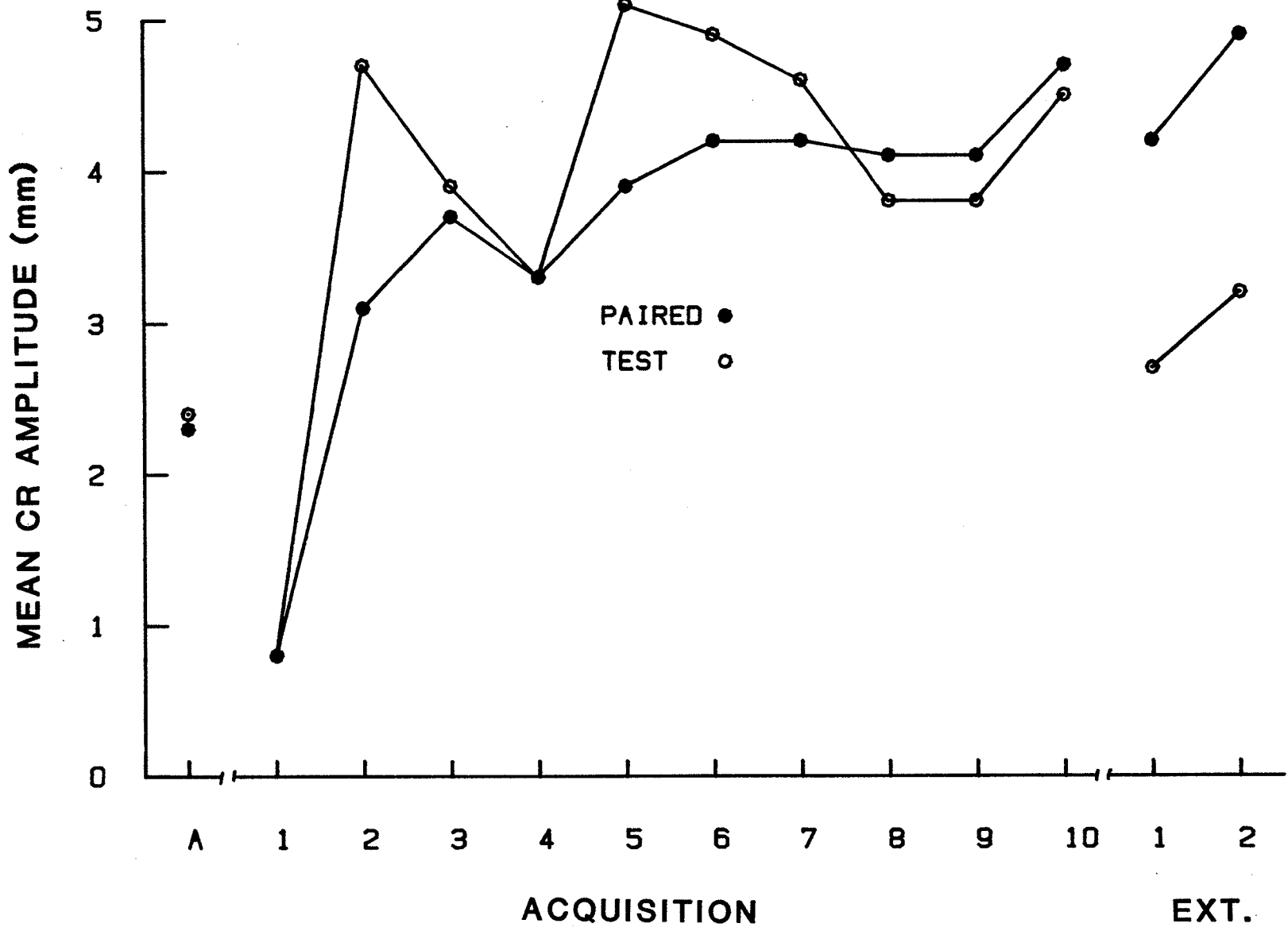


CR amplitude. The CR amplitude measure reflects the maximal deviation from baseline during the CR scoring interval. Figure 6 presents the mean CR amplitudes for Group CS-US in subjects which exhibited CRs. As shown in figure 6, adaptation session CR amplitudes were equivalent on paired and test trials (CR amplitudes=1.5 mm). However, while during the acquisition sessions the paired trial data show a systematic increase in mean CR amplitudes (from 2.2 mm on Day 1 to 3.9 mm on Day 10), the test trial data does not demonstrate the same orderly changes. Test trial performance shows that while Day 1 through 7 amplitudes demonstrate a decrease-increase-decrease pattern of elevations, on Days 8 through 10 the mean CR amplitudes parallel the performance of the Group on paired trials. In extinction, for both paired and test trials, mean CR amplitudes increased over the trial blocks, with paired performance providing a greater increase than test trials.

Unlike the CR peak latency measure, comparison data are available for CR amplitudes in both the aversive NMR (Gormezano, 1972; Smith, 1966, 1968) and the appetitive JMR (Tait, 1974). For both the NMR and appetitive JMR, CR amplitude increases as a function of the number of acquisition trials. The results for both response systems are similar to the effects observed for the aversive JMR on paired trials. Moreover, in the aversive JMR test trial performance variability may reflect incomplete acquisition

during Days 1 to 7, thereby increasing the variability of CR amplitude, since amplitude measures in the aversive NMR are typically represented over 500 or more paired CS-US presentations (Smith, 1966, 1968).

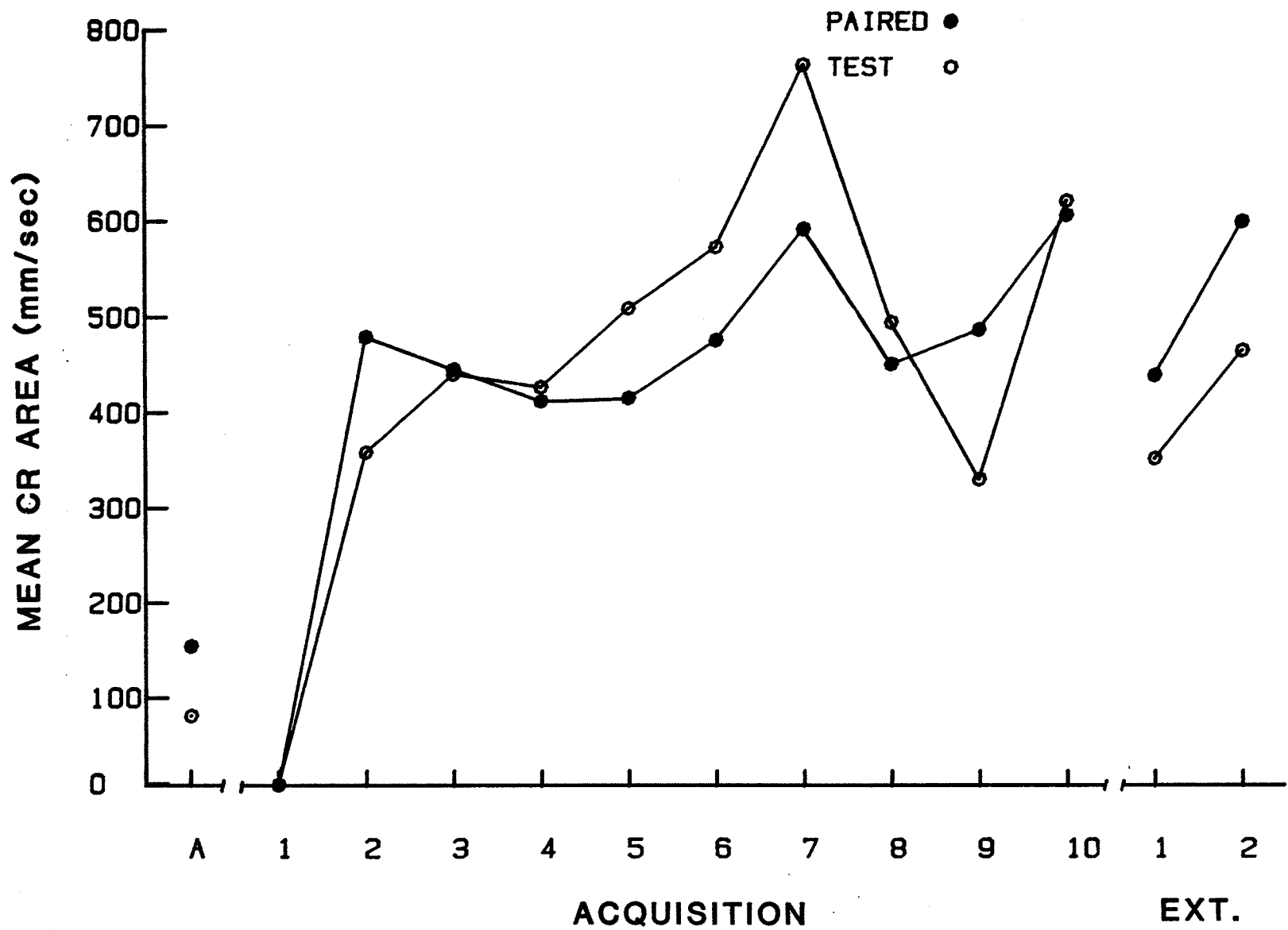
Figure 6: Mean CR amplitude (mm) in Group CS-US for subjects which produced CRs during each session of Experiment 1.



CR area. The CR area measure has been termed the spatial and temporal measure of responding and reflects the area encompassed by the CR and the baseline. Figure 7 presents the mean CR areas of the subjects producing CRs in Group CS-US during Experiment 1. In this figure the paired trial performance is represented by the filled circles and the test trial mean CR areas are presented by the open circles.

During the adaptation session mean CR areas were small on both paired (101 mm/sec) and test (79 mm/sec) trials. During acquisition mean CR areas for both paired and test trials remained roughly parallel. Moreover, other than on acquisition day 7, when both paired and test trial mean CR areas peaked, the area measure increased marginally across training sessions. While in extinction the parallelity of paired and test trial mean CR area performance was again observed with both measures of CR area increasing across the trial blocks. However, during extinction the mean CR area increases appear to fall within the mean CR area limits established for the measure during acquisition.

Figure 7: Mean CR areas (mm/sec) in Group CS-US for subjects which produced CRs in the sessions of Experiment 1.



The CR area measure of conditioned performance has previously been reported for only the aversive NMR (Gormezano, 1972). The report of the NMR CR areas during acquisition have suggested that, as in the case of CR peak latency, CR areas are not readily modified and reflect a direct function of ISI. Thus, with long ISI's there should be longer CR durations, and hence larger CR areas (Gormezano, 1972). The mean CR areas of Experiment 1 appear to support these assertions with respect to the aversive JMR. That is, across acquisition sessions mean CR areas remained relatively fixed, neither increasing nor decreasing substantially, which would be expected if the CR areas were determined by the ISI value employed in the experiment.

Discussion

The principle observations of Experiment 1 were as follows. First, anticipatory JMR CRs were acquired with tone-shock pairings while little responding was observed in control groups. Secondly, the aversive JMR demonstrated a rapid decline in CR frequency levels during extinction. Thirdly, the aversive JM response of CR onset and CR peak amplitude showed orderly changes in acquisition while the measures of CR peak latency and CR area changed only marginally. Fourthly, the aversive JMR demonstrated marginal levels of pseudoconditioned responding. And finally, the paired and test trial assessment of aversive

JMR conditioning identified similar functional relationships with few exceptions. The divergence in functions that occurred between the paired and test trial procedures may only reflect a sampling size difference since the greater number of paired trials may operate through the averaging procedure to reduce the variability observed with the limited test trials.

The major finding of Experiment 1 was the observation that Group CS-US produced an orderly increase in CR frequency on both paired and test trials whereas Groups CS, US, and CS/US maintained low levels of responding during acquisition. Since the performance of Group CS-US was reliably greater than the performance of control groups the incrementing percent CRs for Group CS-CR may not be ascribed to nonassociative factors of pseudoconditioning (Group CS/US), alpha responding (Group CS), or elevated baseline levels of spontaneous responding (Group US). Thus, the negatively accelerated pattern of CR frequency over acquisition training is consonant with: (a) the occurrence of excitatory conditioning; (b) acquisition performance of observed in aversive NMR and appetitive JMR conditioning (c.f., Gormezano, 1965, 1972); and (c) the typical learning-performance curve predicted by theorists (e.g., Hull, 1943; Spence, 1956).

In extinction the aversive JMR showed a rapid decrement in percent CRs that occurred between the first five and the second five extinction trials. Thus, while the rapidity of aversive JM extinction is not consistent with the rate of extinction typically observed in the rabbit's aversive NMR or appetitive JMR, it is consonant with the rate of extinction effects observed with other aversively motivated response systems (e.g., HR, GSR: c.f., Hall, 1976, Kimble, 1961). Thus, although differing response systems vary greatly in their rate of extinction, the mechanisms of such variations have yet to be explicated.

The descriptive analyses of aversive JMR CR topographical characteristics were consonant with the topographical changes observed with both the aversive NMR (Gormezano, 1971; Smith, 1966, 1968) and appetitive JMR (Gormezano, 1972). The CR onset latency was observed to decrease across conditioning sessions while CR amplitude was found to increase. On the other hand, CR peak latency and CR area did not change appreciably over acquisition. Similar effects have been reported for the NMR and appetitive JMR (Gormezano, 1972). Gormezano has indicated that for both the NMR and appetitive JMR, CR onset latency and CR amplitude directly index the acquisition process, whereas the dependent variables of CR peak latency and CR area are static unless ISI or US factors (i.e., intensity, duration) are manipulated. Since in the present experiment

neither the ISI nor US parameters were manipulated, only CR onset and amplitude measures would be expected to change in acquisition. In this respect the CR topographical characteristics of the aversive JMR, aversive NMR, and appetitive JMR are congruent.

Finally, the low levels of responding to the CS in Group CS/US (i.e., 5.1% on paired trials: 2.8% on test trials) suggests that the aversive JMR may resemble the behavioral characteristic of the aversive NMR rather than the appetitive JMR. That is, while the NMR has been demonstrated to be resistant to pseudoconditioning effects (Gormezano, 1966), the appetitive JMR manifests pseudoconditioned responses as an increasing function of the number of stimulus presentations and ISI (c.f., Gormezano, 1972; Sheafor, 1975). In this respect, at the parameters selected for use in Experiment 1, levels of pseudoconditioning for the aversive JMR were substantially less than the levels reported for the appetitive JMR (approx. 12%: c.f., Gormezano, 1972), but consonant with reports of pseudoconditioning levels observed with the NMR (approx. 3%: Smith, 1966).

EXPERIMENT 2

Experiment 1 established that a shock US would support the excitatory forward conditioning of the rabbit's JMR. This demonstration was important since it showed aversive conditioning of the JMR and because it established conditioning parameters that could be used to assess the backward conditioning of the aversive JMR with the classical-classical transfer procedure.

In Experiment 2 the classical-classical transfer design maintained the major associative variables identical to those used by Quesnel, et al. (in press) with two procedural differences. The major differences between the current study and that of Quesnel et al., were: (1) the absence of test trials in the phases of the classical-classical transfer design for the assessment of backward conditioning; and (2) the conditioning of the JMR with shock as the US.

The rationale for the exclusion of test trials was predicated in the results of pilot studies. In pilot studies (c.f., Ten Have & Tait, 1981) test trials yielded no evidence of excitatory outcomes for the aversive JMR during up to 325 backward pairings. Although the associative parameters and procedures in the pilot studies differed from

those utilized by Quesnel et al. (in press), the procedures were sufficiently similar to indicate the relative insensitivity of the test trial procedure for the aversive JMR.

The second major divergence between Quesnel, et al., (in press) and the current experiment was the use of a shock US with the JMR system. With this procedure the expectations were generated that if response system characteristics were important for the determination of the backward conditioning outcome (e.g., Guthrie, 1935) then this procedure should produce evidence of excitatory backward conditioning effects congruent with the effects observed for the appetitive JMR. Conversely, if motivational factors control (e.g., Rescorla & Solomon, 1967; Solomon, 1980; Schull, 1979) the determination of backward conditioning outcomes then the expectation for the current study would be that inhibitory effects similar to those observed for the aversive NMR would be obtained. To assess these expectations Experiment 2 was conducted.

Method

Subjects

The subjects were 96 male and female rabbits (Oryctolagus cuniculus) about 90 days of age and weighing approximately 2.0 kg. The rabbits were obtained from the same supplier as the animals of Experiment 1.

Apparatus, procedure and response specification

The apparatus, procedure, and response specification were the same as those of Experiment 1 with the following exceptions. First, Experiment 2 utilized a three phase classical-classical transfer design which consisted of a treatment phase (phase one), a conditioning phase (phase two), and an extinction phase (phase three). Second, following the adaptation session the subjects were randomly assigned to each cell ($n=8$) of a 3 (Group) x 4 (Phase One Trials) factorial design. The factors were: (a) the type of phase one treatment (i.e., Backward, Unpaired, or No Treatment); and (b) the number of phase one treatment trials (i.e., 5, 25, 125, or 300). Third, twenty-four hours following the adaptation session the animals received the phase one treatments. During phase one the treatments were administered in a single session. For the backward groups (5B, 25B, 125B, and 300B) the onset of the 100 msec, 1.5 mA US preceded the onset of the 500 msec, 80 dB, 1000 Hz by 500 msec and CRs were scored in the 500 msec interval preceding US onset. The backward trials were separated by a mean intertrial interval of two minutes (range=90 to 150 sec). In the unpaired condition the groups (5U, 25U, 125U, and 300U) received explicitly unpaired presentations of the CS and US with the restriction that no more than three CSs or three USs could occur successively and that the mean interval between stimulus presentations was 60 sec (range=50

to 75 sec). The unpaired groups were scored for CR occurrence both during CS presentations and during the 500 msec interval preceding US onset. For the no treatment groups (5N, 25N, 125N, and 300N) subjects were confined to the apparatus for a time period corresponding to the respective backward groups. In the no treatment groups, responses were scored during time intervals equivalent to the intervals scored in the respective backward groups but no stimuli were administered.

On the following day, the first of 10 daily forward conditioning sessions was administered to all subjects. The temporal and stimulus parameters of the phase two conditioning procedure were identical to the parameters employed in Experiment 1 for Group CS-US. During phase two the subjects received 25 CS-US pairing in each session. Following the last reacquisition session, all subjects received two days of extinction. Each extinction session consisted of 25 CS alone presentations at a mean intertrial interval of 120 sec.

Results

The analyses of Experiment 2 data were organized according to the phases of the experimental design (i.e., adaptation, phase one treatment, phase two reacquisition, and phase three extinction). For each analysis, ANOVAs were

applied to the percent CR data and significant effects were further assessed with either orthogonal polynomials for trend or the Newman Keuls range test ($\alpha=.05$).

Adaptation

During the adaptation session responding occurred at low levels for all groups (range = 0 to 5.0%). Moreover, the examination of percent responding by subjects assigned to the Backward (0.67%), Unpaired (1.79%) and No treatment (1.38%) conditions revealed low levels across the Group factor. Across the Phase One Trials factor percent responding was again low (i.e., 5 TRL=1.67%, 25 TRL=0.0%, 125 TRL=2.63% and 300 TRL=0.70%). The between factor ANOVA applied to the adaptation data confirmed these observations by revealing nonsignificant Group ($F(2,84)=0.59$, $p < .60$) or Group by Phase One Trials Interaction ($F(6,84)=0.84$, $p < .55$) effects and a marginally significant Phase One Trials effect ($F(3,84)=2.23$, $p < .10$) which occurred as the result of the absence of responding by the 25 Phase One Trials condition.

Phase one responding

During phase one treatments, while mean levels of responding were low in the Backward and No Treatment conditions (0.0% and 1.1%, respectively), the Unpaired

condition exhibited a relatively greater frequency of responding (3.45%). Moreover, across the number of Phase One Trial conditions, levels of responding were also low (5 TRL=3.08%, 25 TRL = 0.0%, 125 TRL=2.08%, & 300 TRL = 0.90%). The ANOVA confirmed the observations by revealing only a significant Group effect ($F(2,94) = 3.20, p < .059$) which resulted from the difference between the Unpaired and Backward conditions. Neither the Phase One Trials ($F(3,84)=1.41, p < .25$) nor the Group by Phase One Trials interaction ($F(6,84)=1.78, p < .15$) effects approached significance.

Phase two reacquisition

During Phase Two reacquisition, the overall mean percent CRs for the Backward, Unpaired, and No Treatment conditions were 33.88%, 31.94%, and 43.65%, respectively. The differences in percent CRs yielded a significant Group effect ($F(2,84)= 4.49, p < .02$) in a mixed model ANOVA. The Newman-Keuls range test revealed that the Group effect was due to significantly higher levels of percent CRs observed in the No Treatment condition relative to the Backward and Unpaired conditions which did not differ from one another ($\alpha = .05$).

