BLOCKING OF A CS-US ASSOCIATION

BY A US-US ASSOCIATION

BY

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Abstract

In a typical blocking experiment an association between a conditioned stimulus (CS) and an unconditioned stimulus (US) is first established by CS-US pairings. Concurrent presentation of the previously conditioned CS with a second CS is then shown to prevent or attenuate conditioning to the second CS. In the present blocking experiments a US-US association was first established by preexposure with repeated fixed interval US presentations. A single CS was then paired with a US that followed a prior US by the same fixed US-US interval that was used in preexposure. The interval between the US prior to the CS and the US paired with the CS was called the critical US-US interval. In Experiment 1, a 10.5-sec fixed interval between USs was used to show that this procedure can block acquisition to the CS. In Experiment 2, blocking was also shown with a 100.5-sec fixed interval between USs. Experiments 1 and 2 provided evidence in support of the hypothesis that blocking by a US-US association occurs when the prior US predicts the time of arrival of the US with which the CS is paired (time of arrival hypothesis). In Experiment 3a, manipulating the amount of preexposure at a 10.5-sec US-US interval showed rapid blocking of a CS-US association by a US-US association. Experiment 3b showed that the results from Experiment 3a were not

consistent with one alternative account. This alternative account suggested that blocking in Experiment 3a occurred because subjects did learn the CS-US association, but competing responses elicited by learning a short interval US-US association prevented the expression of this learning. Experiment 4 showed that blocking was attenuated with added USs in preexposure at longer US-US intervals than the critical US-US interval. Experiment 5 showed that the results from Experiment 4 were not due to a change in the temporal distribution of USs from preexposure to training. The relationship of US-US blocking to current theories of learning and to other conditioning phenomena was discussed.

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CHAPTER 1

INTRODUCTION

The study of associative learning seeks to determine how organisms learn relations between stimuli. One paradigm for investigating associative formation is to present an organism with an originally neutral stimulus followed by the presentation of a biologically significant stimulus. For example, Pavlov (1927) presented hungry, healthy dogs with the rhythmic ticking sound of a metronome followed by food delivery. By measuring salivation, Pavlov discovered that subjects initially salivated only upon food delivery, but, after metronome-food presentations, subjects salivated to the sound of the metronome alone. Pavlov referred to the metronome sound as the conditional stimulus (CS) and food delivery as the unconditional stimulus (US). Responses to US presentation were referred to as unconditional responses (URs), and responses elicited by the CS following CS-US pairings were conditional responses (CRs).

Blocking

For the analysis of associative learning, it is useful to identify procedures that prevent or reduce CR acquisition. One such procedure is referred to as blocking. Blocking was reported by Kamin (1968, 1969). In one experiment (Kamin, 1968), the following procedure was used to show blocking. In each of 4 sessions, 4, 3-min, white noise CSs were presented and followed immediately by shock. Then, in each of two sessions, four compound CSs consisting of the white noise and a light were presented followed immediately by the shock. Subjects were then given four presentations of the light alone. Control groups received either identical compound CS training without prior noise-shock training, equivalent noise-shock training only, or noise-shock training following, rather than preceding, compound CS training. Results showed that subjects given prior noise-shock pairings showed much weaker CRs to the light in comparison to control groups. The CR was the level of fear shown by subjects. Kamin suggested that conditioning depended on US "surprisingness". When the US was surprising, CS-US pairings resulted in conditioning of the CS. If however, US occurrence was already predicted by other available stimuli, the identical CS-US pairings would not result in conditioning of the CS. Thus, subjects given noise-shock pairings followed by compound noise and light-shock pairings showed poor conditioning to the light because the shock was not surprising; the shock was already predicted by the noise.

Blocking of conditioning to a CS, by the concurrent presentation of another previously conditioned CS, has since been shown in many experiments (Allaway, 1971; Blanchard & Honig, 1976; Dickinson, Hall, & Mackintosh, 1976; Dickinson & Mackintosh, 1979; Kremer, Specht, & Allen, 1980; Mackintosh, Dickinson, & Cotton, 1980; Mackintosh & Turner, 1971; Rescorla & Durlach, 1981; Rescorla & Wagner, 1972; Straub & Gibbon, 1983; Tomie, 1976a,b; Wagner, Mazur, Donegan, & Pfautz, 1980; Wagner & Rescorla, 1972).

The present experiments show blocking of conditioning to a CS when US occurrence is predicted by a prior US rather than by a concurrent CS.

A Simple US-US Blocking Design

A simple US-US blocking design, applied to the case in which the US paired with the CS is predicted by a prior US, is as follows. In preexposure, experimental subjects receive a train of USs separated by a fixed US-US interval. This train of USs is preceded and followed by a time period in which no events are presented. Preexposure in this simple US-US blocking design corresponds to the first phase of a CS-US blocking experiment in which subjects are given initial CS_1-US pairings. By presenting USs at fixed US-US intervals, each US not only elicits URs but signals the time of arrival of a subsequent US. In training, the identical train of USs is presented but, in addition, the second US in the train is signalled by a CS. Training in this simple US-US blocking design corresponds to the second phase of a blocking experiment in which subjects are given CS_1-CS_2-US pairings. The second US in the train is signalled by both the first US in the train and the CS. If the first US signals the time of arrival of the second US, the CS-US association might be blocked, in comparison to control subjects. Control subjects receive identical training but do not receive US preexposure. Thus, attenuated CR acquisition in experimental, in comparison to control, subjects would be consistent with the hypothesis that a CS-US association is blocked if, as a result of preexposure, the delivery of the US with which the CS is paired is predicted by the prior US. There is some support for the claim that if a US arrives at an unexpected time blocking is attenuated (eg. Schreuers & Westbrook, 1982) although there have also been failures to find this result (eg. Kohler & Ayres, 1979).

Alternative Interpretations of Attenuated Acquisition in a Simple US-US Blocking Design

In this simple US-US blocking design, attenuated CR acquisition in experimental, in comparison to control, subjects would be consistent with several alternative interpretations. These alternative interpretations include processes such as habituation, learned US independence, learned laziness and contextual conditioning as well as predictions derived from theory (Scalar Expectancy Theory (SET) and the Opponent-Process Theory).

Habituation

Many experiments show a progressive decline in the vigor of elicited behavior when a stimulus is repeatedly presented (Thompson & Spencer, 1966). Davis (1974) found a progressive decline in the startle response in rats when a brief, loud tone was presented every 30 seconds when relatively quiet noise was in the background. Various theorists have proposed characteristics of the US which may be weakened when subjects receive repeated US presentations. Taylor (1956) claimed that US presentations reduced the sensory impact of the US. Kamin (1961) maintained that US presentations attenuated an "internal emotion reaction" to the US. Macdonald (1946) suggested that US presentations reduced the "motivational reaction" to the US.

Amit and Baum (1970) and Gamzu (1977) argued that US presentations reduced the "novelty" of the US.

Although various theorists differ as to what aspect of the US has been weakened in subjects given USs, all agree that repeated US presentations result in US habituation.

Further, there is abundant evidence that acquisition of conditioned responding is more rapid when subjects are given more intense or larger USs (Annau & Kamin, 1961; Fitzgerald & Teyler, 1970; Ost & Lauer, 1965; Sheafor & Gormezano, 1972; Spence & Platt, 1966; Wagner, Siegel, Thomas, & Ellison, 1964). Therefore, in a simple US-US blocking design, experimental subjects may show attenuated CR acquisition because subjects have habituated to the US and the weakened US subsequently results in poor CR acquisition. Since control subjects do not receive USs prior to CS-US training, subjects would not have habituated to the US and CR acquisition would be strong.

The Opponent-Process Theory

The Opponent-Process Theory of acquired motivation (Solomon, 1977; Solomon & Corbit, 1974) proposes that the relative strengths of two opposing processes determines an organism's affective response to the US. The opposing processes are identified as an _a_ process, elicited by a US, and a _b_ process, elicited by the _a_ process. The _a_ process is postulated to show little habituation or sensitization to the US, whereas the opposing _b_ process increases in intensity and duration and shows decreased onset latency with repeated USs. When a-b is positive the organism is in the A state and when a-b is negative the organism is in the B state. The model also assumes that excitatory classical conditioning results from an association between the CS and the A state of the US.

The model predicts, in a simple US-US blocking design, that the second US in the train will result in a stronger b process in experimental subjects exposed to prior USs, in comparison to control subjects. Therefore, the net A state will be lower, since a-b will be lower, for experimental, in comparison to control, subjects. The result will be attenuated CR acquisition in experimental, compared to control, subjects.

Learned US Independence

Alloy and Ehrman (1981) claim that subjects given US presentations form a cognitive expectation that USs will be independent of all other events, including the CS. Further, this cognitive expectation of US independence hinders later detection of CS-US dependence when subjects are subsequently given CS-US pairings. Alloy and Ehrman (1981) predict that in a simple US-US blocking design, attenuated CR acquisition in experimental subjects given USs prior to CS-US training results because subjects are slower in learning subsequent CS-US dependency in comparison to control subjects which do not have an expectation of US independence.

This account bears some relation to a learned irrelevance account suggested by authors (for example, Baker, 1976; Baker & Mackintosh, 1979) who assume that subjects receiving uncorrelated CS-

US presentations learn this lack of correlation which interferes with conditioning when subjects subsequently receive correlated CS-US presentations.

Learned Laziness

Engberg, Hansen, Welker, and Thomas (1972) showed that pigeon subjects previously receiving random food presentations showed attenuated CR acquisition in comparison to subjects not receiving prior random food presentations (control group). Subjects given operant treadle-press training showed more rapid CR acquisition in comparison to both the control group and the group receiving prior random food.

Engberg et. al. (1972) suggested that subjects receiving random food presentations before CS-US training were made lazy and this "learned laziness" interfered with subsequent CR acquisition. Subjects given operant treadle-press training before CS-US training were more industrious and this "learned industriousness" facilitated CR acquisition.

In a simple US-US blocking design, Engberg et al. (1972) might suggest that CR acquisition would be attenuated in experimental subjects receiving USs prior to CS-US training, in comparison to control subjects, because "learned laziness" in experimental subjects would interfere with CR acquisition.

Context Conditioning

In a simple US-US blocking design, experimental subjects are given USs prior to CS-US training. Control subjects receive identical

CS-US training but are not given prior USs. A context conditioning account suggests experimental subjects receiving USs prior to CS-US training receive those USs in conjunction with various stimuli. These stimuli consist of the features of the experimental chamber (e.g. amount of illumination, ambient noise level, etc.) and are called contextual stimuli or context (Rescorla & Wagner, 1972).

Experimental subjects receiving CS-US training in a context previously associated with US presentations should show attenuated CR acquisition because the context-US association blocks the CS-US association. Control subjects receive CS-US training in a context not previously associated with US presentations. Therefore, CR acquisition should be less attenuated in control subjects, in comparison to experimental subjects, because the context-US association less effectively blocks the CS-US association.

A variety of experimental findings support the interpretation that subjects given USs prior to CS-US training learn a context-US association which can later block a CS-US association. For example, CR acquisition is stronger if prior USs are given in a context different from the one in which CS-US training is given, in comparison to when prior USs are given in the identical context in which CS-US training is given (Balsam & Schwartz, 1981; Hinson, 1982; Randich & Ross, 1984; Tomie, 1976a,b; Tomie, Murphy, Fath, & Jackson, 1980). This may result because when the context is altered between US presentations and CS-US training, the altered context less effectively blocks the CS-US association. When the context is not altered it more effectively blocks the CS-US association.

Further, if the context is presented alone following US presentations, and before CS-US training, CR acquisition is more robust, in comparison to when CS-US training is given immediately following US presentations (Hinson, 1982; Randich, 1981). This may result because presentations of the context alone extinguish the context-US association. Thus, an extinguished context-US association will less effectively block the CS-US association. When the context is not extinguished the context-US association more effectively blocks the CS-US association.

Finally, several studies suggest that subjects given unsignalled USs before target CS-US training show attenuated CR acquisition, in comparison to subjects given signalled USs before target CS-US training (Baker & Mackintosh, 1979; Cannon, Berman, Baker, and Atkinson, 1975; Randich, 1981). This may result because when the prior USs are signalled by another CS, the context-US association is weaker and less effectively blocks the target CS-US association. When the prior USs are unsignalled, the context-US association is stronger and more effectively blocks the target CS-US association.

Scalar Expectancy Theory (SET)

Scalar Expectancy Theory (SET) provides a different explanation for attenuated CR acquisition in a simple US-US blocking design (Gibbon, 1981; Gibbon & Balsam, 1981). According to SET, the critical variable for conditioning is the ratio of the average US expectancy in the CS to the average US expectancy in the context. This ratio is similar to Relative Waiting Time (RWT) (Jenkins, Barnes, & Barrera, 1981). Experiments have shown that a ratio in excess of two is required for the emergence of conditioned responding (Gibbon, 1981; Gibbon, Locurto, & Terrace, 1975). Large ratios (and strong responding) result when each US is preceded by a short CS and there is a long time between USs in the context. Small ratios (and weak responding) result when each US is preceded by a long CS and there is a short time between USs in the context. For experimental subjects given USs prior to CS-US training, the average US expectancy in the context would be higher in comparison to control subjects not given USs prior to CS-US training. In a simple US-US blocking design, SET predicts that experimental subjects given prior USs should show attenuated CR acquisition because the ratio of the average US expectancy in the CS, to the average US expectancy in the context is lower, in comparison to control subjects not given prior USs.

Thus, in a simple US-US blocking design there are many alternative interpretations of attenuated CR acquisition. The present thesis attempts to rule out these alternative interpretations and show blocking of conditioning to a CS when the US with which the CS is paired is signalled by a prior US.

Before preceding to the thesis experiments the evidence on US-US learning and blocking of CS-US learning by US-US learning will be reviewed.

US-US Learning in Operant and Classical Conditioning

The present thesis will show that a CS-US association can be blocked if the US paired with the CS is predicted by a prior US. There is evidence in the literature that subjects can learn a US-US association and that a US-US association can block a CS-US association.

US-US Learning in Operant Conditioning

US-US Learning in Operant Conditioning with Food as the US

In operant conditioning subjects may learn a food-food association when a relationship exists between food delivery and the probability of subsequent food delivery. In one experiment, Catania and Reynolds (1968) showed with various constant-probability variable interval (VI) schedules (for example, VI 79 seconds, VI 379 seconds, VI 40.5 seconds), that when the probability of reinforcement shortly after reinforcement was made high, the local rate of responding at that time was relatively high. Further, when the probability of reinforcement was held roughly constant over the time since reinforcement, local rates of responding remained relatively constant as time passed since reinforcement. Results from Catania and Reynolds (1968) may be understood in terms of a US-US association. When the probability of reinforcement shortly after reinforcement was made high, food presentation signalled that a subsequent food presentation would be available soon. Subjects may have learned this food-food relationship and evidenced this learning by increased responding immediately following food delivery. When the probability of reinforcement after reinforcement was made constant over all VI intervals, food delivery signalled that a subsequent food presentation would be available at a number of different times. Subjects evidenced learning this food-food relationship by maintaining constant responding following food delivery.

In addition, many studies show that subjects given food programmed on a fixed interval schedule show increased responding as the time for subsequent food delivery comes closer (the fixed interval "scallop") (Dews, 1970; Farmer, 1963; Ferster & Skinner, 1957; Millenson, 1963; Schneider, 1969; Staddon, 1972). This may result because subjects are learning a food-food association. Specifically, food delivery may not only reinforce responding but signal the time at which the next delivery of food will become available. Subjects evidence learning this food-food association by increased responding as the time for the next delivery of food comes closer.

US-US learning in Operant Conditioning with Shock as the US

In operant conditioning subjects may learn a shock-shock association when a relationship exists between shock delivery and the probability of subsequent shock delivery. Davis, Memmott, and Hurwitz (1975) showed subjects evidenced little fear in the first minute following shock when shocks were separated by three minute intervals. Subjects receiving equivalent average shock rates, but random times between shocks, evidenced more fear in the first minute following shock. This may result because when shocks were separated by three minute intervals, shock delivery signalled that a subsequent shock would follow in three minutes. Subjects evidenced learning this shock-shock relationship by evidencing little fear in the first minute following shock. When shocks were separated by random times, shock delivery may have signalled that a subsequent shock presentation would follow at a number of different times. Subjects evidenced learning this shock-shock relationship by remaining fearful following shock delivery.

In addition, when shocks are programmed on a fixed interval schedule, subjects show increased fear as the time for shock comes closer (Azrin, 1956; Hendry, Yarczower, & Switalski, 1969). This may result because when shocks are separated by a fixed interval, shock may signal the time of arrival of a subsequent shock presentation. Subjects evidence learning this shock-shock association by increased fear as the time for the next delivery of shock comes closer.

US-US Learning in Classical Conditioning

Drug Administration

One paradigm for investigating classical conditioning is drug administration (for example, Siegel, 1979). In drug administration the CS consists of those external cues or procedures reliably preceding drug administration. The actual central drug effects constitute the UR. Several studies show that the CR may be opposite in direction to the UR (for example, Krank, Hinson, & Siegel, 1981; Pavlov, 1927; Siegel, 1979). Tolerance to drug administration may result because as the association between predrug signals and drug administration increases over trials, drug compensatory CRs would be expected to increasingly cancel the drug URs.

There is evidence that a US-US association may form with drug presentation serving as the US. For example, Greeley, Lê, Poulos, and Cappell (1984) found that subjects given a high alcohol dose reliably preceded by a low alcohol dose showed greater tolerance to the high alcohol dose, in comparison to subjects randomly presented low and high alcohol doses. Further, Greeley et al. (1984) found a drug-opposite response conditioned to the low alcohol dose and that tolerance was extinguished by repeated presentations of the low alcohol dose alone. An association between USs in drug conditioning is especially noteworthy because the response elicited by a drug signalling subsequent drug delivery could be opposite to the UR normally elicited by the drug.

