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Effects of Differential Temporal Onset of Auditory and Visual Conditional Stimuli upon Consummatory Licking Behavior of Rats in a Discriminative Punishment Situation

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EFFECTS OF DIFFERENTIAL TEMPORAL ONSET OF AUDITORY AND VISUAL CONDITIONAL STIMULI UPON CONSUMMATORY LICKING BEHAVIOR OF RATS IN A DISCRIMINATIVE PUNISHMENT SITUATION

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Punishment is an operant conditioning procedure consisting of the advent of noxious stimulation contingent upon the occurrence of a given response (Hoffman and Fleshler, 1965), which effects are directly opposite to those produced by reinforcement (Michael, 1975). A noxious stimulus has been defined by Catania (1968) as a stimulus that affects pain receptors or that produces tissue damage.

Punishment has been operationally defined as a reduction of the future probability of a specific response as a result of the immediate delivery of a stimulus for that response (Azrin and Holz, 1966). The stimulus arranged as the consequence of the punished response is called a "punisher" or a "punishing stimulus."

The reduction of responses by punishment is immediate if the punishment is at all effective (Azrin, 1956; Azrin, 1959a; Azrin, 1959b; Azrin, 1960a; Dinsmoor, 1952; Estes, 1944). The extent and duration of the initial suppression is a direct function of the intensity of punishment.

The major determinants of the effectiveness of a punisher and of a reinforcer are identical:

1) Characteristics of the event:

The sudden introduction of punishment appears to produce a much larger reduction of the punished responses than if punishment intensity is increased gradually (Azrin, Holz and Hake, 1963; Masserman, 1946; Miller, 1960). The suppression of responses by punishment is

accentuated by the sudden introduction of the punishment stimulus at full intensity. A sudden and substantial increase of the prevailing intensity of the punishing stimulus will also accentuate the degree of suppression produced (Azrin, 1959a; Azrin, 1960a; Holz and Azrin, 1962a).

Estes (1944) found that a punishing stimulus was just as effective in reducing responses when it was non-immediate as when it was delivered immediately after the responses. Hunt and Brady (1955) obtained similar results. In both studies the administration of punishment was restricted to less than one hour. Azrin (1956) obtained similar results during the first hour of punishment. After that time, responses recovered substantially and often completely during non-immediate punishment, whereas responses were indefinitely and often completely reduced during immediate punishment. The contiguity between response and punisher significantly increases the effectiveness of punishment (Camp, Raymond and Church, 1967). It seems that the punishing stimulus should be delivered immediately after the response for enduring suppression to occur. One interpretation of the greater suppression observed in an immediate punishment group than in a delay punishment group is that the subject can associate the punisher with the response more clearly in the former case than in the latter (Church, 1969).

The greater the intensity of the punishing stimulus the greater the reduction of the punished responses (Appel, 1963; Azrin, 1959b; Azrin, 1960a; Azrin, 1960b; Azrin, Holz and Hake, 1963; Brethower and Reynolds, 1962; Dinsmoor, 1952; Estes, 1944).

Once the behavior has become completely suppressed the punished response does not recover for a long period of time, even after the punished contingency has been removed (Appel, 1961; Azrin, 1960a; Masserman, 1946; Storms, Boroczi and Broen, 1962). The likelihood of obtaining such enduring suppression is a function of punishment intensity. At lower intensities this enduring and partly irreversible effect of punishment does not occur. Intense punishment reduces responses to an absolute level of zero and, since punishment is delivered only after a response occurs, the subject does not have an opportunity to detect the absence of punishment unless it responds.

Mild punishment allows a characteristic recovery from punishment while the punishment contingency is still in effect. The degree of recovery during punishment is a function of the intensity of punishment. When the intensity is very high no recovery is observed. There is partial recovery at intermediate intensities. There is recovery of responses, both between and within sessions, at lower intensities. This recovery phenomenon has been found in many punishment situations, like bar-slap with rats (Skinner, 1938), noise with pigeons (Holz and Azrin, 1962b), foot-shock with pigeons (Azrin, 1956), electric shock with monkeys (Hake and Azrin, 1963), and conditioned punishment with pigeons (Hake and Azrin, 1965). When time out was used as punisher recovery did not occur (Holz, Azrin, and Ulrich, 1963).

There is a characteristic increase in behavior following the termination of punishment, sometimes at a rate that temporarily exceeds the unpunished level, with shock intensities up to the point of complete suppression (Azrin, 1960a; Azrin, 1960b). This compensatory increase

occurs after extended punishment, even when the response rate during punishment has recovered to pre-punishment levels (Azrin, 1960b), a phenomenon called "punishment contrast effect." This immediate return of responses has been observed only after continuous punishment. Intermittent punishment leads to a gradual recovery of responses after the punishment has been terminated (Azrin, Holz and Hake, 1963; Estes, 1944).

Continuous punishment produces more suppression than intermittent punishment while the punishment contingency is maintained (Azrin, Holz and Hake, 1963; Estes, 1944; Zimmerman and Ferster, 1963). After the punishment contingency is discontinued, continuous punishment allows more rapid recovery of the responses. At very high intensities the relationship is probably more complicated (Azrin and Holz, 1966).

An increase in the duration of punishment has effects similar to an increase in intensity on the degree of response suppression. As the duration of punishment is increased there is, at first, no suppression, then partial suppression with complete recovery, partial suppression without complete recovery and, finally, total suppression without recovery. Similar effects are found with increases in the intensity of punishment (Church, 1969). The intensity and the duration of the punisher combine to determine the severity of punishment, which is directly related to the magnitude of suppression (Church, 1969).

Punishment experiments involve the interaction of reinforcing and punishing stimuli. Reinforcement is required to establish and maintain some behavior that will subsequently be punished. The extent to which a food-reinforced response resists the effects of punishment depends on the degree of food deprivation. Dinsmoor (1952) found that responses

were reduced by punishment whether the subjects were deprived of food to a large or a slight degree. Under severe deprivation of food the responses were reduced by a smaller proportion. When a long history of variable - interval food reinforcement has been in effect, response rate does not change appreciably as a function of the degree of food deprivation (Ferster and Skinner, 1957). When punishment is added to this long history, the punished response rate appears unusually sensitive to even slight changes in food deprivation (Azrin, 1960a; Azrin, Holz, and Hake, 1963). If the responses have been completely suppressed under low food motivation, an increase in motivation does not appear to be effective in restoring responses (Masserman, 1946; Storms, Boroczi, and Broen, 1962).

2) Relationship between response and event:

A noxious stimulus is dependent upon a response if the probability of the noxious stimulus given a response is not equal to the probability of the noxious stimulus given a non-response. If the two conditional probabilities are equal, the noxious stimulus is independent of the response (Church, 1969). The greater the intensity of noncontingent punishment the greater the response suppression, although the magnitude of suppression of a positive instrumental response is greater if the aversive stimulus is contingent upon the response than if it is not (Azrin, 1956; Camp, Raymond and Church, 1967; Gibbon, 1967).

Two variables potentially relevant to the effectiveness of an aversive stimulus dependent on a response are:

- contiguity: temporal proximity between the response and punishment, and

- contingency: probabilistic dependence of punishment upon the response.

The magnitude of response suppression is a function of the temporal contiguity between responses and punishment, even when the dependence of punishment upon the response is held constant.

3) Presence of a discriminative stimulus:

A discriminative stimulus for punishment increases the effectiveness of the event in the presence of the signal and decreases its effectiveness in the absence of the signal (Church, 1969). Seligman (1968) proposed that a crucial variable controlling behavior in aversive situations is the presence of a reliable predictor of "safe" periods.

When responses are punished in the presence of one stimulus (warning signal) and not in the presence of another stimulus (safe period), there may be a reduction of responses during the warning stimulus but little or no lasting reduction during the safe stimulus (Azrin, 1956; Brethower and Reynolds, 1962; Hunt and Brady, 1955). Some suppression of responses generalize to the safe period initially, but after continued exposure the responses during the safe stimulus recover substantially, usually to the unpunished level (Azrin, 1956; Dinsmoor, 1952; Honig and Slivka, 1964). The responses during the safe period eventually reach a level exceeding the level present before punishment was introduced in the other stimulus (Brethower and Reynolds, 1962), an instance of punishment contrast effect. Hymowitz (1973) found that the least amount of overall response suppression occurred when the signal preceded electric shock 100% of the time, as opposed to intermittent pairings.

A previously neutral stimulus paired with electric shock or other aversive stimuli (unconditional stimulus or UCS) will acquire conditioned punishing properties. Conditioned punishment need not be a transitory phenomenon if the previously neutral stimulus (now conditional stimulus or CS) is occasionally associated with the UCS (Azrin and Holz, 1966). Hake and Azrin (1965) found that the 5-second presentation of the CS after each response severely reduced the rate of responding in a conditioned punishment paradigm with pigeons, in which the pairing of the CS and UCS were continued.

A warning stimulus may be more aversive than the noxious event it signals. The reinforcing effect of terminating the warning stimulus may compete with the punishing effect of the coterminus noxious event. Kamin (1956) found that the termination of the warning stimulus in a shuttle-box avoidance situation maintained responding even when responding did not avoid shocks. Under some conditions rats will respond at higher rates to postpone a warning signal than to postpone a shock (Sidman, 1957; Sidman and Boren, 1957).

It appears appropriate to describe punishment as a process similar to reinforcement in terms of its determinants, but opposite in terms of the direction of behavioral change (Azrin and Holz, 1966).

The magnitude of response suppression produced by a noxious stimulus in a punishment procedure is also a function of prior experience of the subject with that stimulus. There are two effects:

- adaptation: prior exposure to the noxious stimulus decreases the effectiveness of punishment (Karsh, 1963).

- sensitization: prior exposure to the noxious stimulus increases the effectiveness of punishment (Pearl, Walters and Anderson, 1964).

Prior exposure to punishment of gradually increasing duration reduces the effectiveness of subsequent long-duration punishment. Some explanations that have been offered for this phenomenon are sensory adaptation, counter-conditioning, conditioning of competing responses, etc. At this point none of them appear sufficient to explain the mentioned effect (Church, 1969).

The effects of punishment depend in part upon which response in a behavior sequence is punished. A behavior sequence may be defined as a series of responses that lead to reinforcement (Church, 1969). Punishment of the first response in a behavior sequence often produces greater response suppression than punishment of the other responses in the sequence. Two possible explanation for this effect are:
- the distance from punishment to reinforcement is greater, and
- punishment for a particular response is more certain.

Subjects may show an anticipation of punishment when an instrumental response in a behavior sequence is followed by a noxious stimulus. This anticipation may be noted by a reduction in response rate shortly before the punishment is due to occur, particularly when the punished response is clearly discriminable from other responses. The effect of punishment can be specifically restricted to the moment at which the punishment is scheduled. Azrin (1956) found that after extended exposure to a fixed - interval (FI) schedule for shock presentation, the response rate dropped to zero as the moment approached for the scheduled punisher to

be delivered. Gibbon (1967) found marked suppression of interstimulus responding just before stimulus onset in rats responding under a variable - interval 40-seconds (VI 40) schedule for water, receiving trials in which one of two stimuli indicated a period of avoidable or unavoidable shocks. This phenomenon will be discussed at more length later on, under temporal discrimination.

Sometimes, when an instrumental response in a behavior sequence is followed by a noxious event, there is a reaction noted as a pause after punishment. Basically, the shorter the distance from punishment to reinforcement the shorter the pause after punishment, relative to that of an unpunished control group on the equivalent response (Church, 1969).

Discriminative punishment procedures involve the presentation of an aversive event contingent on a given response in the presence of an initially neutral stimulus controlled by the experimenter. The discriminative punishment procedure can be contrasted with the conditioned suppression paradigm, also known as conditioned emotional response procedure (CER), defined operationally by Lyon (1968) as a situation in which a "short duration stimulus is superimposed on an operant performance and terminated independently of the animal's behavior coincidently with a brief unavoidable shock." This procedure was first demonstrated by Estes and Skinner (1941), in which an intermittent schedule of food reinforcement was in effect during the session and the behavior maintained by this schedule was suppressed during a period of tone presentation ending with an unavoidable shock. In the discriminative punishment procedure the noxious stimulus is conditional upon an experimenter - controlled stimulus. The basic difference between both procedures is

that in the discriminative punishment paradigm there is a dependency relationship between a response and a stimulus. This dependence does not exist in the CER procedure.

The amount of response suppression during a portion of a session is usually measured by an inflection or suppression ratio (Blackman, 1977). The most frequently utilized suppression ratios are given below. A represents the response rate during the CS, or stimulus that has been previously paired with shock; and B represents the control response rate, usually the rate during the period immediately prior to CS onset. The suppression ratios are:

a) A/B; where complete response suppression during the CS is indicated by a ratio equal to zero. A ratio of 1.0 indicates no suppression of responding during the CS. A ratio less than 1.0 but greater than zero indicates some suppression during the signal; the smaller the ratio the greater the response suppression (Blackman, 1968; Sidman, Stein, and Brady, 1958).

b) A/A+B); where complete response suppression during the CS is indicated by a ratio equal to zero. A ratio of 0.5 indicates no suppression of responding during the CS, and a ratio between 0.5 and zero indicates some suppression of responding during the signal. The smaller the ratio the greater the suppression (Beauchamp, 1966; Church, 1969; Davis, Memmott, and Hurwitz, 1976; Kamin, 1965; Rescorla, 1968).

c) (B-A)/B; where complete response suppression during the CS is indicated by a ratio equal to 1.0. A ratio equal to zero indicates

no suppression of responding during the CS, and a ratio between zero and 1.0 indicates some suppression of responding during the signal; the greater the ratio the greater the response suppression (Hoffman, 1969a; Hoffman and Fleshler, 1965).