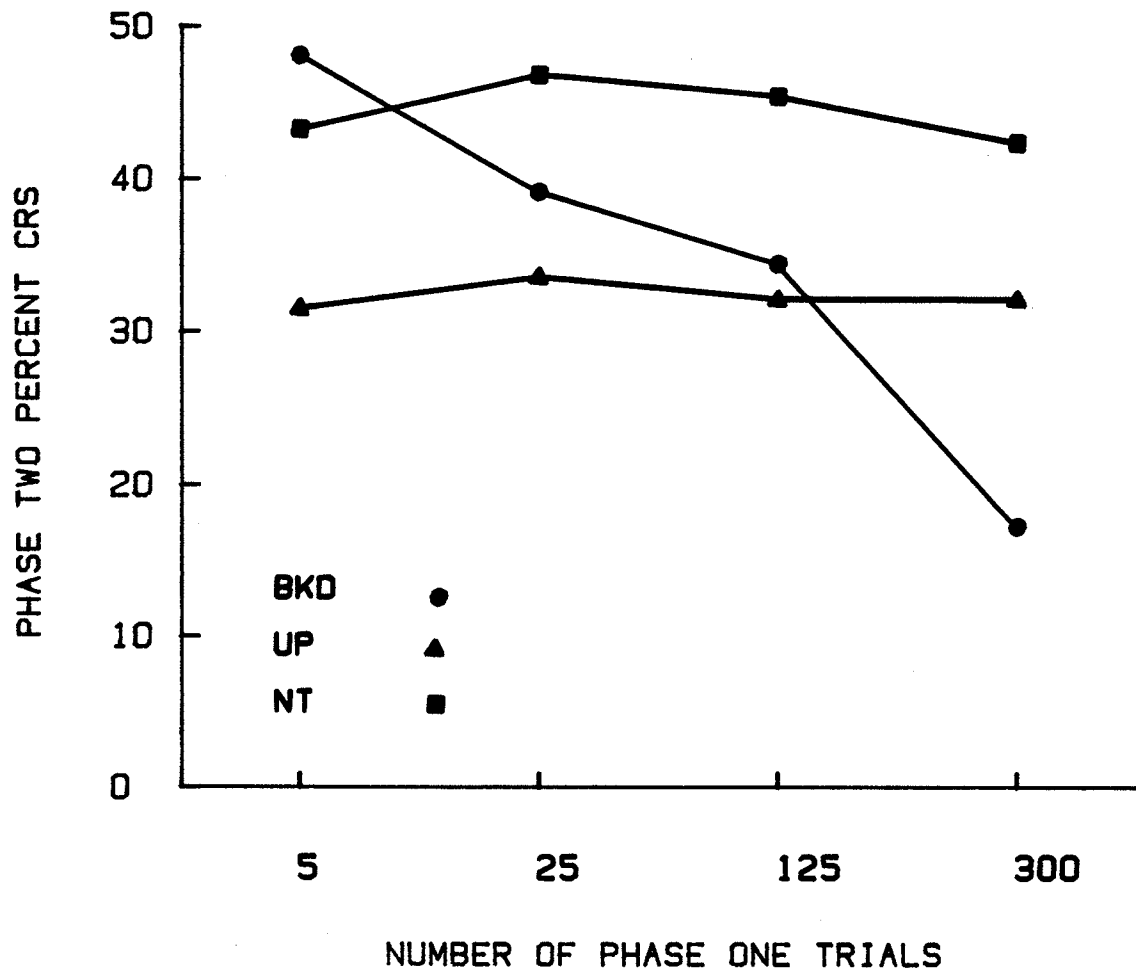
For Phase Two reacquisition mean percent CRs appeared to decrease as a function of the number of Phase One Trials

(i.e., 5 TRLS = 40.12%, 25 TRLS = 39.01%, 125 TRLS = 36.47%, and 300 TRLS = 30.37%). Although the ANOVA did not directly confirm the decreasing function (i.e., Phase One Trials, $F(3,84) = 1.62, p < .20$), a priori orthogonal components for trend revealed a significant decreasing linear trend ($F(1,84)=4.86, p < .05$) over Phase One Trials. Thus, the trend analysis confirmed that the mean percent CRs decreased as a function of the number of Phase One Trials, and the ANOVA indicated that the decrease was a weak effect.

Figure 8 presents the overall mean percent CRs in reacquisition for the Backward (BKD), Unpaired (UP), and No Treatment (NT) conditions as a function of the number of Phase One Trials. The figure suggests that the No Treatment and Unpaired conditions did not change substantially as a function of the number of Phase One Trials, whereas the mean percent CRs for the Backward condition appeared to be inversely related to the number of Phase One Trials. Although the ANOVA revealed a nonsignificant Group by Phase One Trials ($F(6,84)=1.66, p < .15$) interaction, orthogonal components for trend yielded a significant linear trend ($F(2,84)=8.94, p < .01$) to the interaction. The linear component to the interaction resulted from the absence of linear components for the No Treatment ($F(1,84) < 1.0$) and Unpaired ($F(1,84) < 1.0$) conditions and a significant decreasing linear effect for the Backward condition ($F(1,84)=13.65, p < .001$). The linear effect for the Backward

conditioning accounted for 96.8% of the interaction variance.

Figure 8. Overall mean percent CRs of the Backward, Unpaired and No Treatment conditions as a function of the number of Phase One Trials.



The repeated measures component of the mixed ANOVA contained significant days ($F(9,756)=158.54, p < .01$), Phase One Trials by Days ($F(27,756)=1.89, p < .01$), Group by Days ($F(18,756)=3.25, p < .01$) effects and a marginally significant Groups by Phase One Trials by Days interaction ($F(54,756)=1.26, p < .11$). The Days effect indicated that percent and CRs increased over Days and confirmed that the acquisition of the aversive JMR occurred.

Figure 9 depicts the significant mean percent CRs for the 5, 25, 125 and 300 Phase One Trial conditions as a function of Days. The figure shows that the rate of acquisition was inversely related to the number of Phase One Trials. The 5 Phase One Trial condition had the fastest rate of acquisition, which the 300 Trial condition had the slowest rate of acquisition.

Figure 10 depicts the significant Group by Days interaction by presenting the mean percent CRs for the Unpaired, Backward and No Treatment Conditions as a function of Days. The Figure reveals that the Groups were rank ordered on the rate of acquisition. The No Treatment Condition showed the fastest rate of acquisition, the Backward Condition showed the slowest rate, and the Unpaired Condition was between the two other conditions.

Figure 9. Mean percent CRs for the 5, 25, 125 and 300 Phase One Trial conditions across the 10 days of reacquisition.

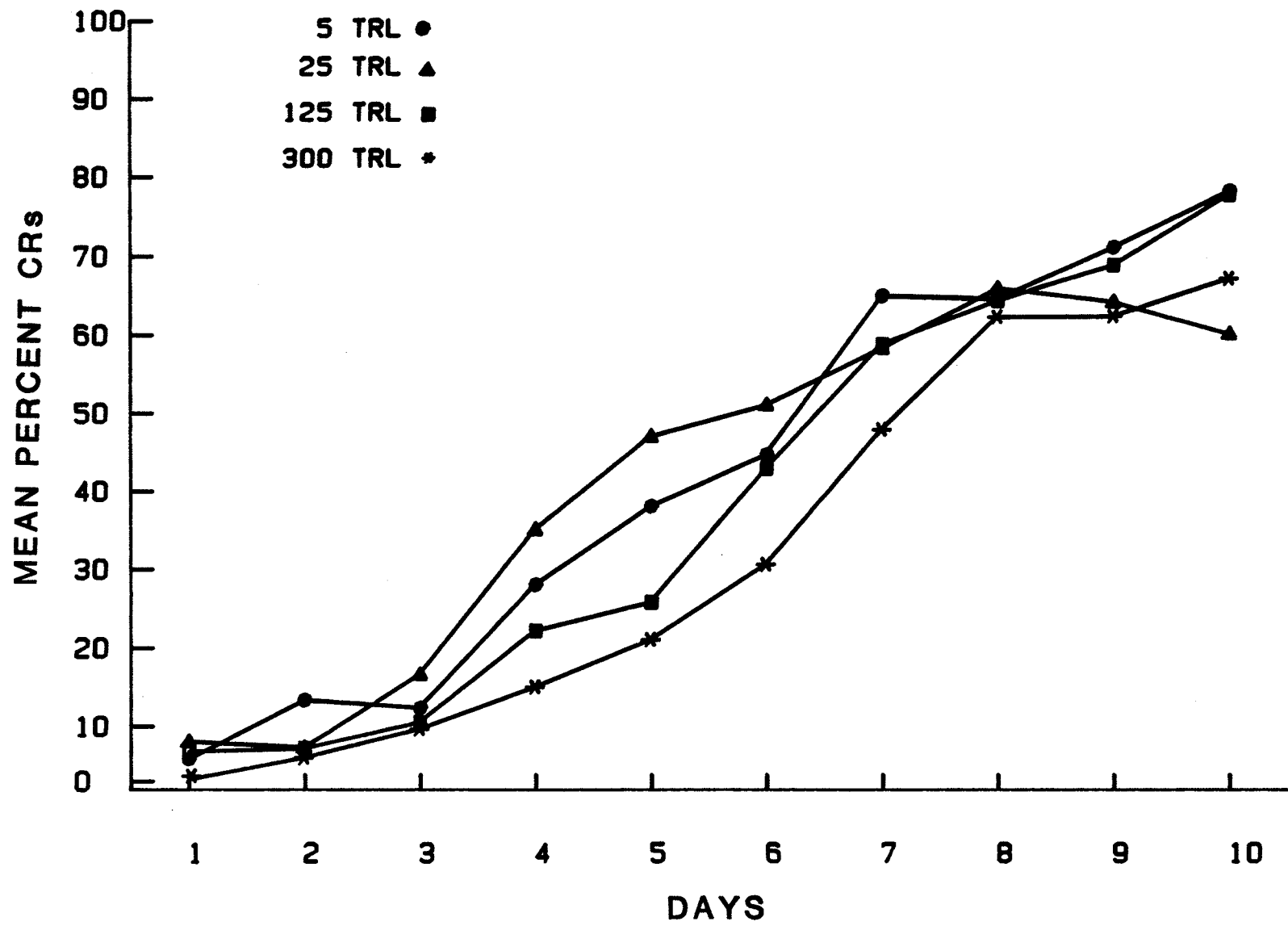


Figure 10: Mean percent CRs for the Backward Unpaired, and No Treatment conditions across the 10 days of reacquisition.

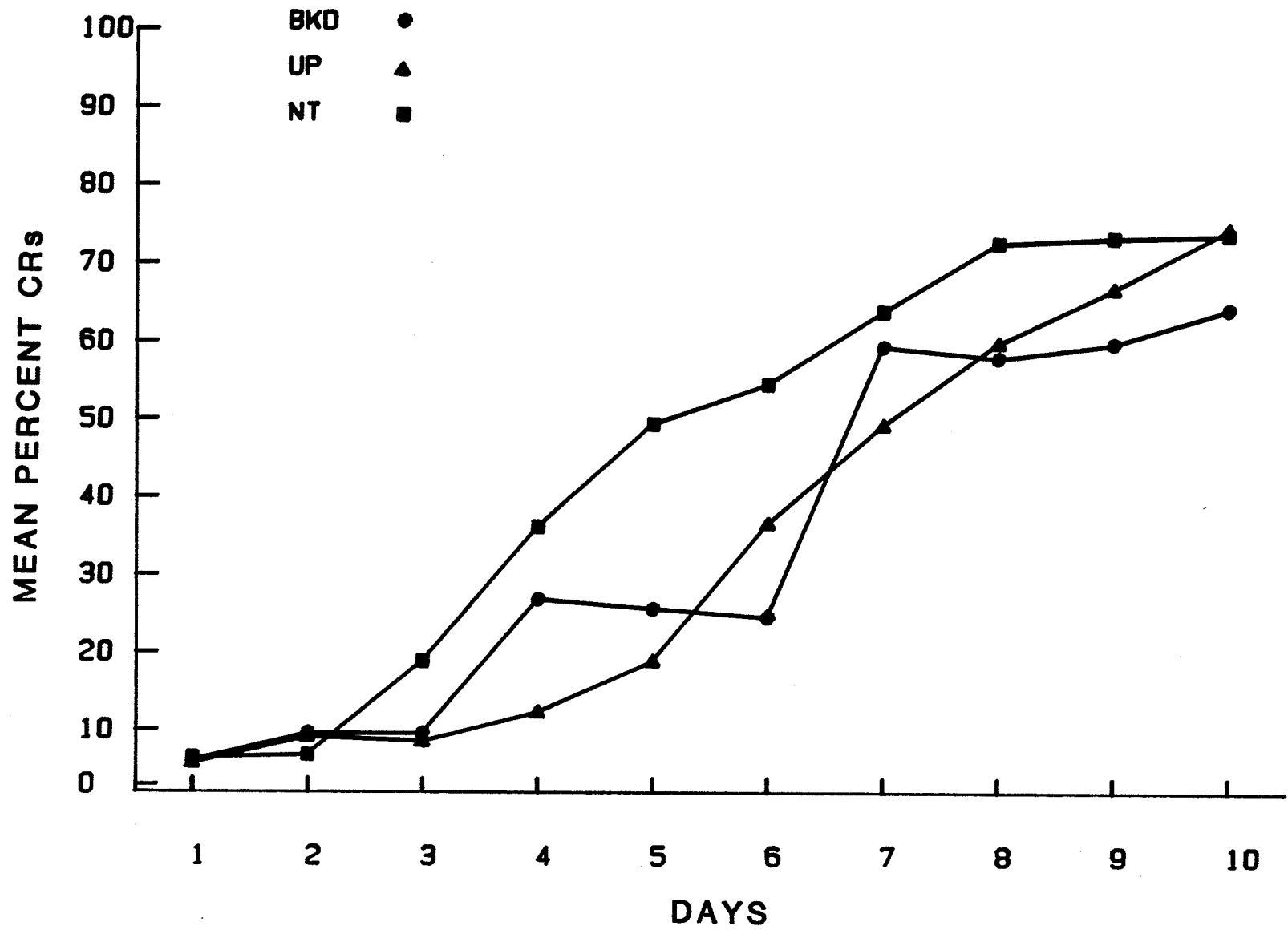
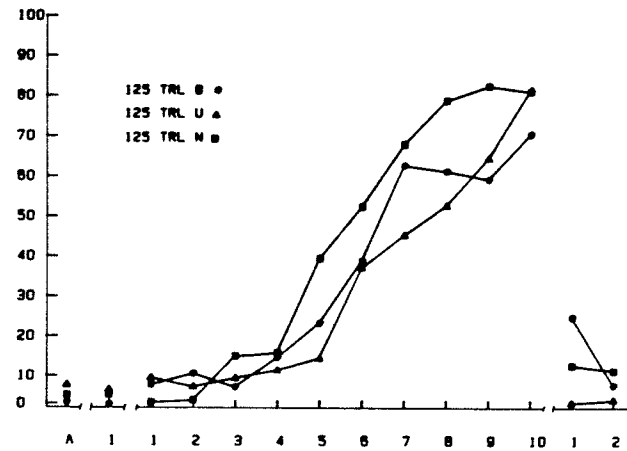
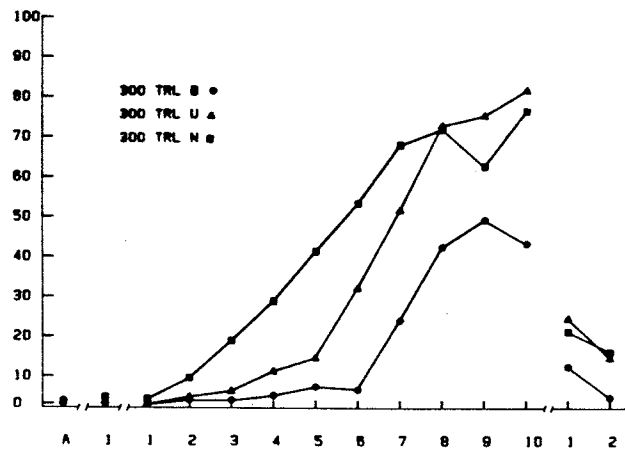
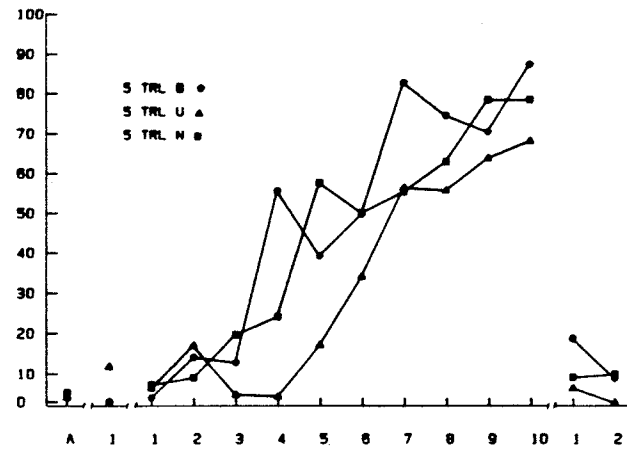
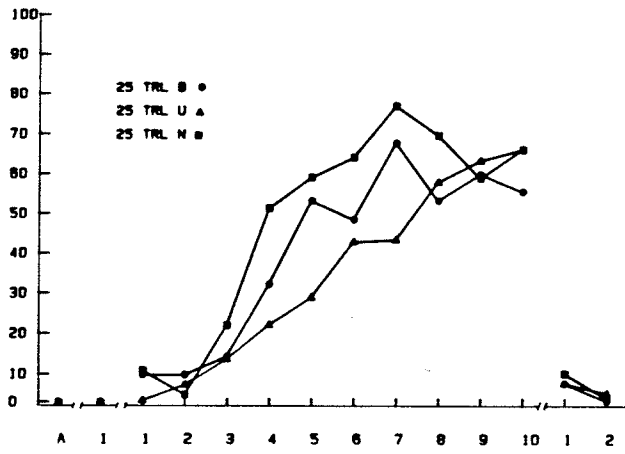


Figure 11: Mean percent CRs of the Backward Unpaired and No Treatment conditions for each of the number of Phase One Trial conditions across the 10 days of reacquisition Panel (a) depicts the 5 Phase One Trials condition; Panel (b) shows the 25 Phase One Trials condition; Panel (c) presents the 125 Phase One Trials conditions; and Panel (d) illustrates the 300 Phase One trials condition.

PERCENT CRS



ACQUISITION

Figure 11 illustrates the triple interaction by plotting the Backward, Unpaired and No Treatment conditions as a function of Days for each level of the Phase One Trials Condition. A comparison of the frames of the figure suggests that the rate of acquisition for the No treatment and Unpaired conditions did not change appreciably over the levels of the Phase One Trials Condition. However, the rate of acquisition for the Backward Condition was inversely related to the number of Phase One Trials. In the frame of Figure 11 depicting acquisition after 5 Phase One Trials the acquisition function for the Backward Condition overlay the acquisition function for the No Treatment Condition. As the number of Phase One Trials increased the slope of the acquisition function for the Backward Condition became successively less than the slopes of the other Functions such that, after 300 Phase One Trials, the Backward Condition acquisition function was clearly lower than either the No Treatment or Unpaired acquisition functions.

Phase three extinction

During Phase Three Extinction, as in Experiment 1, extinction occurred rapidly and only low levels of responding were observed. The mean percent CRs in extinction for the Backward, Unpaired, and No Treatment conditions were 8.42%, 5.87%, and 9.25% respectively. The mean percent CRs for the 5, 25, 125, and 300 Phase One Trial

conditions were 6.71%, 3.63%, 7.94%, and 13.19%, respectively. The low levels of responding precluded observing differences in extinction (Group effect: $F(2,84) = 0.47$, $p < .63$ and Phase One Trials effect: $F(6,84) = 1.10$, $p < .20$).

As in Experiment 1, extinction was essentially completed within the first 25 trial block. The overall mean percent CRs on trial block 1 was 10.1% and the percent CRs on trial block 2 was 4.7%. The decrease of 5.4% from trial block 1 to trial block 2 produced a significant Trial Block effect ($F(1,84) = 11.91$, $p < .05$) but no significant Group by Trial Block ($F(2,84) = 1.92$, $p < .20$), Phase One Trials by Trial Block ($F(3,84) = 0.21$, $p < .90$), or Group by Phase One Trials by Trial Block ($F(6,84) = 0.89$, $p < .55$) effects.