Blocking of a CS-US Association by a US-US Association

Egger and Miller

Blocking of a CS-US association by a US-US association was shown by Egger and Miller (1963). In Egger and Miller (1963), four groups of subjects were used. For one group of subjects (Group SIMPLE CONDITIONING) a two-second CS overlapped three food pellets delivered in the last .5 seconds of the CS. In addition, 35 food pellets were randomly presented in the session. Group REDUNDANT received CS-US training similar to the CS-US training received by Group SIMPLE CONDITIONING. However, the three food pellets were signalled by a food pellet .5 seconds prior to the CS and there were no extra food pellets presented. Group INFORMATIVE received training identical to Group REDUNDANT but, in addition, 35 food pellets were randomly delivered in the session. In Group INFORMATIVE a food pellet less reliably signalled the delivery of food pellets since additional food pellets were randomly presented in the session. Therefore, since the food pellet prior to the CS less reliably signalled the delivery of the three subsequent food pellets, the CS was an informative cue signalling the delivery of the three food pellets. Finally, group PSEUDO-CONDITIONING received explicitly unpaired CS and food presentations. Conditioned response strength was assessed in a secondary reinforcement paradigm in which every third response on a lever was reinforced by CS presentation. Results showed Groups SIMPLE CONDITIONING and INFORMATIVE pressed the lever significantly more than Groups PSEUDO-CONDITIONING and REDUNDANT. Egger and Miller (1963) suggested that if the prior food pellet reliably signalled the delivery of the three subsequent food pellets, the CS-US association would not form because the CS was not "informative". The CS was informative, however, if there was no food pellet prior to the CS-US pairings (Group SIMPLE CONDITIONING) or if the prior food pellet did not reliably predict the delivery of the three subsequent food pellets (Group INFORMATIVE).

Alternative Interpretations and Egger and Miller

It is important to consider the Egger and Miller study in relation to the alternative interpretations of attenuated acquisition in the simple US-US blocking design previously discussed. Results from Egger and Miller were not consistent with habituation, Opponent-Process Theory, learned laziness, learned US independence, SET or context conditioning. These alternative interpretations all predict attenuated CR acquisition in Group INFORMATIVE in comparison to Group REDUNDANT. Because subjects in Group INFORMATIVE received more USs than subjects in Group REDUNDANT, CR acquisition should be attenuated in Group INFORMATIVE compared to Group REDUNDANT. Since Group INFORMATIVE showed better acquisition than Group REDUNDANT, results were not consistent with the alternative interpretations of attenuated acquisition in the simple US-US blocking design previously discussed.

Lambos

The experiment from Lambos (1986) most relevant to the present thesis is Experiment 3. All 5 groups received a single CS-US pairing each day and the data of interest were the acquisition of the keypeck response to this CS over days. In Experiment 3, there were 5 groups of subjects. Group B/3 TRAIN received a CS signalling the third US in a train of 16 USs separated by 10.5-sec US-US intervals. The 4 additional groups differed only in the events presented after the CS-US pairing. For Group B/3 RANDOM, the interval between each of the 13 USs after the CS-US pairing was random. For Group B/3 SPLIT TRAIN there was a wait of about 8 minutes before the 13 USs after the

CS-US pairing were presented at 10.5-sec US-US intervals. For Group B/3 TRIPLET, 12 USs after the CS-US pairing were delivered at 10.5-sec US-US intervals in runs of length three. The 4 triplets of USs after the CS-US pairing were separated by variable durations. For Group B/3 ONLY there were no events presented after the CS-US pairing. Results showed significantly attenuated acquisition in Groups B/3 TRAIN and B/3 SPLIT TRAIN in comparison to the other groups.

Lambos (1986) suggested that attenuated acquisition in Group B/3 TRAIN and B/3 SPLIT TRAIN occurred because each US reliably signalled that another US would follow in 10.5 seconds. When the USs after the CS-US pairing were presented at more widely spaced US-US intervals, a US was a less reliable signal that another US would follow in 10.5 seconds. Acquisition was stronger, therefore, when the USs after the CS-US pairing were presented at intervals longer than 10.5 seconds (Group B/3 RANDOM and B/3 TRIPLET). Lambos (1986) noted that results from Experiment 3 were not consistent with several alternative interpretations. These alternative interpretations were not all the same as the alternative interpretations of attenuated acquisition in a simple US-US blocking design previously discussed. Most relevant for the present thesis, however, was that Lambos (1986) noted that results from Experment 3 were difficult to reconcile with a context conditioning account. Groups B/3 TRAIN, B/3 SPLIT TRAIN, B/3 RANDOM, and B/3 TRIPLET received about the same number of USs (Group B/3 TRIPLET received one less US than B/3 TRAIN, B/3 SPLIT TRAIN and B/3 RANDOM). Since the USs were presented in contexts of identical session length, context conditioning and blocking of the CS-US association by a context-US association should have been equal in Groups B/3 TRAIN, B/3 SPLIT TRAIN, B/3 RANDOM, and B/3 TRIPLET. Results showing poorer acquisition in Groups B/3 TRAIN and B/3 SPLIT TRAIN in comparison to Groups B/3 RANDOM and B/3 TRIPLET were not consistent with a context conditioning interpretation.

Alternative Interpretations and Lambos

It is important to consider Experiment 3 in Lambos (1986) in relation to the other alternative interpretations of attenuated acquisition in a simple US-US blocking design previously discussed. This is necessary because some alternative interpretations relevant to the present thesis were not addressed in Lambos (1986).

It is difficult to reconcile SET with results reported in Experiment 3 by Lambos (1986). (In Lambos (1986) Experiment 3, a modified version of SET was discussed, although earlier experiments had rejected an unmodified version of SET). Subjects in Groups B/3 TRAIN, B/3 SPLIT TRAIN, B/3 RANDOM, and B/3 TRIPLET received about equal average US presentation rates in the context and CS. According to SET, since the ratio of the average expectancy for a US in the CS to the average expectancy for a US in the context would be approximately equal for Groups B/3 TRAIN, B/3 SPLIT TRAIN, B/3 RANDOM, and B/3 TRIPLET, responding should also be about equal for these groups. Results showing significantly poorer acquisition for Groups B/3 TRAIN and B/3 SPLIT TRAIN compared to Groups B/3 RANDOM and B/3 TRIPLET were not consistent with SET.

Results from Lambos (1986) are also difficult to reconcile with Opponent-Process Theory or habituation. Results may, however, be accounted for by learned laziness or learned US independence. These alternative interpretations could specify that learned laziness or learned US independence may be greater when subjects receive USs at shorter, in comparison to longer, US-US intervals. If learned laziness or learned US independence was greater with USs at shorter US-US intervals, acquisition in Groups B/3 TRAIN and B/3 SPLIT TRAIN would be attenuated in comparison to Groups B/3 RANDOM and B/3 TRIPLET receiving USs at longer US-US intervals.

Thesis Objectives

The present thesis attempted to extend the results reported by Lambos (1986) and Egger and Miller (1963) in several important ways. First, the thesis attempted to show blocking of a CS-US association by a US-US association using procedures more closely resembling a typical blocking experiment. In blocking, CS_1-US training occurs prior to CS_1-CS_2-US training. In the present thesis US-US training occurs prior to US-CS-US training. In Lambos (1986) and Egger and Miller (1963), US-US training occurred at the same time as CS-US training.

Secondly, the thesis attempted to determine whether blocking of a CS-US association by a US-US association could be demonstrated using longer US-US intervals than those reported by Lambos (1986) and Egger and Miller (1963). Blocking of a CS-US association by a US-US association was shown only with a 10.5-sec US-US interval in Lambos (1986) and a 2-sec US-US interval in Egger and Miller (1963).

Thirdly, the thesis attempted to obtain evidence on the rapidity by which a US-US association forms, as assessed by its ability to block a CS-US association. This was accomplished by parametrically manipulating the number of short (10.5-sec) US-US intervals received by subjects prior to CS-US training.

Finally, the thesis attempted to extend the results reported by Lambos (1986) and Egger and Miller (1963) while controlling for alternative interpretations of the results. These alternative interpretations included habituation, Opponent-Process Theory, learned laziness, learned US independence, context conditioning and SET. Although these alternative interpretations were strained to account for Egger and Miller's (1963) study, learned laziness and learned US independence were possible alternative interpretations for Lambos' (1986) study. Thus, the thesis attempted to corroborate the conclusion suggested by Lambos (1986) and Egger and Miller (1963) that a US-US association can block a CS-US association.

CHAPTER 2

INTRODUCTION TO THESIS EXPERIMENTS

The thesis contains 5 experiments (labelled Experiments 1-5, inclusive). Experiments 1-5 show that a prior US can signal the time of arrival of a subsequent US, with which the CS is paired, and block the CS-~~US~~ association. Most importantly, Experiments 1-5 were designed to evaluate alternative interpretations of the results.

To show blocking of a CS-US association by a previously acquired US-US association, the present experiments used the autoshaping preparation (Brown & Jenkins, 1968). In the autoshaping preparation, hungry pigeons are presented with the brief illumination of a keylight followed by food delivery. In these experiments the food consisted of mixed grain. Subjects evidence learning the keylight-food association by approaching and pecking the keylight CS.

Experiments 1-5 had three separate phases. In the first phase, subjects were taught to eat reliably out of the food magazine when the food magazine was operated. Reliable eating was obtained when subjects were given a total of 100 food magazine presentations. This phase was referred to as feeder training.

In the second phase, all subjects, except those designated as NOP (no preexposure), received US presentations at certain US-US intervals. The US-US intervals varied with the group of subjects and the experiment. This phase was referred to as preexposure. In preexposure (and in later training), all subjects were initially given a

10-sec priming US. The priming US helped alleviate the effects of subjects being transported from the colony room to experimental chambers. Subjects that do not receive a priming US often remain frozen in the chambers, presumably because of the emotional effect of handling and transporation to the chambers. Subjects then received a train of USs at various US-US intervals. For example, subjects may have received a train of USs at very short US-US intervals. This train of USs was preceded and followed by a time period in which no events were presented. This time period in which no events were presented was necessary in order to present additional groups of subjects with extra USs or USs at longer US-US intervals, while keeping session length constant across groups.

Finally, in the third phase, subjects were given a single 10-sec red keylight presentation which signalled the second US in the train of USs. This phase was referred to as training. The interval between the first and the second US in the train (the second US in the train having been signalled by the CS) was called the critical US-US interval. The term critical US-US interval was used because the interval between the first and second US in the train of USs would determine the degree to which the first US in the train signalled the time of arrival of the second US in the train. The dependent variable was the amount of pecking at the red keylight CS in the train. Experiments 1-5 attempted to show that a high rate of pecking to the CS would occur if the CS-US association was not blocked by the US-US association. A low rate of pecking to the CS would occur if the CS-US association was blocked by the US-US association.

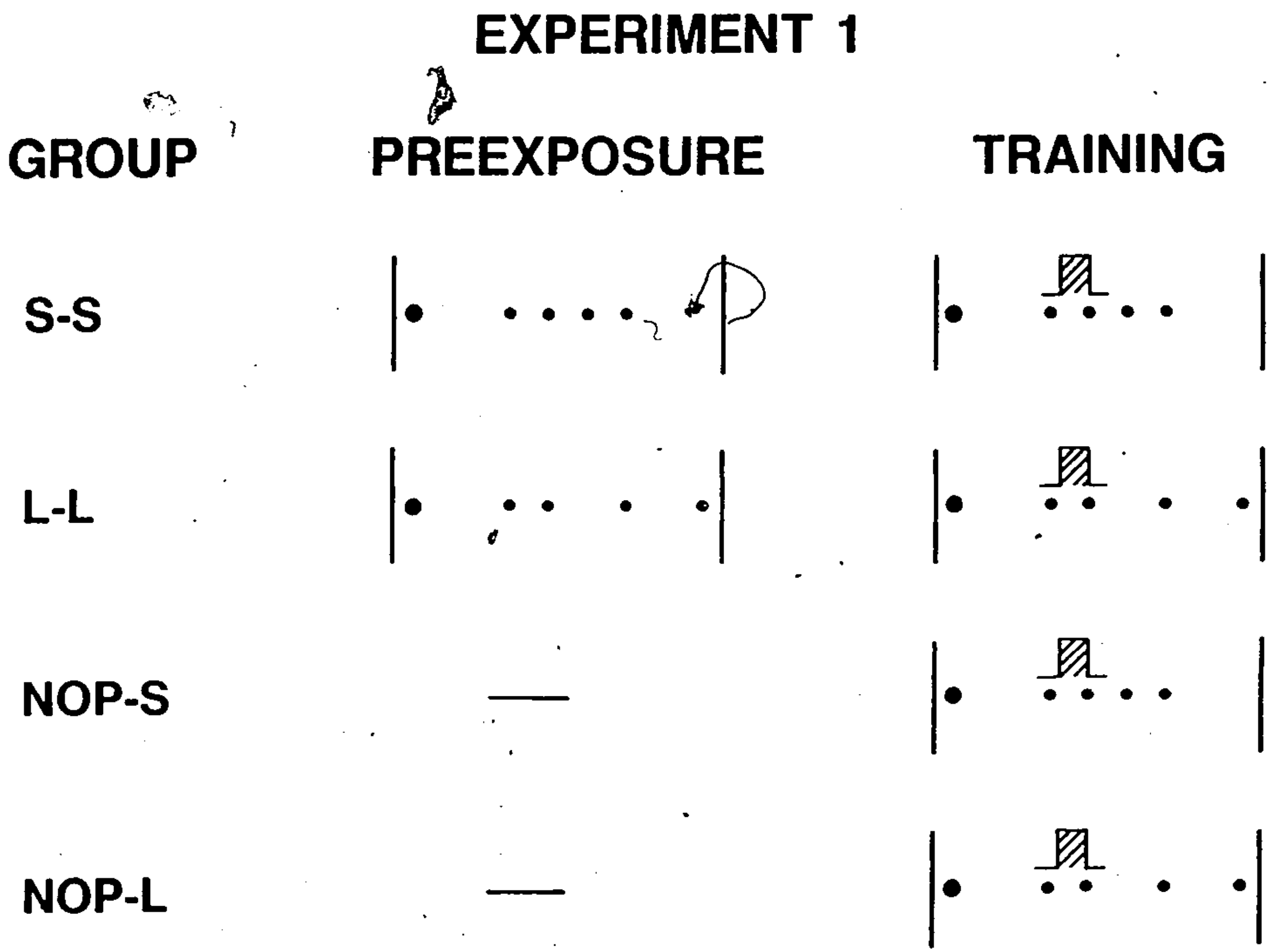
EXPERIMENT 1

The effect of US preexposure should depend on the timing of US-US intervals in preexposure in relation to the critical US-US interval in training. The critical US-US interval in training is the interval between the first US and the second US in the train (the second US in the train being signalled by the CS).

If blocking depends on the ability of a prior US to predict the time of arrival of the US with which the CS is paired, blocking should be greater when all the US-US intervals in preexposure are the same as the critical US-US interval in training than when US-US intervals in preexposure are different from the critical US-US interval in training. The first experiment examined the hypothesis that a US-US association can better block acquisition of a CS-US association when US-US intervals were equal in preexposure and the critical US-US interval in training, in comparison to when US-US intervals were frequently longer in preexposure than the critical US-US interval in training.

The design of Experiment 1 is illustrated in Figure 1. In Experiment 1, and all subsequent experiments, groups received a 10-sec priming US at the beginning of each preexposure and training session. Group SHORT-SHORT then received a train of USs with short US-US intervals. Group LONG-LONG received long US-US intervals in both preexposure and training except that the very first US-US interval in

Figure 1. Design of Experiment 1. S refers to SHORT, L to LONG and NOP to NO PREEXPOSURE. The dots refer to feedings. The large dot at the beginning of the session corresponds to the 10-sec priming US. The smaller dots correspond to the 4-sec USs. Only 4 of the 16, 4-sec feedings in preexposure and training are shown.


EXPERIMENT 1
GROUP
PREEXPOSURE
TRAINING
S-S
L-L
NOP-S
NOP-L

the train of USs was a short interval equal in duration to US-US intervals in the train of USs in Group SHORT-SHORT. Two other groups served as additional controls. They received the same training conditions as Groups SHORT-SHORT and LONG-LONG respectively but received no preexposure (Group NOP-SHORT and Group NOP-LONG). In each training session a single CS was presented. It signalled the second US in the train which in all cases followed the first US in the train after a short interval. The interval between the first and the second US in the train (the second US in the train having been signalled by the CS) was called the critical US-US interval. As a consequence of these conditions, the temporal distribution of USs in Groups SHORT-SHORT and LONG-LONG was unchanged from preexposure to training. The single CS also occurred in exactly the same temporal context of a prior and subsequent US in all groups.

On the hypothesis of blocking by a US-US association, the effects of preexposure should be greater in Group SHORT-SHORT in comparison to Group NOP-SHORT than in Group LONG-LONG in comparison to Group NOP-LONG. This is so because in Group SHORT-SHORT all USs (except the priming US and the last US in each session) are separated by the same short interval which is also the critical interval in training. In Group LONG-LONG, on the other hand, only the first pair of USs in preexposure is separated by the short critical US-US interval; the remaining USs are separated by a much longer interval. Thus, in Group SHORT-SHORT the presentation of a US more reliably predicts that another US will follow in a short time.

Method

Subjects. Subjects were 36 naive, unsexed adult homing pigeons maintained at 75% of their free-feeding weight. They were housed in individual cages with free access to water and grit.