These ratios give a relative measure that may make it easy to compare conditioned suppression of different patterns of operant behavior assuming, arbitrarily, that under constant experimental conditions the warning stimulus (CS) will produce the same relative decrement, independent of the rate of responding at the moment of CS onset (Hoffman, 1969b). There is ample evidence that this assumption is false (Blackman, 1977). Suppression ratios in experiments in which the same pre-shock stimulus is superimposed on different rates of operant behavior are not identical (Blackman, 1966; Blackman, 1967; Blackman, 1968). According to Blackman (1977, p. 348) these findings can be interpreted in two ways:

> "- a suppression ratio may always reflect accurately the strength of a classically conditioned response elicited by the CS. The more severe the disruption of operant behavior as expressed by a suppression ratio the greater the strength of the CR. Different strengths of CR are developed by a uniform procedure when it is superimposed on different operant response rates.
>
> - a standard classical conditioning procedure may always result in a CR of uniform strength. Different suppression ratios describing the effects of a pre-shock stimulus on different patterns of operant behavior may result because this uniform CS interacts differently with these patterns of behavior."

It appears prudent to support inferences based on relative measures, like suppression ratios, with absolute data (Blackman, 1977).

Hunt and Brady (1955) compared the effects of CER and discriminative punishment procedures on lever-pressing by rats under a variable-interval

(VI) schedule of food reinforcement. Both groups showed nearly complete suppression during the stimulus presentation, although other variables could have interferred with the results, like number of shocks, duration of shock, interval between response and aversive stimulus, etc., that differed for both groups.

Beauchamp (unpublished, 1966, in Church, 1969) compared discriminative punishment and CER procedures, exposing his subjects to a VI schedule of reinforcement. The discriminative punishment group received an electric shock at the end of the signal only if they had made one or more responses during the signal. More response suppression during the signal was found for the discriminative punishment group than for the CER group, even though the former group received fewer shocks than the CER group.

Franchel (1972) confirmed Beauchamp's results in a similar experiment. In both studies, variables like response-shock interval and shock duration were equated for both procedures.

In five additional experiments carried out in R. M. Church's laboratory (Church, 1969) comparing discriminative punishment and CER procedures, the magnitude of suppression in the two groups has been roughly comparable. The problem with all these experiments is that the proportion of signals followed by shock has been unequal for both groups.

Orme-Johnson and Yarczower (1974) compared a group of pigeons trained under a discriminative punishment procedure with a yoked group trained under CER procedure. In experiment I, the presentation of the CS alone, contingent on key-pecking, reduced response rates (conditioned punishment effect) in the CER group but not in the discriminative punishment group.

In experiment III, the discriminative punishment group did not show conditioned punishment effect even when positive reinforcers were unavailable during the discriminative punishment schedule. The CS in the CER group acquired the ability to punish behavior, while it did not acquire punishing properties in the discriminative punishment group.

According to Hoffman (1965), comparisons between relative effects of discriminative punishment and CER procedures must be very tenuous. If shocks are too intense or massed, the behavior is obliterated. Noxious stimuli intense enough to modify behavior in escape and avoidance procedures have been observed to produce little or temporary effects within CER and punishment paradigms. When the intensity of the noxious stimulus is between these extremes, the warning signal suppresses ongoing behavior. The two procedures yield distinctive patterns of behavior during the presentation of the warning signal. In punishment procedures there is an abrupt cessation of responding, while in CER procedure there is either no responding or responding at low rates. This procedure tends to suppress baseline responding, while discriminative punishment procedure does not. The effects of discriminative punishment extinguish faster than those of CER procedure, even when number and temporal distribution of shocks are equated for the two procedures.

Sidman (1960) has noted that, in principle, any selected behavior would follow the same general laws. It is reasonable to assume that punishment of specific classes of behavior, such as consummatory and species-specific behaviors, should be governed by the same rules found to govern punishment of instrumental behaviors, such as lever-press and key-peck.

Consummatory operants are presumably those species-specific behaviors that are involved in the consumption of food or water. Church (1969) has noted that consummatory responses are those located at the end of a chain of operants, closer to the reinforcer than earlier links like bar-pressing or key-pecking.

Solomon (1964) initially thought that a consummatory operant, like licking or chewing behaviors, should be highly resistant to suppression by punishment due to its biological significance. However, he concluded that this class of behavior is far more sensitive to the suppressive effects of punishment than operant behavior in general.

There is clear evidence that consummatory behaviors can be suppressed by a response-contingent aversive event, but it is difficult to directly compare these studies with experiments on punishment of instrumental behaviors due to procedural differences.

Masserman (1943) and Lichtenstein (1950) reported permanent suppression of eating in cats and dogs by moderate electric shock or air blasts delivered when the animal was eating. In some cases the suppression was so extreme as to make the animal starve to death.

Beach, Canovitz, Steinberg, and Goldstein (1956) found severe suppression of sexual behavior in male rats by mild punishment. Leaf and Muller (1965) found that marked suppression of licking behavior was produced by intense electric shock and that the degree of suppression was a monotonic function of the shock intensity. Deprivation levels did not differentially affect the amount of suppression.

Quinsey (1971) found that high intensities of electric shock produced consistent licking suppression, while low intensities produced minimal suppression.

Solomon, Turner, and Lessac (1968) found that eating a highly preferred food was completely suppressed in food-deprived dogs when eating was punished by swats with a newspaper. The dogs were allowed to eat a less preferred food as an alternative behavior and this availability may have affected the degree of suppression obtained, since the existence of an alternative response leads to more severe reduction of a punished response (Azrin and Holz, 1966).

Bond, Blackman, and Scruton (1973) found that schedule-induced licking can be suppressed by procedures that suppress operant behavior.

Some studies have directly compared the suppression caused by punishment on both instrumental and consummatory responses:

Church (1969) found that punishment of the instrumental response produced greater suppression than punishment of the consummatory response. DeCosta and Ayres (1971) reported that lever-pressing was consistently more suppressed than licking behavior in a study utilizing a CER procedure.

Contrary to these results, Bertsch (1972) found that punishment of the consummatory response produced greater suppression than punishment of the instrumental response, both during and after punishment.

Feirstein and Miller (1963) found that whether consummatory benavior was more or less suppressed than instrumental behavior depended upon the intensity and frequency of the punishment event.

Myer (1973) found similar suppression of responding when subjects lever-pressing for water were punished with electric shock, either after each press or after drinking. Punishment increased the latency of pressing and reduced the number of sequences initiated, rather than

selectively suppressing the punished behavior for both treatments.

In summary, there are empirical data supporting Solomon's position that consummatory behaviors are more sensitive to the suppressive effects of punishment than instrumental behaviors, as well as data showing the opposite results, and even data showing no difference in the degree of suppression by punishment of instrumental and consummatory responses.

Angerami (1976, unpublished Master's thesis) utilized a discriminative punishment procedure to assess the effects of electric shock intensity in consummatory licking behavior. Rats were trained to lick water from a metal tube during 10-minute sessions. Once per session a tone was presented for 10 seconds and any licks during that stimulus presentation resulted in shock delivered immediately following the stimulus offset. Shock intensity was varied between the groups. In general, Angerami found that the degree of response suppression was a function of shock intensity. These findings are in agreement with the literature on punishment of other classes of operant behavior, such as lever-pressing and key-pecking. The functional relationship between intensity of the aversive event and the degree of suppression is the same in both cases. During recovery sessions Angerami interspersed two sessions during which the subjects were continuously exposed to the tone: the stimulus was turned on at the start of the session and remained on for the whole 10 minutes. There was no suppression of the average session lick rate. A return to baseline conditions resulted in response suppression to the 10-second tone. These findings suggested that the subjects were probably responding to a stimulus complex that included the onset of the tone and the amount of time elapsed since the beginning of the session.

Skinner (1938) initially spoke of the establishment of a temporal discrimination as the differential reaction of an organism to the stimulus at some point and to the stimulus at a certain other point that has been coincidentally related to a second event. Skinner exemplified such discrimination with the performance of rats under a fixed-interval (FI) schedule of food reinforcement. After the delivery of a food pellet rats stopped responding and after some time they began to respond again, as time to the next reinforcer availability approached. This step-like responding was explained by Skinner as due to the fact that responses immediately following food delivery were never reinforced, while responses after the appropriate period of time following food delivery had elapsed were reinforced.

Ferster and Skinner (1957) considered the temporal discrimination evident in FI schedules of food reinforcement, in which the longer the time since the last response the more likely the next response is going to be reinforced. This FI schedule generates a pattern of responding in which a pause follows each food delivery, after which the rate accelerates to a usually moderate value.

Sidman (1954) found evidence of time discrimination in a free operant non-discriminated avoidance situation in the fact that inter-response times (IRT's) of intermediate values occurred more frequently in a cumulative frequency distribution of IRT's than expected assuming random responding. Such discrimination usually occurred after prolonged exposure to the procedure. Five other cumulative frequency distributions presented did not show evidence of temporal discrimination.

Anger (1963) performed an IRT-per-opportunity (IRT/OP) analysis on the five distributions reported by Sidman (1954) as not showing evidence of temporal discrimination. In four of the five cases the IRT/OP curve rose at long IRT's, indicating a temporal discrimination. Anger prefers IRT/OP analysis because of its possibly greater sensitivity in detecting temporal discriminations.

Morse, Mead, and Kelleher (1967), and McKearney (1968), demonstrated that FI schedules of electric shock presentation maintained responding and that the response pattern resembled those reported by Ferster and Skinner (1957). Morse et al (1967) reported that shock delivery usually initiated a brief high rate of responding and further responding occurred just before the next shock was delivered, in subjects with continuous exposure to fixed-time (FT) and FI shock schedules. McKearney (1968) found that response rates were low immediately after each shock delivered in a FI schedule, followed by a gradual increase in responding until the next shock was presented.

Hutchinson, Renfrew, and Young (1971) reported that with continued exposure to FT shock presentation, lever-pressing and chain-pulling responses gradually increased as shock time approached.

The present experiment was designed to replicate Angerami's results during the continuous tone-on condition and to attempt an analysis of these findings by assessing the effects on licking behavior of training with certain fixed CS-onset values, and the effects of testing with different onset times. The effects of visual and auditory stimuli in a discriminative punishment situation were also assessed. The discriminative punishment procedure was the same used by Angerami, with

a 10-minute session and one CS presentation per session. The intensity of electric shock was the same for all groups.

METHOD

Subjects

Twelve experimentally naive male albino rats from The Upjohn Company colony in Kalamazoo, Michigan, served as subjects. They were approximately 80 days old at the beginning of water deprivation, individually housed in a constantly-illuminated, environmentally-controlled room, with Purina laboratory rat chow freely available.

Before the start of the experiment the subjects were placed on a water deprivation schedule until they reached and maintained 80% of their ad-libitum weight.

Apparatus

Four experimental chambers were used, each of which was 12.5 cm wide, 20.5 cm long, and 15.5 cm high, housed in a larger plywood sound-attenuated enclosure. The ceiling and walls were made of plexiglas and the interior surface of the walls was covered with a sheet of aluminum. The clear plexiglas ceiling had small holes for ventilation. The floor was comprised of four tubular aluminum grids, each 1.6 cm in diameter, spaced 3.3 cm apart center-to-center and parallel to the side walls, through which shocks were delivered. A standard rat lever (lehigh Valley Electronics, BRS/LVE, Beltsville, Maryland, model 29A) was located on the front wall with its center 3.5 cm from the left side wall, 10.0 cm above the grid floor, and protruding 2.5 cm into the

chamber. The lever remained inoperative throughout the experiment. Located 10.0 cm from the left side wall and 2.5 cm above the center of the grid floor was a 3.0 cm round hole allowing access to a liquid dipper (Lehigh Valley Electronics, BRS/LVE, Beltsville, Maryland, model 114-02) with its cup 1.5 cm away from the front wall. The dipper was up and dry throughout the experiment. An auditory stimulus was provided by a Sonalert tone generator (Mallory, model SC628, 2900 Hz), mounted on the outside of the left side wall, 7.5 cm from the front wall and 10.5 cm above the grid floor in a 3.0 cm round role protected with a wire mesh. A stimulus light (Chicago Miniature, #1819, 0.96 W) covered with a clear red lens (Dialco) was also mounted on the outside of the left side wall, 7.5 cm from the front wall and 6.5 cm above the grid floor. A 3.0 cm round hole made only in the aluminum sheet covering the plexiglas wall made the light visible to the animal. A 0.96 W bulb (Chicago Miniature, #1819) covered with a white lens (Dialco) was mounted away from the chamber at the rear of the enclosure and served as a diffuse houselight. Masking noise produced by a Grason-Stadler white-noise generator (model 1048) was delivered to a 10.2 cm, 8 ohm speaker (Allied Electronics), mounted at the rear of the enclosure directly behind the left side wall of the chamber. Additional masking noise was produced by a fan providing ventilation.