Discussion

The low baseline responding in adaptation, the low level of responding to the CS by unpaired groups during the treatment phase, the moderate rate of acquisition displayed by most groups during phase two reacquisition, and the rapid rate of extinction observed with all groups, replicated and extended the observations made in Experiment 1 on the aversive conditioning of the rabbit's JMR. Even though in Experiment 2 procedures were interpolated prior to CS-US pairings, the observations that all groups acquired a

reliable aversive JMR CR further confirms the validity of the aversive JMR procedure for the assessment of conditioning effects

In addition, the acquisition of the aversive JMR CR proved to be sensitive to prior treatments. The groups which received No Treatments during the treatment phase demonstrated similar rates of acquisition and levels of conditioning during reacquisition which resulted in a flat percent CR function over the Phase One Trials variable. Similarly, the groups which received Unpaired CSs and USs, also manifested equivalent rates of acquisition, levels of conditioning and also yielded a flat function over the Phase One Trials variable. However, the function obtained for the Unpaired condition was significantly lower than the function obtained for the No treatment condition. Accordingly, the Unpaired condition demonstrated inhibitory reacquisition effects relative to the No treatment control condition. In contrast to the flat functions observed with the No treatment and Unpaired conditions, the Backward condition was an inverse function of the number of Phase One Trials. Moreover, while the performance of the 5B group did not differ from the performance observed in the 5N group, 300B group performance was significantly less than the corresponding Unpaired group, and both were lower than the No treatment level. The increasingly retarded performance observed in the Backward condition as the number of backward

pairings increased indicated that inhibition was being acquired to the backward CS. Furthermore, Experiment 2 indicated that after 300 backward pairings, the backward condition was more inhibitory than the Unpaired condition. Thus, Experiment 2 indicated that backward conditioning of the aversive JMR produces inhibitory effects.

Although the observation of the inhibitory backward conditioning effect was the primary focus of Experiment 2, Unpaired performance provides a question for the notion of inhibitory acquisition processes. In both the present experiment and Qusenel et al. (in press), the aversive backward conditioning of the rabbit's NMR, the unpaired condition yielded a flat function over the number of phase one trials that was consistently lower than the function obtained with no treatment controls. Since it has been advocated and confirmed (e.g., Rescorla, 1969; Wagner & Rescorla, 1972) that the unpaired presentation of stimuli is one method of producing an inhibitory outcome and backward conditioning is a second method, the question arises as to why there is a functional difference between backward and unpaired effects when the number of exposures to the stimuli are equated? That is, for both the aversive JMR and NMR, the differences between Unpaired and No Treatment conditions develops rapidly (i.e., < 5 trials) whereas the inhibitory backward conditioning effects development more slowly (i.e., NMR > 45 trials:aversive JMR < 125 trials). Moreover, the

magnitude of the unpaired inhibitory effect does not change as the number of CSs and USs presented increases, whereas the magnitude of the backward inhibitory effect increases with increased training. Thus, there are distinctly different acquisition functions for the inhibition produced by unpaired and backward treatments. Whether such differences are due to inhibitory process differences or differences in the sensitivity of inhibition to procedural variations has yet to be determined.

GENERAL DISCUSSION

In Experiment 1 the forward conditioning of the aversive JMR was established. The aversive conditioning of the JMR was shown to produce forward conditioning CR acquisition concordant with reports of conditioning for the rabbit's aversive NMR (Gormezano, 1971; Gormezano, Schneiderman, Deaux, & Fuentes, 1962; Smith, 1966), aversive ER (Schneiderman, Fuentes, & Gormezano, 1962) and appetitive JMR (Gormezano, 1972; Smith, DiLollo & Gormezano, 1966). Moreover, the topographical characteristics of the aversive JMR were also found to demonstrate the same characteristic patterns reported for the aversive NMR (Gormezano, 1972; Smith, 1966) and appetitive JMR (Gormezano, 1972; Tait, 1974). Thus, for all measures of forward conditioning the aversive JMR was found to produce results consonant with the reports of conditioning found with other aversive and appetitive responses in the rabbit.

In contrast to the consonance achieved with Experiment 1, Experiment 2 provided further evidence of discordant backward conditioning effects when the classical-classical transfer design was applied to the aversive JMR and compared to the results obtained for the appetitive JMR and the aversive NMR (e.g., Quesnel et al., in press). In

Experiment 2, the US-CS and CS-US conditioning parameters were closely matched to the parameters used by Quesnel et al. (in press) for the establishment of excitatory backward conditioning of the appetitive JMR. However, with these parameters, backward conditioning of the aversive JMR and indicated that the inhibitory effect was acquired as the number of backward pairings increased. These backward conditioning effects observed with the aversive JMR were similar to the inhibitory effects observed with the aversive NMR (Quesnel, et al., in press; Tait et al., in press) and aversive ER (Siegel & Domjan, 1971, 1974) but divergent from the reports of excitatory backward conditioning reported for the appetitive JMR (Quesnel et al., in press; Tait et al., in press).

The observation of an inhibitory backward conditioning acquisition function for the aversive JMR (Experiment 2) and evidence of an excitatory acquisition function for the appetitive JMR (Quesnel, et al., in press), with identical associative parameters and similar response properties, is problematic for most theories of learning. Formulations that would attribute backward conditioning responding to nonassociative factors (e.g., Gormezano, 1972; Hull, 1943; Spence, 1956) may not account for the observations of excitatory or inhibitory effects observed with US-CS pairings. Similarly, theories that would predict the occurrence of only inhibition (e.g., Gray, 1975; Prokasy,

1965, 1972; Rescorla, 1967; Rescorla & Solomon, 1967; Rescorla & Wagner, 1972) or only excitation (e.g., Gormezano, 1972; Hull, 1943), do not allow for the occurrence of both effects either between or within response systems. Only theories which stress either the US elicited response characteristics (e.g., Guthrie, 1935; Solomon, 1980) or the recognition of motivational determinants of behavior (e.g., Konorski, 1967; Rescorla, 1980) might offer possible accounts of the observations of excitatory and inhibitory backward conditioning effects within the JMR system.

Of the theories which might attempt to account for the divergent backward conditioning outcomes, only Guthrie (1935) and Solomon (1980; Solomon & Corbit, 1974) would link the occurrence of excitation or inhibition to an association between a CS and US produced response characteristics. Although the theories are conceptually distinct, the inclusion of a response rule for Solomon's position (1980; Solomon & Corbit, 1974) would lead to both theories requiring response characteristics to control the determination of conditioning outcomes. Briefly, for Guthrie (1935), conditioning was thought to occur as the result of associations between contiguously occurring CS-produced cues and the UR. On the other hand Solomon (1980) has postulated the contiguity of underlying motivational/emotional processes with the CS as the

essential components of association. In Solomon's theory, two opposing components (the A- and B-processes) interact to produce the response activating properties. For this theory, the A-process is thought to produce the response activation properties of the situation while the B-process is thought to determine the response decrement properties. Thus, the subtractive interaction of the processes will determine the moment to moment change in both response and associative characteristics. If the A-process is greater than the B-process when the CS is presented then an excitatory outcome might be expected to occur. Conversely, if the B-process is greater than the A-process at CS occurrence then an inhibitory association between the CS and response would be expected. Therefore, if one assumes that the A-process is represented by UR occurrence and UR offset determines the B-process > A-process state (c.f., Solomon & Corbit, 1974) then both Guthrie and Solomon would reduce to the same formulation.

Tait et al. (in press) and Quesnel et al. (in press) have applied the Guthrie-Solomon response characteristics postulations to the analysis of backward conditioning with the aversive NMR and appetitive JMR. Briefly, these analyses assert that since the NMR is a short latency and short duration response system (c.f., Gormezano, 1966) then with the short US durations and comparatively long ISI employed by Quesnel et al., (i.e., 50 msec US and 500 msec

ISI) the CS onset would most probably overlap the retraction of the NMR rather than its initiation. Since the NMR retraction is antagonistic to the NMR initiation elicited by the US the backward pairings would produce an inhibitory association. A similar analysis holds true for the backward conditioning of the ER. Conversely, since the appetitive JMR is a sinusoidal response pattern of the opening and closing of the rabbits mouth, and the US duration continues until CS onset (500 msec US and 500 msec ISI), then backward associations might maximize response characteristics which facilitate the behavioral expression of excitation. Such an analysis may also be applied to other reports of excitatory backward conditioning obtained with the long latency human GSR (c.f., Champion, 1962; Champion & Jones, 1961). For the GSR the continuation of the slowly developing amplitude response would necessarily overlap the CS and, thus, the association would be formed between the CS and the UR initiation process rather than the decremental UR phase and hence insure the occurrence of excitatory conditioning. Problematically, however, the elicitation of the aversively motivated JMR demonstrates many of the same characteristics as the appetitive JMR (c.f., Figure 1: e.g., duration, amplitude). Since the aversive JMR UR has a sinusoidal component that continues long enough to overlap the CS then excitatory conditioning should also be maximized with this response. Empirically such is not the case. Therefore,

difference in response systems would not appear to produce the divergent effects observed with backward pairings.

However, the response characteristics view could generate an alternative account based on differences in US duration between the studies. That is, for the appetitive JMR (Quesnel et al., in press: Experiment 1) the backward ISI was 500 msec and the US duration was also 500 msec. Therefore, CS onset coincided with US offset. On the other hand, for both the NMR and aversive JMR the US durations were substantially shorter (i.e., 50 msec and 100 msec, respectively) than the 500 msec backward ISI, thereby leaving a nonstimulation interval between US offset and CS onset. Since such intervals produce response decrements in forward (i.e., trace) conditioning paradigms (c.f., Schneiderman & Gormezano, 1962) it could be suggested that the nonstimulated interval between US offset and CS onset produced an inhibitory effect by allowing UR decrements to be maximized prior to CS onset.

Such a factor, however, does not appear to produce the occurrence of excitation in the backward conditioning of the rabbit's NMR (Quesnel, Moser, Ten Have & Tait, 1981). Employing the same design and associative parameters as Quesnel et al. (in press), Quesnel et al. (1981) examined the effects of US durations of 50 msec, 500 msec, or 1000 msec on the backward conditioned NMR. From a response

characteristics view it might be suggested that nonstimulated intervals occurring between US offset and CS onset could produce the inhibitory outcomes observed. As such, by allowing US offset to occur either at CS onset (500 msec US) or at CS offset (1000 msec US) then the NMR closure would overlap the CS and ensure an excitatory backward conditioning outcome. The backward conditioning results obtained by Quesnel et al. (1981) directly opposed an excitatory conditioning outcome. Quesnel et al. (1981) reported that with increasing US durations, and hence greater US-UR-CS overlap, greater evidence of inhibition was observed.

While the response characteristic account (Guthrie, 1935; Solomon, 1980) does not adequately explain the occurrence of excitatory and inhibitory backward conditioning outcomes within the JMR system, two cognitive theories have provided accounts which might be applied. Specifically, Wagner (1981) has postulated a memorial process model and Konorski (1967; Rescorla, 1980) has posited a cognitive drive model to account for conditioning phenomena.

For the memorial model (Mazur & Wagner, in press; Wagner, 1981) the activation and association of short term memory (STM) elements determine excitatory and inhibitory conditioning outcomes (c.f., Appendix B). Briefly, within

this model, CS and US presentations are actively represented by the memory elements in the respective memory areas (i.e., nodes) according to a three state decay process. The first state, the I state, occurs when there is no representation of the stimulus elements active within STM. Following stimulus occurrence, and independent of interelement associations, the elements of the stimulus representation are activated to the A1 state. During A1 state activation there is postulated to be direct cognitive action (i.e., rehearsal) of the active elements allowing the elements to be represented in long term memory (Wagner, 1981). However, over time, activated A1 state elements manifest a rapid decay of activation into a less active state, the A2 state. In the A2 state, while the elements are still represented in STM, the rehearsal process does not occur (Wagner, 1981). And finally, elements represented in the A2 state are thought to demonstrate a less rapid decay into the I state of inactivation. Once elements have returned to the I state, the continued presence, or reoccurrence, of the stimulus may reactivate the elements into the A1 state. To account for the occurrence of excitatory and inhibitory conditioning effects, Wagner (1981) has postulated that the joint occurrence of CS and US representation elements in the A1 state (i.e., joint rehearsal) allows the development of an excitatory association, while the joint occurrence of CS and US elements in the A1 and A2 states, respectively, produces inhibitory associations. Although the model has

not postulated a timeframe for the decay process, Wagner has asserted that excitatory associations may be maximized by the: (a) temporal placing of the stimuli during the pairing; and (b) "surprisingness" or expectedness of the stimulus occurrence on a particular trial (c.f., Wagner & Terry, 1975).

When a CS follows a US the probability of the CS A1 state coinciding with the US A2 state would be high, and therefore, inhibitory effects for backward pairings would be expected by the theory. Thus, the theory is consistent with the aversive classical-classical transfer literature. If "surprisingness" were manipulated during backward conditioning, the theory would expect that either weaker inhibitory, or possibly excitatory, effects would occur. Wagner and Terry (1975) tested this prediction by first administering discrimination training (i.e., CS+ - US, CS-) to rabbits in an aversive ER paradigm. Subsequently, during continued discrimination training two additional CSs were employed (i.e., CSe and CSs) and were paired with the US in a backward fashion on one trial of each of the remaining 48 sessions. During the backward training the expected condition was defined as the CS+-US-CSe pairing and the surprising conditioning was defined as the CS--US-CSs pairing. The backward pairings were arranged with a 600 msec or 1000 msec ISI. On test trials the rabbits responded more to the CSs than to the CSe indicating that the

"surprisingness" sequence allowed greater US rehearsal and therefore less joint rehearsal of the CS A1 state with the US A2 state. Unfortunately, Wagner and Terry (1975) did not employ any assessment procedure for inhibition so that levels of inhibition and excitation could not be determined. Nonetheless, the effectiveness of the "surprisingness" manipulation increases the tenability of Wagner's position.

However, a major problem for Wagner's theory is the observation of excitatory backward conditioning effects with the appetitive JMR at ISIs that produce inhibitory effects for the same response system. Presumably, the aversive inhibitory effects document a preponderance of US A2 activity at the time of CS onset. Switching to appetitive USs should not affect decay times, and therefore, the theory would lead to the falsified expectation of inhibitory effects with appetitive conditioning. For the theory to account for both inhibitory and excitatory backward conditioning effects, two assumptions would have to be appended. The first assumption would assert that motivational characteristics of the US are represented within the activated elements of STM. The second assumption would assert that appetitive motivational elements have a slower decay than aversive motivational elements. The first assumption is consistent with Wagner's (1981) view that the elements represent characteristics of the stimuli; the second assumption is a greater departure from the theory.

Nonetheless, by specifying a slower decay for appetitive USs there would be a higher probability of joint rehearsal of CS and US A1 states with backward pairings, which would lead to the expectation of excitatory conditioning effects.

The inclusion of the two assumptions would produce a unified account of backward conditioning effects. However, even the amended theory would have difficulties accounting for all the excitatory outcomes observed with the appetitive JMR. While Quesnel, et al. (in press) obtained excitatory backward conditioning with the appetitive JMR, they also observed excitatory effects in reacquisition resulting from unpaired presentations of the stimuli (c.f., also Sheafor, 1975). These unpaired excitatory unpaired effects have been obtained on test trials and with reacquisition tests when the CSs and USs have been separated by from 2 minutes to 24 hours. To assert that the unpaired excitatory effects resulted from joint rehearsal of A1 states would severely strain the integrity of the theory. Accordingly, Wagner's (1981; Mazur & Wagner, in press) position appears to have a restricted range of application.

A more general account of the diverse outcomes obtained with appetitive and aversive backward conditioning procedures may be provided by central representation theory (e.g., Konorski, 1967; Rescorla, 1980). Although both Konorski (1967) and Rescorla (1980) have posited similar

central representation accounts of conditioning, Konorski has provided the more systematic account of the associative and conditioning processes. Since both are needed to account for backward conditioning effects, Konorski's (1967) position will be elaborated. The following discussion could be included in Rescorla's (1980) theory if the appropriate assumptions were included.

Like Wagner (1981), who derived some of his concepts from Konorski (1967), Konorski asserted that all perceived stimuli develop representations in the central nervous system. Moreover, for USs the establishment of a US representation is followed by the formation of a no-US center, denoting the inactivity of the US representation. In both aversive and appetitive conditioning situations, the occurrence of the CS representation activation in the presence of the US representation activation is thought to produce excitatory associations, whereas, CS representation at other times is associated with a no-US representation and is thought to produce inhibitory associative effects. However, Konorski also assumed that each US had two representations, one for its sensory characteristics and one for the motivational or drive properties of the US. The drive representation provides a second source of associable activation which differs in properties for aversive and appetitive conditioning situations.

For aversive conditioning, while the CS presentation activates the CS representation, the occurrence of the US activates both the sensory and drive (i.e., fear) representations (Konorski, 1967). Although the sensory representation of the US is of limited duration, the drive representation is rapidly conditioned to the situational cues, thereby producing a constant drive representation within the situation. Thus, the application of the model to forward and backward aversive conditioning is straightforward. In the forward conditioning procedure, the contiguous occurrence of the activated CS and US (sensory) representations allows the development of an excitatory association. With subsequent activation of the CS representations, the US sensory representation is also activated. The associated sensory representation activation is thought to increase the activation of the drive representation to produce evidence of excitatory behavioral effects (Konorski, 1967). In contrast, for aversive backward conditioning, the US-CS presentation is thought to produce, through contiguity, a linkage between the CS and no-US representation. Moreover, since the no-US activation suppresses the activation of the US representation, backward conditioning would produce an inhibitory effect. As such, subsequent presentations of the CS would be expected to activate a no-US sensory representation and neither increase the drive levels nor produce behavioral manifestations

(Konorski, 1967). Therefore, with aversive backward pairing procedures only evidence of inhibitory outcomes would be expected.

On the other hand, in appetitive conditioning, the appetitive drive state is activated by the deprivation imposed on the subject, not just by the US. Moreover, with repeated US presentations, the drive state is assumed to increase. Therefore, situational stimuli that occur in the absence of the US and its sensory representation would be contiguous with the active appetitive drive state and, thus, would lead to the development of an excitatory association. Subsequently, the occurrence of discrete stimuli would trigger the drive representation such that innately organized consummatory behavior is released (Sheafor, 1975).

Sheafor (1972) has used this approach to account for the pseudoconditioning that occurs with unpairings of the CS and US with the appetitive JMR system. Analogously, the excitatory backward conditioning observed by Quesnel, et al. (in press: Experiment 2) could reflect the behavioral release of the drive state by the backward CS on test trials. A problem for this account is the higher levels of responding observed with the backward pairings, relative to a matched unpaired control group. If the drive representation is being triggered under both conditions, then no between group differences should have been observed. To account for the

group differences, a few additional assumptions made by Konorski (1967) need to be introduced. For the appetitive system, Konorski argued that a consequence of the activation of the US sensory representation, and consummatory behavior, is the inhibition of the US drive representation.

Accordingly, inhibition of the US's sensory representation should facilitate the US's drive representation and lead to the greater triggering of behavior. Therefore, if the backward CS developed an inhibitory association with the appetitive US's sensory representation, the test trial presentations of the backward CS should lead to higher performance indices because of the indirect effect the inhibitory association would produce on the US's drive state.

Thus, Konorski's (1967) theoretical position could account for the effects of backward pairings by asserting that inhibitory associations between the CS representation and the US's sensory representation develop in both appetitive and aversive conditioning. The divergent behavioral effects between the two types of conditioning would result from the differences in structure of the appetitive and aversive motivational systems and the expected interactions of the association between the sensory representations with the two motivational systems.

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APPENDIX A:

A review of the effects produced by backward pairings

Unlike forward pairings of CSs and USs, where anticipatory CRs can be used as an associative index, backward orderings of CSs and USs do not provide direct associative indices since the elicitation of the UR obscures the measurement of CR occurrence. Therefore, assessment procedures such as test trials and transfer of training have been employed to measure the associative outcomes of backward pairings. With these methodologies, applications of temporally ordered US-CS sequences have produced effects described as excitatory, inhibitory, or nonassociative (c.f., Quesnel, et al., in press). While such disparate results have led to backward conditioning being relegated to the role of a minor phenomenon (c.f., Tait, 1974), it is possible that differences in assessment procedures may account for the varied outcomes observed with backward pairings. That is, the limitations, or inappropriate interpretational assumptions, of a particular assessment procedure may have produced the differential results. The following sections detail the problems of assessment in backward conditioning and review the effects observed with each procedure.

ASSESSMENT METHODOLOGIES FOR BACKWARD CONDITIONING

Inherent within the backward conditioning paradigm is the problem of indexing the associative strength, or CR occurrence, independent of UR occurrence. That is, while the UR is initiated by US onset, UR duration often continues for some time after US offset (Martin & Levey, 1969; Gormezano & Moore, 1969). Therefore, the experimental operations of presenting the US prior to the CS would necessarily obscure any responses that might develop to the CS since the UR may extend into the CS interval (Tait, Quesnel, & Ten Have, 1979, in press). Such a procedural consideration has resulted in the utilization of two assessment methodologies to counteract US-CS overlap in the measurement of backward conditioning effects. The first method is the direct measurement technique, involving the interspersing of CS along test trials amongst the US-CS pairings. The second method is the indirect assessment technique which employs a transfer design to assess the effects of backward pairings. However, the employment of each of these procedures involves the acceptance of the implicit assumptions underlying each methodology (Tait, et al., in press). Although sometimes unrecognized, the assumptions of these procedures may limit their applications in the assessment of backward conditioning effects.