Apparatus. Six modified Lehigh Valley pigeon chambers were used. They were equipped with a speaker, a solenoid-operated feeder, a ventilating fan, two houselights, and two response keys. The right key was covered and only the left key was used. Chambers had exterior dimensions of 56.5 x 40.5 x 42.5 cm. Chamber interiors were separated by an intelligence panel measuring 30.5 x 34.8 cm. Pigeon subjects were placed in the larger of the two sections measuring 30.5 x 34.8 x 34.9 cm. A 7.6 cm floor platform was inserted in the larger section, raising the floor and reducing the height to 22.9 cm. The speaker was located on the lower left of the intelligence panel. The left response key was a 3.2 cm square of hinged plastic located 12 cm above the platform floor and offset from the midline of the panel by 1.6 cm. The center of the key was a .7 cm diameter circle which could be backlighted by a white lamp encased in a red plastic cap.

Centered on the front panel, 4 cm above the floor, was a 5 x 7 cm opening through which mixed grain was made available by feeder operation. An infrared phototransmitter and receiver positioned 1 cm behind and on either side of the feeder opening was operated when the pigeon's head entered the feeder opening. Chamber illumination was provided by two houselights mounted 3 cm from the ceiling and separated by 2° cm. Lamps were enclosed in housings which directed the light to the ceiling. Keylight, feeder light and houselights were miniature white bulbs, GE 1829. Masking noise was provided by ventilating fans. Programming and recording was accomplished by a Commodore PET computer located in an adjacent room.

Procedure. Subjects were trained to eat from the feeder. When subjects were first placed in the chamber, grain was available in the raised feeder. After subjects had taken grain, an automatically programmed food delivery schedule was used in which the feeder-up period and interfeeding interval for each US was timed from the interruption of the photocell beam. Subjects were allowed to eat for 15 seconds for the first 3 USs and 4 seconds for the remaining 27 USs. The interfeeding interval was 15 seconds. Two sessions of this phase of feeder training were given. In the third session, subjects received 40, 4-sec USs separated by one minute intervals scheduled independently of behavior. Subjects were then randomly divided into 4 groups of 9 subjects.

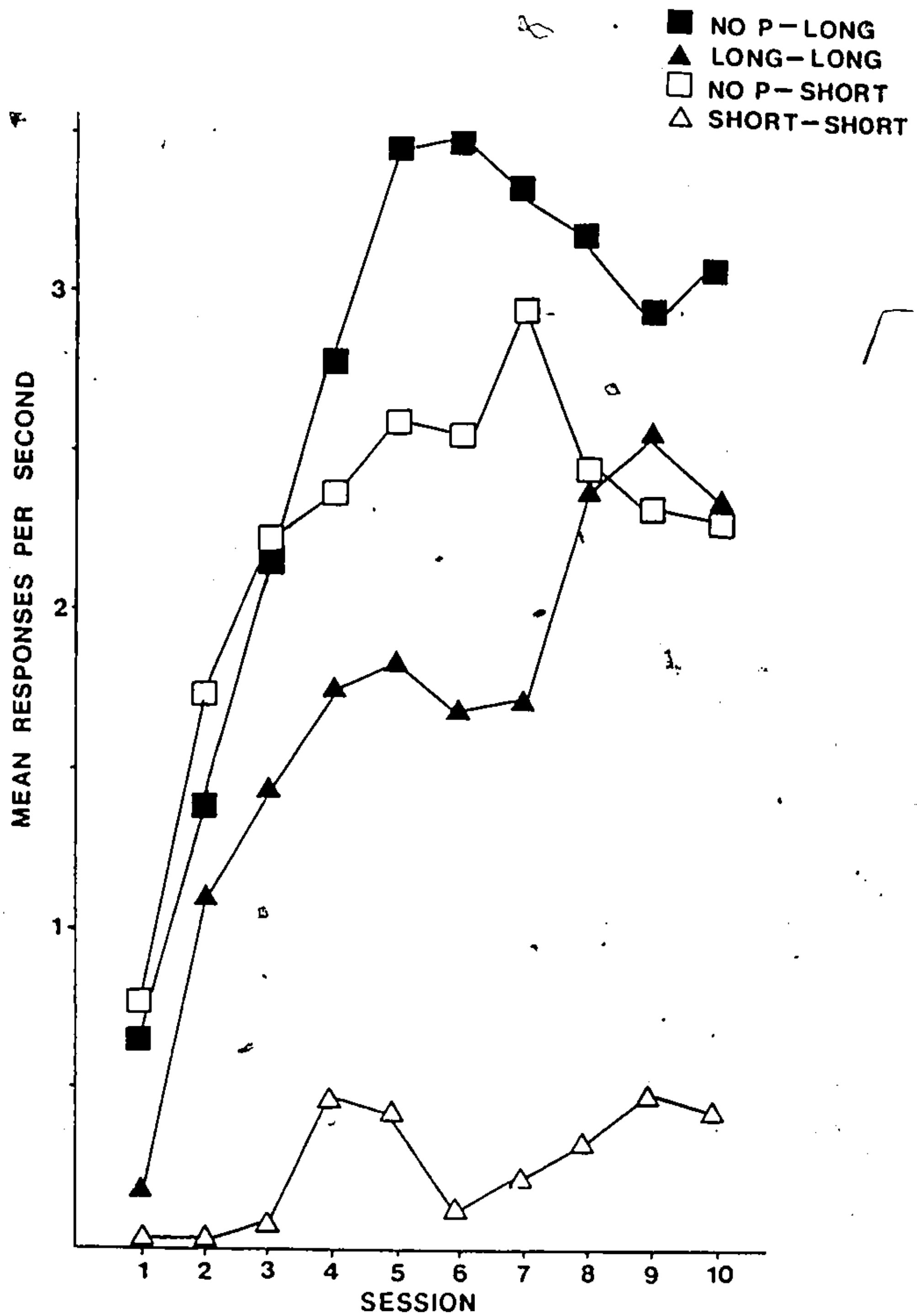
Five US preexposure sessions followed feeder training. At the beginning of each preexposure session Group SHORT-SHORT received a 10-sec US. The 10-sec US at the beginning of each session was the priming US. The priming US was followed after 880 seconds by a train of 16, 4-sec USs at 10.5-sec US-US intervals. After the last US in the train there was a 1350-sec period in which no events were presented. The houselights were then turned off to end the session. Group LONG-LONG also received a 10-sec priming US at the beginning of the session followed after 880 seconds by a train of 16, 4-sec USs.

The first two USs in the train were separated by 10.5 seconds. The remainder were separated by 100.5 seconds. Following the final US, the houselights were turned off and the session ended. The session length was approximately 40 minutes in both groups. Groups NOP-SHORT and NOP-LONG remained in their homecages during this time.

Ten CS-US training sessions followed US preexposure. In all groups a single red keylight CS was presented per training session. In each case onset of the CS was 0.5 seconds after the offset of the first US in the train of USs. Offset of the CS occurred 10 seconds later and was coincident with the onset of the second US in the train of USs. It should be noted that for the groups which received preexposure, the number and timing of USs during training was unchanged from preexposure. Groups NOP-SHORT and NOP-LONG received the same training as Groups SHORT-SHORT and LONG-LONG, respectively.

Results and Discussion. Results from Experiment 1 are shown in Figure 2 and Table 1. Averaged over the 10 sessions of CS-US training, Group SHORT-SHORT showed less acquisition to the CS than did Group NOP-SHORT ($U = 4$, $p < .005$). Group LONG-LONG also showed less acquisition than Group NOP-LONG ($U = 19.5$, $p < .05$). Group NOP-SHORT did not differ significantly from Group NOP-LONG ($U = 35$, $p > .05$). Group SHORT-SHORT showed less acquisition than did Group LONG-LONG ($U = 4$, $p < .005$). There was a greater preexposure effect, as implied by the time of arrival hypothesis, in Group SHORT-SHORT in comparison to Group NOP-SHORT than in Group LONG-LONG in comparison to Group NOP-LONG.

Figure 2. Mean responses per second to the CS in Experiment 1.



NO P—LONG
LONG—LONG
NO P—SHORT
SHORT—SHORT
MEAN RESPONSES PER SECOND
3
2
1
1
2
3
4
5
6
7
8
9
10
SESSION

Table 1

Mean responses per second to the CS in Experiment 1

(± standard error)

Group	Responses per second
SHORT-SHORT (n=9)	.26 ± .16
NOP-SHORT (n=9)	2.24 ± .44
LONG-LONG (n=9)	1.70 ± .28
NOP-LONG (n=9)	2.63 ± .36

A greater preexposure effect in Group SHORT-SHORT and Group LONG-LONG in comparison to corresponding control groups, provides the evidence for blocking of a CS-US association by a previously established US-US association. Even when Groups SHORT-SHORT and LONG-LONG were equated on the number of USs in preexposure and training, the position of the CS with respect to the first and second US in the train, the session length in preexposure and training, and the events in each session prior to the CS-US pairing, Group SHORT-SHORT showed attenuated CR acquisition in comparison to Group LONG-LONG. Results show that the development of a CS-US association was blocked by a US-US association.

These results are difficult to reconcile with the nonblocking accounts previously identified. One important reason why other nonblocking accounts cannot account for attenuated CR acquisition in Group SHORT-SHORT in comparison to Group LONG-LONG, is that they cannot account for the dependence on the timing of USs in preexposure in relation to the critical US-US interval in training. Only when the critical US-US interval, between the first US in the train and the second, signalled US, equals US-US intervals in preexposure is the CS-US association blocked.

Other accounts do not make this prediction. For example, preexposure with USs could result in habituation and a consequent attenuation of acquisition in training. Although that could account for the differences in acquisition between Groups SHORT-SHORT and NOP-SHORT and between Groups LONG-LONG and NOP-LONG, it could not account for greater blocking in Group SHORT-SHORT than in Group LONG-LONG in as much as the same number of USs were received by these groups in preexposure. Moreover, less long-term habituation may occur with higher-rate US presentations (Davis, 1970); a finding in the opposite direction to the present one of poorer acquisition with USs presented at a higher rate in preexposure (Group SHORT-SHORT) than at a lower rate (Group LONG-LONG).

Contextual conditioning suggests a CS-US association can be blocked in a particular context if subjects have previously received US presentations in that context. In Groups SHORT-SHORT and LONG-LONG, events prior to and immediately after the CS were identical and groups were equated on the number of USs received in preexposure and training in sessions of identical length. In fact, it is possible that contextual associative strength was higher for Group LONG-LONG, than for Group SHORT-SHORT, because Group SHORT-SHORT had a long period of time after the last US in which no events were presented. Thus, there was more opportunity for contextual extinction during the last portion of each preexposure and training session in Group SHORT-SHORT compared to group LONG-LONG. Poorer contextual conditioning at the time of the CS presentation in Group SHORT-SHORT would result in stronger, rather than weaker CR acquisition, in comparison to Group LONG-LONG.

The Opponent-Process Theory suggests that attenuated CR acquisition in subjects given prior USs results because of a strengthened <u>b</u> process and a weakened A state during CS-US pairings.

The Opponent-Process Theory can adequately account for differences in acquisition between Groups SHORT-SHORT and NOP-SHORT and between Groups LONG-LONG and NOP-LONG. (Note that habituation accounts could also account for poorer acquisition in Group SHORT-SHORT compared to Group NOP-SHORT, and for poorer acquisition in Group LONG-LONG compared to Group NOP-LONG). However, the Opponent-Process Theory cannot account for attenuated CR acquisition in Group SHORT-SHORT in comparison to Group LONG-LONG. The Opponent-Process Theory predicts identical CR acquisition because the <u>b</u> process elicited by a US would be equivalent in subjects equated for US number in preexposure and training.

Scalar Expectancy Theory holds that CR acquisition is a function of the ratio of average expectancy for a US in the CS to the average expectancy for a US in the context. Less acquisition in Group SHORT-SHORT than in Group LONG-LONG is incompatible with SET because subjects in each group have equal average US expectancies in the CS and equal average US expectancies in the context.

The hypotheses that US preexposure results in learned laziness (Engberg et al., 1972), or learned US independence (Alloy and Ehrman, 1981), are also unable to account for attenuated CR acquisition in Group SHORT-SHORT in comparison to Group LONG-LONG unless it is held that subjects are made lazier or form a stronger expectation of US independence by shorter rather than longer US-US intervals in preexposure or training. These alternative interpretations were also possible for the results of Experiment 3 in

Lambos (1986) (see Introduction). Results from the next experiment bear on this possibility.

EXPERIMENT 2

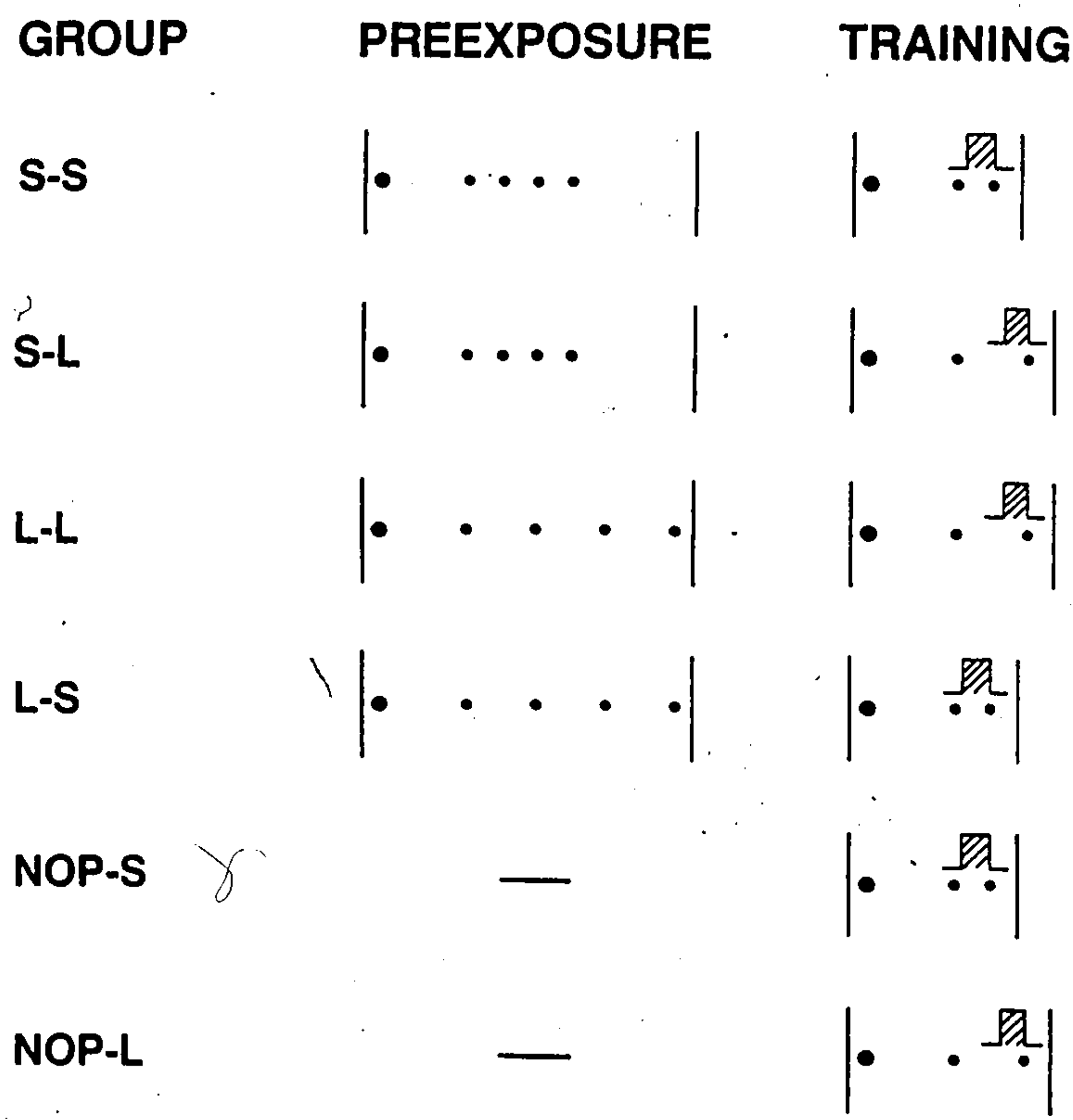
Experiment 2 investigated whether blocking by a US-US association extends to longer fixed intervals between USs or is restricted to the very short fixed intervals of 10.5 seconds used in Experiment 1. A closely related question, also unanswered by the first experiment, is whether the first US in the train blocks acquisition because it signals that the second US in the train will occur in a short time or, on the other hand, because it signals the time of arrival of the second US in the train (the second US in the train being signalled by the CS). This latter possibility is referred to as the time of arrival hypothesis.

The design of Experiment 2 is illustrated in Figure 3. The design included all four combinations of short and long US-US intervals in preexposure and training. In addition, Groups NOP-SHORT and NOP-LONG were given training without US preexposure. According to the time of arrival hypothesis, blocking of a CS-US association by a US-US association would only be obtained when US-US intervals in preexposure are the same as the critical interval in training but not when that interval is changed from short to long or long to short between preexposure and training.

In Experiment 2 only a single pair of 4-sec USs was presented in each training session rather than a train of 16, 4-sec USs as in

Figure 3. Design of Experiment 2. S refers to SHORT, L to LONG and NOP to NO PREEXPOSURE. The dots refer to feedings. The large dot at the beginning of the session corresponds to the 10-sec priming US. The smaller dots correspond to the 4-sec USs. Only 4 of the 16, 4-sec feedings in preexposure are shown.