Shocks were delivered by a 325-volt step-up transformer for 0.24 second at 2.0 mA (60 Hz) across four successive grids. The aluminum walls and lever-cover were electrically grounded and served as one part of the shock circuit.

On the wall opposite the lever, 9.0 cm from the left side wall and 4.0 cm above the grid floor (center-to-center) was a 1.0 cm round hole through which the subject could gain access to a metal drinking tube resting on the plexiglas portion of the wall. The opening at the end of the tube, 3.0 mm in diameter, could be reached only by the animal's tongue. A water bottle was held outside the chamber by a metal clamp mounted on the wall of the sound-attenuated cabinet. The bottle was connected to the licking tube through a piece of rubber hose. The lick transducer was a lickometer assembled from an EICO 1800 electronic kit, produced by EICO, New York, New York.

All programming and data recording were done by means of a PDP 8/e computer manufactured by Digital Equipment Corporation of Maynard, Massachusetts, located in a nearby room. The computer was connected to the chambers via a digital logic and relay interface supplied by State Systems, Incorporated, of Kalamazoo, Michigan, and utilized a time-sharing system that allows programming and data analysis to be conducted while the experiment is in progress (Snapper, 1976; Snapper, Stephens, Cobez, and van Haaren, 1976). The state tables used in this study, written in the SKED language (Snapper, Stephens, and Lee, 1974; Snapper, Stephens, Cobez, and van Haaren, 1976), are on file with the SKED Users' Group (Western Michigan University, Kalamazoo, Michigan) and will be distributed upon request.

Procedure

The subjects were maintained in free food and free water for four weeks to allow for acclimatation to the new environment and to obtain

weight records. Then water deprivation was started consisting of a daily period, ranging from three to fifteen minutes, during which water was available in the home cage. Subjects were weighed every day before the watering period, which was adjusted accordingly to weight loss. Once the rats reached 80% of their free-feeding weight (the average of the last three days of the acclimatation period), they were randomly assigned to three groups of four subjects each and, beginning with the initial training session and throughout the study, they only had access to water during the daily sessions.

Experimental sessions were conducted seven days a week, were 10 minutes long, and drinking was non-contingent upon any direct manipulation. A neutral stimulus was presented once every session for 10 seconds, except during testing sessions in which the length of the stimulus presentation varied. All subjects were exposed to three different training procedures:

1- Baseline: the subjects had free access to water for 10 minutes in the experimental chamber. The first response (lick) started the session, turning on the background stimuli. The neutral stimulus onset occurred at some fixed point during the session, and remained on for 10 seconds. The subject's behavior had no effect, except for starting the session.

2- Discriminative punishment: these sessions were similar to those in the Baseline procedure with the exception that a 2 mA electric shock was delivered immediately after the neutral stimulus offset if the subject had emitted one or more responses during the 10-second stimulus presentation. The neutral stimulus was thus associated with shock delivery and will be referred to as conditional stimulus (CS). If the

subject did not respond during the CS presentation, the electric shock was not delivered.

3- Recovery: the conditions during these sessions were the same as under the Baseline procedure.

In addition, several testing procedures were interspersed in training sessions and will be described in detail for each group later on. They all consisted of 10-minute sessions in which the same training CS was turned on at a different time, remaining on for the rest of the session. The animal's behavior had no effect during test sessions and no shocks were delivered.

The groups were formed on the basis of the following different training conditions or independent variables:

- nature of the stimulus: either visual or auditory, and
- time of stimulus onset during training: either at the middle of the session or at the beginning of it.

In addition, all subjects were tested on a third independent variable:

- time of stimulus onset during testing: at the beginning of the session, at the middle, and at the end of the session.

Responses were recorded in 60 10-second bins. Several dependent variables were computed daily for each subject:

1- Pre-CS response rate: mean response rate (in licks per second) during the 10 seconds immediately prior to CS onset.

2- CS response rate: mean response rate during the 10 seconds of stimulus presentation.

3- Post-CS response rate: mean response rate during the 10 seconds immediately following CS offset.

4- Mean session response rate: average response rate for the whole session (600 seconds).

5- Suppression ratio: the amount of response suppression during some period in the session was computed by the formula A/B, where A represents the response rate during that given period and B represents the mean session response rate. A subject responding during the period in question at the same rate maintained, on the average, during the session would have a ratio of 1.0; a subject not responding at all during that period would have a ratio of zero. The lower the ratio the greater the response suppression.

During discriminative punishment conditions the percent of shocks received by the subject was also calculated.

The number of sessions and the order in which procedures were presented for each group are shown in Table I.

Figure 1 shows the basic state diagram for the discriminative punishment procedure used for all the groups. State set one (S.S.1,) is initialized by the first licking response (R3) which turns on the background stimuli (A), starting the session. After a fixed time has elapsed from the beginning of the session (t1), a stimulus (B) is presented and, if the subject makes no responses during the following 10 seconds, the stimulus is turned off (C) and the session continues for a fixed amount of time (t2), after which all stimuli are turned off. Any responses made during the stimulus presentation (B) generate a pulse (Z5) that sets up the shock delivery in S.S.2, without affecting the

stimulus duration. State set two (S.S.2,) controls the delivery of shock. The pulse generated by a response during the stimulus presentation (B) sets up the delivery of a 0.24-second shock (S-) to occur coincidentally with the offset of the stimulus (C).

The basic state diagram for baseline and recovery procedures is the same, consisting only of S.S.1 for the punishment procedure (Fig. 1).

Table II shows the stimuli conditions and time values for all training procedures for each group.

Figure 2 shows the basic state diagrams for the different test procedures used for all groups. For Test 1 the CS was turned on with the first lick, remaining on for the whole session. With the exception of Group 1B, the houselight was also turned on with the first lick and remained on until the end of the session for all the testing procedures. For Test 2 the first lick initialized the session, turning on the background stimuli (A). After 10 seconds the CS was presented, reamining on for the rest of the session. For Test 3 the first lick initialized the session, and after 580 seconds the CS was presented, ramining on for the last 20 seconds of the session. For Test 4 the first lick initialized the session, turning on the CS that remained on for the whole session, except for the 10 seconds in the middle when the CS was turned off.

A detailed description of the procedures used for each group follows:

Group 1:

Phase A: four subjects were trained for this phase with a 2900 Hz tone turned on for 10 seconds as CS at the middle of the session. The

Table I: Sequence of procedures and number of sessions in each condition for each group.

TABLE 1

SEQUENCE OF PROCEDURES AND NUMBER OF SESSIONS IN EACH CONDITION FOR EACH GROUP.

PROCEDURE	NUMBER OF SESSIONS			
	Group 1A	Group 1B	Group 2	Group 3
Baseline	14	14	13	13
Punishment I	14	14	14	14
Recovery I	14	8	9	9
Punishment II	5	6	8	8
Test 1	2	2	2	2
Recovery II	5	2	2	2
Punishment III	3	3	3	3
Test 2	2	2	2	2
Recovery III	4	2	2	2
Punishment IV	3	4	3	3
Test 3	2	2	2	2
Recovery IV	3	2	2	2
Punishment V	3	3	3	3
Test 4	2	2	2	2
Recovery V	1	1	1	1

Figure 1: Basic state diagram for the discriminative punishment procedure used for all groups.

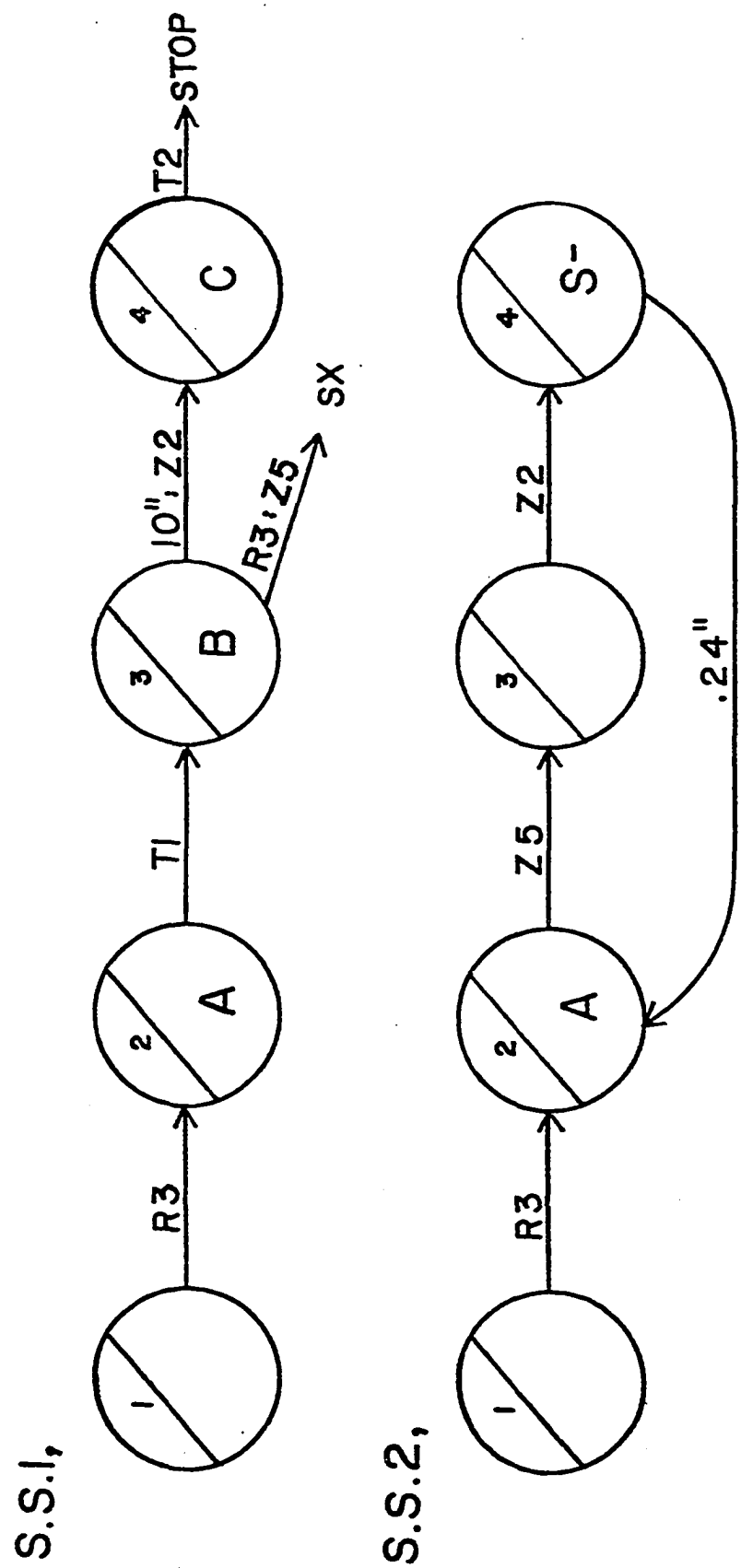


Table II: Stimuli conditions and time values for training procedures for each group. See Fig. 1 for a description of the procedures.