For the test trial procedure, the occurrence of a CR is thought to reflect an index of excitation accruing to the CS as the result of US-CS pairings. Moreover, this procedure is thought to allow the efficient examination of the development of excitatory conditioning at intervals during the course of backward stimulus pairings (c.f., Tait, et al., in press). However, the test trial procedure is limited by one assumptional restriction and two methodological constraints. The assumptional restriction is the notion that backward pairings result in either of two possible outcomes: the accruing of excitation, or no associative effect (c.f., Spooner & Kellogg, 1947). Therefore, while this procedure may be employed to assess excitatory conditioning effects, possible inhibitory effects resulting from the backward pairings cannot be assessed, since the absence of responding could be equally due to a failure of the procedures to produce a behavioral effect. In this respect, the test trial procedure is unable to differentiate inhibitory from the absence of associative effects. The methodological constraints are based on the observed effects of discrimination training and partial reinforcement schedules in classical conditioning (c.f., Kimble, 1961). The first methodological constraint is that the test trials must be widely spaced during the conditioning procedure. This assertion is based on the notion that if test trials occur close enough together

during a conditioning session, the organism may learn to discriminate the sequence of occurrence of test and paired trials. For example, Grant, Riopelle, and Hake (1950) have reported that the sequence of paired and test trials may seriously reduce the performance observed on test trials. As such, it may be concluded that the spacing of test trials might be a critical factor for the assessment of excitatory conditioning effects in this procedure. The second methodological restriction is that the test trials must be few in number. This assertion is based on the observed influences of partial pairing schedule, the occurrence of a CS in the absence of the US during some trials of a conditioning session, on the acquisition of conditioned responding (c.f., Kimble, 1961). Partial pairing schedules during classical conditioning have been observed to retard CR acquisition (c.f., Kimble, 1961; Pavlov, 1927, 1928; Reynolds, 1958). Therefore, the test trials may not be a sensitive index of excitation if the retardation effects resulting from the partial pairing schedule are greater than the excitation resulting from the backward pairing. In this respect, it is incumbent upon the methodology to restrict the number of test trials such as to minimize the possible inhibitory effects of the partial pairing schedule (Kimble, 1961). Moreover, this restriction also serves to restrict the analytical power of the procedure, since few observations reduce the statistical efficiency of parametric

tests (e.g., Cohen, 1969). These methodological and assumptional considerations limit the employment and sensitivity of the test trial procedure to experimental designs in which large excitatory effects are expected or observed.

The second methodology used for the assessment of backward pairings is the indirect assessment techniques which also has assumptional and interpretational difficulties. Indirect assessment techniques frequently denoted as transfer of training, can be subdivided into two sets of procedures; the classical-instrumental transfer (e.g., Heth, 1976) and the classical-classical (e.g., Plotkin & Oakley, 1975; Scavio, 1972, 1974) transfer paradigms.

In the classical-instrumental transfer design for backward conditioning, the effects of US-CS pairings are typically assessed in a three phase experimental design. In phase 1 the organism's responding is established with the presentation of operant contingencies. During phase 2, US-CS presentations are delivered independent of the subject's behavior. Moreover, the phase 2 procedure may be administered either in the presence of the phase 1 operant contingency (i.e., the on-line procedure) or in a different apparatus without the presence of the phase 1 contingency (i.e., the off-line procedure). The assessment of the US-CS

pairings occur during phase 3 where the phase 2 CS is superimposed on the phase 1 operant response. In this procedure the CS produced changes in the operant response levels are thought to reflect the effects of the phase 2 pairings (Rescorla, 1969).

For the classical-classical transfer paradigm, a two phase procedure is most often utilized. Phase 1 represents the treatment phase during which US-CS pairings are presented to the subject and the target response system is monitored. During phase 2, the effects of the treatment phase are assessed with forward pairings of the CS and US and the monitoring of conditioned response development during the reacquisition.

A further distinction has been made for both classical-instrumental and classical-classical transfer designs. This distinction has been manifest in terms of the motivational character supporting the phase one and phase two responses (c.f., Overmier & Lawry, 1979). That is, if the motivational effects of the US and response in phase two are the same as the motivational effects of the US and response in phase one, the transfer design is denoted as a within motivational system transfer (Tait, Quesnel, & Ten Have, in press). If the motivational effects of the US and response of phase one differ from the motivational effects of the US and response in phase two, then the transfer

procedure has been termed cross motivational state transfer. The interpretation of the results of within and cross motivational states transfer paradigms, excitation is inferred if the phase two responding is facilitated or enhanced relative to control group performance, and inhibition is inferred if phase two responding is retarded or suppressed relative to controls (see Rescorla & Solomon, 1967; Tait, et al., in press). However, in the cross motivational system transfer symmetrically opposite inferences are made. That is, if phase two responding is facilitated, then inhibition is inferred, and if phase two responding is suppressed or retarded then excitation is inferred (c.f., Rescorla, 1969; Rescorla & Solomon, 1967).

Problematically, the transfer design approach to the assessment of backward pairings is predicated on three interpretational assumptions of questionable validity. The first assumption relates to the notion that in the classical-instrumental transfer design the underlying processes of conditioning in the separate phases are independent. Moreover, this assumption suggests that once each conditioning phase is complete, the conditioning is unaffected by, and may be documented without change even though, other conditioning procedures may be interpolated between the initial acquisition and its assessment (c.f., Overmier & Lawry, 1979; Tait, et al., in press). Thus, for the transfer design, phase 3 responding is thought to result

from the interaction of two independent processes (i.e., the phase 1 operant conditioning of a response and the phase 2 Pavlovian conditioning of an inferred CR) which do not demonstrate response tendency decreases until they are juxtaposed in testing.

Such a view of the classical-instrumental transfer design may be inappropriate. According to Scavio (1972, 1974, 1975) a theoretical analysis of the classical-instrumental transfer paradigm allows for the development of multiple sources of interaction which may determine the observed outcomes while obscuring underlying processes. Within the transfer paradigm there is the possible development of: (1) a situational CR (i.e., CR₁) to control the development and maintenance of the phase 1 operant response (i.e., IR₁); and (2) the phase 2 CR (i.e., CR₂) controlled acquisition of an operant/instrumental response (IR₂) which might act to modulate US effectiveness since phase 2 responding is unmonitored. As such, phase 3 responding may result from the interaction of undeterminant interacting components (e.g., IR₁-IR₂; CR₂-IR₂; etc.) thereby obscuring the processes underlying the backward conditioning outcome (c.f., Scavio, 1972). Moreover, given that such undocumented interactions (Overmier & Lawry, 1979) occur, the procedures of the classical-instrumental transfer paradigm do not necessitate that the order or number of interacting components remain fixed from subject to subject

or from experiment to experiment, thus further obscuring processes and outcomes of the backward conditioning phenomenon.

The second interpretational assumption is that the motivational rules for the assessment procedure may be expressed as the simple combination of motivational factors in both phases. That is, during the assessment, conditioned responding is assumed to result from the linear combination of the motivations present in each of the preceding phases and that such motivations produce isomorphic states of excitation and inhibition (c.f., Dickinson & Pearce, 1976). Although the basis for these two assumptions appear likely, the lack of an empirical base results in some question of the adequacy of transfer designs for the assessment backward conditioning effects.

Finally, the third assumption relates to control procedures needed for the unequivocal demonstration of excitation or inhibition outcomes in the transfer paradigm. Traditionally, transfer designs have utilized unpaired CS and US presentations as the adequate control for the documentation of: (a) nonassociative contribution to responding; and (b) a null point on the associative continuum (c.f., Gormazano, 1966). Therefore, the backward groups location relative to the unpaired control is thought to define the occurrence of excitatory or inhibitory

backward pairing effects. Such a strategy, however, may be inappropriate for a documentation of the occurrence of levels of excitation and inhibition (c.f., Prokasy, 1965; Rescorla, 1967). Theoretical assessments of the unpaired control procedure have indicated that the absence of a temporal relationship between the CS and US is the sufficient condition for the development of inhibition (Diamianopoulos, 1982; Kremer, 1971; Prokasy, 1965; Rescorla, 1967). Furthermore, there appears to be empirical support for such an assertion (c.f., Bromage & Scavio, 1978; Rescorla & LoLordo, 1965; Tait, et al., 1979, in press). Given the occurrence of inhibition with the unpaired control procedure, the procedure is an inadequate control for documenting absolute levels of excitation and inhibition and allows only the identification of relative levels of inhibition. Therefore, in the assessment of backward pairing effects with the unpaired control, backward conditioned performance may be assessed as either more or less inhibitory relative to the unpaired control or as more or less excitatory relative to the unpaired control. In either case, the absence of a control providing a null associative value allows only relative assessments to occur. Although current assessment strategies have incorporated upper boundary excitatory controls (e.g., the forward pairing group in classical-classical transfer designs), the performance of the upper boundary also provides a relative

level of excitation against which outcomes may be assessed. Thus, since neither the upper boundary control nor the unpaired control define a null point at which the outcome changes in direction (i.e., excitation vs inhibition) the adequate control procedure remains one of choice. Since the preponderance of backward conditioning studies have relied upon the unpaired control to define the occurrence of excitatory or inhibitory outcomes, the present review will maintain the historical precedent of the unpaired control group as the minimum necessary control for the assessment of relative levels of excitation and inhibition.

Since both the test trial and the transfer design procedures have apparent limitations, the results from the applications of these procedures might lead one to divergent conclusions about the effectiveness of the backward conditioning procedures. Such divergent conclusions seem to be the case. That is, while the test trial procedure has been instrumental in studies which have concluded that backward pairings produce primarily nonassociative effects (e.g., Cason, 1935; Grether, 1938; Switzer, 1930; Trapold, Homzie, & Rutledge, 1964), the employment of the transfer design to assess backward pairings has resulted in reports of excitation (e.g., Heth, 1976; Heth & Rescorla, 1973; Keith-Lucas & Gutman, 1975; Mahoney & Ayres, 1976; Terry & Wagner, 1976) or inhibition (e.g., Ayres, Mahoney, Proulx & Benedict, 1976; Moscovitch & LoLordo, 1968; Seigel & Domjan,

1971). These results are reviewed in detail in the following sections.

Effects of backward pairings observed with test trials

Historically, the use of test trial procedures for the assessment of backward conditioning effects may be traced to the experiments of Kreps, Podkopaev, Prorokov, and Kaupalov, Krestovnikov, and Pavlov in Pavlov's laboratory (Pavlov, 1927). Although, from the passages, the precise assessment methodologies are unclear, Pavlov's (1927, lecture II) earlier comments on research methodology implicates the use of test trial procedures. Pavlov presents two accounts of the effects of backward pairings. Initially, Pavlov addresses the experiment by Krestovnikov to indicate that backward pairings do not result in the development of a CR (1927, pp. 27-28). Subsequently, the observations of Podkopaev, Prorokov, and Koupalov and Pavlov that UR diminution occurred during backward pairings and that CRs occurred to the CS early in training, led Pavlov (1927, pp. 391-391) to reconsider and suggest that the backward conditioning paradigm produces a biphasic conditioning function. That is, over training, CRs were observed to occur early in training but disappear as the training continued. Correlated with this performance was the observation that as training continued the characteristics of the UR decreased. From these observations Pavlov

suggests that while the initial effects of backward pairings might be excitatory, with extended training backward pairings caused the CS to become inhibitory (Pavlov, 1927, 1928, 1932). However, this assertion may be an overstatement of the observed results, since tests developed to identify the presence of behavioral inhibition were not conducted. Therefore, a more empirically bound statement might be expressed as while the initial effects of backward pairings might be excitatory, with extended training the CS loses this excitation, although the mechanism by which such a loss of excitation occurs is unknown.

For North American psychologists there has been less corollary evidence for either the inference of excitation or inhibition. For example, Wolfle (1930, 1932) examined the effects of backward pairings on the human finger flexion response. Initially, Wolfle (1930) examined the effects that had US onset either 0.50 or 0.25 sec prior to CS onset. Test trials were administered in each block of 20 trials for 17 blocks of trials, where the flexion of the finger on CS alone test trials constituted a CR. For this experiment, the CS was a bell produced tone and the US was a variable electric current. The results of the experiment suggested that the effectiveness of the US-CS pairings increased as the ISI neared simultaneity, but did not reveal any substantial backward conditioning effect. That is, while the 0.50 sec group exhibited only 10% CRs on test trials,

the 0.25 sec group exhibited approximately 15% responding on test trials. While these results suggest that backward conditioning effects may be observed, the absence of control groups which received unpaired presentations of the CS and US, US alone presentations, or CS alone presentations preclude the interpretation of excitatory backward conditioning effects independent of contributions of pseudoconditioning or sensitization processes.

Subsequently, Wolfle (1932) employed the same paradigm to assess backward ISIs of 2.0, 1.0, 0.6, and 0.2 sec. The results of this experiment did indicate unsystematic proportional differences between groups, but none of the groups exhibited more than 12% responding. As in the 1930 experiment, no controls were included to assess the occurrence of excitation in this experimental design.

In a similar experiment, Switzer (1930) was the first to include a control procedure for the assessment of excitatory backward conditioning effects. In this experiment, Switzer employed a group which received forward trace conditioning with a 20 sec ISI as a control procedure for the backward conditioning of either the eyelid or the patellar reflex at backward ISIs ranging from 0.5 to 2.0 sec. In a number of subjects from both conditioning paradigms, concomitant recording of the GSR was taken. Employing a "hammer striker" apparatus to deliver the US either to the region of the eye (US for the eyelid response:

(ER) or the knee (US for the patellar reflex response) and a buzzer CS, Switzer administered CS alone test trials to the human subjects following the first occurrence of a "double blind" ER during a US-CS trial, and employed a similar criterion for the patellar reflex response. Switzer (1930) reports that for the backward conditioned ER, subjects responded near 90% on the test trials. On the other hand, subjects which received backward pairings in the patellar reflex training procedure responded on only 40% of the test trials. In contrast to the performance of the ER and patellar reflex response groups, no evidence of conditioning was obtained for either the concomitant measurement of the GSR or for the long trace control group.

Contrary to the evidence reported by Switzer (1930), Grether (1938) attempted to condition a fear response in monkeys with backward pairings of a "snake blowout device" US and a bell CS. The CR was defined as an "anxious state". Moreover, for this experiment, a US alone control group was employed to assess the contributions of pseudoconditioning. Extinction followed after trial nine. The results of this experiment indicated that the backward pairing group did exhibit the "anxious state" response, but the observed magnitude of the response did not substantially differ from the magnitude of responses exhibited by the US alone control group. As the result of this observation, Grether (1938) concluded that pseudoconditioning was an important factor in the reports of backward conditioned phenomenon.

Contrary to the observations of Switzer, and consonant with the observations of Wolfle and Pavlov, Spooner and Kellogg (1947) obtained some evidence indicative of a decremental backward pairing effect with human finger flexion response. Spooner and Kellogg administered 80 backward pairings, separated by a mean intertrial interval (ITI) of 60 sec, of a buzzer CS and an electric shock US at backward ISIs of 0.50 and 0.25 sec. Interspersed amongst the 80 paired trials were 20 CS alone test trials. Similar to the results of Wolfle (1930, 1932), Spooner and Kellogg found little evidence of finger flexion conditioning in either of the backward ISI groups, with groups 0.25 and 0.50 exhibiting overall test trial performance levels of eight and ten percent, respectively. However, when the test trials were examined in five blocks of four test trials each, the results appear to confirm Pavlov's description of the results of backward pairings. That is, for the first block of test trials, the backward pairings initially produced a level of responding near 20%, a performance level similar to that observed for the forward conditioning group. However, over the remaining blocks of test trials, the backward pairing groups exhibited a subsident phase of responding until, for the last block of trials, responding has declined to a near zero level. Although responding for the backward groups appear initially excitatory, the failure to include control groups for the assessment of

nonassociative factors precludes the interpretation of excitatory, or the waning of excitatory, backward conditioning effects.

In an attempt to conceptually replicate the findings of Spooner and Kellogg, Fitzwater and Reisman (1952) assessed the effects of 80 backward pairings and 20 CS alone test trials on the human finger flexion response. In this experiment, the CS was a 200 msec tone, the US was a 200 msec electric shock, the backward ISI was 500 msec, and the mean ITI was 17.5 sec. The results of this experiment indicated no evidence of backward conditioning relative to an unpaired control group either in overall effects or over blocks of four test trials.

More recently, Champion and Jones (1961) have provided evidence of excitatory backward conditioning of the human GSR. Employing a 20 msec tone CS and a 6000 msec, 3.2 mA, electric shock US, these authors assessed the effects of seven paired, five CS alone test trials, and six interpolated US alone trials on the forward (500 msec ISI) and backward (750 msec ISI) conditioning of the GSR. Moreover, an explicitly unpaired control was employed to assess possible pseudoconditioning effects. Examination of the test trials data revealed that while the forward group increased performance over trials, so did the backward group, albeit at a lower level than the forward group. In

contrast to the performance of the forward and backward groups, the unpaired group exhibited a decline in responding over trials. The results of this experiment indicated that excitatory backward conditioning occurred. In addition, support for the conclusion of excitatory backward conditioning effects with the human GSR has also been obtained by Champion (1962). Monitoring the GSR, Champion administered three backward pairings of the tone CS and shock US to two groups which differed only in terms of the backward ISI (i.e., 1200 or 2800 msec) and compared them to a forward pairing group which was conditioned at an ISI of 400 msec. The results of this experiment indicated that the 1200 msec backward ISI group evidenced significantly greater changes in GSR than did either the 2800 msec backward ISI group or the 400 msec forward ISI group, which did not significantly differ. These results clearly support Champion and Jones (1961) notion that backward conditioning of the GSR produce excitatory effects, and extend the notion to include the control of such effects by the backward ISI.

In contrast to the results obtained by Champion (1962) and Champion and Jones (1961), Trapold, Homzie, and Rutledge (1964) attempted to condition human GSR, finger flexion, and ER with backward ISI's of 40 to 1500 msec. In this procedure, 23 paired trials of a 500 msec increase of illumination of the CS and a 50 msec airpuff US (for the ELR) or 50 msec electric shock US (for finger flexion and

GSR) were administered, amongst which were interspersed seven CS along test trials. The results of this experiment revealed no effect within response systems for the backward ISI's, nor an increase in responding over test trials. Furthermore, there was no evidence of a response decrement over trials. Therefore, while there was no nonassociative (e.g., unpaired) or excitation (i.e., forward paired) control groups, Trapold, et al., (1964) concluded that the absence of either an incremental or decremental function of responding over test trials was sufficient to indicate the absence of a backward conditioning effect in the GSR, finer flexion, and ER systems.

While, with the exception of Grether (1938), all the studies reviewed so far have employed human subjects, more recently two studies have employed animals as subjects in backward classical conditioning paradigms. Smith, Coleman, and Gormezano (1969) conducted an experiment to assess the effect of ISI on the acquisition of the rabbit's nictitating membrane response (NMR). In this experiment they employed a 60 msec backward ISI group which received 80 pairings and 21 test trials of a 50 msec, 4.0 mA paraorbital electric shock US and a 50 msec tone CS, each day for eight days. The results of this study revealed that performance of the backward group did not differ from the performance of a group which received explicitly unpaired presentations of the CS and US, in that neither group responded above six

percent on the test trials. From this evidence, Smith, Coleman, and Gormezano concluded that there was no evidence of the formation of an association in the backward group.

Consonant with Smith, et al.'s (1969) analysis of the effectiveness of backward pairings in the production of CRs, Patterson (1975) examined the effects of backward pairings on the acquisition of the cat's hind limb flexor nerve response. For this experiment, spinally transected cats received a CS of .020 to .040 mV stimulation of the nerve and a US of 50 V delivered to the nerve on 75 paired trials. The stimuli were presented with a backward ISI of 250 msec. The results of this experiment indicated no evidence of backward conditioning although a forward pairing group did acquire a response. However, the absence of control groups makes even the assertion of forward pairing effects suspect.

In summary, the test trial procedure has been ambivalent in the delineation of backward conditioning effects. That is, the test trial procedure has produced reports of both excitation (Champion, 1962; Champion & Jones, 1961) and no associative effects (Grather, 1938; Wolfle, 1932). In addition, test trial applications to the assessment of backward pairings effects on response systems and ISI's have revealed a failure in the production of reliable and consistent backward conditioning effects. It should be noted, however, that North American studies of

backward conditioning have concentrated on aversive conditioning paradigms to the exclusion of appetitive conditioning paradigms, perhaps due to the ease of quantification of stimulus characteristics and parameters. There have been some reviews of the Russian conditioning literature (e.g., Razran, 1956, 1971) which suggest that test trial procedures may identify excitatory backward conditioning effects when employed with appetitive responses. With only incomplete experimental protocols available, however, it is difficult to assess this literature. In any case, data obtained from North American backward conditioning experiments which employed the test trial procedure have produced limited evidence for the occurrence of excitatory backward conditioning.