EXPERIMENT 2



Experiment 1. The use of a single pair of 4-sec USs provided a closer parallel to the typical blocking experiment in which the pretrained CS is presented during training only in compound with the to-be-conditioned CS. Experiment 2 also provided further tests of the applicability of certain nonblocking accounts to attenuated acquisition in groups given US preexposure.

Method

Subjects. Subjects were 60 naive, unsexed adult homing pigeons maintained at 75% of their free-feeding weight. They were housed in individual cages with free access to water and grit.

Apparatus. The apparatus was the same as was used in Experiment 1.

Procedure. Subjects were first trained to eat from the feeder using the same feeder training regime as used in Experiment 1. Subjects were then randomly divided into 6 groups of 10 subjects each.

Five US preexposure sessions followed feeder training. At the beginning of each preexposure session Groups SHORT-SHORT and SHORT-LONG received a 10-sec priming US followed after 880 seconds by a train of 16, 4-sec USs at 10.5-sec US-US intervals. After the last US in the train, a 1350-sec period followed in which no events were presented. The houselights were then turned off and the session ended. Groups LONG-LONG and LONG-SHORT also received a 10-sec priming US at the beginning of the session followed after 880 seconds by 16, 4-sec USs at 100.5-sec US-US intervals. Following the last US, the houselights were turned off and the session ended. The session length was approximately 41 minutes in each of these groups. Group NOP-LONG and Group NOP-SHORT remained in their homecages during this time.

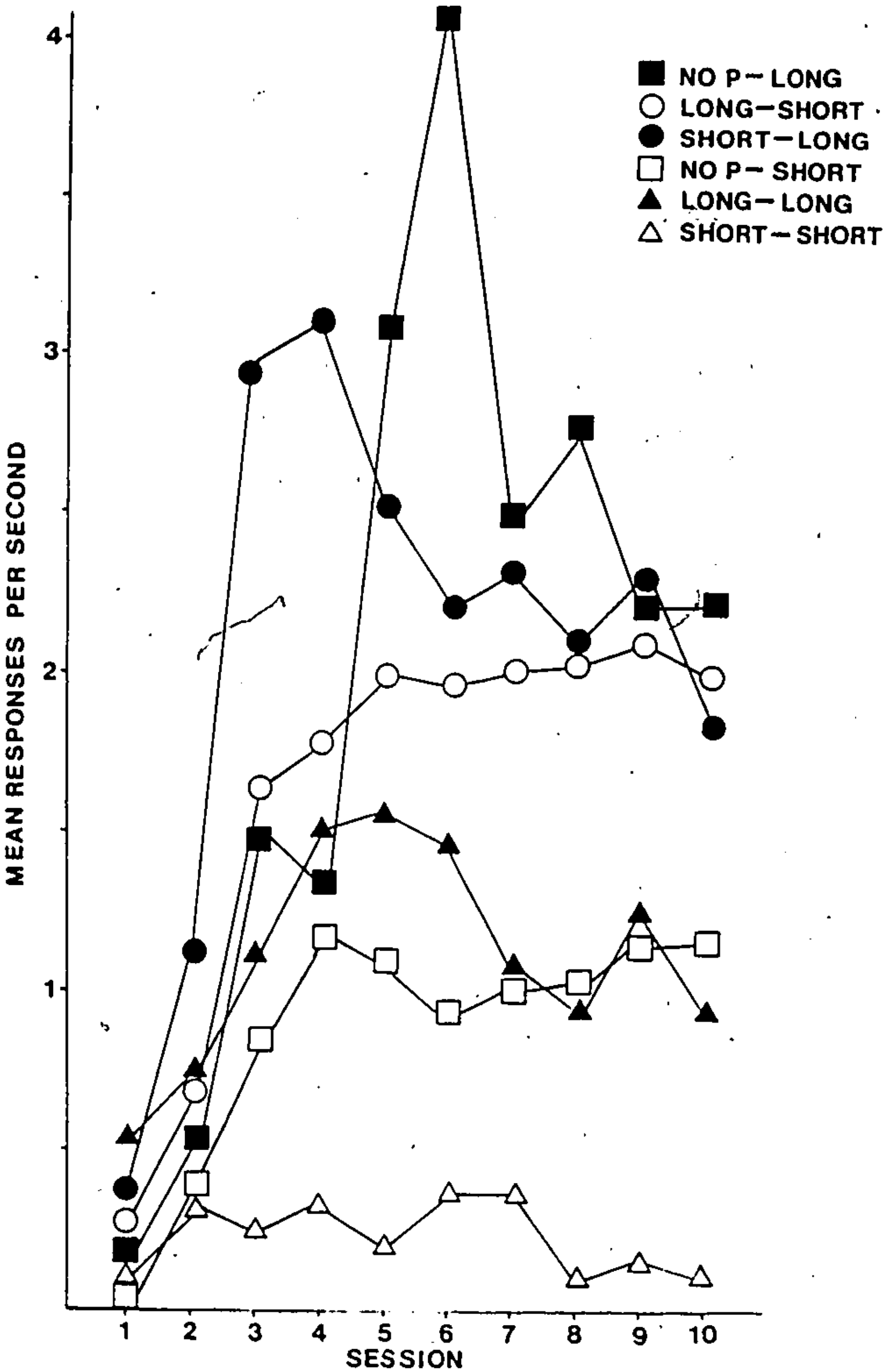
Ten CS-US training sessions followed US preexposure. All groups received a 10-sec priming US at the beginning of each training session. After an 880-sec wait a single pair of 4-sec USs was presented. The second US of the pair of 4-sec USs was preceded by a 10-sec red keylight CS, the offset of which coincided with the onset of the US. At the offset of the US, the houselights were turned off and the session ended.

In Groups SHORT-SHORT, LONG-SHORT and NOP-SHORT the pair of 4-sec USs following the 880-sec wait was separated by 10.5 seconds. Therefore, the total length of the session was approximately 15 minutes in these three groups. In Groups LONG-LONG, SHORT-LONG, and NOP-LONG the pair of 4-sec USs following the 880-sec wait was separated by 100.5 seconds. Therefore, the total length of the session was approximately 16.5 minutes in these three groups.

Results and Discussion

The results of Experiment 2 are shown in Figure 4 and Table 2. Responding in Group SHORT-SHORT was significantly less than in Group NOP-SHORT ($U = 21.5$, $p < .025$), whereas responding in Group LONG-SHORT was not less than in Group NOP-SHORT. Responding in Group LONG-LONG was significantly less than in Group NOP-LONG ($U = 23$, $p < .025$), whereas responding in Group SHORT-LONG was not less than in Group NOP-LONG.

Figure 4. Mean responses per second to the CS in Experiment 2.



NO P – LONG
LONG – SHORT
SHORT – LONG
NO P – SHORT
LONG – LONG
SHORT – SHORT
MEAN RESPONSES PER SECOND
4
3
2
1
1
2
3
4
5
6
7
8
9
10
SESSION

Table 2

Mean responses per sec to the CS in Experiment 2

(± standard error)

	Training	
Preexposure	Short US-US interval	Long US-US interval
Short US-US interval	.24 ± .11[a]	2.04 ± .30[d]
Long US-US interval	1.61 ± .26[b]	1.10 ± .26[e]
No preexposure	.85 ± .27[c]	1.97 ± .29[f]

a. Group SHORT-SHORT
b. Group LONG-SHORT
c. Group NOP-SHORT

d. Group SHORT-LONG
e. Group LONG-LONG
f. Group NOP-LONG

These findings show that blocking by a US-US association is not restricted to the case in which the US predicts that another US will follow in a short time. The critical result demonstrating blocking with long US-US intervals is that Group LONG-LONG showed significantly less conditioning than Group NOP-LONG whereas Group SHORT-LONG did not. The reduction in conditioning to the CS cannot therefore be attributed to mere US preexposure. The reduction depends on the timing of USs in preexposure in relation to their timing in training.

An unexpected result was that Group LONG-SHORT showed significantly stronger conditioned responding to the CS in training than did Group NOP-SHORT ($U = 25$, $p < .05$). During training, the CS in Group LONG-SHORT was presented and reinforced during a period which may have been inhibitory. The long US-US intervals in preexposure could have established a US as a signal that no US would occur within a short period immediately following the US. If so, the CS during training was being presented and reinforced in conjunction with an inhibitory state, a condition that has been shown to result in increased CR acquisition (Wagner, 1969a,b).

Results also showed significantly attenuated CR acquisition in Group SHORT-SHORT in comparison to Group LONG-LONG ($U=12$, $p < .005$). These results may indicate better blocking of a CS-US association by a US-US association with short (10.5-sec) in comparison to longer (100.5-sec) US-US intervals.

This result requires further elaboration with respect to the time of arrival hypothesis. When subjects are given short (10.5-sec), in comparison to long (100.5-sec) fixed interval US presentations, the expectation for a US which follows a prior US may be greater for short (10.5-sec) in comparison to long (100.5-sec) fixed interval US presentations. One possibility is that the overall quantity of expectation for the arrival of a US may be equivalent for short and long fixed interval US presentations, and this expectation may be maximal at the time at which the US would have been presented (that time being established in preexposure). However, there may be greater variability in the expectation for a US after preexposure at long (100.5-sec) in comparison to short (10.5-sec) US-US intervals. With greater variability in the expectation for a US, the peak of expectation at the time at which a US would have been presented in preexposure would be lower in the longer (100.5-sec) US-US interval case.

Results from Experiment 2 show blocking of a CS-US association by a US-US association when no additional USs were presented after the CS-US pair. In Experiment 1, blocking of a CS-US association by a US-US association was shown with additional USs presented after the CS-US pair. Results from Experiment 2 increase the similarity between the typical blocking experiment and US-US blocking in which a pretrained stimulus is presented only in compound with the to-be-conditioned CS. One anomaly in the results, however, was that responding in Group NOP-SHORT was lower in Experiment 2 than in Experiment 1. This difference is not readily accounted for.

The results of Experiment 2 also provide further evidence against the other previously identified interpretations of reduced conditioning to the CS following US preexposure. None of the other possible accounts explain why the reduction depends on having US-US intervals in preexposure equal to the critical US-US interval.

Alternative interpretations of Experiment 1 suggested that learned laziness or learned US independence might somehow be facilitated when USs are presented at a high rate. That possibility, is, however, not in accord with the present results since these alternative interpretations fail to account for attenuated acquisition in Group LONG-LONG in comparison to either Groups SHORT-LONG ($U = 23$, $p < .025$) or LONG-SHORT ($U = 27$, $p < .05$, averaged over the last 5 sessions). Possible accounts based on habituation, Opponent-Process Theory, context conditioning, or SET also fail for the same basic reason; they do not account for the dependence on the timing of USs in preexposure in relation to their timing during training.

EXPERIMENT 3a

Experiment 3a investigated US-US learning by parametrically manipulating the number of short interval (10.5-sec) US-US presentations in preexposure. Experiment 3a attempted to determine the rapidity with which a short interval US-US association can form, as assessed by the ability of the US-US association to block the CS-US association.

One problem, however, with investigating the rapidity by which a short interval US-US association can form, is that a US-US association may also form when subjects are given feeder training. For example, if short US-US intervals were used in feeder training, only a few short US-US intervals in preexposure might be required for a short interval US-US association to block a CS-US association. This, however, would not show rapid blocking of a CS-US association by a short interval US-US association, as a US-US association may also have formed in feeder training.

To ensure that subjects were not learning a short interval (10.5-sec) US-US association in feeder training, prior to preexposure, Experiment 3a used long (100.5-sec) intervals between USs in feeder training.

Method

Subjects. Subjects were 50 naive, unsexed adult homing pigeons maintained at 80% of their free-feeding weight. They were housed in individual cages with free access to water and grit.

Apparatus. The apparatus was the same as was used in Experiment 1.

Procedure. Subjects were first trained to eat from the feeder. Long interfeeding intervals were used in feeder training. When subjects were first placed in the chamber, grain was made available in the raised feeder. After subjects had taken grain, an automatically programmed food delivery schedule was used in which the feeder-up period and interfeeding interval for each US was timed from the interruption of the photocell beam. Subjects were allowed to eat for 15 seconds for the first 3 USs, and 4 seconds for the remaining 17 USs. The interfeeding interval was 100.5 seconds. Three sessions of this phase of feeder training were given. In the next two sessions, subjects received 20, 4-sec USs at 100.5-sec US-US intervals scheduled independently of behavior. Subjects were then randomly divided into 5 groups of 10 subjects.

Preexposure followed feeder training. Group SHORT-5 received a 10-sec priming US followed after 880 seconds by a train of 16, 4-sec USs at 10.5-sec US-US intervals. After the last US in the train, 880 seconds followed in which no events were presented. The houselights were then turned off to end the session. Group SHORT-5 received 5 sessions of US preexposure. Groups SHORT-3 and SHORT-1 received the identical number and distribution of USs in preexposure but received only three and one preexposure session, respectively, before being returned to home cages.

Group 2 SHORT-5 received a 10-sec priming US followed after 880 seconds by a pair of 4-sec USs separated by 10.5 seconds. After the last US in the pair, 1083 seconds followed in which no events were presented. The houselights were then turned off to end the session. Group 2 SHORT-5 received 5 preexposure sessions.

Group LONG-5 was first presented a 10-sec priming US followed after 880 seconds by a train of 16, 4-sec USs at 69-sec US-US intervals. After the last US in the train, the houselights were turned off to end the session. Group LONG-5 received 5 preexposure sessions. The session length for all groups in preexposure and training was approximately 33 minutes.

Ten CS-US training sessions followed US preexposure. All groups first received a 10-sec priming US followed after 880 seconds by a train of 16, 4-sec USs at 10.5-sec US-US intervals. After the last US in the train, 880 seconds followed in which no events were presented. The houselights were then turned off to end the session. US parameters in training were identical to those used in preexposure in Groups SHORT-5, SHORT-3, and SHORT-1. The second US in the train of USs was preceded by a 10-sec red keylight CS, the offset of which coincided with the onset of the US.

Results and Discussion

Results from Experiment 3a are shown in Figure 5 and Table 3. Responding in Group SHORT-5 was significantly less than in Group LONG-5 ($U = 6$, $p < .005$). Responding in Groups SHORT-3 and SHORT-1 was also less than in Group LONG-5 ($U = 26$, $p < .05$ and $U = 20$, $p < .025$, respectively). However, responding in Group 2 SHORT-5 was not less than in Group LONG-5 ($U = 43$, $p > .05$).

The finding that acquisition in Group 2 SHORT-5 was not attenuated leaves open the possibility that multiple US presentations are necessary for a US-US association, but it is also possible that more preexposure sessions with a pair of USs would have established a US-US association, as assessed by the ability of the US-US association

Figure 5. Mean responses per second to the CS in Experiment 3a.

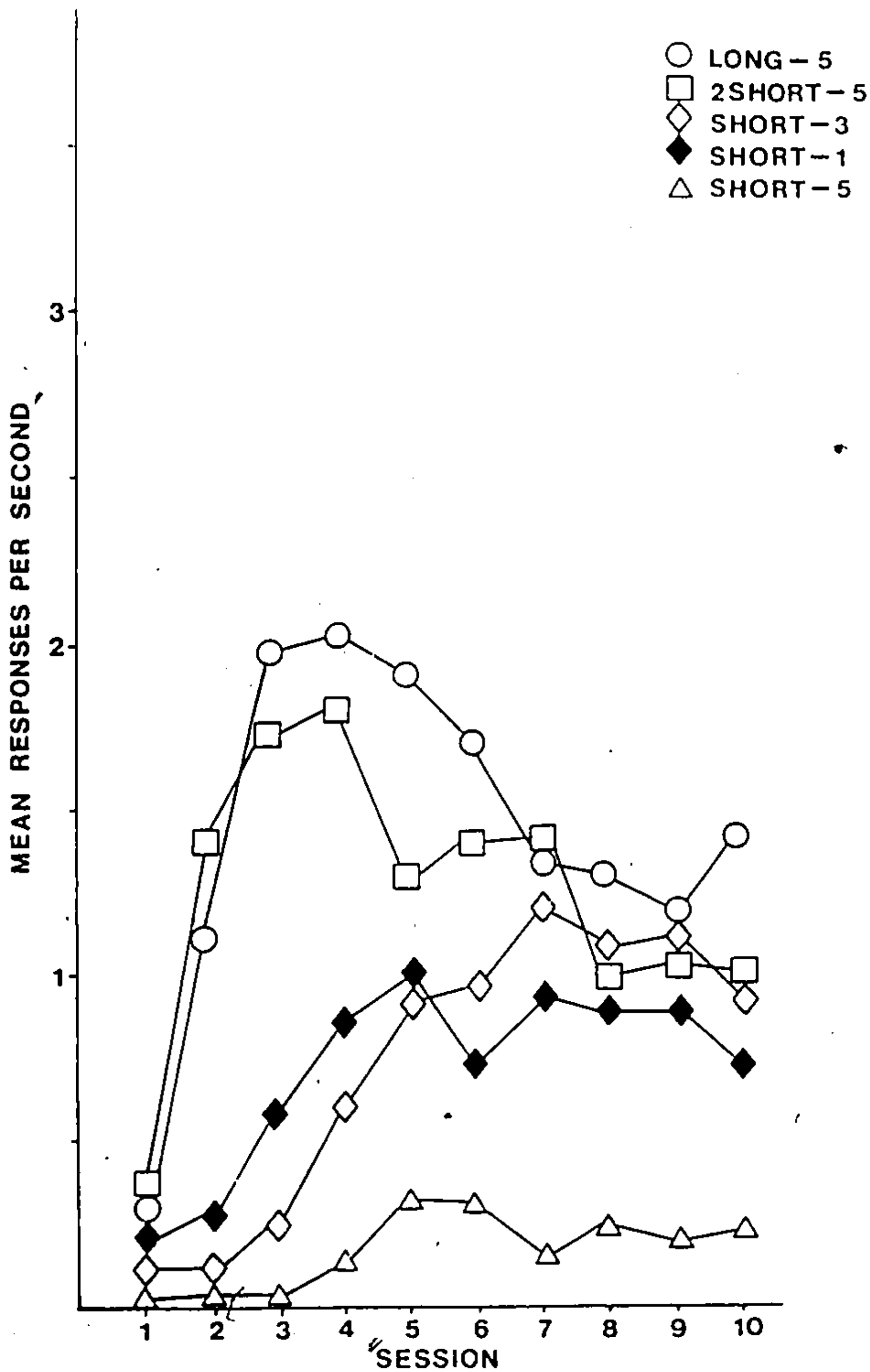

LONG – 5
2SHORT – 5
SHORT – 3
SHORT – 1
SHORT – 5
MEAN RESPONSES PER SECOND
3
2
1
1
2
3
4
5
6
7
8
9
10
SESSION

Table 3

Mean responses per second to the CS in Experiment 3a

(± standard error)

Group	Responses per second
SHORT-5 (n=10)	.17 ± .14
SHORT-3 (n=10)	.72 ± .20
SHORT-1 (n=10)	.69 ± .39
2 SHORT-5 (n=10)	1.24 ± .36
LONG-5 (n=10)	1.42 ± .28

to block the CS-US association. However, in general, results from Experiment 3a show rapid acquisition of a US-US association, as assessed by the ability of the US-US association to block the CS-US association. With a short (10.5-sec) critical US-US interval, subjects with only one session of preexposure, with 16 USs at short (10.5-sec) US-US intervals, showed poorer CR acquisition than subjects receiving more preexposure with longer (100.5-sec) US-US intervals.