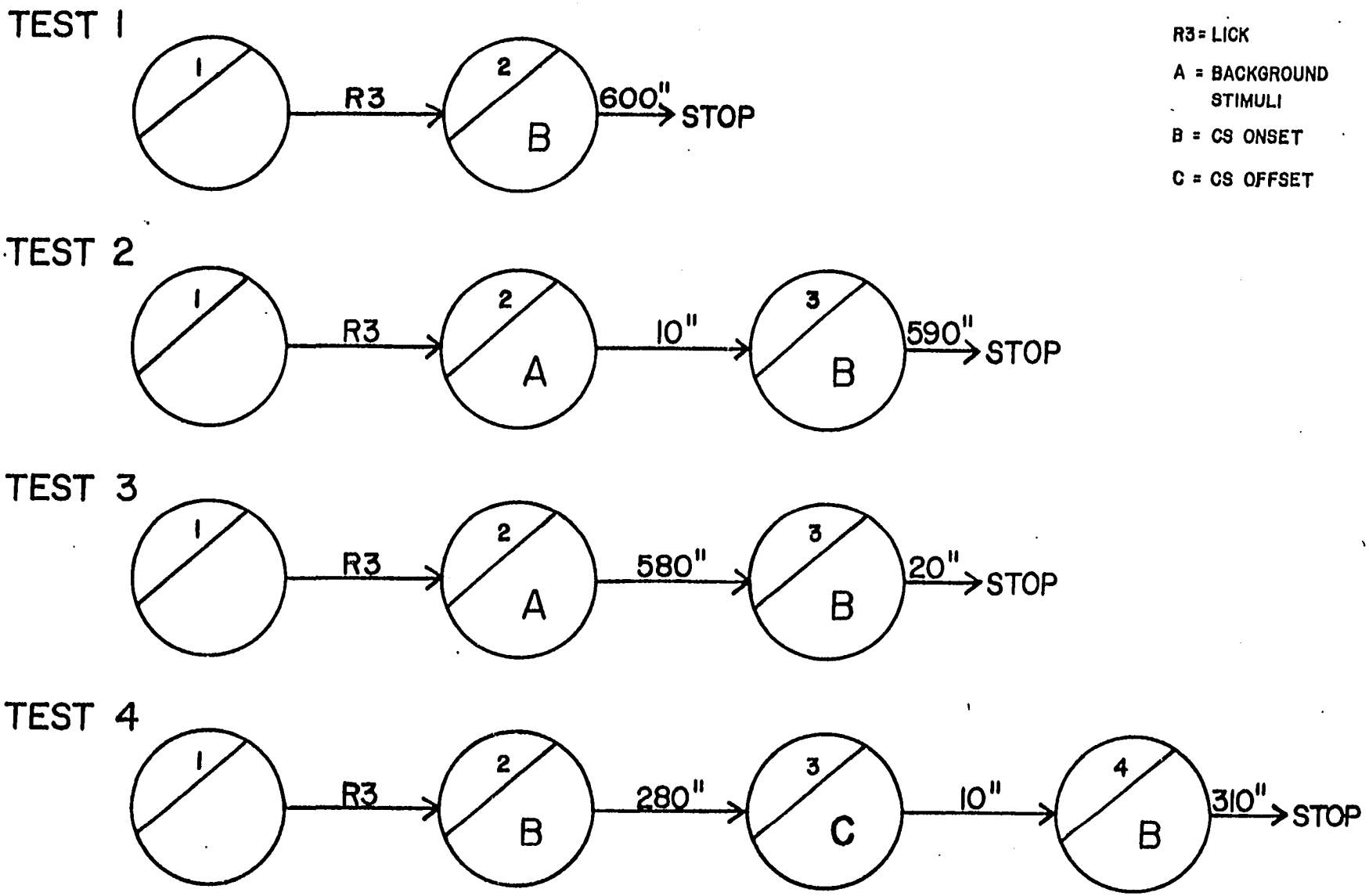
TABLE II

STIMULI CONDITIONS AND TIME VALUES FOR TRAINING PROCEDURES FOR EACH GROUP.

	Group 1A	Group 1B	Group 2	Group 3
A	Houselight on Tone off	Houselight on Tone off	Houselight on Tone off	Houselight on Tone on
B	Tone on	.4" houselight off, .4" houselight on	Tone on	Tone off
C	Tone off	Houselight on	Tone off	Tone on
T1	280 seconds	280 seconds	10 seconds	280 seconds
T2	310 seconds	310 seconds	580 seconds	310 seconds

A= Background stimuli for session
B= CS onset
C= CS offset
T1= Time from start of session to CS onset
T2= Time from CS offset to end of session

Figure 2: Basic state diagrams for the different test procedures used for all groups.



background stimuli (A, in Fig. 1) for this group consisted of houselight on, tone off; the stimulus onset (B) was tone on; stimulus offset (C) was tone off. The time from the start of the session to stimulus onset (t1) was 280 seconds; the time from stimulus offset to the end of the session (t2) was 310 seconds.

Test 1 (see Fig. 2) consisted of the tone being turned on for the whole session. For Test 2 the tone was turned on after the first 10 seconds and remained on for the rest of the session. For Test 3 the tone was turned on for the last 20 seconds of the sessions. For Test 4 the tone was on for the whole session, being turned off for 10 seconds at the 280th second of the session.

Phase B: the same four subjects from phase A were then trained with the houselight flickering on and off every 0.4 second for 10 seconds as the CS. The trial was presented at the middle of the session, as before. The background stimuli (A, in Fig. 1) for this group were houselight on, tone off; the CS onset (B) was the houselight flickering on and off; CS offset (C) was the houselight continuously on. The time from the start of the session to CS onset (t1) was 280 seconds; the time from CS offset to the end of the session (t2) was 310 seconds.

Test 1 (see Fig. 2) consisted of the houselight flickering on and off for the whole session. During Test 2 the houselight was on for the first 10 seconds and then started to flicker for the remainder of the session. During Test 3 the houselight was flickering for the last 20 seconds of the session, being continuously on for the first 580 seconds. During Test 4 the houselight was flickering for the

whole session, being continuously on at the middle of the session for 10 seconds, after which it started to flicker again for the rest of the session.

Group 2:

Four different subjects were trained with a 2900 Hz tone as the CS and the trial was presented after the first 10 seconds of the session. The background stimuli (A, in Fig. 1) for this group were houselight on, tone off; the CS onset (B) was tone on; CS offset (C) was tone off. The time from the start of the session to CS onset (t1) was 10 seconds; the time from CS offset to the end of the session (t2) was 580 seconds.

The test procedures (see Fig. 2) utilized for this group were exactly the same as those used for group 1A.

Group 3:

Four new subjects were trained with a CS consisting of turning off a 2900 Hz tone for 10 seconds. The trial was presented at the middle of the session. The background stimuli (A, in Fig. 1) for this group were houselight on, tone on; the CS onset (B) was tone off; CS offset (C) was tone on. The time from the start of the session to the CS onset (t1) was 280 seconds; the time from CS offset to the end of the session (t2) was 310 seconds.

Test 1 (see Fig. 2) consisted of the tone being off during the whole session. For Test 2 the tone was on for the first 10 seconds and then it was turned off for the rest of the session. For Test 3

the tone was on for the first 580 seconds of the session and then it was turned off for the remaining 20 seconds. For Test 4 the tone was off during the whole session, being turned on in the middle for 10 seconds.

RESULTS

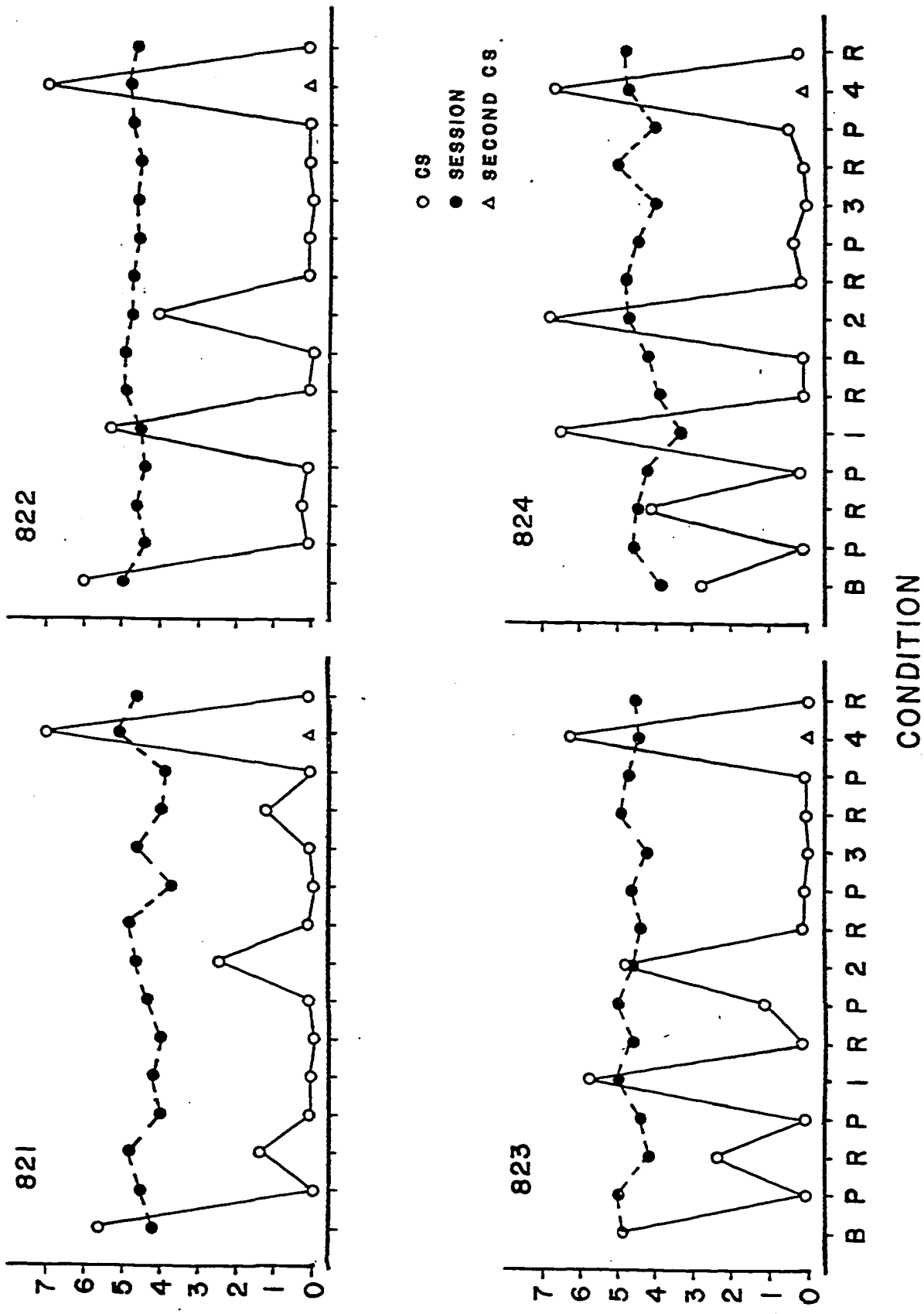
For all the figures in this section, CS response rates (open circles) indicate the average licking rate, in responses per second, during the 10 seconds of the CS presentation for training conditions, and the average licking rate during the first 10 seconds of the CS for test conditions. Second CS response rates (triangles) indicate the average response rate during the first 10 seconds of the re-initiation of the CS during Test 4. Session response rates (filled circles) indicate average response rates during the whole session.

Suppression ratios were calculated by dividing the 10-second response rate during the period in question (either before, during, or after CS presentation) by the average response rate during the whole session. A ratio of 1.0 indicates no suppression of licks during the 10-second period, while a ratio of zero indicates complete suppression of responding during that period.

Group 1:

Figure 3 shows the mean response rate, in responses per second, for all subjects in group 1, phase A, for each condition. Baseline data shows that CS response rates were higher or equal to average session rates for three of the four subjects. Overall response rates were very stable across conditions for all subjects and, except for R824 during Test 1, there was no overall suppression of responding

Figure 3: Mean response rates (in licks per second) as a function of conditions, for each subject in group 1A. B indicates baseline procedure; P indicates punishment; and R indicates recovery. Test procedures are indicated by the numbers 1 to 4. Data points for baseline, punishment, and first recovery conditions are averages of the last two days in those conditions. Data points for recovery conditions after each test are averages of the first two days in that condition. Data points for test procedures indicate response rates in the first day of the condition.



during test conditions. The first punishment procedure produced almost complete suppression of responding during CS presentation in all subjects, and recovery was variable across rats. For each subject, the amount of recovery following the second punishment condition decreased, generally, to a very low level. During Test 1, reponse rates during the first 10 seconds of the CS (0 to 10 seconds from start of session) were higher than the mean session rates for three of four subjects. For the subject whose rate was suppressed during the CS to punishment levels, the mean session rate was not depressed. During Test 2 rates in the first 10 seconds of the CS (10 to 20 seconds from start of session) were higher than the average for that session in two of the subjects, while rates were lower than the overall but above the CS rates during training conditions for the other two subjects. R824 had its highest response rate during this test. The data for Test 3 showed almost complete suppression of responding during the first 10 seconds of the CS (580 to 590 seconds from start of session) for all subjects. Test 4 data showed very high response rates during the first 10 seconds of the CS (0 to 10 seconds from start of session) for all subjects. For three of the four subjects their highest response rates occurred during this first presentation of the CS, which onset occurred at the same time as in Test 1. Two of the subjects showed little discrepancy between the response rates for the two conditions, another rat showed some discrepancy, and the fourth subject showed a dramatic difference between the two conditions, with response rates during Test 4 being higher in all cases. After 280 seconds had elapsed from the start of the session the CS was turned off for 10

seconds and then presented again. Responding during the first 10 seconds of the second CS presentation (290 to 300 seconds from the start of session) was almost completely suppressed for all subjects. This CS onset occurred only 10 seconds after the usual CS onset time during training conditions, and there is no discrepancy between the CS response rates during this part of the test and CS rates during training conditions for any of the subjects.