Effects of backward pairings observed in transfer designs

As previously mentioned, experimental procedures have been used to divide transfer designs into classical-instrumental and classical-classical transfer procedures (c.f., Scavio, 1974). Moreover, the transfer designs have been further subdivided into transfers that occur either within or between motivational systems (c.f., Overmier & Lawry, 1979; Scavio, 1974, 1975; Tait, et al., Notes 1 and 2). The following sections maintain these subdivisions in the review of backward conditioning effects observed with transfer designs.

Classical-instrumental transfer: The effects of backward pairings within motivational systems. The use of the within motivational system, classical-instrumental transfer paradigm to assess the effects of backward pairings has been limited to manipulations of the aversive motivational system by electric shocks administered in both the classical and instrumental phases (e.g., Maier, Rapaport, & Wheatley, 1976; Moscovitch & LoLordo, 1968; Nagaty, 1951). In a limited study by Nagaty (1951), rats were first trained in a wheel turn avoidance task with a buzzer signal preceding a 240 V electric grid shock by two sec. If a wheel turn response occurred during the buzzer, then the buzzer was terminated and shock to the grid flooring was not delivered. In contrast, if no response occurred to the buzzer signal, electric shock was delivered and its duration was controlled by the animal's latency to execute the wheel turn response. Following avoidance training to a fixed criterion of 10 consecutive successful avoidances, the animals were subdivided into three treatment conditions. The treatments were either 50 backward pairings of the shock and buzzer with shock termination preceding buzzer onset by one sec, 50 backward pairings with shock termination preceding buzzer onset by 20 sec, or 50 buzzer alone presentations. For both phases of this experiment the training and treatments occurred in the same apparatus with the same buzzer signal and shock intensities. The results indicated that during the treatment phase, both backward

groups maintained an elevated level of wheel turning relative to the buzzer alone group. Moreover, the absolute level of wheel turning in the backward groups appeared controlled by the backward ISI with the one sec backward group responding frequently more than the 20 sec backward group. Furthermore, for all groups, responding to the buzzer decreased during the treatment phase, although not to the same levels of responding. In addition, following the treatment phase, 60 buzzer alone presentations were administered to all groups. While this procedure revealed no differences between the backward groups, there were substantial initial differences between the backward groups and the buzzer alone group. However, following 30 buzzer alone presentations, the performance of all groups had declined to a common level. The failure to include an unpaired control group makes the delineation of excitatory or inhibitory processes difficult to interpret. Since the performance of all groups declined during the treatment phase, the effects of the backward pairings could be viewed as increasingly the resistance to extinction. Whether this change in resistance to extinction is due to excitatory process or just weaker inhibitory processes cannot be determined.

A better controlled aversive-aversive transfer study was conducted by Moscovitch and LoLordo (1968). In this experiment, dogs were trained in a barrier jump avoidance

task on a Sidman avoidance schedule, followed by a Pavlovian conditioning phase of 120 presentations of the CS and US in the same apparatus during the treatment phase, and the effects of the Pavlovian phase was assessed by superimposing CS alone presentations on the Sidman avoidance performance. For the Sidman avoidance training a six mA electric shock was applied to the grid flooring for 0.25 sec every 10 sec unless the dog jumped over the barrier separating the two compartments (shock - shock interval = 10 sec). If the animal executed the barrier jump response prior to shock onset, the shock was postponed for 30 sec (response - shock interval = 30 sec). During the Pavlovian phase, one group of dogs was confined to one of the two compartments and 24 backward pairings of a five sec tone CS was presented one sec following US offset (mean ISI = five sec). Subsequently, the dogs were again allowed to execute the barrier jump response but no shocks were scheduled and the tone CS was presented 24 times during this session. The results suggested that the backward pairing procedure produced a decline in responding relative to both a no treatment control and a truly random control (c.f., Rescorla, 1967). The results are consonant with the interpretation that backward conditioning produces inhibition since, responding during extinction indicated that the backward group was suppressed relative to the truly random and no treatment control groups; and, such

suppression has been defined for the within motivational system transfer design as inhibition (c.f., Rescorla & Solomon, 1967). In contrast to this interpretation, however, is the notion that the observed results of this study may have occurred due to the asymmetries of the stimulus parameters employed between the two phases. That is, the two differing shock intensities (i.e., six mA vs three mA) and the differing US durations (i.e., 0.25 sec vs an average five sec) employed in the instrumental and Pavlovian phases may have contributed to the observed effect since such differential US applications have been reported to produce response decrements (c.f., Burstein, 1965).

If in Experiment 1 the backward pairings contributed to the observed inhibition, then an independent variable manipulation that is presumed to affect the strength of backward conditioning should alter the observed levels of inhibition. To test this assumption Moscovitch and LoLordo (1968) manipulated the backward ISI in the same experimental paradigm. For one group, the backward ISI was the same as in the preceding experiment with CS onset occurring one sec after US offset. The second group received backward pairings with the CS onset occurring 15 sec after US offset. The results of this experiment revealed that the backward ISI controlled the absolute level of extinction phase performance with the one sec backward ISI group showing substantially less suppression than the 15 sec backward ISI

group. Therefore, to summarize the results of both experiments, backward pairings appeared to produce a reliable inhibitory effect the level of which appeared to be controlled by the backward ISI.

More recently, Maier, Rapaport, and Wheatley (1976) extended the examination of backward ISI effects for within motivational system transfers by examining the effects of backward pairings with either three sec or 30 sec separating the CS and US. Employing a two-way shuttle box with a Sidman avoidance schedule (shock - shock interval = 2 sec, response - shock interval = 12.5 sec), the experiment utilized a "brief" one mA grid shock for the avoidance training sequence. Following 20 Sidman avoidance sessions, the rats were confined to one chamber of the apparatus and received 20 US-CS pairings each day for four days. The CS was a 10 sec tone and the US was a five sec, one mA electric grid shock. The effects of the backward pairings were assessed in three extinction sessions, each of which was comprised of six CS alone presentations. Performance during the extinction sessions revealed that while the 30 sec backward ISI group was not differentiated from the unpaired control group, the three sec backward ISI group was significantly suppressed relative to both the unpaired control and 30 sec backward ISI group. Coupling these results with the results of Moscovitch and LoLordo, it suggests that backward pairings of aversive USs and CSs

produces an inhibitory conditioning effect when assessed in transfers within motivational systems. However, the failure to equate US durations (Maier, et al., 1976; Moscovitch & LoLordo, 1968) and US intensities (Moscovitch & LoLordo, 1968) and US intensities (Moscovitch & LoLordo, 1968) between the instrumental and Pavlovian phases of each study makes the assessment of the absolute effects of backward pairings difficult to interpret without additional studies to document the possible decremental effects of such problems. In any case, all three studies of the effects of backward pairings on aversively motivated instrumental responding suggest the development of inhibition accrues to the CS during the treatment phase. Unfortunately, the observation of parallel results is not always obtained with indirect assessment procedures.

Classical-instrumental transfer: The effects of backward pairings across motivational systems. As with the within motivational system transfer design, only a limited selection of cross motivational transfer designs have been employed to assess the effects of backward pairings. Specifically, two variants of aversive-appetitive transfer have been employed; conditioned suppression and conditioned punishment. In both paradigms, an appetitive instrumental response is trained, then aversive Pavlovian conditioning is applied, and subsequently assessed by superimposing the CS during the performance of the instrumental response. The

paradigms differ, however, in that for conditioned suppression the CS is applied in a non-contingent manner, while in conditioned punishment CS application is contingent on the execution of the instrumental response. For both paradigms, excitation is inferred from response suppression to the CS, while inhibition is inferred from response facilitation during the CS. Accordingly, if the effects of backward pairings are to parallel those obtained with the within motivational system transfer, response facilitation, or behavioral inhibition should be observed. However, the two cross motivational paradigms do not show the expected consistent results. With conditioned suppression as the vehicle for assessing the effects of backward pairings behavioral inhibition has been observed (e.g., Ayres, Mahoney, Proulx, & Benedict, 1976; Siegel & Domjan, 1971, 1974), however, with conditioned punishment as the assessment tool, behavioral excitation appears to result from backward pairings (e.g., Heth, 1976; Heth & Rescorla, 1973).

One of the first examinations of the effects of backward pairings with the conditioned suppression paradigm was conducted by Kamin (1963). Employing rats as subjects, Kamin applied three different Pavlovian conditioning procedures, after the instrumental bar pressing response (for food pellets) was acquired. The first group received four US-CS pairings of a one sec, 1.5 mA grid shock US and

three min, 69 dB white noise CS. The second group received nine US-CS pairings of a one sec, 1.5 mA grid shock US and 20 sec, 75 dB, 1200 Hz tone CS, while the third group was subdivided to receive the same stimulus parameters as the other two groups, but arranged in a forward pairing fashion. Testing in extinction, while the rats were bar pressing for food, showed that while the forward group demonstrated reliable suppression, the backward pairing groups revealed no evidence of either suppression or facilitation.

To contrast the absence of backward pairing effects reported by Kamin (1963), Siegel and Domjan (1971, 1974) reported that backward pairings produced inhibitory effects when assessed with a conditioned suppression paradigm. In their first experiment, Siegel and Domjan (1971 Experiment 1) trained rats in a bar press for food task during stage one. For the phase two treatments, rats were presented with the following conditions. Group N received no stimulus presentations. Group CS received 25 presentations of a two min, 1400 Hz tone. Group US received 25 presentations of a 0.5 sec., one mA, grid shock. Group R received 25 presentations of the CS and US arranged in a random manner. Group B was presented with 25 CSs and USs, arranged such that US offset coincided with CS onset. Following the Pavlovian treatment, all the groups received three sessions of four CS-US pairings per session, while bar pressing for food, in a reacquisition test of conditioned suppression.

The assessment of the backward pairings occurred during the reacquisition pairing phase of the experiment and indicated that the development of the suppression of bar pressing to the CS was retarded in Group B relative to the other groups. This observation led Siegel and Domjan (1971) to conclude that backward pairings resulted in the acquisition of inhibition.

In a second study, Siegel and Domjan (1974, Experiment 1) investigated the effects of the number of backward pairings on rats in a conditioned paradigm. Employing the same procedures as Siegel and Domjan (1971), rats were pre-exposed to either 0 (no treatment), 5, 10, 25, or 50 backward pairings of the 0.5 sec, one mA grid shock US and one min, 1400 Hz, tone CS, which was followed by three sessions of four CS-US pairings per session. This procedure revealed that during the forward pairing reacquisition phase, the number of prior backward pairings inversely controlled the acquisition rate of conditioned suppression. That is, as the number of backward pairings increased, the rate of acquisition of conditioned suppression was increasingly retarded. From these two experiments, Siegel and Domjan (1971, 1974) concluded that, for the conditioned suppression procedure, there was no evidence of excitatory backward conditioning effects. Rather, as the number of backward pairings increased, there was increased amount of inhibition.

Additional evidence for the assertion of inhibitory effects accruing from the applications of backward pairings has been reported by Ayres, Mahoney, Proulx, and Benedict (1976). In this experiment rats were trained in a multi-phase conditioned suppression procedure. Initially, all subjects received bar press training with sucrose as the reward. Following the instrumental training, all subjects received the phase one treatment of 20 forward pairings of a 20 sec tone CS which terminated with the onset of a two sec, 1.6 mSA grid shock US in the same chamber as the instrumental training. In the second phase, the experimental treatments were administered. These treatments consisted of either; 20 backward pairings of the CS and US, 20 CS alone presentations, or no treatment. Following a recovery period for the instrumental response, consisting of 300 reinforced bar press responses, the third phase of the experiment was conducted. The third phase consisted of seven sessions of CS alone (extinction) presentations in which one tone was administered in each session while the subjects were bar pressing for the sucrose reward. Following the extinction test, phase four, the reacquisition of conditioned suppression was administered. In this phase all subjects received one trial per session, for eight sessions, of the forward paired CS and US. In the final phase, six CS alone presentations were administered in a re-extinction session. The effects of the phase two

backward pairings were assessed during the third, fourth, and final phases. The results of this experiment revealed that during phase three extinction, while the no treatment control exhibited substantial, and slowly decreasing, conditioned suppression, the backward pairing group exhibited substantially less initial evidence of conditioned suppression with more rapid extinction of the suppression. During the fourth phase reacquisition, the conditioned suppression of the bar press response was retarded relative to the other two groups. In the final extinction phase, the backward pairing group manifested more rapid extinction of the conditioned suppression, than did either of the other groups. Thus, the lower levels of conditioned suppression during phase three extinction, the retarded phase four reacquisition, and facilitated fifth phase extinction of the backward pairing group, led Ayres, et al., (1976) to conclude that the backward pairings yielded an inhibitory effect.

In contrast to the relatively few studies employing conditioned suppression paradigms for the assessment of the effects of backward pairings, the conditioned punishment paradigm has been a popular assessment vehicle. The first assessment of the effects of backward pairings in a conditioned punishment paradigm was conducted by Mowrer and Aiken (1954). Although the experiment was designed to evaluate the relative reinforcement capabilities of US onset

and US offset, the experimental design of Mowrer and Aiken (1954) was one of backward pairings of US and CS. In the experiment they examined the effects of delayed, simultaneous, and two backward ISIs on the conditioned punishment of a bar press response for food reward. Employing a three sec flickering light CS and a 10 sec grid shock US, these authors constructed two backward ISIs. One backward ISI was arranged such that US onset preceded CS onset by seven sec, and both US and CS offsets coincided. In the second backward ISI, US onset preceded CS onset by 10 sec, thus arranging that US offset coincided with CS onset. The results of this experiment indicated that while both backward ISI groups produced less response decrement in the assessment phase than the delayed and simultaneous groups, the backward ISI groups produced more response decrements than did a US alone control. Additionally, the backward ISI appeared to control the magnitude of response decrement for the backward groups. That is, the seven sec ISI produced greater response decrements than did the 10 sec backward ISI. Although, Mowrer and Aiken (1954) did not include the appropriate unpaired control group for the assessment of backward pairing effects, their results suggest that the observed effects resulted from a backward association since performance of the backward groups were controlled by the backward ISI. Similar excitatory results have been obtained by Matsumiya (1960), Nishizawa (1972), and Nishizawa and

Umeoka (1963). However, as in the Mowrer and Aiken (1954) study, these authors have not assessed backward conditioning effects as the principle focus of their experiments. Rather these studies have been concerned with theoretical arguments associated with primary and secondary reinforcement characteristics of US application. As such, control procedures employed in these studies have not allowed the direct assessment of backward conditioning effects. Several recent studies, employing the conditioned punishment paradigm, have explicitly examined the effects of backward pairings.

Substantive agreement with the results of Mowrer and Aiken's (1954) study has been obtained by Heth and Rescorla (1973). Comparing the effectiveness of backward ISI's of 0.25, 1.00, 2.00, 4.00, and 4.50 sec, these authors employed a two sec tone-light (simultaneous compound of 1800 Hz and 6.5 w, respectively) and a four sec 0.5 mA grid shock US in the Pavlovian phase. Following the establishment of a bar press response for food pellets, the rats were presented with 20 backward pairings of the CS and US. The assessment of the experimental effects was conducted during the extinction phase of the experiment where the CS occurrence was made contingent on the occurrence of a bar press response. The results of the experiment indicated that a gradient of conditioning was established across the backward ISI groups. That is, the effectiveness of the backward

pairings, represented by the degree of instrumental response decrement during extinction, was shown to be directly related to the temporal proximity of CS onset to US onset. Finally, relative to an unpaired control group, all the backward ISI groups produced excitatory conditioning effects.

Analogous results have been obtained for the effects of the number of backward pairings administered during the treatment phase. Heth (1976) investigated the effects of 10, 20, 40, and 80 backward pairings of the CS and US. Utilizing the same experimental procedures and stimuli as Heth and Rescorla (1973), but with a one sec backward ISI, Heth (1976) provided evidence that indicated an inverse relation between the number of backward pairings and effectiveness of the CS in the production of response decrement during the assessment phase. Moreover, these results were confirmed and extended in a second experiment which employed 0, 10, or 160 backward pairings of the CS and US. The results of this experiment were congruent with the results of the preceding experiment in that while 10 US-CS pairings produced substantial assessment phase instrumental response decrement nor did they differ from one another. The results of these two experiments provide evidence for the occurrence of excitatory backward conditioning effects and document the waning of such excitation over the number of backward pairings.

While both conditioned suppression and conditioned punishment paradigms have yielded consistent results in their respective applications, the differential results obtained between the two paradigms makes a unitary account of backward conditioning effects difficult. That is, while both cross motivational, classical-instrumental transfer design paradigms employ similar motivational methodologies, the results from the conditioned suppression paradigm have yielded inhibitory outcomes, whereas, results from the conditioned punishment paradigm have revealed excitatory outcomes from backward pairing administrations. However, the different response requirements of the two procedures suggest a possible explanation for the divergent outcomes obtained in the two paradigms. While both paradigms employ the same procedures for the establishment of the instrumental response and the administration of the Pavlovian treatments, they differ in the assessment phase. In the conditioned suppression paradigm assessment is accomplished through noncontingent presentations of the CS whereas, in the conditioned punishment paradigm, CS occurrence is contingent on the occurrence of the instrumental response. From the two factor account of classical-instrumental transfer paradigms (Rescorla & Solomon, 1969), the results obtained from applications of the conditioned suppression paradigm would reflect the acquisition of instrumental response (IR_1), the acquisition

of a Pavlovian conditioned response (CR_2), and their interaction during the assessment phase. In contrast, the conditioned punishment paradigm would be viewed as the development of IR_1 and CR_2 during the first and second phases, as well as the development of an additional IR during the assessment phase. Therefore, the conditioned punishment paradigm assessment phase allows the possibility of IR_1 - CR_2 - IR_3 interactions to produce the observed results. Such differential interactions in the assessment phases of the conditioned suppression and conditioned punishment paradigms may lend themselves to the differential results observed with the applications of these procedures to the assessment of backward pairing effects.

Additionally, however, the two factor theory interpretation of the transfer design and the transfer methodology indicate that other sources of response may also contribute to the control of performance. That is, according to the logic of two factor theory, classical conditioning processes contribute to the acquisition of the phase one IR_1 (c.f., Perkins, 1955; Scavio, 1972, 1974; Spence, 1956). Therefore, accepting the assumption of the occurrence of a situational CR during phase one instrumental training the test phase interaction becomes a triple interaction (CR_1 - IR_1 - CR_2 during assessment. Moreover, methodologically, the phase two Pavlovian treatment might also allow the development of an instrumental response (IR_2)

to mediate the US application (c.f., Trapold & Overmier, 1972) and may be reinforced by their control over US's effectiveness (e.g., jumping off the grids or rolling onto its back such that the animal's fur provides a source of insulation from the shock). As such, given the simplest transfer methodology (i.e., conditioned suppression), the theoretical-methodological argument would suggest that the basic assessment phase interaction might reflect a $CR_1-IR_1-CR_2-IR_2$ interaction controlling the observed behavior (c.f., Gormezano & Kehoe, 1975; Scavio, 1972, 1974).

The inability of the classical-instrumental transfer procedures to isolate and identify all sources of responding in the experimental situation may have contributed to the inconsistent results observed with the backward pairing manipulation and seriously mitigate the conclusions which might be drawn from studies utilizing this procedure. Support for such an assertion has been provided by Tait, Saladin, Williams and Quesnel (1984) through the utilization of a more controlled phase two treatment procedure.

Employing a mixed conditioned punishment - classical conditioning reacquisition procedure Tait, et al. (1984) presented water-deprived rabbits with a four phase experimental procedure. During the five day phase 1 training rabbits were exposed to a lick-response task and

the latency to complete 280 licks was monitored. In the phase 2 treatment stage subjects were removed to a classical conditioning apparatus where they received either 65 CS-US, 65 US-CS, 65 CS alone, 65 US alone presentations in a nictitating membrane response (NMR) preparation.

Additionally, one group of animals was confined to the apparatus, for a time period corresponding to the confinement interval experienced by the other groups, but received no stimulus presentations. The effects of the phase 2 treatments were assessed in phases 3 and 4 by two distinct methodologies. In phase 3 the subjects were again exposed to the lick-response apparatus but following the 140th response the CS was presented and its effects on the lick-responses rate monitored. For phase 4 assessment the rabbits received NMR reacquisition training in the classical conditioning apparatus. During this phase all subjects received 50 forward CS-US pairings for each of four days.

In this experiment Tait, et al. (1984) report that the observed effects of backward pairing differ dependent on the methodology of assessment. With the conditioned punishment procedure these authors report significant levels of lick-response suppression for the forward (i.e., CS-US) and backward (i.e., US-CS) groups relative to the performance of the control groups. Moreover, the absence of significant difference between the forward and backward groups further support the observation of excitatory backward conditioning effects with the conditioned punishment test procedure.