EXPERIMENT 3b

Experiment 3b investigated whether weaker responding in Group SHORT-5 compared to Group LONG-5 in Experiment 3a resulted because subjects in Group SHORT-5 did not learn the CS-US association whereas subjects in Group LONG-5 did learn the CS-US association. Alternatively, it is possible that attenuated responding represented a performance effect rather than blocking of the CS-US association. Group SHORT-5 may have learned the CS-US association, but competing responses elicited by learning a US-US association may have attenuated the expression of this learning.

Group SHORT-5 in Experiment 3a might have learned a short interval US-US association in preexposure and, in training, remained close to the feeder site shortly after the first US in the train. This competing response might have resulted in less keypecking even though subjects might have learned the CS-US association. Group LONG-5 in Experiment 3a might have learned a long interval US-US association in preexposure and, in training, might not have remained close to the feeder site shortly after the first US in the train. Since there would be no competing response elicited by the first US in the train, Group LONG-5 in Experiment 3a would have responded more to the keylight.

Performance, rather than associative, accounts of blocking in autoshaping have frequently been considered (Balsam & Schwartz, 1981; Engberg et al., 1972; Gamzu, Williams & Schwartz, 1973; Tomie et al., 1980). For example, Balsam and Schwartz (1981) proposed an alternative account of their data which suggested that context blocking might result because the induction of activity in pigeon subjects following US delivery in a context might interfere with subsequent keypecking. It should be noted, however, that Balsam and Schwartz (1981) did not believe that this performance account could adequately account for their results.

Experiment 3b tested the possibility that attenuated CR acquisition in Group SHORT-5, in comparison to Group LONG-5, in Experiment 3a resulted because the CS-US association did not form. In Experiment 3b, Groups SHORT-5 and LONG-5 from Experiment 3a received CSs in extinction separated by long intervals. If attenuated responding in Group SHORT-5 compared to Group LONG-5 in Experiment 3a resulted because a short interval US-US association resulted in activity incompatible with keypecking, US removal should result in increased keypecking in Group SHORT-5. Alternatively, if attenuated responding in Group SHORT-5 compared to Group LONG-5 in Experiment 3a resulted because the CS-US association did not form, Group SHORT-5 should continue to show attenuated responding compared to Group LONG-5.

Method

Subjects. Subjects were 20 unsexed adult homing pigeons used in Experiment 3a. Subjects previously were in Groups SHORT-5 and LONG-5. Subjects were maintained at 80% of their free-feeding weight and were housed in individual cages with free access to water and grit.

Apparatus. The apparatus was the same as was used in Experiment 1.

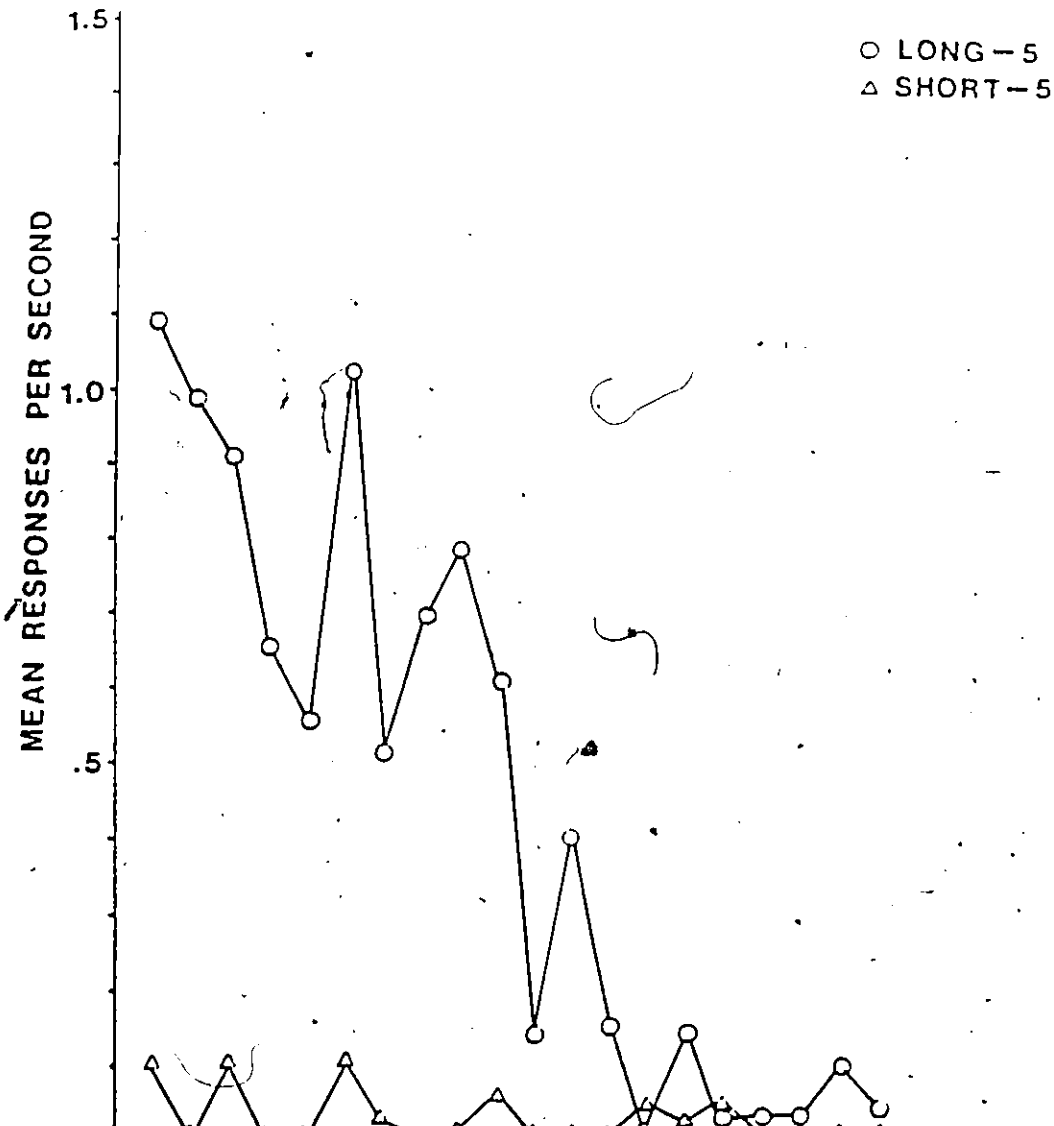
Procedure. All subjects were tested in extinction with the red keylight CS. Five, 10-sec CSs, at 170-sec intervals, were presented in each of four sessions. No other events were presented. Following the last CS, the houselights were turned off to end the session. The session length was 15 minutes for both Groups SHORT-5 and LONG-5.

Results and Discussion

Results from Experiment 3b are shown in Figure 6 and Table 4. Averaged over the 4 extinction sessions, Group LONG-5 responded significantly more to the CS than Group SHORT-5 ($U = 12.5$, $p < .005$). Responding in Group SHORT-5 remained low. Responding in Group LONG-5 declined over extinction sessions until, in the last session, there were no differences in responding between Groups LONG-5 and SHORT-5.

Results from Experiment 3b were consistent with the hypothesis that attenuated responding in Group SHORT-5, compared to

Figure 6. Mean responses per second to the CS in Experiment 3b.



O LONG—5
Δ SHORT—5
MEAN RESPONSES PER SECOND
1.5
1.0
.5
5
10
15
20
TRIAL

Table 4

Mean responses per second to the CS, over 20 extinction trials, in Experiment 3b

(± standard error)

Group	Responses per second
SHORT-5 (n=10)	.03 ± .02
LONG-5 (n=10)	.44 ± .13

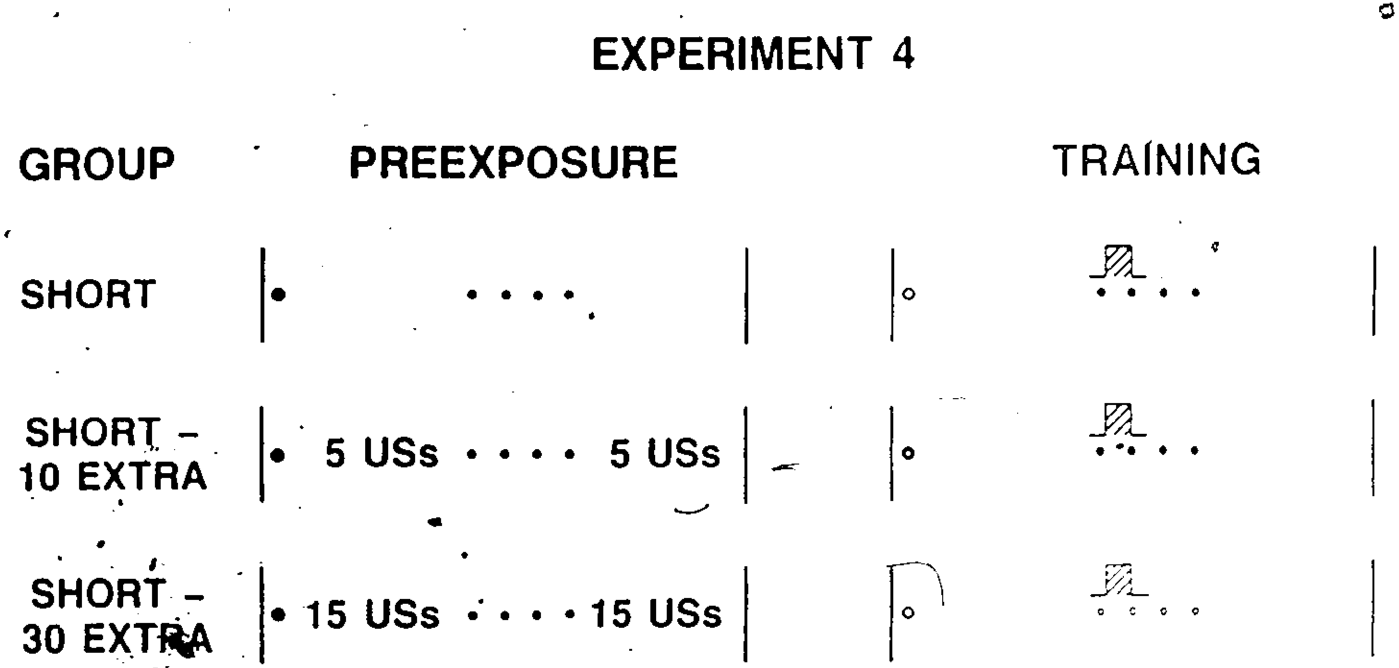
Group LONG-5, in Experiment 3a was an associative deficit. Results were not consistent with one alternative account of the results from Experiment 3a. This account suggested that Group SHORT-5, in comparison to Group LONG-5, did learn the CS-US association, but competing responses elicited by learning a short interval US-US association prevented the expression of this learning.

EXPERIMENT 4

Experiment 4 attempted to show that the time of arrival hypothesis may predict results directly opposite to other alternative interpretations such as habituation, Opponent-Process Theory, learned laziness, learned US independence, context conditioning or SET. Experiment 4 tested whether a short interval US-US association may be attenuated if, in addition, subjects receive more USs in preexposure at longer US-US intervals. Thus, weaker blocking of a CS-US association by a short interval US-US association (and, therefore, better CR acquisition) may be shown in subjects receiving more USs in preexposure.

The design of Experiment 4 is illustrated in Figure 7. In Experiment 4, Group SHORT received preexposure with a train of USs separated by short US-US intervals. In training, the single CS signalled the second US of the train. Groups SHORT-10 EXTRA and SHORT-30 EXTRA received identical training and the same number of short US-US intervals in preexposure. Groups SHORT-10 EXTRA and SHORT-30 EXTRA also received extra USs at longer US-US intervals in

Figure 7. Design of Experiment 4. The dots refer to feedings. The large dot at the beginning of the session corresponds to the 10-sec priming US. The smaller dots correspond to the 4-sec USs. Only 4 of the 16, 4-sec feedings in preexposure and training are shown.


EXPERIMENT 4
GROUP
PREEXPOSURE
TRAINING
SHORT
SHORT –
10 EXTRA
5 USs
5 USs
SHORT –
30 EXTRA
15 USs
15 USs

preexposure. Group SHORT-10 EXTRA received 10 extra USs at longer US-US intervals and Group SHORT-30 EXTRA received 30 extra USs at longer US-US intervals, in comparison to Group SHORT. This design resembles Egger and Miller's (1963) experiment because a short interval US-US association was attenuated by presenting additional USs at longer US-US intervals. The design less closely resembles Lambos (1986). In Lambos (1986) a short interval US-US association was attenuated by presenting USs at longer US-US intervals, but subjects with an attenuated short interval US-US association (for example, Group B/3 Random) received the same number of USs compared to subjects with an intact short interval US-US association (for example, Group B/3 Train).

Because Groups SHORT-10 EXTRA and SHORT-30 EXTRA received extra USs at longer US-US intervals, a US would less reliably predict a subsequent US following in a short interval. Thus, blocking of the CS-US association by a short interval US-US association would be attenuated in Groups SHORT-10 EXTRA and SHORT-30 EXTRA in comparison to Group SHORT. Therefore, CR acquisition should be stronger in Groups SHORT-30 EXTRA and SHORT-10 EXTRA, in comparison to Group SHORT. Alternative interpretations such as habituation, Opponent-Process Theory, learned laziness, learned US independence, context conditioning and SET predict better CR acquisition in Group SHORT in comparison to Groups SHORT-30 EXTRA and SHORT-10 EXTRA.

Method

Subjects. Subjects were 30 naive, unsexed adult homing pigeons maintained at 75% of their free-feeding weight. They were housed in individual cages with free access to water and grit.

Apparatus. The apparatus was the same as was used in Experiment 1.

Procedure. Subjects were first trained to eat from the feeder using the same feeder training regime as used in Experiment 1. Subjects were then randomly divided into 3 groups of 10 subjects.

Five US preexposure sessions followed feeder training. Group SHORT received a 10-sec priming US followed after 880 seconds by a train of 16, 4-sec USs at 10.5-sec US-US intervals. After the last US in the train, 880 seconds followed in which no events were presented. The houselights were then turned off to end the session. Group SHORT-10 EXTRA also received a 10-sec priming US and a train of 16, 4-sec USs at 10.5-sec US-US intervals. In addition, 10 evenly spaced 4-sec USs were presented, 5 prior and 5 after the train of USs. Thus, Group SHORT-10 EXTRA received a 10-sec priming US followed by 5, 4-sec USs at 143-sec US-US intervals, the train of 16, 4-sec USs at 10.5-sec US-US intervals, and 5 additional 4-sec USs at 143-sec US-US intervals. Following the last US, the houselights were turned off to end the session. Group SHORT-30 EXTRA also received a 10-sec priming US and a train of 16, 4-sec USs at 10.5-sec US-US intervals. In addition, 30 evenly spaced 4-sec USs were presented, 15 prior and 15 after the train of USs. Thus, group SHORT-30 EXTRA received a 10-sec priming US followed by 15, 4-sec USs at 51-sec US-US intervals, the train of 16, 4-sec USs at 10.5-sec US-US intervals, and 15 additional 4-sec USs at 51-sec US-US intervals. Following the last US, the houselights were turned off to end the session. The session length in all groups in preexposure and training was approximately 33 minutes.

Ten CS-US training sessions followed US preexposure. All subjects received a 10-sec priming US followed after 880 seconds by a train of 16, 4-sec USs at 10.5-sec US-US intervals. After the last US in the train, 880 seconds followed in which no events were presented. The houselights were then turned off to end the session. Thus, the US distribution in training was identical to the US distribution received by Group SHORT in preexposure. In addition, the second US in the train of USs was preceded by a 10-sec red keylight CS, the offset of which coincided with the onset of the US.