Table III shows the absolute number of licks recorded in 10-second bins for the first 40 seconds of the session, for the 50 seconds in the middle, and for the last 40 seconds of the session. Data are presented for each subject for the first day of each test condition and for the first day of recovery procedures after test days. The last discriminative punishment session before Test 1 is also shown. This group was trained with the CS presented during bin 29. Underlined numbers indicate the first 10 seconds of the CS presentation for each session. During training sessions the CS in bin 29 markedly reduced licking for all subjects. The average response rate, in licks per second, during each bin is calculated by dividing the number of licks in the bin by ten. Generally, the CS response rate in the first recovery condition after each test is quite low, between .00 and .02 licks per second. In most cases, there was no marked decrease in responding during the 20 seconds preceding the onset of the CS (bins 27 and 28), while responding during the 10 seconds after CS offset (bin 30) did not reach the levels found before CS presentation. Recovery of responding to this pre-CS level was usually found after the 11th second from CS offset (bin 31). Responding during the first

Table III: Number of licks in 10-second bins at beginning, middle, and end of session for the last day of discriminative punishment condition before Test 1, for the first day of each test condition, and for the first day of recovery procedure after each test, for subjects in group 1A.

TABLE III

NUMBER OF LICKS IN 10-SECOND BINS AT BEGINNING, MIDDLE, AND END OF SESSION FOR SUBJECTS IN GROUP 1A.

CONDITION	BIN NUMBER											
	1	2	3	4...27	28	29	30	31...57	58	59	60	
821												
P	56	35	66	63	66	65	1	21	67	0	40	24	25
T1	1	0	19	65	61	62	60	61	61	0	0	32	68
R	66	62	61	59	61	61	0	16	64	9	0	0	4
T2	69	24	68	66	56	0	29	62	60	0	1	67	0
R	70	67	68	66	63	62	1	36	65	0	0	56	41
T3	65	64	63	62	43	53	41	63	49	67	61	1	0
R	72	70	67	67	4	65	23	65	67	13	48	48	65
T4	70	66	67	64	0	62	63	1	53	4	0	0	0
R	67	65	64	62	62	62	1	22	65	67	50	30	46
822												
P	68	64	62	62	60	46	0	13	67	66	65	26	10
T1	53	60	60	60	57	30	0	35	63	62	62	49	2
R	68	65	63	65	63	63	1	37	64	0	37	68	66
T2	65	40	65	64	3	0	28	65	62	65	5	0	0
R	70	66	64	63	61	61	1	26	65	31	2	0	0
T3	68	63	62	62	41	0	15	63	62	41	27	0	0
R	70	65	64	63	45	17	0	51	62	0	38	23	0
T4	70	65	64	62	61	59	49	1	45	62	62	35	0
R	70	66	54	64	4	54	1	38	65	68	21	16	23
823												
P	70	66	65	60	49	0	0	34	42	0	0	42	40
T1	57	65	64	62	64	63	61	59	61	30	40	64	62
R	66	66	62	52	62	36	1	54	66	64	24	62	38
T2	72	48	65	66	65	50	0	44	46	54	17	65	0
R	74	73	60	58	47	62	0	29	68	28	27	25	20
T3	64	65	53	62	63	63	8	45	49	0	7	0	0
R	66	66	69	61	65	64	2	18	68	53	0	0	0
T4	63	67	65	57	64	64	61	0	0	0	0	0	0
R	71	64	60	67	0	0	0	31	68	65	36	55	30
824												
P	70	56	53	4	57	52	1	42	57	57	56	37	49
T1	65	52	28	10	10	0	59	45	58	58	58	59	58
R	65	64	54	11	24	49	0	0	22	60	55	57	55
T2	72	68	63	36	59	57	46	57	62	14	3	64	0
R	74	67	39	45	56	54	0	57	60	58	60	52	63
T3	65	63	47	35	55	17	0	33	60	56	36	0	10
R	70	54	39	61	58	57	1	24	63	63	59	58	55
T4	67	61	55	48	49	55	41	1	34	10	55	53	57
R	68	61	25	3	49	59	2	45	61	59	57	58	57

40 seconds of the session was very stable within subjects and at high rates. R824 showed a consistent decrease in licks around bins 3 and 4. Responding during the last 40 seconds of the session was variable, but usually at lower levels than earlier in the session. Test data show the amount of reduction in responding, if any, during each bin. In some cases there was a marked decrease in responding during bins 27, 28, 29 and/or 30, the usual place of CS onset, for all subjects. R822 showed this effect for three of the four test procedures.

Table IV shows the mean pre-CS, CS, and post-CS suppression ratios for each condition for subjects in group 1A. Baseline, punishment, and first block of recovery conditions are averages of the last two sessions in each procedure. All other recovery conditions are averages of the first two sessions in that procedure. Test conditions are data for the first day in each procedure. In most cases there was more suppression after the CS offset than before its presentation. CS ratios were very close to zero, indicating a marked suppression of responding during the CS, except for baseline condition and some test days.

Figure 4 shows the mean response rates for all subjects in group 1, phase B, for each condition. Baseline CS response rates were higher or equal to overall response rates for three of the four subjects. Session response rates were stable across conditions for three of the subjects, and there was some variability for the other subject. R821 showed a decrease in overall response rate during Test 4, R822 showed a decrease in overall rate during Test 3, and the overall session rates for R824 and R822 were slightly lower than average during Test 1. There

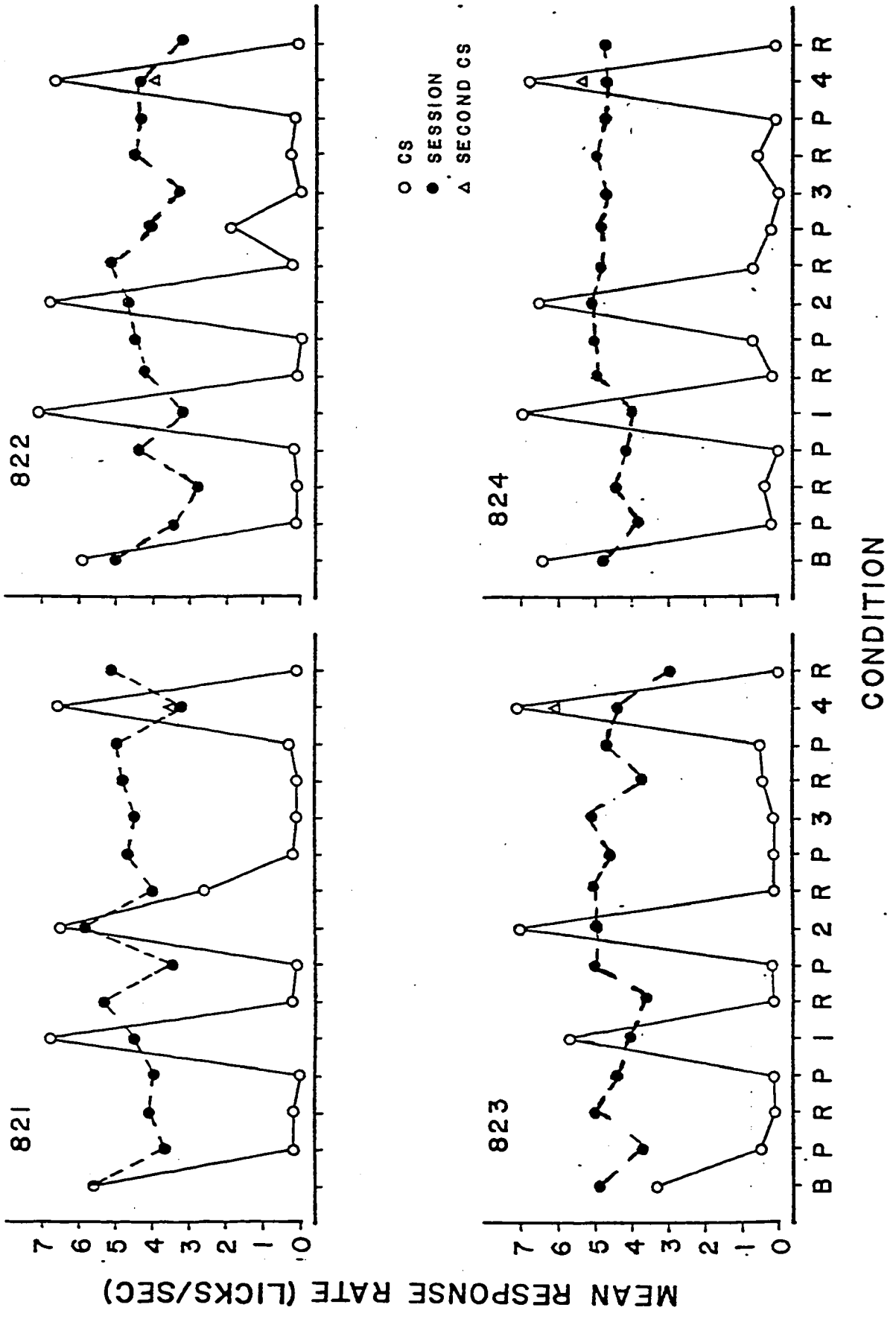
Table IV: Mean pre-CS, CS, and post-CS suppression ratios for each condition for subjects in group 1A. Baseline, punishment, and first block of recovery conditions are averages of the last two sessions in each procedure. All other recovery conditions are averages of the first two sessions in that procedure. Test conditions are data for the first day in each procedure.

TABLE IV

MEAN PRE-CS, CS, AND POST-CS SUPPRESSION RATIOS FOR EACH CONDITION FOR SUBJECTS IN GROUP 1A.

SUBJECT	821			822			823			824		
CONDITION	PRE	CS	POST	PRE	CS	POST	PRE	CS	POST	PRE	CS	POST
B	1.26	1.33	1.21	1.16	1.20	.86	1.19	1.00	.09	.76	.74	.61
P	.57	.00	.11	1.15	.02	.68	.98	.02	.92	1.21	.02	.87
R	.21	.29	.64	1.32	.07	.87	.89	.57	1.29	1.10	.91	1.20
P	1.08	.03	.64	1.23	.02	.27	.69	.02	.97	1.29	.05	1.12
T1	-	.02	-	-	1.18	-	-	1.14	-	-	1.97	-
R	1.55	.00	.30	1.21	.02	.42	.39	.02	1.24	1.39	.03	.28
P	.56	.02	.47	.90	.00	.91	1.28	.22	1.04	1.38	.02	.67
T2	1.50	.52	-	1.38	.85	-	1.57	1.04	-	1.53	1.45	-
R	1.29	.02	.61	1.22	.02	.72	.74	.02	.60	1.12	.04	1.14
P	1.03	.00	.23	.86	.02	.53	1.37	.02	1.01	1.29	.09	.93
T3	1.33	.02	-	.59	.00	-	.17	.00	-	.90	.00	-
R	1.41	.30	.81	.60	.02	.88	1.02	.02	.56	1.17	.02	.41
P	.56	.03	.41	1.26	.02	.26	1.36	.02	1.21	1.15	.13	.58
T4 (1st CS)	-	1.37	1.24	-	1.46	1.02	-	1.43	1.39	-	1.43	.87
(2nd CS)	1.24	.02	-	1.02	.02	-	1.39	.00	-	.87	.02	-
R	1.35	.02	.48	1.17	.02	.83	.00	.00	.69	1.23	.04	.94

Figure 4: Mean response rates (in licks per second) as a function of conditions, for each subject in group 1B. B indicates baseline procedure; P indicates punishment; and R indicates recovery. Test procedures are indicated by the numbers 1 to 4. Data points for baseline, punishment, and first recovery conditions are averages of the last two days in those conditions. Data points for recovery conditions after each test are averages of the first two days in that condition. Data points for test procedures indicate response rates in the first day of the condition.



was no overall suppression during the other test procedures. The first punishment procedure produced almost complete suppression of responding during CS presentation in all subjects, and little recovery occurred after this condition. Recovery after the second punishment condition was variable across rats. During Test 1 response rates were higher than the mean session rates during the first 10 seconds of the CS (0 to 10 seconds from start of session) for all subjects. Three rats showed the highest rates during this session. In Test 2, response rates during the first 10 seconds of the CS (10 to 20 seconds from start of session) were higher than the session mean for all subjects. Data for Test 3 showed almost complete suppression of responding during the first 10 seconds of the CS (580 to 590 seconds from start of session) for all subjects. Test 4 data showed high response rates during the first 10 seconds of the CS (0 to 10 seconds from start of session) for all subjects. Three of the four subjects showed almost no discrepancy between CS response rates during Test 1 and the first presentation of the CS in Test 4. R823 showed some discrepancy between the rates of these conditions and, except for this subject, response rates were higher during Test 1. Response rates during the first 10 seconds of the second onset of the CS (290 to 300 seconds from start of session) were lower than for the first onset for all subjects. However, these rates were higher than the mean overall rates for that session for three of the rats. The second onset of the CS in Test 4 occurred only 10 seconds after the usual CS onset time for training conditions and, in all cases, there is a very marked discrepancy between the CS rates for the second onset in this test and CS rates

in training conditions. This effect is in strong contrast with the findings in phase A during the second part of this test, utilizing the same subjects but different CS.