In contrast, the classical conditioning reacquisition test revealed that backward pairings had accrued significant levels of inhibition. That is, while NMR acquisition was significantly enhanced for the forward treatment group relative to the controls, the backward group demonstrated significant retardation of acquisition relative to the CS-alone, US-alone, and no treatment controls.

With the observations of Tait et al. (1984) it has become apparent that the inability of the classical-instrumental transfer paradigm to control for multiple sources of interaction may obscure the contributions of the underlying classical conditioning processes. The conflicting results obtained by Tait et al. (1984) strengthen the assertion that the classical-instrumental transfer design, due to the confounded response factors, allow the associative processes to interact in unknown ways to produce the observed outcomes (Scavio, 1972, 1974). To circumvent the problem, classical-classical transfer designs have been advocated as the superior vehicle for identifying associative processes since the designs restrict and remove possible sources of instrumental responding (e.g., Dickinson & Dearing, 1979; Dickinson & Pearce, 1977; Plotkin & Oatley, 1975; Quesnel, et al., in press; Scavio, 1972, 1974, 1975; Siegel & Domjan, 1971, 1974; Tait, et al., 1979, in press).

Classical-classical transfer: Backward conditioning across motivational system. The

classical-classical transfer design has been the least frequently employed assessment vehicle for the evaluation of backward pairing effects. Only seven backward conditioning studies have employed this methodology (i.e., Holmes, 1971; Plotkin & Oatley, 1975; Quesnel, et al., in press; Siegel & Domjan, 1971, 1974; Tait, et al., 1979, in press) and of these, only one has examined the effects of backward pairings across motivational systems (i.e., Tait, et al., in press).

Recently Tait, Quesnel and Ten Have (in press) have investigated the effects of 22 backward pairings on the acquisition of the rabbits NMR and jaw-movement response (JMR) in a cross motivational classical-classical transfer design. The CS was a 500 msec, 1000 Hz tone, and the USs were either a 500 msec, one cc, water injection into the rabbit's oral cavity (JMR) or a 50 msec, 2.5 mA, paraorbital shock (NMR). In the treatment phase, the backward ISI was 500 msec. The backward pairings for the JMR were subsequently assessed on the acquisition of the NMR in the forward conditioning phase, and backward pairings for the NMR were assessed on the forward conditioning of the JMR.

The results of the experiment suggest that the transfer across motivational systems produced weak excitatory effects. That is, with the transfer from the backward JMR to the forward conditioned NMR, phase one backward pairings retarded the initiation of NMR CRs (i.e., number of trials to the first CR) but had no effect on subsequent differences in acquisition rates or asymptotic levels of performance. The NMR-JMR transfer produced no evidence of retardation of the initiation of JMR performance, but did appear to retard the acquisition rate and asymptotic level of the JMR relative to no treatment and unpaired controls. Given the assumption that retarded acquisition reflects the action of an inhibitory agent (c.f., Hearst, 1970; Rescorla, 1969), and that an excitatory effect in one motivational system will inhibit the other motivational system (e.g., Gray, 1971), the retarded acquisition from the cross motivational transfers would implicate excitatory effects resulting from backward pairings.

Classical-classical transfer: The effects of backward pairings within motivational systems. As previously noted, while there have been relatively few examinations of backward pairing effects in classical-classical transfer designs, a majority of these have employed transfers within motivational systems. Moreover, rather than the limited applications of aversive-aversive transfer utilized for

classical-instrumental transfer, classical-classical transfers have employed both aversive-aversive and appetitive-appetitive transfers with similar independent variable manipulations investigated with each motivational system. That is, while aversive-aversive transfers have documented the occurrence of an inhibitory backward pairing effect for the rabbit's eyelid (ER) response (Siegel & Domjan, 1971) and NMR (Tait, et al., 1979, in press), aversive-aversive transfers have also investigated the effects of the number of backward pairings for both of these response systems (c.f., Quesnel, et al., Note 3; Siegel & Domjan, 1974) and the effects of backward ISIs for the rabbit's NMR (Holmes, 1971; Plotkin & Oakley, 1975). Similarly, appetitive-appetitive transfers have documented the occurrence of excitatory backward pairing effects for the rabbit's JMR (Tait et al., in press), as well as the effects of the number of backward pairings in the same response system (Quesnel, et al., in press).

Perhaps the first study to employ the classical-classical transfer design for within motivational systems assessment of backward pairings was conducted by Siegel and Domjan (1971, Experiment 2). In this experiment rabbits were assigned to either a backward treatment group, a no treatment group, a CS alone group, a US alone group, or a random unpaired group for ER conditioning. During phase one treatments, the groups received 550 trials of the

appropriate conditions for each group. Following the phase one treatments, all groups received 350 trials of the forward paired CS and US. For all phases of this experiment, the CS was a 500 msec tone and the US was a 6.0 mA, 100 msec electric shock to the orbital region. The results of this procedure revealed that, during phase two forward pairings, conditioning was retarded for all of the treatment groups relative to the no treatment control. Moreover, while all of the treatment groups were retarded in phase two acquisition, the ordering of the main effects indicated that the backward treatment group accrued more inhibition than the random unpaired group, the US alone group, and the CS alone group (in declining order of degree of inhibition).

Siegel and Domjan (1974; Experiment 2) subsequently attempted to document the development of inhibition in the backward pairing effect for the rabbit's ER. Employing the same stimuli, parameters, and ISI previously employed to demonstrate inhibitory backward pairing effects, Siegel and Domjan varied the number of backward pairings in phase one. In this experiment, rabbits received either 0, 5, 10, 25, or 50 backward pairings prior to the forward conditioning the ER. The results of this experiment indicated that while there was little inhibition developed between the 0 and 5 backward pairing groups, as the number of backward pairing increased beyond the 5 backward trial condition the

magnitude of acquisition retardation was a direct function of the number of backward pairings. While Siegel and Domjan (1974) identified a functional relationship the absence of appropriate contrast control precludes confirmation that inhibition was developed.

Results similar to those observed for the rabbit's ER, have also been obtained for the rabbit's NMR (Quesnel, et al., in press; Tait, et al., in press). Tait, Quesnel, and Ten Have (in press) assessed the effects of within motivational system transfer for the rabbit's NMR. Employing the same stimulus parameters as in the cross motivational transfer, the transfer effects of 22 backward pairings were assessed on the reacquisition of the NMR during phase two forward pairings of the CS and US. The phase two acquisition, and subsequent extinction phase, revealed a marginally inhibitory effect resulting from the phase one backward pairings, relative to no treatment and unpaired controls.

To document the acquisition of inhibition with backward pairings on the rabbit's NMR, Quesnel, Ten Have, and Tait (in press) varied the number of backward pairings during the phase one treatments. In this experiment, groups received either 5, 15, 25, 45, or 65 backward pairings, unpairings, or no treatments during phase one. For all groups, the stimulus parameters were the same as those employed by Tait,

Quesnel, and Ten Have (in press). The results of this experiment revealed that at all values of the number of treatment trials, the unpaired groups were inhibited relative to the corresponding no treatment controls. Moreover, while the 5 and 15 backward pairing groups approximated the levels of the no treatment controls, and were excitatory relative to the unpaired controls, the 45 and 65 backward pairing groups were inhibitory relative to both the no treatment and unpaired controls. As with the results of Siegel and Domjan's (1974) investigation of the number of backward pairings on the rabbit's ER, Quesnel, Ten Have, and Tait (in press) have presented data suggesting that there may be an initial point on the number of backward pairings continuum where inhibitory states are not clearly manifest, but with increased training inhibition is apparent.

Although the results reported for the rabbit's NMR and ER appear similar to the results reported for the classical-instrumental within motivational system transfer (c.f., Moscovitch & LoLordo, 1968), attempts to obtain a backward ISI function with the rabbit's NMR have produced conflicting results. For example, Plotkin and Oakley (1975) investigated the effects of a 400 msec and a 700 msec backward ISI on the subsequent acquisition of the forward conditioned NMR. Employing a 200 msec tone CS and a 200 msec, 3.0 mA, paraorbital electric shock US during the 125

trial phase one treatment, for the phase two forward conditioning treatment the CS duration was expanded to 500 msec, with an ISI of 300 msec, in a delayed conditioning paradigm. During the phase two acquisition of the forward conditioned NMR, the phase one backward pairings were observed to yield an inhibitory acquisition effect relative to the no treatment, short trace (forward conditioning), CS alone, and unpaired control groups. There was no indication of a backward ISI effect. However, this possible lack of difference for the backward ISI groups may have been due to the small difference in the backward ISIs (i.e., 400 vs 700 msec).

Such a possibility is suggested by the experiments of Holmes (1971). In a similar experimental paradigm, Holmes investigated the effects of backward ISIs of 50, 500, 5000, or 1000 msec with 100 backward pairings of a 50 msec, 4.0 mA paraorbital shock US and a 300 msec, 1000 Hz, tone CS during phase one treatments. Subsequently, all subjects received 300 forward pairings of the CS and US, in a delayed conditioning paradigm with a 250 msec ISI. While the results of the phase two forward conditioning indicated that all the backward groups were inhibited relative to the unpaired and CS alone controls, the backward ISI function revealed a decreasing function with the 50 msec backward group demonstrating less inhibition than any of the other backward groups.

To assess this possibility, Holmes (1971, Experiment 2) employed a slightly different research strategy. Rather than employing phase one as the treatment phase and phase two as the reaction phase, Holmes reversed the order of the phases. That is, employing the same CS and US values and parameters of Experiment 1, Holmes initially conditioned the rabbit's NMR during 300 forward pairings of the CS and US, and then assessed the effects of the backward pairings on the already established level of responding, over 700 backward paired trials. With this procedure, Holmes employed the backward ISIs of 50, 500, 5000, and 10000 msec to reveal the greatest evidence of a backward ISI effect in the classical-classical, aversive-aversive transfer. While all backward groups demonstrated response decrements from the forward conditioning levels of responding, the magnitude of response decrement was a direct function of the backward ISI.

Although reports of backward pairing effects for the rabbit's NMR suggest a unitary inhibitory effect, contrary evidence has been obtained in appetitive-appetitive transfers of the rabbit's JMR (c.f., Quesnel, et al., in press; Tait, et al., 1979, in press). Tait, Quesnel, and Ten Have (1979, in press) also examined the within motivational system transfer of the appetitive JMR with a backward pairing paradigm. Employing a 500 msec tone CS and 500 msec, one cc, water injected into the oral cavity as the US,

22 backward pairings, unpairings, or no treatments were administered during phase one treatments. Following the phase one treatments, all rabbits received 250 forward pairings of the CS and US. The results of this experiment clearly indicated the excitatory effects of backward pairings with the main effects of phase two conditioning, ordered from largest to smallest, as backward, unpaired, and nothing groups.

To further document the time course associated with the development of excitatory backward pairing effects with the appetitively motivated JMR, Quesnel, Ten Have, and Tait (in press, Experiment 2) presented rabbits with either 25, 175, or 325 backward pairings, unpairings, or no treatments of the same CS and US parameters as employed by Tait, Quesnel, and Ten Have (in press). Test trial performance during phase 1 treatments revealed low levels of responding for the backward groups that were significantly greater than the response frequency of the no treatment control but not the unpaired groups. Moreover, as the number of backward trials increased so did the frequency of responding in the backward groups. Following the phase one treatments, all subjects received 250 forward pairings of the CS and US in a reacquisition test of the effects of the phase one treatments. The results of phase two were unequivocal. At values of the number of phase one trials, the phase two reacquisition test revealed that the backward groups were

excitatory relative to both the unpaired and no treatment controls.

Backward conditioning: Summary and conclusions

From the preceding studies a pattern of results emerge. With the test trial procedures, controlled studies typically report no associative effects with backward pairings (e.g., Smith, Coleman, & Gormezano, 1969). However, when excitatory effects have been observed, they have been reported in two situations. In aversive conditioning excitatory effects have been observed under conditions of relatively few backward pairings applied to long latency responses, such as the GSR (e.g., Champion, 1962; Champion & Jones, 1961). On the other hand, excitatory appetitive backward conditioning has been demonstrated with relatively greater numbers of backward pairings and a short latency response, the JMR (e.g., Quesnel, et al., in press). Since the test trial assessment procedure cannot distinguish nonassociative from inhibitory outcomes, the failure to observe associative effects could reflect the procedures insensitivity to inhibitory effects. Thus, the observation of inhibitory backward pairing effects obtained with transfer designs does not produce an inconsistent outcome, relative to test trial results, but rather confirms the flaws inherent in the test trial procedure.

One major source of discordance for identifying backward pairing effects has been the literature generated with cross motivational classical-instruments transfer paradigms. The functionally divergent results occur when two variables (i.e., conditioned suppression & conditioned punishment) of the paradigm are employed. While the differences in outcome might reflect the major differences in conditioning parameters (e.g., US duration, CS duration, relative CS-US duration, etc.) employed in the two variants, it is equally likely that the differences due to an inappropriate analysis of and/or inadequate methodological control within, the classical-instrumental transfer design. However, one additional possibility, as suggested by the outcomes obtained with the test trial procedure, might account for the disparate results obtained with the classical-instrumental transfer paradigms. In the test trial procedure, excitatory effects have been observed with long-latency responses. Since the classical-instrumental transfer paradigms do not assess response system properties it is not possible to determine whether the conditioned response systems have short or long latency characteristics. Therefore, if the backward pairing effects reflect response system contributions (e.g., Gormezano, 1972; Guthrie, 1935; Solomon, 1980) then the differential sensitivities of response systems to the various classical-instrumental transfer paradigms may account for a portion of the observed discrepancy.

In contrast to the explanations cited for the discordant results obtained in classical-instrumental paradigms, the results obtained with the application of classical-classical (within motivational systems) transfers are more easily isolated but less easily explained. In the aversive NMR experiments (Quesnel, et al., in press; Tait, et al., in press) and the appetitive JMR experiments (Quesnel, et al., in press; Tait et al., in press), presumed major associative variables were identical. That is, all CS parameters, US-CS and CS-US intervals, and trial densities were matched. The only variables that were not equated were the motivational systems activated by the US (aversive for the NMR; appetitive for the JMR), and the response system characteristics monitored.

Both variables are viable candidates for yielding the discrepant data. In North America, just three experiments (Quesnel, et al., in press; Tait, et al., in press) have examined appetitive conditioning, all the remaining experiments have employed aversive USs. The appetitive studies are consistent with each other and with the fragmentary results reported for Russian appetitive backward conditioning results (Razran, 1956, 1971). Since several theorists (Bindra, 1978; Konorski, 1967; Scavio, 1974) have suggested a basic asymmetry between central appetitive and aversive motivational states, and others (e.g., Rescorla, 1978, 1979, 1980) have posited the conditioning of

qualitative components of motivational states it is possible that the asymmetrical backward conditioning effects may be due to motivational variables.

Differences in response systems being monitored is also a possible factor in producing the functional divergent results. Several theorists (e.g., Gormezano, 1972; Guthrie, 1935; Hull, 1943; Solomon, 1980) state conditions under which excitatory backward conditioning will be determined by UR characteristics. If such is the case then the previously noted excitatory backward conditioning of the long latency GSR is consistent with all of these theoretical formulations. While both the NMR and JMR have short latencies (20-50 msec for the NMR; 140-210 for the JMR) the responses do differ, significantly, in topographical features. The unconditioned NMR is a closure that terminates shortly after US onset. However, the appetitive JMR is a sequence of jaw openings and closings that continue long after the US ceases to occur. The long duration (Guthrie, 1935; Solomon, 1980) and sinusoidal topography (Guthrie, 1935) could be used to predict excitatory backward JMR conditioning. Therefore, at present, the major variables which might be implicated in the determination of backward classical conditioning outcomes are motivational factors and/or response system characteristics. As such, further research becomes necessary to more fully clarify the underlying mechanisms and processes which determine backward classical conditioning effects.

APPENDIX B:

Theoretical Accounts of Backward Conditioning

Following the introduction of the classical conditioning methodology to North American psychology (Pavlov, 1908; Yerkes & Margulis, 1909), Watson's (1916, 1925) analysis of the classical conditioning procedures emphasized the objective relation of the occurrence of stimuli (i.e., CSs and USs) to the development of associations which controlled conditioned response (CR) development and maintenance. Moreover, Watson incorporated the classical conditioning methodology as the vehicle by which both innate and learned behavior might be studied to elucidate the laws of association (Gormezano & Moore, 1969).

At the core of Watson's position were the following four assumptions. First, classical conditioning processes were the associative components necessary for the establishment of the CR, the basic element of responding to which all complex behaviors might be reduced (Watson, 1925). Second, the development of associations, as manifest in the CR, was thought to be controlled by the temporally contiguous occurrence of the CS and US. Third, CR occurrence and its controlling association were thought to represent a one-to-one correspondence. Fourth, while the associative process was thought to be the dynamic factor in classical conditioning, CR performance was conceptualized as a static variable that represented the unconditioned response (UR) occurring prior to US onset. Accordingly, the CR was presumed to have the same fixed features (e.g.,

latency, amplitude, etc.) as the UR (Watson, 1916). Although each of Watson's basic assumptions was subsequently challenged (e.g., Hilgard, 1919; Pavlov, 1927; Thorndike, 1932), the assertion of the classical conditioning paradigm as the methodology for the documentation of associative learning processes provided the impetus for the development of alternative theories describing association formation.

While the various theories of classical conditioning each stipulate the importance of stimulus factors (i.e., temporality, intensity, number of exposures, etc.) for the development of associations, and hence conditioned performance, the major factor differentiating these theories has resulted from the invocation of differing mechanisms of reinforcement through which the development of associations occur. For theories of classical conditioning, the mechanisms asserted to underlie the development of an association, and thus the acquisition of conditioned responding, have involved: (a) the simple contiguity of stimulus and response (i.e., S-R; Guthrie, 1935, 1952); (b) the S-R relation involving a motivational factor (e.g., S-R; Hull, 1943); (c) cognitive processes determining the association of stimulus events (e.g., Rescorla, 1978, 1980a, 1980b; Rescorla & Solomon, 1967; Wagner, 1981); and (d) the contiguity of affective processes (e.g., Schull, 1979; Solomon, 1978, 1980). The following sections review each of the theories with respect to: (1) the operation of the mechanisms to produce an association; (2) the determination

of performance; and (3) the predictions relating temporal asynchronies of stimuli to association formation.

S-R Contiguity Theory

Watson's notion that the acquisition of conditioned behavior results from S-R contiguity became a central theoretical tenet for some subsequent theorists (c.f., Estes, 1950, 1958, 1959; Guthrie, 1935, 1952; Smith & Guthrie, 1921). In its simplest form, contiguity theory specifies that while the US produces observable behavior (i.e., the UR), the presumably neutral CS also elicits unmonitored responses (e.g., orienting responses, visceral & muscular responses, etc.) that generate proprioceptive cues. The contiguous occurrence of the proprioceptive cues and the UR was postulated to provide the necessary and sufficient conditions for the development of an association (Guthrie, 1933, 1935, 1952). The proprioceptive cues were thought to act as a stimulus pattern, such that if the precise stimulus pattern reoccurs, its past association with the UR will produce a CR (Guthrie, 1935). Accordingly, the occurrence of a CR on any given trial was a function of the similarity and completeness of the stimulus pattern that occurred on that trial to the stimulus pattern that was conditioned on previous trials (Voeks, 1950). While an S-R association is hypothesized to be formed the first time the stimulus pattern and response are contiguous, the observation that a

number of CS-US pairings are needed before a CR is manifested is accounted for by the additional hypothesis that the CS-produced proprioceptive cues may not follow a precise sequence or, may vary on some psychophysical dimension (e.g., vigor, saliency). As a result, response tendency is a function of the sequence and properties of the stimulus cues that occur on any trial. As the number of conditioning trials increase, there is a greater number of stimulus pattern variations that become associated with the UR (Voeks, 1950). Consequently, over conditioning trials, there is a greater probability of obtaining a stimulus pattern that is similar to an already conditioned stimulus pattern, and thus, both the response tendency and the probability that the CR will occur increases (Guthrie, 1952; Voeks, 1950).

To account for the superiority of delayed conditioning procedures to backward and simultaneous conditioning procedures (e.g., Wolfle, 1930, 1932), Guthrie (1932, 1933) asserted that physiological processes which generated proprioceptive cues to a CS occurred over a finite amount of time. Accordingly, when the CS precedes the US, proprioceptive cues are generated during the CS-US interval, and contiguity of the proprioceptive cues and UR is ensured. With simultaneous and backward conditioning procedures, the UR is initiated prior to the proprioceptive cues such that the essential contiguous events would be the proprioceptive

cues and UR offset. Since, in this situation, the response being conditioned is opposite in direction to the response elicited by the US, simultaneous and backward conditioning procedures should yield behavioral inhibition. For Guthrie, the above argument is restricted by UR characteristics. The defining feature of conditioning is the strict contiguity of a response with proprioceptive cues. With long latency response systems (e.g., galvanic skin response; GSR) some simultaneous and backward CS-US arrangements could produce excitatory conditioning effects. Thus for Guthrie the occurrence of either excitatory or inhibitory backward conditioning effects would depend on the temporal intervals employed, US characteristics controlling the vigor of the UR, and the response system employed.