Results and Discussion

Results from Experiment 4 are shown in Figure 8 and Table 5. Group SHORT showed weaker responding in comparison to Group SHORT-10 EXTRA ($U = 22$, $p < .025$) and Group SHORT-30 EXTRA ($U = 10$, $p < .005$). Group SHORT-10 EXTRA also showed weaker responding in comparison to Group SHORT-30 EXTRA ($U = 12$, $p < .005$).

Results were consistent with the time of arrival hypothesis. Preexposure reduced subsequent CS conditioning when short US-US intervals were the same as the critical US-US interval in training. Conditioning to the CS was stronger when US-US intervals in preexposure were frequently longer than the critical US-US interval,

Figure 8. Mean responses per second to the CS in Experiment 4.

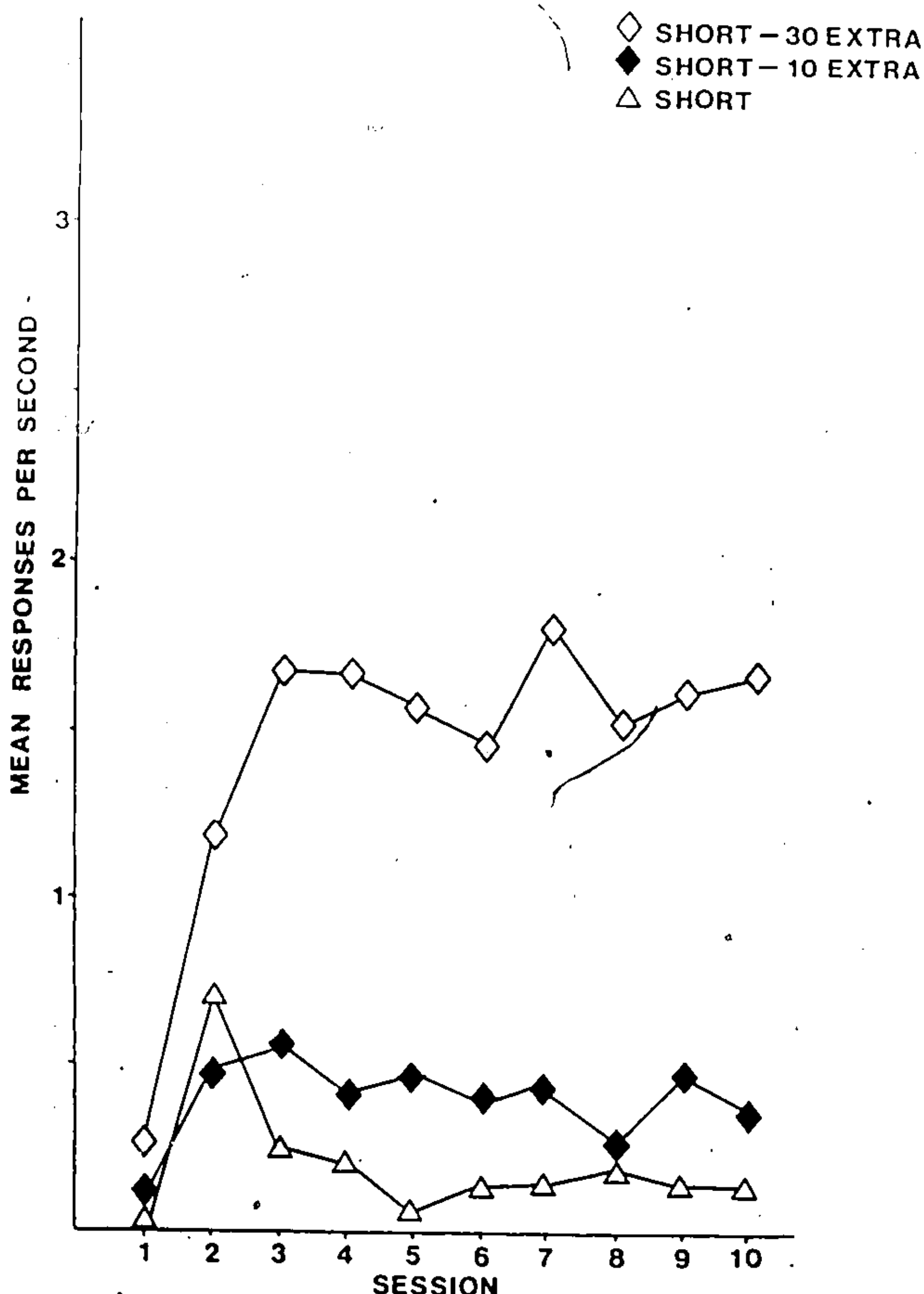

SHORT – 30 EXTRA
SHORT – 10 EXTRA
SHORT
MEAN RESPONSES PER SECOND
3
2
1
1
2
3
4
5
6
7
8
9
10
SESSION

Table 5

Mean responses per second to the CS in Experiment 4

(± standard error)

Group	Responses per second
SHORT (n=10)	.19 ± .12
SHORT-10 EXTRA (n=10)	.38 ± .12
SHORT-30 EXTRA (n=10)	1.43 ± .27

even though subjects receiving US-US intervals longer than the critical US-US interval received more USs in preexposure.

Results were not consistent with alternative accounts. Habituation, Opponent-Process Theory, learned laziness, learned US independence, context conditioning, and SET all predict, in their present level of development, weaker, rather than stronger, conditioned responding as USs are added in preexposure.

It is important to consider an extension of a context conditioning analysis which may provide an alternative interpretation for the results of Experiment 4. Note that in Experiment 4, Groups SHORT-10 EXTRA and SHORT-30 EXTRA not only received more USs in preexposure but received a greater change in the US schedule from preexposure to training in comparison to Group SHORT. Group SHORT received the identical USs in preexposure and training. Groups SHORT-10 EXTRA and SHORT-30 EXTRA did not receive the extra USs in training. If context were a compound stimulus consisting of cues normally considered context (ambient noise level, houselight illumination, etc.) plus schedule-generated US cues, Groups SHORT-30 EXTRA and SHORT-10 EXTRA may have had a greater contextual change from preexposure to training compared to Group SHORT. Since the context was altered more from preexposure to training for Groups SHORT-30 EXTRA and SHORT-10 EXTRA, in comparison to Group SHORT, blocking of the CS-US association by context may have been attenuated in Groups SHORT-30 EXTRA and SHORT-10 EXTRA, in comparison to Group SHORT. Thus, this alternative interpretation also predicts poorer CR acquisition in Group SHORT in comparison to Groups SHORT-10 EXTRA and SHORT-30 EXTRA.

This alternative interpretation is supported by Neely and Wagner's (1974) study showing that cues produced by the US schedule must also be accounted for in a context blocking analysis. Experiment 5 tested this alternative interpretation.

EXPERIMENT 5

Experiment 5 attempted to rule out an alternative contextual conditioning interpretation for the results of Experiment 4. There were two groups of subjects in Experiment 5, Group SHORT-30 EXTRA and Group SHORT. Group SHORT in Experiment 5 received the same conditioning history as Group SHORT in Experiment 4. However, Group SHORT-30 EXTRA in Experiment 5 was given the 30 extra USs both in preexposure and training. In Experiment 4, Group SHORT-30 EXTRA was given the 30 extra USs only in preexposure.

Like Experiment 4, the time of arrival hypothesis predicts better blocking of a CS-US association by a short interval US-US association in Group SHORT, in comparison to Group SHORT-30 EXTRA. This is because in Group SHORT-30 EXTRA blocking of the CS-US association by a short interval US-US association would be attenuated since subjects receive extra USs in preexposure and training at longer US-US intervals. Thus, the time of arrival hypothesis predicts better CR acquisition in Group SHORT-30 EXTRA in comparison to Group SHORT.

The alternative contextual conditioning interpretation from Experiment 4 predicts better context blocking in Group SHORT-30 EXTRA in comparison to Group SHORT. This is because Group SHORT-30 EXTRA receives more USs in a context in preexposure in comparison to Group SHORT. Because the US schedule is not altered from preexposure to training in Group SHORT-30 EXTRA (as it was in Experiment 4), contextual associative strength is not attenuated from preexposure to training. Thus, the alternative contextual conditioning interpretation from Experiment 4 predicts better CR acquisition in Group SHORT in comparison to Group SHORT-30 EXTRA.

<u>Method</u>

<u>Subjects</u>. Subjects were 20 naive, unsexed adult homing pigeons maintained at 80% of their free-feeding weight. They were housed in individual cages with free access to water and grit.

<u>Apparatus</u>. The apparatus was the same as was used in Experiment 1.

<u>Procedure</u>. Subjects were first trained to eat from the feeder using the same feeder training regime as used in Experiment 1. Subjects were then randomly divided into 2 groups of 10 subjects.

Five preexposure sessions followed feeder training. Groups SHORT and SHORT-30 EXTRA received the same preexposure as corresponding groups in Experiment 4.

Ten CS-US training sessions followed preexposure. Each group received the same US distribution as it received in preexposure. In addition the second US in the train of USs was preceded by a 10-sec red keylight CS, the offset of which coincided with the onset of the US. Unlike Experiment 4, Group SHORT-30 EXTRA received the 30 additional USs in preexposure and training.

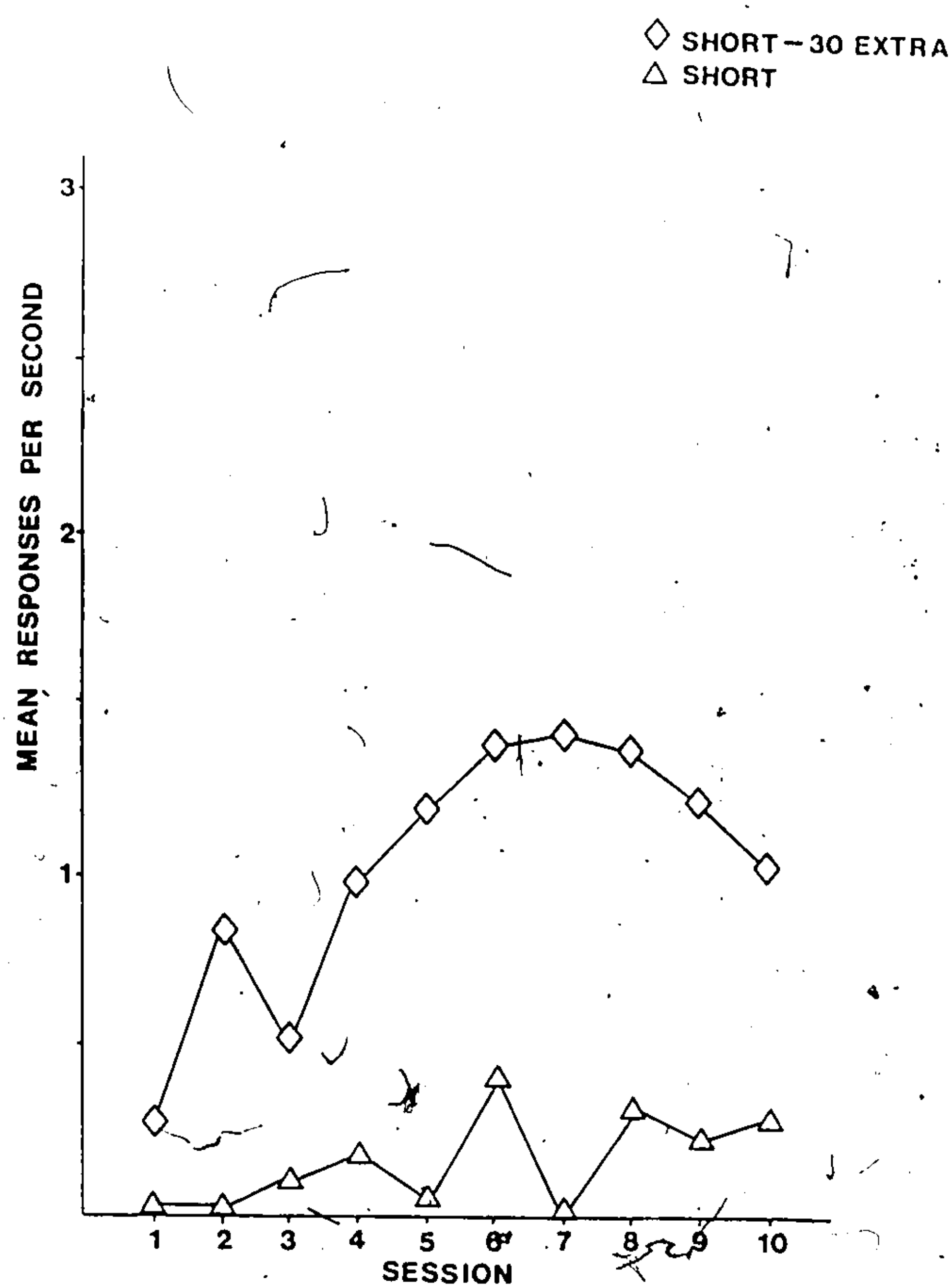
Results and Discussion.

Results from Experiment 5 are shown in Figure 9 and Table 6. Group SHORT showed weaker responding compared to Group SHORT-30 EXTRA (U=17, $p < .01$).

As in Experiment 4, results were consistent with the time of arrival hypothesis. Subjects in Group SHORT received USs in preexposure at short (10.5-sec) US-US intervals. In Group SHORT, preexposure resulted in each US signalling a subsequent US following in a short interval. When Group SHORT received a CS-US pairing but the signalled US was preceded 10.5 seconds earlier by a US, the CS-US association was blocked by a short interval US-US association. Subjects in Group SHORT-30 EXTRA received USs in preexposure at short (10.5-sec) and long (51-sec) US-US intervals. In Group SHORT-30 EXTRA, preexposure resulted in a US signalling a subsequent US following in either a short or long interval. When Group SHORT-30 EXTRA received a CS-US pairing and the signalled US was preceded 10.5 seconds earlier by a US, the CS-US association was less effectively blocked by a short interval US-US association, in comparison to Group SHORT.

In Experiment 4, an alternative contextual conditioning interpretation was presented which could account for the obtained results. This account suggested that the context consisted of both

Figure 9. Mean responses per second to the CS in Experiment 5.



SHORT — 30 EXTRA
SHORT
MEAN RESPONSES PER SECOND
3
2
1
1
2
3
4
5
6
7
8
9
10
SESSION

Table 6

Mean responses per second to the CS in Experiment 5

(± standard error)

Group	Responses per second
SHORT (n=10)	.17 ± .11
SHORT-30 EXTRA (n=10)	1.03 ± .27

characteristics of the experimental chamber and the US distribution in the chamber. Since Group SHORT-30 EXTRA received 30 extra USs in preexposure but not in training, context may have been significantly altered from preexposure to training. This altered context would less effectively block the CS-US association, in comparison to Group SHORT, in which the context was not altered from preexposure to training.

In Experiment 5, Group SHORT-30 EXTRA received more USs in preexposure and training in comparison to Group SHORT. Context conditioning should have been greater in Group SHORT-30 EXTRA in comparison to Group SHORT. The context, consisting of cues normally considered context plus cues generated by the US distribution, was not altered from preexposure to training for both Group SHORT and Group SHORT-30 EXTRA. Therefore, blocking of the CS-US association by a context-US association should have been greater in Group SHORT-30 EXTRA in comparison to Group SHORT.

Results showed greater acquisition in Group SHORT-30 EXTRA in comparison to Group SHORT. Results were consistent with the time of arrival hypothesis but were not consistent with an alternative contextual conditioning interpretation suggested to account for the results of Experiment 4.

CHAPTER 3

GENERAL DISCUSSION

Experiments 1-5 showed a CS-US association can be blocked by a US-US association. When the critical US-US interval equalled US-US intervals in preexposure, subjects showed weaker responding compared to subjects in which the critical US-US interval was shorter than many US-US intervals in preexposure. This resulted even when subjects were equated on US number and average US rate in preexposure and training (Experiment 1). The result was not specific to short US-US intervals or continued exposure to the US train in training, as attenuated responding also resulted with long US-US intervals and the absence of continued exposure to the US train in training (Experiment 2). Blocking of a CS-US association by a US-US association resulted with only one session of preexposure at short (10.5-sec) US-US intervals (Experiment 3a). Further, blocking of a CS-US association by a US-US association was not consistent with one alternative account of the results from Experiment 3a. This account suggested that subjects in Experiment 3a learned the CS-US association but competing responses elicited by learning a short interval US-US association prevented the expression of this learning (Experiment 3b). Finally, blocking of a CS-US association by a short interval US-US association was stronger when subjects received only short US-US intervals in preexposure, in comparison to subjects given extra USs in preeposure at longer US-US intervals (Experiment 4). This resulted even when the US distribution was unchanged from preexposure to training (Experiment 5). Results from Experiments 1-5 support the hypothesis that blocking occurs because the prior US predicts the time of arrival of the US with which the CS is paired. Results were not consistent with alternate accounts including habituation, Opponent-Process Theory, learned laziness, learned US independence, context conditioning or SET.

US-US Blocking and Current Theories of Learning

The present results show that a US-US association can block a CS-US association. The results extend blocking to the case in which a CS-US association is blocked by a US-US association, rather than a CS-US or context-US association.

Current theories of learning include theories developed by Rescorla and Wagner (Rescorla & Wagner, 1972; Wagner & Rescorla, 1972), Wagner (Wagner, 1981), Pearce and Hall (Pearce & Hall, 1980) and Mackintosh (Mackintosh, 1975). Because these theories can account for blocking they can also account for the results of Experiments 1-5, since Experiments 1-5 also demonstrate blocking. To account for the results of Experiments 1-5, however, the theories must posit that the blocking stimulus is a prior US, rather than the context or a concurrent CS.