Table V shows the absolute number of licks recorded in 10-second bins for the first 40 seconds of the session, for the 50 seconds in the middle, and for the last 40 seconds of the session. Data are presented for each subject for the first day of each test condition and for the first day of recovery procedure after test days. The last discriminative punishment session before Test 1 is also shown. This group was trained with the CS presented during bin 29. Underlined numbers indicate the first 10 seconds of the CS presentation for each session. During training session, the CS presented in bin 29 markedly reduced licking for all subjects. The average response rate in licks per second during each bin is calculated by dividing the number of licks in the bin by ten. Generally, the CS response rate in the first recovery condition after each test is quite low. There was no marked decrease in responding during the 20 seconds preceding the onset of the CS (bins 27 and 28) in most cases and the increase in responding observed during the 10 seconds after CS offset (bin 30) was variable, in some cases the rate was still very low. Recovery of responding to pre-CS levels was usually observed after the 11th second from CS offset (bin 31). Responding during the first 40 seconds of the session was very stable within subjects and at high rates. Responding during the last 40 seconds of the session was consistently high for R821, while it was more variable for the other subjects. Test data showed that responding was suppressed only for Test 3, for the last 20 seconds

Table V: Number of licks in 10-second bins at beginning, middle, and end of session for the last day of discriminative punishment condition before Test 1, for the first day of recovery procedure after each test, for subjects in group 1B.

TABLE V

NUMBER OF LICKS IN 10-SECOND BINS AT BEGINNING. MIDDLE AND END OF SESSION FOR SUBJECTS IN GROUP 1B.

CONDITION	BIN NUMBER												
	1	2	3	4...27		28	29	30	31...57		58	59	60
821													
P	70	66	61	55	39	4	0	10	27	41	42	52	46
T1	67	63	63	62	35	0	1	66	62	26	30	65	65
R	69	65	64	65	64	63	2	0	61	65	33	36	25
T2	68	65	64	63	59	60	60	60	60	54	64	64	48
R	69	65	64	64	66	55	26	29	26	55	69	69	43
T3	65	66	64	63	22	60	46	19	0	20	68	1	0
R	68	64	64	63	48	0	0	35	70	9	51	7	66
T4	66	64	62	24	9	20	0	35	41	48	39	37	36
R	69	66	65	64	36	44	1	44	68	51	53	62	37
822													
P	71	66	65	65	27	17	1	43	71	0	40	56	21
T1	71	68	66	65	45	0	7	59	65	5	1	24	1
R	72	68	66	67	26	57	1	17	63	3	0	20	16
T2	73	68	67	65	65	53	0	5	66	38	51	0	0
R	70	64	64	62	60	59	2	0	61	62	63	62	61
T3	70	67	65	64	0	38	68	66	30	23	0	0	0
R	71	66	65	64	20	66	4	0	66	40	0	28	52
T4	67	63	60	60	13	0	0	40	60	41	62	50	61
R	68	63	61	59	17	5	1	0	29	53	49	1	0
823													
P	57	52	43	56	45	48	1	49	46	5	9	53	53
T1	57	57	45	63	25	26	51	59	21	0	0	35	66
R	53	58	3	2	16	25	0	35	16	42	15	18	41
T2	73	70	64	62	44	49	48	62	68	42	67	39	53
R	70	68	66	65	29	27	1	54	67	61	65	1	10
T3	70	63	57	58	65	48	58	5	45	68	25	1	0
R	71	64	68	67	36	67	7	49	70	68	23	0	46
T4	71	68	67	59	20	15	60	61	52	65	11	0	53
R	68	60	58	28	30	14	0	15	39	51	51	38	33
824													
P	72	66	39	64	28	55	0	40	55	54	48	57	58
T1	70	66	63	57	60	9	52	63	62	0	0	0	16
R	71	68	66	62	50	55	2	49	54	51	48	56	56
T2	73	65	63	63	58	55	60	63	50	0	43	61	12
R	71	68	67	66	52	63	13	0	52	0	0	43	65
T3	70	67	65	64	57	64	68	67	63	16	52	0	0
R	70	67	65	64	62	49	7	62	64	68	11	37	64
T4	68	66	60	62	35	0	30	54	61	9	58	55	39
R	70	64	63	64	60	63	1	52	67	0	0	45	69

of the session. Except R823 that showed some suppression, all the other subjects showed marked suppression of responding during the bins 27, 28, 29, 30 and/or 31, the usual place of CS onset, in some of the test days. R822 showed this effect during all test conditions.

Table VI shows the mean pre-CS, CS, and post-CS suppression ratios for each condition for subjects in group 1B. Baseline, punishment, and first block of recovery conditions are averages of the last two sessions in each procedure. All other recovery conditions are averages of the first two sessions in that procedure. Test conditions are data for the first day in each procedure. In most cases, there was more suppression after the CS offset than before its presentation. CS ratios were generally low, close to zero, indicating a marked suppression of responding during the CS, except for baseline condition and some test days.

Group 2:

Figure 5 shows the mean response rates for all subjects in group 2, for each condition. CS response rates were higher than the overall response rates for all subjects. Session response rates were stable across conditions for all subjects. R818 and R820 showed a slight decrease in overall response rates during Test 1, and R817 and R819 showed the same effect during Test 3. The first punishment procedure produced complete suppression of responding during the CS presentation for two of the subjects, marked suppression of responding for another, and very little suppression for R820. There was a high amount of recovery of CS response rate for R817, while there was none or very

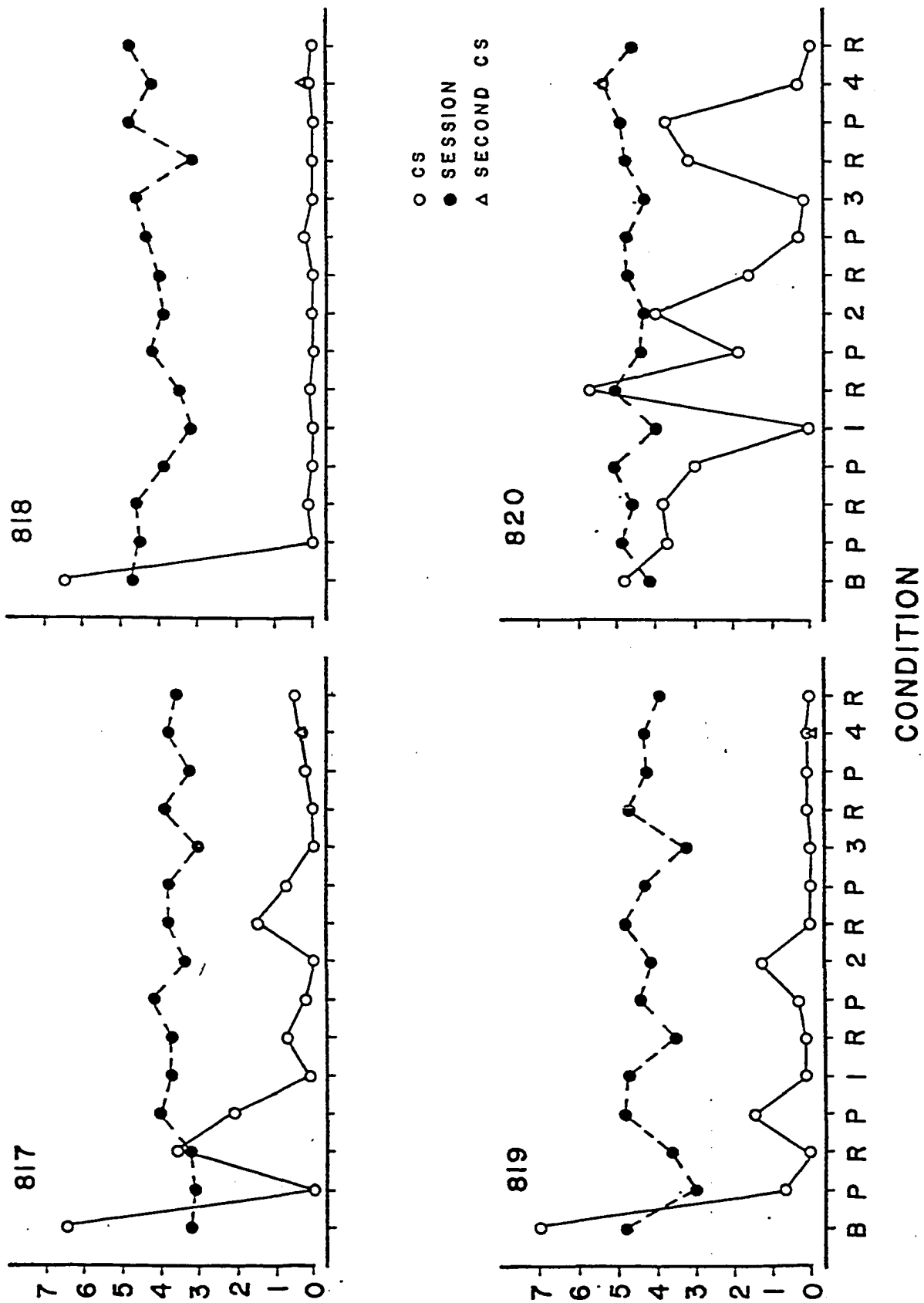
Table VI: Mean pre-CS, CS, and post-CS suppression ratios for each condition for subjects in Group 1B. Baseline, punishment, and first block of recovery conditions are averages of the last two sessions in each procedure. All other recovery conditions are averages of the first two sessions in that procedure. Test conditions are data for the first day in each procedure.

TABLE VI

MEAN PRE-CS, CS, AND POST-CS SUPPRESSION RATIOS FOR EACH CONDITION FOR SUBJECTS IN GROUP 1B.

SUBJECT	821			822			823			824		
CONDITION	PRE	CS	POST	PRE	CS	POST	PRE	CS	POST	PRE	CS	POST
B	1.13	1.00	1.11	1.08	1.18	1.12	1.47	.66	1.34	1.34	1.33	1.32
P	1.31	.05	1.01	1.10	.03	1.64	1.21	.14	1.26	1.07	.03	.79
R	1.42	.05	.43	1.54	.04	.84	1.19	.02	1.01	1.34	.09	1.06
P	,79	.00	.21	.37	.05	1.04	1.03	.02	1.14	1.36	.00	1.08
T1	-	1.49	-	-	2.22	-	-	1.39	-	-	1.71	-
R	1.19	.04	.32	1.36	.02	.20	1.14	.03	1.07	1.10	.04	.91
P	.00	.03	.64	.49	.00	.69	1.04	.02	1.16	.97	.14	1.00
T2	1.17	1.12	-	1.62	1.51	-	1.46	1.40	-	1.43	1.27	-
R	1.36	.65	.73	1.16	.04	.00	.54	.02	1.08	1.02	.14	.53
P	1.37	.04	1.16	.63	.46	.84	.70	.02	1.13	1.22	.04	1.24
T3	1.51	.02	-	.00	.00	-	.50	.02	-	1.08	.00	-
R	.58	.02	.57	1.10	.07	.01	.91	.11	1.04	.70	.13	.65
P	1.13	.06	1.05	1.05	.05	1.09	1.06	.11	1.22	1.30	.02	.05
T4 (1st CS)	-	2.06	.00	-	1.56	.00	-	1.61	1.36	-	1.45	.64
(2nd CS)	.00	1.09	-	.00	.93	-	1.36	1.39	-	.64	1.15	-
R	.86	.02	.86	.16	.03	.00	.50	.00	.54	1.21	.02	1.08

Figure 5: Mean response rates (in licks per second) as a function of conditions, for each subject in group 2. B indicates baseline procedure; P indicates punishment; and R indicates recovery. Test procedures are indicated by the numbers 1 to 4. Data points for baseline, punishment, and first recovery conditions are averages of the last two days in those conditions. Data points for recovery conditions after each test are averages of the first two days in that condition. Data points for test procedures indicate response rates in the first day of the condition.



little recovery for the other three subjects. The second punishment condition was less effective in reducing responding during the CS than the first punishment condition. With the exception of R820, CS response rates were low for all the other training conditions. CS response rates for R820 were very variable and the highest amount of suppression was found during test days. The punishment procedure did not, in general, produce a marked decrease in responding during the CS for this subject. During Test 1 there was almost complete suppression of responding during the first 10 seconds of the CS (0 to 10 seconds from start of session) for all subjects. The CS in this test condition was presented only 10 seconds earlier than usual for training conditions. The effect is similar to the one found in the second part of Test 4 for group 1A. During Test 2, responding during the first 10 seconds of the CS (10 to 20 seconds from start of session) was completely suppressed for two subjects, while there was an increase in responding for the other two subjects, although response rates did not reach the level of mean overall session rates. The CS during this test for group 2 was presented at the usual onset time for training conditions. These data are in conflict with the results obtained in Test 1 for these two subjects. Furthermore, the data for R819 during this test are in discrepancy with the usual CS response rates during training conditions for this subject. Data for Test 3 showed almost complete suppression of responding during the first 10 seconds of the CS (580 to 590 seconds from the start of the session) for all subjects. Test 4 data showed very low responding during the first 10 seconds of the CS (0 to 10 seconds from start of session) for all subjects. Again, this presentation

of the CS occurred only 10 seconds earlier than the usual CS onset time for training conditions. There was almost no discrepancy between the CS response rates during Test 1 and the first part of Test 4, for which the CS was presented at the same moment in the session. After 280 seconds had elapsed from the start of the session the CS was terminated for 10 seconds and then presented again for the remainder of the session. Responding during the first 10 seconds of the second CS onset (290 to 300 seconds from start of session) was almost completely suppressed for three of the four subjects, although this onset differed markedly from the time of usual onset of the CS for training conditions. The CS response rate during this second part of Test 4 for R820 reached the mean overall level of responding.