Effect Theories

With the advent of observations of primary and acquired motives directing and maintaining conditioned performance, (e.g., Bugelski, 1938; Hovland, 1937; Humphreys, 1939) and the apparent limitations of consequences as a critical factor for association formation were developed (e.g., Hilgard & Marquis, 1940; Hull, 1943; Kimmel & Burns, 1975; Martin & Levey, 1969; Perkins, 1955, 1968; Prokasy, 1965). Effect theories of classical conditioning have been expressed in two distinct formulations, which differ in how motivation acts on association, CR acquisition, and

maintained performance. For Hullian theory (Hull, 1943, 1952), motivation is thought to directly control association, as manifested by CR acquisition, through motivational properties and physiological changes produced by the US. In contrast to Hullian theory, response shaping theory suggests that CR acquisition and performance occurs through motivational changes resulting from CR produced modifications of the sensory (motivationally perceived) consequences of the US (c.f., Kimmel & Burns, 1975; Perkins, 1955; 1968; Prokasy, 1965).

Hullian theory

Like Guthrie, Hull (1943, 1952) was an S-R theorist and argued that associations occurred between the CS representation and the URs. Unlike Guthrie, Hull further argued that the association would be formed only if a motivational change was contiguous with the CS representation and the UR, and the manifestation of the association would occur only if a motivation state was active when the CS was presented.

Within Hull's framework, an association was the result of the contiguous occurrence of three components. The first component was a hypothetical construct, termed the molar stimulus trace (MST), which was generated by, and thought to represent physiologically, the CS. The second component was

the reinforcement provided by the change in motivational properties (i.e., drive reduction) that occurred either with US onset (appetitive conditioning) or offset (aversive conditioning). The final component was the elicitation of the UR by the US.

The MST is presumed to result from CS onset, where CS onset impinges upon a suitable receptor, generating a self propagating afferent trace. The properties of the CS elicited MST were asserted as: (1) an initial short latent period, occurring for no more than 200 msec after CS onset, during which the MST does not change in strength from the nonstimulated baseline levels; (2) following the latent period, the MST undergoes a rapid recruitment in strength (analogous to the amount of neuronal activity), reaching its maxima about 450 msec after CS onset; (3) subsequently, a subsident phase of substantially longer duration than the recruitment phase; and (4) both the strength of the MST and the duration of the subsident phase were thought to be a direct function of CS intensity at CS onset. Moreover, Hull stipulated that the momentary strength of the MST at the point in time that a motivational state change and a response coincide determine the amount of association that developed from a CS-US experience. With repeated CS-US experiences, additional increments in association develop. (In Hull's terminology, an association was termed a habit and the strength of the habit was represented by sHr). For

Hull (1943), the properties of the MST were presumed fixed both within and across species and, therefore, optimal association would occur at the MST peak, or 450 msec after CS onset. In response to the observation that the optimal CS-US asynchrony for the development of associations did not always occur with CS-US interval of 450 msec (c.f., Gormezano & Moore, 1969), Gormezano (1972) proposed that the time course of the MST might not be fixed, but reflect the physical characteristics of the CS (e.g., onset/offset parameters, sensory system activation) and/or the characteristics of the organism. Thus, for Gormezano, the form and action of the MST was similar to that proposed by Hull (1943) with the additional assertion that the time course of the MST phases were not invariant but reflected independent variable manipulation.

The second component conceived as a necessary factor for the development of the association was the reduction of a biological need or drive. While Hull (1943) posited drive as a performance variable controlling response exhibition and response characteristics, the presence of drive was conceptualized as an intrinsically displeasing state. Thus, reduction of the drive was posited to produce a gratifying or reinforcing phenomenon and thereby providing the reinforcing impetus for the S-R association. Moreover, the timing of maximal drive reduction was determinable by the classification (i.e., appetitive or aversive) of the stimuli

used as the US within the particular classical conditioning paradigm. For appetitive conditioning, Hull asserted that drive was provided by the deprivation regime imposed on the organism and thus both drive reduction and the UR were produced by US onset. In contrast, for aversive conditioning the US presentation was posited to indicate both the drive and the UR, while US offset defined the point of maximal reduction. The final component required for the development of the association was the US initiated response, the UR.

By coupling the concepts of MST, drive reduction, and UR exhibition, Hull asserted that, in classical conditioning, the development of an association is an incremental process that occurs to the point on the MST that is contiguous with the UR and drive reduction. Moreover, the amount of associative strength accruing at the occurrence of the triple contiguity of components is a joint function of the elevation of the MST point and the magnitude of drive reduction. Furthermore, as the S-R association accrues to the point on the MST, a gradient of generalization is established since points on the MST are thought to differ only in terms of relative elevation (Hull, 1943). Therefore, CRs may be exhibited when the generalization gradient extends into the interval prior to US onset.

For Hullian theory (1943, 1952) performance (sEr =reaction potential) in the classical conditioning paradigm was expressed as a joint function of the associative variable with a motivational variable (D =drive), and a variable with both motivational and associative properties (I =inhibition). In this model the construct of drive represented the physiological state of the organism and could be quantitatively linked to experimental operations such as deprivation regimes and US applications. Moreover, drive was assumed to have both associative and performance consequences. As previously noted, a reduction in drive provided by either US onset (for appetitive USs) or US offset (for aversive USs) was the source of reinforcement for the development of habit strength. Thus, drive was viewed as integrally linked to the associative processes. In addition, drive was assumed to provide a general activation or energization of behavior such that performance indices would be directly related to drive variables. Since Hull asserted that, in any situation, performance was a multiplicative interaction of habit strength and drive, some level of drive is necessary if the development of an association is to be measured behaviorally. The performance consequence of drive resulted in an interpretational difficulty for the account of anticipatory CRs in classical aversive conditioning. Since Hull (1943) indicated that US onset was the source of drive in these situations, there

should be no drive and hence no performance prior to US onset. Spence (1958) addressed the aversive anticipatory CR problem by postulating that an aversive US has the capacity to arouse a hypothetical emotional (i.e., fear) reaction (re). This emotional consequence of an aversive US was a function of the intensity of the aversive US; decreased slowly over time; but persisted until the next trial. As such, the source of drive present during any trial was thought to represent the summation of the simultaneous drive levels of the psychological state and re .

While increases in habit strength and drive levels produced greater performance indices, increases in the strength of inhibition was thought to result in a decrement in response tendencies. Hull (1943) posited two sources of inhibition that summated to decrement performance: reactive inhibition (I_r) and conditioned inhibition (sI_r). Reactive inhibition was conceptualized as a negative drive accruing as a function of the effort required for response execution (i.e., a fatigue factor). Reactive inhibition assumed to persist for some minimal interval; to accumulate over trials; and, to be inversely related to the duration separating conditioning trials. While reactive inhibition was viewed as a motivational contributor to performance, conditioned inhibition was viewed as an associative contributor. Conditioned inhibition was defined as the conditioned tendency not to execute the experimenter-defined

response (i.e., CR or UR). Inhibitory conditioning was stipulated to result from the conditioning of stimuli occurring contiguously with the cessation of the response in the presence of "appreciable" reactive inhibition (Hull, 1943, 1952).

Thus Hull's simplified performance equation for classical conditioning may be expressed as:

$$sEr = sHr \times D - (Ir + sIr).$$

The observation of CRs will result only if $sHr \times D > (Ir + sIr)$. The absence of CRs, however, cannot be used to identify the presence of inhibition, since sEr will equal zero if either $sHr = 0$ or $D = 0$.

Temporal asynchrony. The application of the Hullian model to forward conditioning procedures readily account for the development of CRs. In the delayed and trace conditioning paradigms CS onset, instigating the temporal course of the MST, occurs prior to the US administration. Hence, paradigms utilizing ISIs greater than 200 msec, but less than the longest extent of the MST, should maximize the contiguous presence of the MST, drive reduction, and the UR. Since the CS precedes the US occurrence, conditioning of the antagonistic response will not occur and no conditioned inhibition should result. With spaced trials little reactive inhibition should develop and therefore, with these paradigms $sHr \times D > (Ir + sIr)$. Hence, maximal excitatory

associations should develop limited only by the strength of the MST occurring at the point of conditioning.

The application of this model to the simultaneous conditioning paradigm is less obvious. That is, the coincidence of CS and US onsets may mediate the possibility of excitatory conditioning depending upon the type and duration of the US employed. For instance, simultaneous appetitive conditioning should produce little evidence of excitatory conditioning since drive reduction and the UR are purported to occur at US onset. Therefore, these events would be contiguous with the latent period of the MST. On the other hand, simultaneous conditioning of the CS with an aversive US should produce excitation under the conditions that: US duration exceeds the latent period of the MST since US offset is the purported drive reduction mechanism, and, the UR has a long onset latency (Gormezano, 1972). That is, with longer latency URs and aversive USs, simultaneous CS-US presentations would yield excitatory conditioning effects, if the UR occurred during the dynamic phase of the MST.

For backward conditioning procedures, the Hullian framework would predict the absence of conditioning effects in most cases. For instance, in appetitive backward conditioning situations, the occurrence of the US prior to CS onset would mean that drive reduction and the UR occurred

before excitation of the MST, precluding the occurrence of an excitatory associative outcome. However, if in this conditioning situation US offset, and presumably UR cessation, coincides with CS onset, then the conditions necessary for the production of conditioned inhibition have occurred.

In aversive backward conditioning the presumed mechanisms operate differently. While maximal drive reduction is tied to US onset for appetitive procedures, in aversive conditioning maximal drive reduction is thought to occur at US offset. Additionally, for the aversive case, US onset is thought to initiate an emotional reaction which is maintained through to the following trial. As such, excitatory aversive backward conditioning effects might be expected under conditions where: (1) long latency responses allow the UR to overlap, by 200 msec or more, MST generation and the emotional reaction (i.e., drive); and, (2) the use of a short backward ISI allows the US, and thus the UR, to overlap the CS by 200 msec or more, such that US offset is contiguous with the elevated MST. In contrast, experimental operations in which the US and UR terminate prior to CS onset would produce either no associative conditioning effects or inhibitory condition effects dependent upon the degree of non overlap of the CS and UR cessation in the presence of drive reduction (i.e., subsident re,

In summary, Hull (1943; 1952; Spence, 1958) postulated a theory of conditioning in which the contiguous occurrence of drive-reduction, the UR, and a point on the MST are necessary for the development of an association. The association (i.e., habit) is then thought to interact with concomittant drive and inhibitory potentials to control conditioned performance. However, while these factors and conditions may be maximized to produce excitatory conditioning effects with forward conditioning procedures, simultaneous and backward conditions procedures are postulated to produce excitatory effects only under limited conditions. In all other circumstances simultaneous and backward procedures would be expected to result in either no associative or inhibitory effects.

Response shaping theory

The second variant of effect theory has argued for an S-R-S analysis of classical conditioning. For response shaping theory the occurrence of a CR overlapping US onset is thought to mediate US affectiveness and thus allow for the association of the CR and the stimulus conditions present (Prokasy, 1965). For response shaping theory, the possibility of local adaptive consequences of responding prior to US onset are stressed (c.f., Prokasy, 1965). According to this formulation, the mechanism of reinforcement for classical conditioning is a response

produced modification of the sensory consequences of the US. That is, when a CR overlaps US onset, it is presumed that the hedonic value of the US is altered, and the response (CR) that produces the alteration is increased in strength. For example, in a classical aversive eyelid conditioning situation, CR overlap of US onset is presumed to reduce the aversiveness of an air puff US by allowing the subject to receive the air puff on the external eyelid rather than the cornea. Thus, classical aversive conditioning is viewed as analogous to an instrumental avoidance contingency. In contrast, in classical appetitive salivary conditioning situations, delivery of the food powder US into the organism's mouth stimulates salivation to aid both the ingestion and digestion of the substance. Salivation accompanying US delivery is conceived as enhancing food flavor and ingestion (Schlosberg, 1937). The US enhancement is believed to reinforce the response (salivation during the CS) that produced it, so that again, CR development reflects response-reinforcer contiguity.

The response shaping analysis of classical conditioning makes several assumptions with respect to CR acquisition and topography as the result of the contiguous CR-US notion of maximal reinforcement. First, it is assumed that the first CR is a random event, controlled by spontaneous rates of response emission (Martin & Levey, 1969). Second, once the CR has occurred, and has been reinforced by the reduction or

enhancement of the sensory consequences of the US, the association is formed but a longer instrumental shaping process is required to maximize CR-US overlap. Third, the process of locating a CR within the CS-US interval is hypothesized to involve a temporal discrimination by the subject, such that with repeated trials and a sharpening of the discrimination, responses come to overlap US onset. And fourth, it is asserted that a subset of CR topographical features maximize the reinforcement process and therefore are differentially strengthened.

There appears to be some differences between advocates of response shaping theory as to the critical feature of the CR that maximizes the reinforcement process. For instance, while Kimmel and Burns (1975) have stressed CR onset latency, CR amplitude, and CR peak latency as the topographical features which are important for reinforcement, other authors (e.g., Martin & Levey, 1969) have suggested the similarity or blending of the CR and UR features as the conceptual relation for the analysis of reinforcement. That is, while some response shaping formulations have suggested that the topographical feature which maximizes reinforcement would be those features which would allow the CR peak to overlap US onset, Martin and Levey have indicated that blending of the CR into the UR would reduce the effort expended during responding and would add to the reinforcement obtained. In all cases, the one

conceptual requirement for reinforcement is the occurrence of the CR such that some feature overlaps US onset.

Temporal asynchrony. The predictions of response shaping theory for the outcomes of forward, simultaneous, and backward conditioning are as follows. In forward delayed and trace conditioning paradigms, if the ISI is brief, there is not sufficient time for either the temporal gauging mechanism to operate or for the generation of a response prior to the US, and therefore no associations should develop. With longer ISIs, the occurrence of the first reinforced CR initiates the temporal discrimination process that operates to maximize reinforcement by controlling the temporal location of subsequent responses. Therefore, intermediate ISIs should lead to the development of strong associations. Finally, as the interval between the CS and US increases, the difficulty of the temporal discrimination increases and, hence, weak associations are developed and conditioning is poorer.

The application of response shaping to simultaneous and backward conditioning paradigms yields the predictions that no excitatory conditioning effects should be observed. Since in both paradigms, the occurrence of the CS does not allow the subject to prepare for the US onset, CR-US overlap will not normally occur, and hence no excitatory conditioning should be observed. Excitatory conditioning

might only occur in one set of circumstances. That is, with short and fixed ITIs a temporal discrimination might be possible such that the organism might use the temporal gauging mechanism to assess the time between trials and thus maximize CR-US overlap. Therefore, if a spontaneous response were to overlap US onset, the reinforcement provided plus the temporal gauging mechanism might lead to some minimal expectation of excitatory backward conditioning effects if the intertrial interval was sufficiently short. However, such a possibility is unlikely since evidence for temporal conditioning between trials (i.e., the gauging mechanism) has not been reported in North America (c.f., Razran, 1971). Accordingly, the theory does not readily provide excitatory accounts of simultaneous or backward conditioning. Rather, under most conditions simultaneous and backward conditioning procedures would be expected to produce no associative effects.

In summary, response shaping theory presents the classical conditioning analogy to instrumental conditioning. In this formulation a random response overlapping the US onset is reinforced through sensory modifications of the US effects. The response probability is increased over subsequent trials by a shaping process which purports to maximize the CR features producing reinforcement. While such an analysis may be applied to the forward conditioning situation, it is limited in its applications to simultaneous

and backward conditioning procedures. That is, simultaneous and backward conditioning would, in most cases, be expected to produce no associative effects.

Effect theories: Conclusions

Two variants of effect analyses of classical conditioning were examined. Both formulations were principally developed to account for the excitatory effects observed with the forward ordering of the CS and US. As such, both variants maximize the accounts of conditioning phenomena resulting from the application of delayed and trace conditioning paradigms. However, the formulations have ignored the possibility of backward conditioning as a general case. Thus, only under restricted conditions would the possibility of excitatory backward conditioning effects be possible or expected. Under most backward arrangements of stimuli these formulations would predict either inhibitory (Hull, 1943, 1952) or no associative (Hull, 1943, 1952; Martin & Levey, 1969; Prokasy, 1965) outcomes.

Cognitive theories

In contrast to the S-R contiguity (Guthrie, 1952) and effect (Hull, 1943; Prokasy, 1965) accounts of classical conditioning, recent theories have postulated cognitive components as central to association processes (e.g., Gray, 1971; Rescorla, 1967, 1978, 1980; Rescorla & Solomon, 1967).

The major cognitive theories have taken one of two forms: accounts which postulated the perceptual processing of information about the relationship between stimulus events (e.g., Gray, 1971; Prokasy, 1965; Rescorla, 1967); and, accounts which posit the association of internal representations of stimulus events (e.g., Hebb, 1955; Konorski, 1967; Mazur & Wagner, in press; Rescorla, 1975, 1978, 1979a, 1980; Wagner, 1978, 1979, 1980, 1981).

Information processing accounts of conditioning

Central to the information processing model of conditioning are the following assumptions. First, while contiguity of stimulus events is necessary for the development of an association, it is not the sufficient condition for an association. Rather, the association represents an identification and evaluation of the relationship of the CS and US (e.g., Eggar & Miller, 1962; Prokasy, 1965; Rescorla, 1967). Therefore, while the CS and US may occur temporally close together, conditioned responding will not occur until the organism recognizes the predictive relationship between the two stimulus events. Second, the information processing theory makes the inherent assumption that there is a one to one relation between the rules governing association and the statistical rules governing the description of the predictive relation of the CS and US (i.e., correlations). That is, the degree of

associability of two stimulus events is directly represented by the correlation reflecting the probabilities of joint and nonjoint occurrences of the two stimuli (c.f., Prokasy, 1965; Rescorla, 1967). Third, is the assumption that while the recognition of the relation predicting the joint occurrence of the CS and US leads to excitatory associations, the recognition of the predictive relation representing the nonjoint occurrence of the CS and US leads to inhibitory associations (Rescorla, 1967). This assumption has been restricted to conditioning procedures in which the CS predicts the occurrence or nonoccurrence of the US (Prokasy, 1965). The fourth assumption is that the degree of predictability or nonpredictability represent symmetrical probabilities of excitation and inhibition (Rescorla, 1967, 1969). That is, the subtractive combination of the correlations representing the degree that the CS predicts the US and the degree to which the CS predicts the absence of the US will determine the excitatory or inhibitory associative tendency resulting from conditioning procedure. And fifth, CRs will result from excitatory associative tendencies, but be suppressed by net inhibitory associative tendencies.

These assumptions might best be expressed in terms of the representations of conditions and procedures under which the joint probabilities of the CS and US would predict excitatory and inhibitory conditioning effects. For a

conditioning procedure to accrue an excitatory associative potential, the probability of a CS in the presence of a US ($P(\text{CS}/\text{US})$) must be greater than zero. For a conditioning procedure to accrue an inhibitory associative potential, the probability of a CS in the absence of a US ($P(\text{CS}/\text{US})$) must be greater than zero. And finally, conditioning performance will be determined by the subtractive relation of the two probabilities. That is, if $P(\text{CS}/\text{US})$ is greater than $P(\text{CS}/\text{US})$ then excitatory conditioning will result; if $P(\text{CS}/\text{US})$ is less than $P(\text{CS}/\text{US})$ then inhibitory conditioning will occur; and if $P(\text{CS}/\text{US})$ equals $P(\text{CS}/\text{US})$ then no evidence of an associative effect will be observed.

Temporal asynchrony. The above description provides a general definition of the information processing account of classical conditioning. However, it is important to note that there have been two variants of the information processing approach to classical conditioning (c.f., Prokasy, 1965; Rescorla, 1967). While both variants provide the same account of forward conditioning (delayed and trace) procedures, only Rescorla (1967) has extended the theory to encompass backward conditioning procedures. That is, in delayed and trace conditioning procedures both variants would predict the $P(\text{CS}/\text{US})$ to equal 1.0, the $P(\text{CS}/\text{US})$ to equal 0.0, and maximal excitatory

conditioning to result (c.f., Prokasy, 1965; Rescorla, 1967). In contrast to the forward conditioning paradigms, Rescorla (1967) would expect that the backward conditioning paradigm would produce maximal inhibitory effects. That is, with backward pairings, the CS predicts a time period free from the US. Accordingly, the $P(\text{CS}/\text{US})$ would always equal 0.0, while the $P(\text{US}/\text{CS})$ would equal 1.0. As the result of the organism's recognition of this relation, Rescorla would predict that the CS would become an inhibitory cue, and responding would be suppressed.