US-US Blocking and the Relative Waiting Time Hypothesis

Results from Experiment 1-5 are inconsistent with the Relative Waiting Time (RWT) Hypothesis (Jenkins, Barnes, & Barrera, 1981). The Relative Waiting Time Hypothesis is similar to SET but suggests that the ratio of the relative waiting time for a US in the context to the relative waiting time for a US when the CS is present (the RWT ratio) determines conditioned responding. According to RWT, larger ratios correspond to increased responding.

Results from Experiments 1-5 showed responding was not importantly a function of the RWT ratio. This was clearly seen in Experiment 5 in which subjects with a lower RWT ratio (Group SHORT-30 EXTRA) showed better, rather than poorer, responding in comparison to subjects with a higher RWT ratio (Group SHORT). Results from Experiments 1-5 support results by Lambos (1986). Lambos (1986) also showed CR acquisition was not importantly a function of the RWT ratio. For example, subjects with one CS-US pairing showed significantly stronger responding, with equal RWT ratios, when the CS signalled the first, rather than the sixteenth, US in a train of regular recurring, closely spaced USs.

Most perplexing for the hypothesis that a US-US association can block a CS-US association is the results of an experiment by Jenkins, Barnes, and Barrera (1981, Experiment 9). In Experiment 9, 5 groups of subjects received 35 preexposure sessions in which 30, 3-sec USs were delivered at a fixed interval of 65 seconds. Subjects then received one 10-sec CS which signalled the 16th US. For one group of subjects the 16th US occurred exactly as it did in preexposure (65 seconds after the fifteenth US). For another group of subjects the sixteenth US occurred shortly after the fifteenth US (13 seconds after the fifteenth US). The other 3 groups of subjects received the 16th US at intervals intermediate between 13 and 65 seconds after the fifteenth US. Results showed no significant differences in CR acquisition between groups. Results were inconsistent with results from Experiments 1-5 which showed better blocking of a CS-US association when the critical US-US interval equalled US-US intervals in preexposure.

One explanation may be that a US-US association only forms if there is a long time period where no events are presented (a long empty interval) which precedes and follows US presentations. For example, Group SHORT-SHORT in Experiment 1 received a train of 16 USs preceded and followed by a long empty interval. This procedure may have resulted in a US-US association. Subjects in Jenkins et al. did not receive US presentations preceded and followed by a long empty interval. This procedure may have prevented the formation of a US-US association.

However, results from Experiment 2 showed blocking of a CS-US association by a US-US association with long US-US intervals (for example, Group LONG-LONG compared to Group SHORT-LONG). Group LONG-LONG received a long empty interval preceding, but not following, US presentations. This might suggest that a long empty interval preceding, but not following, the US train may be essential for the formation of a US-US association.

However, the hypothesis that a preceding long empty interval is essential for US-US associative formation cannot account for results from other studies. For example, Catania and Reynolds (1968) showed in operant conditioning with food as the US, that when the probability of reinforcement soon after reinforcement was high, with no long empty interval preceding US presentation, local responding at that time was high, in comparison to subjects in which reinforcement probability was constant throughout the session. Results were consistent with the hypothesis that subjects learned a US-US association without a long empty interval preceding US presentation. Subjects evidenced learning this US-US association by increased responding when US probability was high.

An additional possibility may be that a US-US association may form without a long empty interval preceding US presentation but the US-US association will not necessarily block a CS-US association. Results from Catania and Reynolds (1968) may show the formation of a US-US association without a long empty interval preceding US presentations but this US-US association may not block a CS-US association. Subjects in Jenkins et al. may have formed a US-US association without a long empty interval preceding US presentations but the US-US association was not sufficient to block a CS-US association. Although there was no long empty interval in Egger and Miller (1963) the average wait for a US when a US was presented was much shorter than the average US wait in the session.

It is possible that Jenkins et al., (1981, Experiment 9) did not show US-US blocking because their experiment did not use a sufficiently large sample of subjects to obtain significant blocking, whereas Experiments 1-5 did. In Experiment 1, nine subjects per group were used and in Experiments 2-5, 10 subjects per group were used. In Jenkins et al., 1981, Experiment 9, 4 subjects were used in each of four groups and three subjects were used in one group.

US-US Learning and Other Conditioning Phenomena

US-US learning may be involved in other conditioning phenomena. For example, blocking of a CS-US association by a US-US association may be involved in the US preexposure effect and CS-US contingency. Further, US-US learning may be involved in studies of habituation. However, it is important to explicitly note that neither the time of arrival hypothesis nor the data provide a basis for extrapolating US-US learning from the fixed US-US interval case to the variable US-US interval case. Therefore, the involvement of a US-US association in other conditioning phenomenon depends on the untested assumption that a US-US association may form and block a CS-US association with variable US-US intervals.

US-US Blocking and the US Preexposure Effect

Blocking of a CS-US association by a US-US association may be involved in the US preexposure effect. The US preexposure effect is the finding that subjects given prior USs show attenuated CR acquisition in comparison to subjects not given prior USs.

Results from Experiment 2 showed that a US preexposure effect was obtained when US-US intervals in preexposure were equal to the critical US-US interval. Thus, in Experiment 2, Group SHORT-SHORT showed attenuated CR acquisition in comparison to Group NOP-SHORT and Group LONG-LONG showed attenuated CR acquisition in comparison to

Group NOP-LONG. Groups LONG-SHORT and SHORT-LONG did not, however, show attenuated CR acquisition in comparison to Groups NOP-SHORT and NOP-LONG, respectively. Thus, results from Experiment 2 suggest that the US preexposure effect may depend on the maintenance of equal US-US intervals in preexposure and CS-US training. In fact, many US preexposure studies have used fixed and equivalent US-US intervals in preexposure and CS-US training (for example, Balsam and Schwartz, 1981; Mis and Moore, 1973), or variable and equivalent US-US intervals in preexposure and CS-US training (for example, Downing and Neuringer, 1976; Engberg et al., 1972; Hinson, 1982; Randich, 1981; Randich and Haggard, 1983; Randich and LoLordo, 1979; Tomie, 1976a,b; Tomie et al., 1980).

In the autoshaping paradigm, US-US intervals in preexposure and CS-US training are commonly programmed ranging from a VT 15 to VT 45 second schedule (Downing and Neuringer, 1976; Engberg et al., 1972; Tomie, 1976a,b; Tomie et al., 1980). Since the present experiments show blocking of a CS-US association by a US-US association with 100.5-sec US-US intervals, US-US intervals in autoshaping studies of the US preexposure effect are well within these limits. As noted earlier, however, blocking of a CS-US association by a US-US association, as an interpretation of autoshaping studies of the US preexposure effect, depends on the untested assumption that a US-US association will form and block a CS-US association with variable US-US intervals.

In conditioning paradigms other than the autoshaping paradigm, US preexposure studies often use equal, but much longer (longer than 100.5-sec), average US-US intervals in preexposure and CS-US training (Hinson, 1982; Randich, 1981; Randich and Haggard, 1983; Randich and LoLordo, 1979). For example, in rabbit eyelid conditioning, Hinson (1982) used three minute average US-US intervals while in rat fear conditioning, Randich and LoLordo (1979) used 27 minute average US-US intervals. In the present experiments, blocking of a CS-US association by a US-US association with these longer US-US intervals was not examined.

The US preexposure effect may be determined by a number of factors, only one of which may be blocking of a CS-US association by a US-US association. For example, US-US blocking does not account for the finding that only one prior US may attenuate CS-US learning (Cannon, Berman, Baker, & Atkinson, 1975). Nevertheless, in a number of US preexposure studies, US-US intervals are not altered from preexposure to CS-US training. Results from the present experiments suggest that this condition might have been important for studies obtaining a US preexposure effect.

US-US Blocking and CS-US Contingency

Another frequently investigated finding in classical conditioning is the contingency between a CS and US necessary for CR acquisition. Many experiments show that CR acquisition, normally produced by CS-US pairings, is attenuated when extra USs are added, reducing the CS-US contingency (Ayres, Benedict, & Witcher, 1975;

Durlach, 1983; Dweck and Wagner, 1970; Gamzu and Williams, 1971, 1973; Gibbon, Locurto, & Terrace, 1975; Goddard and Jenkins, 1987; Jenkins et al., 1981; Rescorla, 1966, 1968). The present experiments suggest that attenuated CR acquisition with poorer CS-US contingency may result because the addition of extra USs results in shorter US-US intervals. Results from Experiment 2 suggested that blocking of a CS-US association by a US-US association was greater with shorter, rather than longer, US-US intervals (Group SHORT-SHORT in comparison to Group LONG-LONG). Therefore, the addition of extra USs might result in stronger blocking of a CS-US association by a US-US association, than when extra USs are not added.

In many noncontingent CS-US presentations, US-US intervals are within the 100.5-sec US-US interval in which the present experiments demonstrate blocking (for example, Durlach, 1983; Goddard and Jenkins, 1987; Jenkins et al., 1981). Further, US-US intervals are not as variable as one might expect. Because there is often a substantial minimum interstimulus interval between USs (Durlach, 1983; Goddard and Jenkins, 1987; Jenkins et al., 1981), US-US intervals resemble to some extent the fixed US-US interval case in which the present experiments demonstrate blocking.

In CS-US noncontingency if the extra USs are signalled by another CS, CR acquisition is stronger than if the extra USs are unsignalled (Durlach, 1983; Goddard and Jenkins, 1987). This might result because signalling extra USs might attenuate context conditioning which would otherwise block target CS-US conditioning if the extra USs were unsignalled. Another possibility might be that as a US-US association might block a CS-US association (Experiments 1-5), a CS-US association might block a US-US association. Thus, when extra USs are signalled, a US-US association might be blocked. Because the US-US association would not form, the US-US association could not block the target CS-US association. For example, Davis et al. (1975) found that when shock USs were separated by 3 minute intervals, subjects were significantly less fearful in the first minute following shock than when shock USs were signalled by a tone CS. Results were consistent with the suggestion that when shocks were unsignalled, subjects learned a shock-shock association and evidenced learning this association by showing less fear in the first minute following shock. When shocks were signalled, subjects did not learn a shock-shock association.

Further, blocking of a CS-US association by a US-US association in noncontingency accommodates results showing that if a few chance CS-US pairings are presented in succession, early in noncontingency, CR acquisition is obtained (Ayres et al., 1975; Benedict and Ayres, 1972). When CS-US pairings are presented early in noncontingency, it is possible that a CS-US association forms prior to a US-US association. Thus, a US-US association will not effectively block a CS-US association. When CS-US pairings are not presented early in noncontingency, a US-US association may quickly form (Experiment 3a) and block a CS-US association. This explanation has also been suggested by Lambos (1986). Presenting USs separate from

CS-US training may result in context blocking (eg. see Ayres, Bombace, Shurtleff, and Vigorito, 1985) but this does not necessarily mean that when USs and CS-US pairings are not separated (as in noncontingency) the results are also due to context blocking. When USs are presented in the same session as CS-US training attenuated CR acquisition can still be the result of a US-US association blocking a CS-US association.

US-US Learning and Habituation

Finally, US-US learning may be a factor in studies of habituation. Many studies have shown that responsiveness to a US declines over repeated stimulus presentations (see Thompson and Spencer, 1966 for a review). Because USs are frequently presented at regular, recurring intervals (for example, Bridger, 1961; Buchwald, Halas, & Schramn, 1965; Davis and Wagner, 1968; Geer, 1966; Prosser & Hunter, 1936; Simons, Dunlop, Webster, & Aitkin, 1966; Thompson and Spencer, 1966), studies of habituation more closely resemble the present experiments which show US-US learning at fixed US-US intervals (as assessed by the blocking of CS-US learning). At constant US-US intervals, one US may serve to signal the time of arrival of a subsequent US and decreasing US responsiveness might reflect the fact that each US presentation may be predicted by a prior US. This is consistent with results showing that when a US is predicted by a prior CS, there is frequently a conditioned diminution of the UR (Brown, Meryman, & Marzocco, 1956; Buckland, Buckland, Jamieson, & Ison, 1969; Donegan, 1980; Hoffman & Searle, 1965; Kimble and Ost, 1961; Kimmel, 1966). In addition, habituation often occurs more rapidly with short, rather than long US-US intervals (Bridger, 1961; Buckwald, et al., 1965; Davis, 1970; Geer, 1966; Simons, et al. 1966), compatible with results from Experiment 2 showing better blocking at short, rather than long, US-US intervals. Similarly, some habituation studies suggest habituation is more rapid with constant, rather than variable, US-US intervals (Davis, 1970; Mackworth, 1968; McDaniel and White, 1966; Pendergrass and Kimmel, 1968). This, of course, might reflect the fact that a US is a better predictor of the time of arrival of a subsequent US when US-US intervals are fixed rather than variable.

Problematic for a US-US associative account of habituation is the finding by Davis (1970) that if a US was preceded 2 seconds earlier by a prior US, habituation was weaker, rather than stronger, for subjects exposed 1 minute or 24 hours earlier to USs at 2-sec, compared to 16-sec, US-US intervals. Further, US-US learning may not be the only associative factor involved in habituation. Other studies show habituation may be context-specific, suggesting context - US associations may also be a factor in habituation (Peeke and Veno, 1973; Wagner, 1976). Nonetheless, US-US learning should certainly be considered as one factor which may be involved in studies of habituation.

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Appendix A

Responses per Second over the 10 sessions
for Subjects in Experiment 1

Group SHORT-SHORT

Subject	Session 1	2	3	4	5	6	7	8	9	10	X̄
1	0	0	0	.7	.7	.4	.6	0	.3	0	.27
2	0	0	0	.2	0	0	0	0	0	0	.02
3	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0
7	0	0	.5	1.0	.2	.8	1.3	.4	.6	.4	.52
8	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	2.4	2.9	0	0	2.6	3.4	3.6	1.49
X̄	0	0	.06	.48	.42	.13	.21	.33	.48	.44	

Group LONG-LONG

Subject	Session 1	2	3	4	5	6	7	8	9	10	X̄
1	0	1.6	3.6	3.9	3.9	2.8	3.7	3.7	3.5	3.8	3.05
2	0	0	0	0	0	.4	1.4	2.8	2.5	1.6	.87
3	0	.7	1.2	2.1	2.2	2.5	2.1	2.0	2.0	1.0	1.58
4	1.2	2.3	2.6	.7	3.3	3.1	3.2	2.9	2.5	2.5	2.43
5	0	.1	1.1	1.8	1.5	2.2	.7	.5	1.1	1.5	1.05
6	.2	3.1	3.3	3.8	3.0	3.3	.4	2.8	3.5	3.6	2.70
7	0	2.1	1.3	2.4	1.8	0	2.3	2.7	2.8	2.4	1.78
8	0	0	0	1.2	.7	.8	1.2	2.4	2.8	2.5	1.16
9	0	0	0	0	0	0	.5	1.7	2.4	2.3	.69
X̄	.16	1.1	1.46	1.77	1.82	1.68	1.72	2.39	2.57	2.36	

Group NOP-SHORT

Subject	Session 1	2	3	4	5	6	7	8	9	10	X̄
1	1.0	3.2	2.8	1.8	1.5	.6	.6	.7	1.7	1.5	1.54
2	0	.6	3.2	3.7	3.8	4.0	3.6	3.4	3.7	3.2	2.92
3	1.3	3.4	3.7	4.2	3.6	3.6	3.5	4.2	3.5	3.9	3.49
4	.3	0	1.7	3.4	3.1	2.6	2.8	2.6	2.3	2.6	2.14
5	1.1	4.0	5.2	2.4	5.3	4.8	5.0	4.6	4.5	5.1	4.20
6	1.5	1.3	.7	2.2	0	0	3.5	0	0	0	.92
7	1.9	3.0	0	3.3	2.9	4.5	4.9	4.9	4.4	4.2	3.40
8	0	0	.8	0	3.0	3.0	2.5	1.5	1.0	.7	1.25
9	0	.2	2.1	.4	.2	0	0	0	0	0	.29
X̄	.79	1.74	2.24	2.38	2.60	2.57	2.93	2.43	2.34	2.36	

Group NOP-LONG

Subject	Session 1	2	3	4	5	6	7	8	9	10	X̄
1	0	.3	1.9	2.1	2.4	1.3	1.8	1.6	1.7	1.0	1.41
2	0	.4	0	.2	2.1	3.4	3.5	3.4	3.4	3.4	1.98
3	.1	.1	1.1	2.2	3.0	3.3	2.7	2.7	2.8	1.5	1.95
4	3.4	3.0	2.8	2.3	2.0	2.3	1.6	1.7	1.7	1.3	2.21
5	0	.5	1.4	2.6	3.6	3.3	3.0	2.6	3.5	3.8	2.43
6	0	0	3.5	4.1	4.4	3.5	4.2	3.9	2.6	4.2	3.04
7	.5	1.9	3.5	4.2	3.5	4.2	3.3	3.3	3.2	3.0	3.06
8	1.6	6.2	5.5	6.0	6.2	5.2	5.2	5.1	5.0	5.5	5.15
9	0	0	0	1.2	3.7	4.6	4.5	4.2	2.5	3.9	2.46
X̄	.62	1.38	2.19	2.77	3.43	3.46	3.31	3.17	2.93	3.07	

Appendix B

Responses per Second over the 10 Sessions for Subjects in Experiment 2

Group SHORT-SHORT

Subject	Session 1	2	3	4	5	6	7	8	9	10	X
1	.2	1.3	.8	.1	.4	.7	1.4	.8	1.4	.8	.79
2	0	0	0	0	0	0	0	0	0	0	0
3	0	2.5	1.4	1.2	.7	1.4	1.1	.1	0	0	.84
4	0	0	0	0	0	0	0	0	0	0	0
5	0	0	.1	0	.2	1.3	1.2	0	0	0	.28
6	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	.2	.2	.04
8	0	0	0	0	0	0	0	0	0	0	0
9	.4	.1	.2	1.9	.8	.2	.1	.1	.1	.1	.40
10	0	0	0	0	0	0	0	0	0	0	0
X	.06	.39	.25	.32	.21	.36	.38	.10	.17	.11	