Table VII shows the absolute number of licks recorded in 10-second bins for the first 40 seconds of the session, for the 50 seconds in the middle of the session, and for the last 40 seconds of the session. Data are presented for each subject for the first day of each test condition and for the first day of recovery procedures after test days. The last discriminative punishment session before Test 1 is also shown. This group was trained with the CS presented during bin 2. Underlined numbers indicate the first 10 seconds of the CS presentation for each session. During training sessions the CS presented in bin 2 markedly reduced licking for three of the subjects. The average response rate, in licks per second, during each bin is obtained by dividing the number of licks in the bin by 10. The CS response rate during the first training condition after each test was usually very close to zero for the three subjects that suppressed consistently. Responding during the

Table VII: Number of licks in 10-second bins at beginning, middle, and end of session for the last day of discriminative punishment condition before Test 1, for the first day of each test condition, and for the first day of recovery procedure after each test, for subjects in group 2.

TABLE VII

NUMBER OF LICKS IN 10-SECOND BINS AT BEGINNING, MIDDLE, AND END OF SESSION FOR SUBJECTS IN GROUP 2.

CONDITION	BIN NUMBER											
	1	2	3	4...27	28	29	30	31...57	58	59	60	
817												
P	32	42	21	65	59	59	53	59	23	0	0	0	0
T1	1	0	0	9	0	0	54	60	61	57	48	0	0
R	23	13	29	64	61	47	59	51	59	0	33	48	0
T2	14	0	7	48	7	61	18	0	0	0	0	0	0
R	18	0	26	59	60	9	0	42	61	0	13	34	0
T3	10	0	20	43	60	60	59	59	9	38	0	0	0
R	13	0	0	0	51	60	12	0	13	0	0	53	11
T4	3	0	36	61	0	42	62	3	59	22	22	0	0
R	3	5	45	66	58	60	56	34	0	0	15	33	0
818												
P	1	0	0	4	48	24	32	52	54	43	44	9	0
T1	0	0	0	0	47	47	36	49	54	47	43	39	0
R	0	0	0	0	45	51	34	41	54	4	1	1	10
T2	1	0	0	3	50	50	52	50	58	0	20	52	56
R	0	0	3	2	48	50	55	2	43	53	6	8	47
T3	7	8	8	67	53	54	32	52	53	32	33	0	0
R	3	0	7	41	60	51	57	51	52	43	49	35	53
T4	1	0	0	2	54	60	63	2	59	48	57	50	54
R	1	0	16	63	54	57	45	53	50	37	47	43	51
819												
P	36	12	35	67	42	52	48	48	30	40	59	29	44
T1	1	0	24	51	49	9	52	59	57	43	56	44	5
R	0	0	33	53	1	2	26	60	47	47	35	41	44
T2	3	13	42	46	56	37	47	44	23	12	22	45	44
R	23	0	38	56	40	7	60	59	62	47	59	55	41
T3	0	27	2	11	29	20	42	1	23	50	50	0	0
R	30	2	65	57	58	55	56	53	56	62	64	59	64
T4	1	5	32	63	50	48	51	0	47	57	64	54	22
R	6	0	0	0	48	45	0	43	56	61	55	2	0
820												
P	32	59	66	70	56	65	55	42	56	66	67	3	0
T1	0	0	0	8	31	50	40	39	51	51	35	51	3
R	42	60	53	61	56	59	54	61	56	64	62	66	46
T2	4	40	60	55	43	64	13	50	61	0	25	65	29
R	44	0	27	32	37	56	37	27	27	52	57	38	49
T3	14	28	50	53	41	66	43	66	1	13	70	1	37
R	48	53	64	62	38	40	58	54	51	12	68	61	0
T4	3	5	12	32	58	34	47	54	67	68	65	54	49
R	0	0	0	0	35	52	64	58	60	0	14	63	54

10 seconds preceding CS onset (bin 1) was lower than during later portions of the session for all subjects, and the levels of licking during the 10 seconds after CS offset (bin 3) were also low. Higher response rates, comparable to rates found towards the middle of the session, were observed after the 11th second from CS offset (bin 4) for three subjects. Responding during the last 40 seconds of the session was variable between subjects, while during the middle of the session responding was generally high. Test data showed almost complete suppression of responding for every test condition, except for R820 during Test 2 and second part of Test 4. The second part of Test 4 (bin 30) resulted in a marked suppression of responding during the first 10 seconds of the CS for three of the subjects, while rates recovered to previous levels during the next 10 seconds (bin 31). This group had never experienced CS onset at this point in the session. Test 3 data showed marked suppression of responding in the absence of the CS during the first 30 seconds of the session (bins 1, 2, and 3) for three subjects, and during the first 20 seconds for the fourth rat.

An effect found by observation of the subjects and not measured objectively was that, in contrast with the rats in the other three groups that would start licking as soon as they were placed in the boxes, the subjects in group 2 would delay starting the session for long periods of time, in some cases up to 10 minutes.

Table VIII shows the mean pre-CS, CS, and post-CS suppression ratios for each condition for subjects in group 2. Baseline, punishment, and first block of recovery conditions are averages of the last two sessions in each procedure. All other recovery conditions are averages

Table VIII: Mean pre-CS, CS, and post-CS suppression ratios for each condition for subjects in group 2. Baseline, punishment, and first block of recovery conditions are averages of the last two sessions in each procedure. All other recovery conditions are averages of the first two sessions in that procedure. Test conditions are data for the first day in each procedure.

TABLE VIII

MEAN PRE-CS, CS, AND POST-CS SUPPRESSION RATIOS FOR EACH CONDITION FOR SUBJECTS IN GROUP 2.

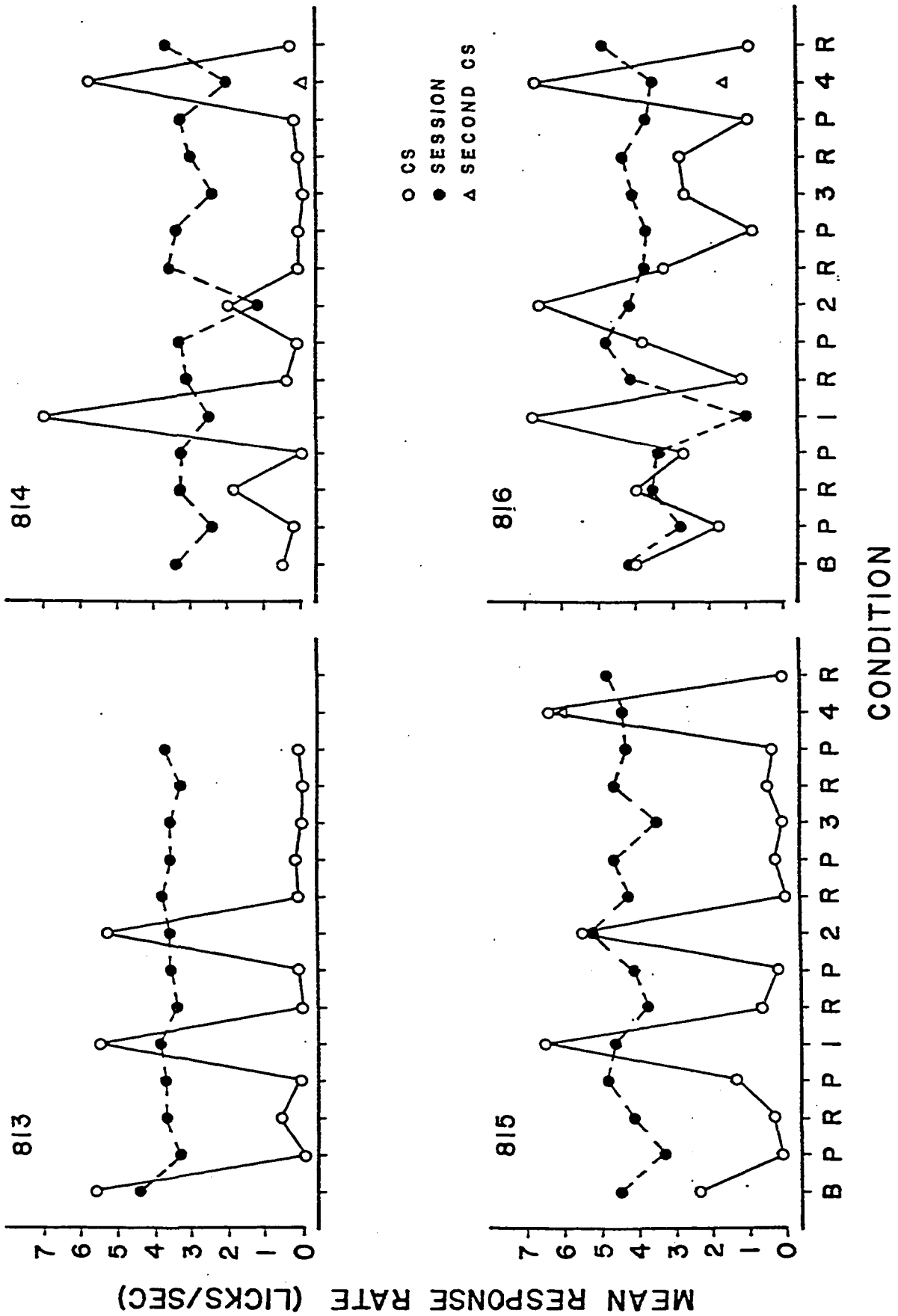
SUBJECT	817			818			819			820		
CONDITION	PRE	CS	POST	PRE	CS	POST	PRE	CS	POST	PRE	CS	POST
B	2.16	2.03	1.78	1.40	1.38	1.12	1.35	1.46	1.15	1.41	1.14	.85
P	.26	.00	1.11	.00	.00	.00	1.03	.23	.00	.70	.76	.78
R	1.50	1.13	1.69	.11	.02	.32	.07	.00	.53	.39	.83	1.07
P	.40	.53	.26	.03	.00	.00	.55	.31	.89	.35	.59	.76
T1	-	.03	-	-	.00	-	-	.02	-	-	.00	-
R	.32	.19	.39	.03	.03	.06	.06	.03	.47	.54	1.12	1.13
P	.37	.05	.07	.07	.00	.10	.53	.07	.77	.59	.43	1.01
T2	.42	.00	-	.03	.00	-	.07	.32	-	.09	.93	-
R	.88	.40	1.13	.00	.00	.11	.48	.00	.79	.76	.34	.93
P	.91	.18	.72	.02	.05	.73	.02	.00	.65	.16	.06	1.02
T3	.00	.00	-	.72	.00	-	1.56	.00	-	1.63	.02	-
R	.58	.00	.50	.10	.00	.23	.61	.02	1.14	.60	.67	1.11
P	.14	.06	.81	.02	.00	.29	.13	.02	.61	.33	.78	1.16
T4 (1st CS)	-	.08	1.63	-	.02	1.50	-	.02	1.19	-	.06	.87
(2nd CS)	1.63	.08	-	1.50	.05	-	1.19	.00	-	.87	1.00	-
R	.08	.14	1.25	.02	.00	.33	.15	.00	.00	.00	.00	.00

of the first two sessions in that procedure. Test conditions are data for the first day in each procedure. In most cases, suppression ratios are low, both before and after the CS presentation, an effect not found with the other groups. CS ratios were very low for three subjects, except during baseline condition. Data for R820 was very variable, pre-CS ratios usually showed some suppression of responding, while post-CS ratios are very high. CS ratios for this subject generally showed some suppression of responding, but in many cases the pre-CS ratios were lower than during the CS, an effect also observed, to a lesser degree, only in R816 in group 3.