Central representation theories: Memory and cognitions

While the information processing model of classical conditioning postulates the recognition of the relationships between stimuli for the acquisition of responding, central representation theory stipulates that the CS and US are internally represented and for conditioning to be observed, associative bonds or linkages between the central representations must be formed (e.g., Bindra, 1976, 1978; Hebb, 1949, 1955; Konorski, 1948, 1967, Pavlov, 1927, 1928, 1932; Rescorla, 1978, 1980; Rescorla & Solomon, 1967; Tolman, 1932). Although variants of this theoretical approach differ in terms of how the cognitions are represented (e.g., cognitively or physiologically), structurally, the theoretical formulations suggest that the

same type of processes are involved in the formation of associations (c.f., Konorski, 1967; Rescorla, 1978, 1980; Rescorla & Solomon, 1967; Tolman, 1932).

All versions of central representation theory assert that following the first experience with a stimulus event the organism forms a relatively imprecise central representation of the physical event, which is activated, and becomes a more precise representation, with subsequent closures to the stimulus (Hebb, 1955; Konorski, 1967; Rescorla, 1980; Wagner, 1981). With repeated paired presentations of a CS and US, the concomitant overlapping excitation of the two representations is thought to result in the formation of associations between the stimulus representations (c.f., Bindra, 1978; Hebb, 1955; Konorski, 1967; Rescorla, 1978, 1980). The major difference between the versions of the theory related to the hypothesized processes involved in linking the central representations (e.g., Bindra, 1976, 1978; Hebb, 1955; Konorski, 1967; Rescorla, 1978, 1980; Wagner, 1981). That is, while memorial (Mazur & Wagner, in press; Wagner, 1981), emotional (Hebb, 1955), motivational (Solomon & Rescorla, 1967), physiological (Konorski, 1967), and spatio-temporal (i.e., imaginative, Rescorla, 1980) processes have each been postulated as the important aspects of central representations linked during association formation, currently two representational theories are gaining

ascendancy in North American psychology: Wagner's (1981) memorial model and Rescorla's (1980) imaginal model. However, while the assumptions defining the structure and action of the memorial model (Wagner, 1981) specify the mechanisms accounting for effects observed with temporally asynchronous stimulus presentations, the other theoretical models are more general formulations and are less precise (e.g., Bindra, 1978; Hebb, 1955; Rescorla, 1980). For the latter theories, an analysis of the structure and actions of the emotional, motivational, physiological, and imaginative representational accounts suggest close parallels in their approach to conditioning phenomenon. Accordingly, the following section presents first the memorial (Wagner, 1981) approach and a general outline of the broader representational approach utilized in the other theories (e.g., Hebb, 1955; Konorski, 1967; Rescorla, 1980).

Memory representations

Wagner (1976, 1978, 1979, 1981) and associates (Donegan, 1981; Pfautz, Donegan & Wagner, 1978; Mazur & Wagner, in press; Pfautz, & Wagner, 1976; Terry, 1975; Whitlow, 1976) have posited a short-term memory (STM) model of association. This memory model, denoted as SOP (i.e., Standard Operating Procedure or Sometimes Opponent Process: Wagner, 1981), suggests that stimulus occurrence results in the active representation of the stimulus event in STM. The

representation is viewed as a memory node that contains a set of elements, where the elements loosely correspond to physical attributes of the environmental stimulus.

According to Wagner (1981; Mazur & Wagner, in press) the memory node, within which the stimulus representation is incorporated, operates according to a three-state decay process. The occurrence stimulus in the subject's environment activates elements from the representation into a primary activation state, labelled the A1 state. In the A1 state, direct cognitive action (e.g., rehearsal) occurs on the stimulus representation. Elements decay from the A1 state over time into the second state, labelled A2, which is a less active process. A further transition to the third state, denoted as the I state, also occurs by decay. In the I state none of the elements were active (Mazur & Wagner, in press).

Explicit within Wagner's (1981) SOP model are the following assertions. First, the model assumes that at any moment there is limited number of necessary nodes which may be active in either the A1 or A2 states. Specifically, Wagner (1981) asserts that no more than 2 or 3 nodes are simultaneously activated in the A1 state, and no more than 10 or 15 nodes are active in the A2 state. Second, the model assumes that the decay is temporally bound continuous decay of the nodal elements rate from the A1 state is higher

than the decay rate from the A2 state. That is, the A1 state is thought to decay about five times faster than the A2 state thus insuring that STM may maximize I to A1 state transitions in the presence of the stimulus event. Third, transitions within STM may occur from the I state to either the A1 or A2 state but once the nodal elements have been activated, the elements must decay to the inactive state before they can again be made active. That is, elements in the A1 state must follow the A1-A2-I sequence, and elements in the A2 state must follow the A2-I sequence, before these elements may again be activated. As a consequence of this assumption, elements which are already active in STM may not be modified to produce either longer duration activation or enhanced activation (Wagner, 1981). Fourth, Wagner (1981) hypothesized that repeated paired stimulus presentations (e.g., a CS and US) generates an associative connection between the respective memory nodes such that the activation of a CS node will come to activate the US representational node (Mazur & Wagner, in press). The model, however, also provides for a limitation of the degree of activation accruing through associative processes in that the associative link from the CS node may only activate US nodal elements from the I state to the A2 state. Fifth, SOP allows for bidirectional excitatory and inhibitory associations between nodal representations (Wagner, 1981). Wagner asserts that excitatory associative connections occur

only if there is temporal contiguity between active A1 states of the CS and US, whereas, inhibitory associative connections result only if there is temporal contiguity between an active A1 state for on stimulus (e.g., CS) and an active A2 state for the other (e.g., US) stimulus.

Temporal asynchrony. While Wagner's (1981; Mazur & Wagner, in press) SOP model yields no precise predictions for its application to the various conditioning paradigms, thus allowing the occurrence of excitatory or inhibitory outcomes, the following outcomes might be expected with delayed, trace, simultaneous, and backward conditioning procedures. In delayed conditioning paradigms excitatory CS-US associations would result only if the proportion of CS nodal elements in the A1 states exceed the proportion in the A2 state when the US nodal elements are activated to the A1 state. This state of affairs is typically observed with relatively short ISIs. However, for any particular ISI, the amount of excitation accrued on a trial would reflect the proportion of nodal elements in the CS A1 state and US A1 states minus the effects of the temporal decay from the CS A1 state, the amount of inhibitory (A2) activation of the US elements by the CS, and the decay of the CS produced US A2 state activation.

The application of SOP to trace conditioning paradigms leads to the expectations of excitatory or inhibitory

outcomes dependent upon the correspondence of the interval to the CS A1 states into A2 states then inhibitory associations would be expected. Conversely, if the trace interval minimized the CS A2 and US A1 overlap and produced CS A1 and US A1 overlap then excitatory associations would result.

Simultaneous conditioning procedures should maximize the SOP model's mechanisms for the formation of excitatory associations. That is, with the simultaneous onset of the CS and US, the highest degree of overlap of CS A1 and US A1 levels of activation should occur. As such, the only limitation to the development of the excitatory association might be related to the limitation of the number of CS and US nodal elements activated to the A1 state simultaneously and the relative ratio of the decay of the active (A1) elements within the nodes.

For backward conditioning paradigms, dependent upon the temporality of stimulus presentations, the theory might predict the occurrence of either excitatory or inhibitory associative outcomes in memory operations (Whitlow, 1976). That is, excitatory US-CS associations would occur only if the proportion of US A1 elements exceed the number of US elements in the A2 state at CS nodal elements activation to the A1 state. Moreover, the SOP theory would suggest that maximal excitatory backward conditioning would be observed

with few trials since through association, over trials as associations develop; US element activated to the A1 state would produce greater amounts of CS A2 activation yielding greater inhibitory potentials. Thus, with extended backward conditioning training, as the number of backward trials increase there should be expected an increase in the proportion of CS A2 element activation, at US A1 activation, leading to an inhibitory outcome. While the foregoing expectations for ISI effects are derived from the SOP model's assumptions, the time parameters of the decay process makes absolute predictions of associative and behavioral outcomes impossible.

Cognitive Representational Theory

Analogous to Wagner's (1981) SOP model of memory processing other authors (e.g., Bindra, 1978; Hebb, 1966; Konorski, 1967; Pavlov, 1927; Rescorla, 1978, 1980) have proposed theories which speculate less on the activity of the mind and more on the contents of cognitions during conditioning. As a rule, cognitive central representation theories suggest that following the first presentation of the CS or US or both, a central representation of the physical event(s) is(are) formed. It has been postulated that these CS and US representations imprecisely approximate the physical properties of the activating stimulus event, and, in addition, contain some of the concomittant

emotional-physiological properties produced by the physical stimulus (Hebb, 1949, 1955; Rescorla, 1978). Over successive stimulus presentations the central representation is thought to be more closely approximate with the physical and emotional-physiological-arousal eliciting properties of the stimuli (c.f., Konorski, 1967; Rescorla, 1978).

Although it is unspecified within the theory, either simultaneous with or sequential to the formation of the central representations of the stimulus events, the CS and US centers form an associative bond such that the excitation of one center will come to excite the other (Bindra, 1978; Hebb, 1949; Konorski, 1967; Pavlov, 1927, 1928, 1932; Rescorla, 1978). Formulations which posit this occurrence have differed in terms of a possible restriction placed upon the temporal directionality component of the associative bond. While some theorists (c.f., Bindra, 1976, 1978; Konorski, 1967) have suggested that the associative bond is bidirectional in its formation, for other theorists (c.f., Hebb, 1949; Pavlov, 1927; Rescorla, 1978, 1980; Rescorla & Solomon, 1967) it is temporally unidirectional in development and action. That is, theorists who posit temporal bidirectionality of the association would stipulate that the sequential presentation of two stimuli, produces at least two associative connections. One between the temporally first stimulus and the temporally second stimulus, and a second, between the temporally second

stimulus and the temporally first stimulus. On the other hand, theorists who posit a unidirectional associative connection would expect that the sequential presentation of two stimuli to result in a single association between the temporally first and the temporally second stimulus.

Irrespective of the temporal directionality of the association, responding is thought to occur when the strength of the association has sufficiently developed such that excitation of one representation produces above threshold excitation of the second representation (e.g., Hebb, 1949; Konorski, 1967). The manifestation of responding, while considered to accrue from the above process, has been variously interpreted as representing informational qualities (e.g., Rescorla & Solomon, 1967) or expectancies (Rescorla, 1980).

Temporal asynchrony. Such assumptions have direct implications for backward conditioning paradigms. That is, the coupling of the notion of how relations between stimuli are learned with what the relations mean, result in two possible predictions for the backward conditioning paradigm. For the unidirectional association theorists, US-CS pairings should lead the organism, on the presentation of the CS alone, to expect no US. Therefore, such a procedure should produce no evidence of excitatory conditioning and possibly evidence of inhibitory conditioning. In contrast, the

adherents to bidirectional associations would suggest that independent of the tempoal order of presentation of stimuli during the pairings, the administration of one of the stimuli should produce the excitation of the other stimulus representation. From this perspective, if the necessary associative strength has been developed between the two representations, then the presentation of the CS alone after backward conditioning should result in the occurrence of a CR (i.e., excitatory conditioning effects).

The derivation of predictions for the cognitive model, for specific conditioning procedures, however, is mitigated by the absence of performance rules for many formulations. That is, while many models posit the method (i.e., contiguity) by which associations will come to be formed, often such models do not present rules for the translation of the association into the execution of the response. In contrast to S-R contiguity and effect theories which posit a one to one relation between association and performance, some versions of the cognitive representation theory (e.g., Rescorla, 1978) suggests no such arrangement. The absence of performance rules suggest that while the models may be fitted to any data collected under any experimental procedure, the meaningfulness of such interpretations is unclear.

Representation theories: Conclusions

Cognitive theories of classical conditioning have provided three general models which readily account for forward conditioning effects. However, the theories diverge on their predictions for backward conditioning. While the cognitive representation theories of conditioning do not yield specific predictions for backward conditioning procedures, the information processing model has the uniform prediction of inhibitory effects resulting from such paradigms. However, neither theory appears to have the flexibility to account for the observations of excitatory, inhibitory, and nonassociative effects which have been reported with the application of the backward conditioning paradigm.

Contiguity of affective states: Opponent process theory

Solomon and associates (Hoffman & Solomon, 1974; Schull, 1979; Solomon, 1980; Solomon & Corbit, 1974; Starr, 1974) have postulated a theory of opposing affective states to provide an account of conditioned (e.g., Overmeier, Payne, Brackbill, Linder, & Lawry, 1979; Schull, 1979), unconditioned (e.g., Solomon, 1980; Solomon & Corbit, 1974), and innate (e.g., Hoffman & Solomon, 1974; Starr, 1978) phenomena. Conceptually, the theory invokes the affective components of contrast, habituation, and withdrawal to provide the effective control of behavior (Brody, 1983).

Specific to this formulation the concept of affective contrast refers to the argument that the administration of a biologically significant stimulus produces a hedonic congruent affective state that lasts until stimulus termination. Upon stimulus termination a second, hedonically opposing, affective state is thought to be initiated (Denny, 1971; Mowrer, 1947, 1960; Solomon & Corbit, 1974). Moreover, Solomon (1980) asserts that the characteristics of the primary stimulus related affective state may be reduced or manipulated through affective reduction via habituated processes. In addition, affective withdrawal is thought to refer to the dynamic increment of the hedonically opposing affective state over repeated stimulus presentations.

Therefore, from the theoretical assessment of stimulus applications, the administration of the US is thought to generate an affective state which produces a second opposing affective state, both of which differ in elemental properties (Solomon, 1980). The opposing affective states have been termed the A and B states and have been presumed to correspond to elicitation-excitation and decrement-inhibition of responding, respectively (Solomon, 1980).

As such, within the framework of opponent process theory, the application of a US is hypothesized to elicit a

characteristic A state which in turn is thought to instigate the B state. However, while the differential properties of the A state and B state serve, initially, to reduce the magnitude and degree of temporal overlap of the two states, repeated administrations of the US are thought to magnify the overlap through changes in the properties of the B state. That is, the properties of the B process are thought to change with repeated A process elicitation, whereas the A process is assumed to be a static process. The properties of the A process are postulated to be: (1) an immediate rapid recruitment of the strength of the A process at US onset; (2) subsequently, a stable value of A process strength is maintained while the US is present; (3) at US offset there is a rapid and immediate subsidence of the A process to its prestimulation level; and (4) the absolute level of the A state strength is a direct function of US intensity or magnitude (Solomon, 1980; Solomon & Corbit, 1974; Schull, 1979).

In contrast to the static properties of the A process, the B process is assumed to have dynamic properties. That is, with repeated A state elicitation, the B process increases in strength and duration. The properties of the B state have been characterized as: (1) with A state onset, the B process is initiated and exhibits a slow recruitment to its initial maxima; (2) the B process is maintained at its maxima until the A process starts to decrease in

strength; (3) as the A process declines the B process begins a "lingering" subsident phase; (4) the duration of the subsident phase is determined by the absolute level of the B process at its maxima; and (5) the maxima of the B process is directly related to two factors: the degree of a duration of the A process generated by the US, and the frequency of A process elicitation (Solomon, 1980).

The exhibited characteristics of a behavior are thought to reflect the moment by moment sum of the opposing strengths of the A- and B-processes. Given the differing time courses of the A- and B-processes, the response characteristics may variously represent A-state control (i.e., where A-process strength exceeds B-process strength), or a B-state control (i.e., where B-process strength exceeds A-process strength). Thus, for the elicitation of a behavior, the time course of the behavior which showed the initial rapid recruitment of the response to its maxima should reflect just the action of the A-process, and hence, A-state control. On the other hand, the decrement of the response from its maxima must represent the subtractive interaction of the A- and B-processes leading to the B-state control of the behavior.

Solomon (1980) has exemplified the occurrence of A- and B-state control of behavior by the application of the opponent-process model to the temporal course of heart rate

(HR) changes elicited by an aversive US. For elicitation with an electric shock US the HR response demonstrates a temporal pattern of responding which is characterized by HR acceleration, a reduction of HR during the US, and then, at US offset, deceleration to a level below the prestimulation HR rate. According to Solomon's analysis the initial acceleration of HR to the US reflects only the action of the A-process but as the US continues the recruitment and maintenance of HR, the B-process would be expected to produce some degree of HR decrement. Moreover, at US offset, the immediate decline of the A-process should leave only the B-process active and thus HR decrements below the pre-US level of HR responding would be expected.

Schull (1979) has extended Solomon and Corbit's (1974) response elicitation-decrement model to conditioning situations. This extrapolation of the opponent process theory to conditioned phenomena requires additional assumptions. First, it is assumed that the laws which govern Pavlovian-classical conditioning use the laws which govern the association of the CS to the A-process as well as the development of the B-process. Secondly, through Pavlovian processes, when the CS is paired and associated with the A-state there is a presumed increase in the CS's ability to elicit the conditioned opponent affective (i.e., B-) state and other CRs. Third, when the CS is paired with B-state occurrence a direct associative decrease in the CS's

ability to elicit the conditioned opponent (i.e., the B-state) is assumed to occur while the CS's ability to inhibit these states and associated behavior, presumably increases (Schull, 1979).

Temporal asynchrony. For delayed conditioning paradigms, the simultaneous occurrence of the CS and the A-process (produced by the US) yields an association between the two such that the CS becomes capable of initiating the A-process prior to US onset. As the result of this associated A-process the CS becomes excitatory, that is, capable of CR production. Moreover, the CS-related A-process production concomitantly initiates the B-process. And since there is a delay between A-process initiation and B-process instigation the pre-US occurrence of the A-process may allow B-process to overlap US occurrence. As such, the maximal overlap of the opposing A-process and B-process, with the US may reduce the affective quality of the US to produce affective-reduction (i.e., reinforcements). Therefore, delay conditioning would be expected to produce the greatest evidence of excitation.

Similarly, in trace conditioning paradigms, the same processes would be expected to occur but with the following reservation. As the interval between the practical CS and A-process initiation (i.e., US onset) increased there would be a progressively weaker association between the CS and

A-process. As such, with progressively weaker association, there should be less probability of A-process initiations to the CS and hence less likelihood of B-process instigation prior to an overlapping US occurrence. Therefore, the outcome of this paradigm would predict little difference between trace and delayed conditioning procedures at short trace intervals but as the trace interval increases there would be expected less evidence of excitatory conditioning.

In the simultaneous conditioning paradigm it would be expected that the simultaneous occurrence of the CS and US would produce the greatest overlap, and association of, the CS with the A-process. That is, the temporality of the stimuli and the A-process would be expected to minimize the overlap with the US-B-state and hence produce no evidence of conditioning effects relative to a US alone control. However, if in the simultaneous procedure the CS extends beyond US offset to maximize the CS-B-process overlap, and association, then the expected outcome might be one of inhibition.

And finally, in backward conditioning paradigms, Schull's (1979) model would expect that procedures which maximize the overlap of the CS with just the B-state would produce evidence of inhibition, while procedures which maximize the overlap of the CS with both A- and B-processes might yield evidence of excitation. That is, backward

conditioning procedures in which there is an interval between US offset and CS onset should maximize the association of the CS with the B-state. Accordingly, an inhibitory outcome might be expected. On the other hand, experimental situations in which CS onset overlapped the US occurrence might be expected to yield some minimal evidence of excitation as determined by the momentary sum of the affective states at that point.

Theoretical accounts of backward conditioning: Conclusions

As can be seen, the expectations for the backward pairings manipulation clearly differentiate amongst the different classes of theories of classical conditioning. Effect theories (e.g., Hull, 1943, 1952; Kimmel & Burns, 1975) would predict no associative effects as the general case, and limited excitatory effects to occur under restricted experimental operations and with only a few response systems. Information processing and opponent process accounts of the effects of backward pairings result in the prediction of uniform inhibitory effects (c.f., Rescorla, 1967; Schull, 1979). And contiguity (Guthrie, 1935) and cognitive representation (e.g., Konorski, 1967) theories would suggest that backward pairings could result in observations of either excitation or inhibition. However, the ascendancy of a particular theoretical account has been precluded by inconsistent results obtained in backward

conditioning experiments. That is, the applications of backward pairings has resulted in reports of nonassociative effects (e.g., Carson, 1922, 1935; Fitzwater & Reisman, 1952; Grether, 1938; Kamin, 1963; Patterson, 1976; Smith, Coleman, & Gormezano, 1969; Switzer, 1930; Trapold, Homzie, & Rutledge, 1964; Wolfle, 1932), inhibitory effects (Ayres, Mahoney, Proulx, & Benedict, 1976; Holmes, 1971; Maier, Rapaport, & Wheatley, 1976; Moscovitch & LoLordo, 1968; Nagaty, 1951; Quesnel, Ten Have & Tait, in press; Tait, et al., 1979, in press), and excitatory effects (Burkhardt, 1980; Champion, 1962; Champion & Jones, 1961; Heth, 1976; Heth & Rescorla, 1973; Mahoney & Ayres, 1976; Matsumiya, 1960; Nishizawa, 1962; Nishizawa & Umeoka, 1963; Quesnel, et al., in press; Spooner & Kellogg, 1947; Switzer, 1930; Tait, et al., 1979, in press).