Group LONG-LONG

Subject	Session 1	2	3	4	5	6	7	8	9	10	X
1	2.2	2.7	2.0	1.4	1.3	.7	.6	.5	1.1	.3	1.28
2	0	0	0	.9	1.1	.7	1.2	.1	1.5	.6	.61
3	.9	2.1	2.4	3.6	3.6	6.8	1.9	1.3	1.2	1.0	2.48
4	1.3	1.0	1.6	1.3	1.9	1.3	.6	.2	.5	.4	1.01
5	0	0	0	0	0	0	0	0	0	.5	.05
6	0	0	.1	.6	1.6	.4	1.6	2.3	2.6	2.4	1.16
7	.1	.1	0	0	0	0	0	0	1.2	.2	.16
8	.1	0	.4	1.7	1.4	.3	.5	.4	.1	.2	.51
9	.5	.7	2.9	3.1	2.4	2.9	2.7	3.0	2.9	2.9	2.40
10	.3	.6	1.5	2.3	1.9	1.2	1.7	1.6	1.1	.8	1.30
X	.54	.72	1.09	1.49	1.52	1.43	1.08	.94	1.22	.93	

Group NOP-SHORT

Subject	Session 1	2	3	4	5	6	7	8	9	10	X
1	0	.1	0	.1	0	0	.6	1.0	2.1	1.1	.50
2	0	0	0	0	0	.4	.5	.6	.2	0	.17
3	.1	.1	.2	.1	0	0	.2	.7	0	.2	.16
4	0	0	0	0	0	0	.4	.3	.4	.2	.13
5	0	0	.2	.3	2.4	2.4	1.5	.6	.1	0	.75
6	0	.6	4.2	3.7	2.1	2.7	2.3	3.4	3.6	3.4	2.60
7	0	.2	.5	2.6	1.0	.8	.5	.2	.2	.2	.62
8	0	0	1.3	1.2	1.5	.5	.9	.8	.2	.1	.65
9	0	0	0	0	0	0	3.0	0	1.6	3.3	.79
10	.1	2.8	2.0	3.3	3.7	2.2	0	2.3	2.6	2.6	2.16
X	.02	.38	.84	1.13	1.07	.90	.99	.99	1.10	1.11	

Group NOP-LONG

Subject	Session 1	2	3	4	5	6	7	8	9	10	X
1	0	0	.7	0	3.6	17.8	7.8	4.8	3.7	2.8	4.12
2	0	.3	1.6	.6	2.1	1.9	1.2	1.5	1.4	1.0	1.16
3	.2	1.8	2.5	0	3.3	3.9	2.3	4.6	2.5	4.4	2.55
4	0	.7	3.4	2.9	2.3	2.7	0	2.0	1.7	.9	1.66
5	0	.7	2.5	3.1	4.2	3.2	2.1	2.3	.9	1.4	2.04
6	0	0	.1	.7	5.2	1.3	1.1	1.3	1.3	1.0	1.20
7	.1	.1	0	.1	1.8	2.6	1.9	1.5	1.1	1.6	1.08
8	0	.1	.7	3.6	5.5	2.5	3.1	3.0	3.2	2.9	2.46
9	.3	0	2.9	2.2	2.2	.6	2.1	2.4	2.9	2.5	1.81
10	0	1.4	0	0	0	2.8	2.4	3.5	2.9	3.1	1.61
X	.06	.51	1.44	1.32	3.02	3.93	2.40	2.69	2.16	2.16	

Group LONG-SHORT

Subject	Session 1	2	3	4	5	6	7	8	9	10	X
1	0	0	.7	1.5	2.2	2.5	2.0	2.1	2.2	1.2	1.44
2	0	0	0	0	0	0	0	0	0	0	0
3	0	.6	2.5	2.9	2.6	3.0	3.2	3.0	3.1	3.5	2.44
4	.4	1.9	3.2	3.2	3.3	3.4	3.1	2.9	2.9	3.2	2.75
5	0	.4	1.2	.7	.6	1.1	1.0	1.0	1.0	1.8	.88
6	0	0	1.9	1.7	.9	1.8	2.5	2.4	2.0	2.5	1.57
7	.9	.8	1.9	2.0	2.0	1.4	1.7	2.5	2.2	2.3	1.77
8	1.3	2.9	2.4	2.6	2.8	3.2	3.2	2.3	2.2	1.9	2.48
9	.5	.5	1.7	2.5	1.9	2.1	2.0	1.8	2.0	1.2	1.62
10	0	0	0	.3	3.1	.6	1.0	1.9	2.9	1.9	1.17
X	.31	.71	1.55	1.74	1.94	1.91	1.97	1.99	2.05	1.95	

Group SHORT-LONG

Subject	Session 1	2	3	4	5	6	7	8	9	10	X
1	.1	0	2.4	2.2	1.9	1.3	2.2	1.4	1.7	1.3	1.45
2	1.4	2.6	6.1	2.1	2.4	2.4	2.6	2.7	2.3	2.4	2.70
3	.1	.9	.6	1.4	1.3	.7	.9	.9	.3	.2	.73
4	1.4	2.2	5.7	4.4	3.8	3.9	3.0	3.1	6.3	3.1	3.69
5	0	.8	2.6	6.8	3.4	3.2	2.8	2.7	2.1	2.9	2.73
6	.2	2.0	2.5	3.7	2.1	2.5	2.1	2.0	3.0	1.7	2.18
7	0	1.0	2.5	3.9	3.4	1.9	2.3	1.8	1.5	1.0	1.93
8	.5	1.0	4.2	1.1	.3	.1	.6	.5	1.3	.9	1.05
9	.1	.5	2.5	2.2	1.6	1.2	.8	.7	.8	1.3	1.17
10	0	0	1.0	1.4	4.4	4.5	5.3	4.3	3.2	3.1	2.72
X	.38	1.10	3.01	2.92	2.46	2.17	2.26	2.01	2.25	1.79	

Appendix C

Responses per Second over the 10 Sessions
for Subjects in Experiment 3a

Group SHORT-1

Subject	Session 1	2	3	4	5	6	7	8	9	10	X
1	0	0	0	0	0	0	0	0	0	0	0
2	.3	2.1	4.4	4.4	4.6	4.7	4.5	5.4	4.9	3.8	3.91
3	0	.1	0	0	0	0	0	0	0	0	.01
4	0	0	0	0	0	0	0	.6	0	0	.06
5	0	0	0	0	0	.5	0	0	0	0	.05
6	0	.2	.4	.4	.3	.1	0	0	1.8	1.0	.42
7	.3	0	0	0	0	0	0	0	0	0	.03
8	0	.3	.9	2.0	1.9	2.2	2.3	1.9	1.7	1.8	1.50
9	0	0	0	0	0	0	0	0	0	0	0
10	0	.1	0	1.8	2.7	0	2.6	1.0	.7	.7	.96
X	.06	.28	.57	.86	.95	.75	.94	.89	.91	.73	

Group SHORT-3

Subject	Session 1	2	3	4	5	6	7	8	9	10	X
1	0	0	0	.8	2.6	2.4	2.7	2.6	2.8	2.9	1.68
2	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	.2	.02
5	0	0	.7	1.3	1.3	.4	2.2	2.1	1.8	.7	1.05
6	0	0	.9	.8	1.5	1.6	1.0	.3	.3	.1	.65
7	0	0	0	0	.3	.8	1.6	2.2	2.4	2.0	.93
8	0	0	0	.5	.7	.8	.5	.4	.3	.2	.34
9	.3	1.1	.9	2.7	2.7	2.6	1.7	.7	1.9	1.4	1.60
10	0	0	0	0	0	1.2	2.3	2.2	1.9	1.9	.95
X	.03	.11	.25	.61	.91	.98	1.20	1.05	1.14	.94	

Group SHORT-5

Subject	Session 1	2	3	4	5	6	7	8	9	10	X̄
1	0	0	0	0	0	0	0	0	0	0	0
2	0	0	.3	0	.5	.7	0	.6	0	.8	.29
3	.1	0	0	0	0	0	0	0	0	0	.01
4	0	.3	0	0	.1	0	0	0	0	0	.04
5	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	.1	0	0	0	.01
8	0	0	0	0	0	0	0	0	0	0	0
9	0	.1	0	1.5	2.6	2.5	1.7	1.8	2.0	1.6	1.38
10	0	0	0	0	0	0	0	0	0	0	0
X̄	.01	.04	.03	.15	.32	.32	.18	.24	.20	.24	

Group LONG-5

Subject	Session 1	2	3	4	5	6	7	8	9	10	X̄
1	0	1.5	2.4	.8	1.2	1.3	1.1	1.5	.3	1.3	1.14
2	0	.2	1.7	2.1	1.5	2.1	1.0	.8	.9	1.9	1.22
3	.4	1.2	3.6	3.5	3.5	3.2	3.1	3.0	2.9	3.3	2.77
4	.9	2.3	0	2.7	3.7	2.2	1.4	1.3	.9	.8	1.62
5	.1	1.2	2.0	.7	.5	.1	0	0	0	0	.46
6	0	.4	2.7	3.4	3.6	3.5	3.1	3.2	3.5	3.5	2.69
7	0	1.0	3.4	3.2	2.4	3.0	1.8	1.0	1.8	2.0	1.96
8	0	.1	.2	1.5	1.8	.8	.3	.5	.4	.1	.57
9	0	0	0	.2	0	.3	.7	.5	.2	.7	.26
10	.5	3.1	3.8	2.1	1.0	.6	1.1	1.3	.7	.7	1.49
X̄	.19	1.10	1.98	2.02	1.92	1.71	1.36	1.31	1.16	1.43	

Group 2 SHORT-5

Subject	Session 1	2	3	4	5	6	7	8	9	10	X̄
1	0	0	0	0	0	0	0	0	0	0	0
2	0	2.4	2.5	3.1	2.9	2.7	1.7	1.9	1.8	.8	1.98
3	0	.7	2.1	2.1	2.0	1.6	.7	.8	.1	.3	1.04
4	.4	1.0	1.1	.7	.9	.5	.7	.3	.4	.1	.61
5	0	.4	.6	1.4	.5	2.5	1.6	.6	1.0	.3	.89
6	.4	2.6	3.2	2.9	2.7	2.8	2.4	2.2	1.6	1.4	2.22
7	.3	3.0	3.5	3.9	0	0	2.9	.4	.4	2.8	1.72
8	.4	.9	0	0	0	0	0	0	1.8	.6	.37
9	1.5	3.0	4.3	3.9	4.0	4.0	3.8	3.8	3.8	3.6	3.57
10	0	0	0	0	0	0	0	0	0	.1	.01
X̄	.30	1.40	1.73	1.80	1.30	1.41	1.38	1.00	1.09	1.00	

Appendix D

Responses per Second over the 20 Extinction Trials for Subjects in Experiment 3b

Group SHORT-5

Subject	Session 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	X
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	1.0	0	.8	0	0	1.1	0	0	0	0	0	0	0	0	0	.5	0	0	0	0	.17
3	0	0	.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	.01
4	0	0	0	0	0	0	0	0	.1	.6	0	.1	.1	.5	.3	0	0	0	0	0	.09
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	.01
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	0	.1	.2	0	0	0	.3	0	0	0	0	0	0	0	0	0	0	0	0	0	.03
10	.1	0	0	0	0	0	0	0	.1	0	0	0	0	0	0	0	0	0	0	0	.01
X	.11	.01	.11	.01	0	.11	.03	0	.02	.06	0	.01	.01	.05	.03	.05	0	0	0	0	

Group LONG-5

Subject	Session 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	X
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	1.1	.9	0	0	0	2.4	0	1.2	2.3	0	.7	1.7	1.5	0	0	.2	0	0	0	0	.60
3	2.5	3.5	3.4	1.8	.9	2.1	.3	.8	1.7	3.5	0	.5	0	0	0	0	0	0	0	0	1.05
4	1.2	1.6	1.1	.6	.2	.2	0	0	0	0	0	0	0	.1	0	0	0	0	0	0	.25
5	0	0	.5	.7	1.4	1.0	1.2	1.6	1.4	1.5	.2	1.0	0	0	1.4	.2	0	0	0	0	.61
6	2.7	0	.9	0	0	.7	.4	1.7	.3	0	0	0	0	0	0	0	0	0	0	0	.34
7	1.0	2.3	3.2	3.5	3.1	2.0	3.0	1.6	2.0	1.1	0	0	0	0	0	0	0	0	0	0	1.14
8	.1	.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	.01
9	.8	.1	.1	0	0	.3	.1	0	0	0	.5	0	0	0	0	0	0	0	0	0	.10
10	1.4	1.3	0	0	0	1.5	.5	0	0	0	0	.8	0	0	0	0	0	0	1.0	.4	.35
X	1.08	.98	.92	.66	.56	1.02	.55	.69	.77	.61	.14	.40	.15	.01	.14	.04	0	0	.10	.04	

Appendix E

Responses per Second over the 10 Sessions for Subjects in Experiment 4

Group SHORT

Subject	Session 1	2	3	4	5	6	7	8	9	10	X̄
1	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0
3	0	3.7	1.9	.4	.2	1.2	1.2	1.4	.9	.9	1.18
4	.1	1.1	0	0	.1	0	0	0	0	0	.13
5	0	.1	0	.4	0	0	0	0	0	0	.05
6	0	0	0	0	0	0	0	0	0	0	0
7	0	2.0	.3	.2	0	.1	.3	.5	.5	.3	.42
8	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	.9	.2	0	0	.1	0	.1	.13
10	0	0	.1	0	0	0	0	0	0	0	.01
X̄	.01	.69	.23	.19	.05	.13	.15	.20	.14	.13	

Group SHORT-10 EXTRA

Subject	Session 1	2	3	4	5	6	7	8	9	10	X̄
1	.4	0	.1	0	.4	.2	.2	.1	0	0	.14
2	0	1.4	1.4	1.2	1.1	1.4	1.2	1.5	1.5	1.2	1.19
3	.1	1.2	0	.1	.3	0	0	0	0	0	.17
4	0	0	0	0	.3	0	0	0	0	0	.03
5	0	.4	.8	.3	.5	.8	1.3	.2	1.1	.7	.61
6	0	.2	.1	.9	.9	.6	.5	.1	1.0	1.2	.55
7	0	.3	1.4	.7	.8	.9	.8	.6	.9	.7	.71
8	.3	.6	1.0	.6	.2	0	.1	0	0	0	.28
9	0	.5	.7	.1	0	0	0	0	0	0	.13
10	0	0	0	0	0	0	.2	0	.1	0	.03
X̄	.08	.46	.55	.39	.45	.39	.43	.25	.46	.38	

Group SHORT-30 EXTRA

Subject	Session 1	2	3	4	5	6	7	8	9	10	X̄
1	0	0	0	0	0	0	0	0	0	0	0
2	.8	2.3	2.3	1.4	1.5	1.7	1.3	2.2	.7	.3	1.45
3	.2	3.9	4.5	6.4	4.0	3.9	3.1	2.4	2.0	2.3	3.27
4	0	0	1.2	1.0	1.2	.4	1.1	1.0	.7	.6	.72
5	.2	.6	.1	1.3	1.7	1.5	.7	1.4	.7	1.1	.93
6	.5	1.1	3.2	2.2	2.0	1.9	1.8	0	1.0	0	1.37
7	0	.5	1.5	1.9	2.0	1.8	2.5	2.6	2.4	2.8	1.80
8	.8	1.8	3.2	1.8	.6	1.2	1.4	2.4	2.5	2.8	1.85
9	0	0	.3	0	2.4	1.3	1.9	1.7	2.9	2.5	1.30
10	.1	1.4	.4	.5	0	.8	4.2	1.4	3.0	4.2	1.60
X̄	.26	1.16	1.67	1.65	1.54	1.45	1.80	1.51	1.59	1.66	

Appendix F

Responses per Second Over the 10 Sessions for Subjects in Experiment 5

Group SHORT

Subject	Session 1	2	3	4	5	6	7	8	9	10	X
1	0	0	0	0	.4	0	0	0	0	0	.04
2	0	0	.1	0	0	.1	.1	.1	0	.2	.06
3	0	0	.7	0	0	.1	.3	0	0	.3	.14
4	0	0	.2	1.4	.2	.6	0	.2	0	0	.26
5	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	.5	0	3.3	0	3.0	2.4	2.4	1.16
7	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0
X	0	0	.10	.19	.06	.41	.04	.33	.24	.29	

Group SHORT-30 EXTRA

Subject	Session 1	2	3	4	5	6	7	8	9	10	X
1	.7	1.7	0	1.3	1.9	2.3	1.9	.8	.4	.9	1.19
2	0	0	0	0	0	0	0	0	0	0	0
3	.1	.3	.2	0	0	0	0	0	.2	.1	.09
4	.8	0	0	.9	2.7	3.4	2.6	2.7	2.0	2.1	1.72
5	.1	1.3	2.4	3.0	3.0	.8	3.7	3.9	3.4	1.1	2.27
6	0	.4	0	0	0	0	0	0	0	0	.04
7	.2	2.0	2.0	2.3	2.2	2.9	2.6	2.3	2.3	2.1	2.09
8	.1	2.1	.7	.2	.2	.9	.4	.7	1.5	.7	.75
9	.8	.7	0	1.8	.5	1.1	.8	.4	.1	.2	.64
10	0	0	0	.2	1.6	2.5	2.3	2.9	2.4	3.0	1.49
X	.28	.85	.53	.97	1.21	1.39	1.43	1.37	1.23	1.02	