Group 3:

Figure 6 shows the mean response rates for all the subjects in group 3, for each condition. Baseline CS response rates were lower than the mean overall session rates for three of the subjects. Session rates were very stable for one subject, and the variability for the other subjects was mainly observed during test conditions. Test 1 produced a decrease in overall response rates for two subjects; Test 2 reduced the overall rate for one subject; Test 3 produced a slight decrease in overall response rate for two subjects; and Test 4 depressed the overall rate for one subject. R814 was the only subject that showed a decrease in overall response rate for each test condition. The first punishment condition produced almost complete suppression of responding during the CS presentation for three subjects, and some suppression for the fourth subject. This condition also depressed overall response rates for all subjects, an effect not generally observed in the other

Figure 6: Mean response rates (in licks per second) as a function of conditions, for each subject in group 3. B indicates baseline procedure; P indicates punishment; and R indicates recovery. Test procedures are indicated by the numbers 1 to 4. Data points for baseline, punishment, and first recovery conditions are averages of the last two days in those conditions. Data points for recovery conditions after each test are averages of the first two days in that condition. Data points for test procedures indicate response rates in the first day of the condition. Rat 813 was withdrawn from the experiment just before Test 4 due to illness.



groups. There was recovery of overall and of CS response rates for all subjects. The second punishment condition was less effective in suppressing CS responding for two of the rats, and it did not depress overall response rates for any subject. During Test 1, response rates were very high during the first 10 seconds of the CS (0 to 10 seconds from start of session) for all subjects. In Test 2, response rates during the first 10 seconds of the CS (10 to 20 seconds from start of session) were higher than the mean overall session rates for all the subjects, although not as high as CS rates during Test 1. The data for Test 3 showed almost complete suppression of responding for three of the four subjects during the first 10 seconds of the CS (580 to 590 seconds from the start of the session). The CS response rate for R816 was lower than the mean overall rate for that session. Test 4 data showed very high response rates during the first 10 seconds of the CS (0 to 10 seconds from start of session) for all three subjects that experienced this condition, although the rates were lower than CS rates during Test 1, in which the CS onset occurred at the same moment in the session. R813 was withdrawn from the experiment just before Test 4 due to illness. After 280 seconds had elapsed from the start of the session, the CS was terminated for 10 seconds and then presented again for the remainder of the session. The response rate during the first 10 seconds of the second CS onset (290 to 300 seconds from start of session) was completely suppressed for one subject, somewhat depressed below the mean overall rate for the session for another rat, and quite high, almost to the level obtained during the first onset of the CS for the third subject. The CS in this part of Test 4 was presented only 10 seconds

after the usual onset time for training conditions and the data for R815 is the only one showing discrepancy between the CS response rate for the second CS onset in Test 4 and the usual CS rates during training conditions.

Table IX shows the absolute number of licks recorded in 10-second bins for the first 40 seconds of the session, for the 50 seconds in the middle, and for the last 40 seconds of the session. Data are presented for each subject for the first day of each test condition and for the first day of recovery procedure after test days. The last discriminative punishment session before Test 1 is also shown. This group was trained with the CS presented during bin 29. Underlined numbers indicate the first 10 seconds of the CS presentation for each session. During training sessions, the CS presented in bin 29 markedly reduced licking for all subjects. The average response rate, in licks per second, can be calculated by dividing the number of licks in each bin by 10. CS response rate was usually very low, except for R816, whose rate was slightly higher. In most cases, there was reduction in responding during the 20 seconds preceding the onset of the CS (bins 27 and 28), and responding was still reduced 10 seconds after CS offset (bin 30) in some cases. Recovery of responding to average session levels occurred after the 11th second from CS offset (bin 31), except for R816, whose rate was sometimes lower during this bin than in the bins immediately preceding or following CS presentation. Responding during the first 40 seconds of the session was usually very stable within subjects and response rates were high. Test data showed the amount of reduction in responding, if any, during each bin. Every

Table IX: Number of licks in 10-second bins at beginning, middle, and end of session for the last day of discriminative punishment condition before Test 1, for the first day of recovery procedure after each test, for subjects in group 3. Rat 813 was withdrawn from the experiment just before Test 4 due to illness.

TABLE IX

NUMBER OF LICKS IN 10-SECOND BINS AT BEGINNING, MIDDLE, AND END OF SESSION FOR SUBJECTS IN GROUP 3.

CONDITION	BIN NUMBER												
	1	2	3	4...27	28	29	30	31...57	58	59	60		
813													
P	66	53	61	51	56	36	1	56	56	37	0	51	10
T1	55	64	61	47	25	55	52	23	53	3	58	23	51
R	66	63	62	60	60	17	0	53	35	56	29	33	38
T2	61	53	62	61	28	36	42	25	42	16	56	0	0
R	65	63	63	55	45	38	1	38	33	0	60	8	41
T3	67	55	60	51	32	55	0	32	37	62	12	0	2
R	64	64	62	51	43	18	0	17	61	26	41	0	22
T4	-	-	-	-	-	-	-	-	-	-	-	-	-
R	-	-	-	-	-	-	-	-	-	-	-	-	-
814													
P	70	65	58	60	60	1	0	53	25	6	29	3	37
T1	70	65	56	36	13	11	23	40	0	11	0	0	0
R	68	64	62	29	0	55	4	46	62	53	51	12	20
T2	66	20	58	44	1	1	3	2	0	16	9	13	0
R	67	55	29	61	20	57	1	12	65	0	0	0	19
T3	60	41	65	61	5	0	0	0	0	32	0	0	0
R	47	51	62	46	6	65	1	0	51	16	38	0	0
T4	58	26	0	39	1	5	0	0	0	0	7	24	0
R	68	10	44	63	0	31	3	29	63	46	66	27	55
815													
P	65	63	57	56	58	57	6	51	60	20	7	41	0
T1	65	59	51	56	51	58	51	50	10	56	10	0	47
R	64	59	55	56	59	51	1	22	60	40	40	59	50
T2	65	55	60	60	61	59	46	60	61	62	62	61	61
R	45	5	22	0	56	39	0	31	59	54	53	19	0
T3	25	16	52	18	5	20	42	57	55	53	42	1	32
R	68	64	58	61	59	32	10	51	63	42	31	36	51
T4	64	62	61	60	56	42	45	61	53	38	38	2	0
R	69	64	63	62	58	18	0	0	0	63	26	5	48
816													
P	68	65	62	60	39	36	13	34	27	34	9	35	7
T1	68	63	62	61	0	0	6	2	3	10	0	7	11
R	70	64	63	63	49	10	11	0	28	7	27	0	0
T2	70	66	63	63	44	59	61	47	29	30	27	57	35
R	33	2	11	26	36	36	11	9	0	39	46	44	39
T3	70	63	63	62	64	45	33	36	66	0	0	27	27
R	67	65	60	62	61	61	30	41	39	47	22	30	0
T4	67	65	37	18	32	9	7	16	27	53	52	52	60
R	70	66	64	65	58	57	9	39	61	4	62	58	54

subject showed a dramatic decrease in responding during bins 27, 28, 29, 30 and/or 31 (usual place of CS onset) during some test conditions. R814 showed this effect for all four tests.

Table X shows the mean pre-CS, CS, and post-CS suppression ratios for each condition for subjects in group 3. Baseline, punishment, and the first block of recovery conditions are averages of the last two sessions in each procedure. All other recovery conditions are averages of the first two sessions in that procedure. Test conditions are data for the first day in each procedure. There was usually no suppression before the CS onset. CS ratios were very close to zero, indicating a marked suppression during the CS, except for baseline and some test conditions for three of the subjects. CS ratios for R816 were high, but still indicating suppression. Post-CS ratios were usually lower than pre-CS ratios.

Table XI shows the percent of shock received by each subject during all discriminative punishment procedures. On the average, subjects in group 2 were the most successful in avoiding shocks by completely suppressing during the CS (passive avoidance), followed by subjects in group 3. The least efficient subjects in suppressing licks and avoiding shocks were the ones in group 1B.

It should be remembered that groups 1A and 1B consisted of the same subjects. It is interesting to compare the percent of shocks received by the same subject under two different training conditions. Three of the four rats avoided more shocks when the CS was a tone than when the CS was a flickering houselight. R824 showed the opposite effect, switching from being the subject with the highest percent of shocks

Table X: Mean pre-CS, CS, and post-CS suppression ratios for each condition for subjects in group 3. Baseline, punishment, and first block of recovery conditions are averages of the last two sessions in each procedure. All other recovery conditions are averages of the first two sessions in that procedure. Test conditions are data for the first day in each procedure. Rat 813 was withdrawn from the experiment just before Test 4 due to illness.

TABLE X

MEAN PRE-CS, CS, AND POST-CS SUPPRESSION RATIOS FOR EACH CONDITION FOR SUBJECTS IN GROUP 3.

SUBJECT	813			814			815			816		
CONDITION	PRE	CS	POST	PRE	CS	POST	PRE	CS	POST	PRE	CS	POST
B	.74	1.27	.63	.83	.15	1.57	.00	.53	1.42	1.07	.95	.91
P	.99	.00	.00	1.00	.08	.50	1.50	.03	.64	.96	.64	.89
R	.97	.16	1.20	.32	.55	1.12	1.27	.07	.34	.51	1.11	.51
P	.88	.03	1.35	.03	.00	1.61	1.13	.27	.93	1.44	.79	1.21
T1	-	1.41	-	-	2.80	-	-	1.41	-	-	6.80	-
R	.50	.00	1.56	1.77	.13	1.48	.87	.16	.30	.24	.27	.00
P	1.44	.03	.97	.67	.03	.62	.79	.05	.88	1.24	.79	.72
T2	1.69	1.47	-	.55	1.67	-	1.23	1.04	-	1.67	1.57	-
R	1.07	.03	1.29	1.63	.03	.50	.93	.00	.74	.47	.84	.87
P	1.28	.06	1.33	1.47	.03	.06	1.29	.07	1.05	1.04	.22	.69
T3	.33	.00	-	.00	.00	-	1.20	.03	-	.00	.66	-
R	.74	.00	.50	2.17	.03	.00	.35	.11	1.24	1.42	.64	.96
P	1.23	.03	1.41	.14	.06	.53	.48	.09	1.11	1.37	.24	.99
T4 (1st CS)	-	-	-	-	2.90	.00	-	1.45	1.02	-	1.91	.20
(2nd CS)	-	-	-	.00	.00	-	1.02	1.39	-	.20	.46	-
R	-	-	-	.84	.08	.78	.38	.00	.00	1.16	.18	.80

Table XI: Percent of shock received by each subject during discriminative punishment conditions, and averages for each group.

TABLE XI

PERCENT OF SHOCKS RECEIVED BY EACH SUBJECT DURING DISCRIMINATIVE PUNISHMENT CONDITIONS, AND AVERAGES FOR EACH GROUP.

GROUP 1A	821	822	823	824	GROUP AVERAGE
	53.8%	61.5%	65.4%	84.6%	66.3%
GROUP 1B	821	822	823	824	GROUP AVERAGE
	67.9%	82.8%	86.2%	65.5%	75.6%
GROUP 2	817	818	819	820	GROUP AVERAGE
	54.8%	30.0%	51.6%	80.6%	54.3%
GROUP 3	813	814	815	816	GROUP AVERAGE
	56.7%	40.0%	77.4%	72.4%	61.6%

received in group 1A to being the subject with the lowest percent of shocks received in group 1B, while the other subjects kept their relative positions within the groups.

Only two of the subjects in the experiment received less than 50 percent of all scheduled shocks, and they belonged to different groups.

DISCUSSION

A comparison between groups indicates that subjects in groups 1A and 1B showed the most stable overall session response rates. The subjects in group 3 had the most variability in overall session response rates throughout the experiment. The conditions in group 1A (tone on as CS presented at the middle of the session) seemed to produce the least disruption of overall session responding during testing procedures. The conditions in group 3 (tone off as CS presented at the middle of the session) seemed to produce the most disruption of overall session responding during test days.

The discriminative punishment procedure appeared to produce more reliable effects for subjects in group 1A, for which this procedure almost completely suppressed responding during the CS. The subjects in group 2 showed the most variability in the amount of suppression of responding during the CS under discriminative punishment conditions. One subject in this group had a maximum CS rate of almost four licks per second, in the average, during punishment conditions, while another subject reached a maximum CS rate of .2 licks per second, in the average, for the punishment procedure. The CS rate for this subject was almost completely suppressed throughout the experiment, except for baseline condition.

The subjects in group 2 showed suppression of responding in the 10 seconds prior to CS onset during all conditions, and subjects in group 3 showed some reduction in the 20 seconds prior to CS onset during

training conditions. The subjects in the other groups usually did not show a reduction of responding prior to CS onset during training conditions. All the groups showed suppression of licking during the 10 seconds after CS offset with rates usually recovering to the level of pre-CS rates after the 11th second from CS offset.

Test 1 (CS on from the start) did not suppress CS response rates below overall session rates, except for one subject in group 1A, and for subjects in group 2, in which the CS was presented only 10 seconds earlier than during training conditions. The highest rates in the experiment for three of the subjects in group 3 and three of the subjects in group 1B were found during this test. Test 1 produced a slight decrease in overall response rates for one subject in each group, and some decrease for one subject in group 2 and another rat in group 3.

Test 2 (CS on 10 seconds after start) did not suppress CS response rates below overall session rates for subjects in groups 1B and 3, and for two of the subjects in group 1A. This procedure did not suppress CS response rates to the levels found during training conditions for the other two subjects in group 1A and for two subjects in group 2. This test caused some decrease in overall session rate for one subject in group 3 only.

Test 3 (CS 580 seconds after start) produced the most consistent results between groups. This procedure almost completely suppressed CS response rates for all subjects, except for R816 in group 3 that had very variable CS rates throughout the experiment, and whose CS rate was lower than the overall session rate for this test. Test 3 produced a slight decrease in overall response rates for one subject in group 2,

and it produced some suppression for one subject in group 1B, one subject in group 2, and two subjects in group 3.

The first onset in Test 4 (CS at start) did not suppress CS response rates below overall session rates, except for subjects in group 2, for which the CS was presented only 10 seconds earlier than during training conditions. This first onset is identical to Test 1 and there is little or no discrepancy between the results of both tests. Three of the subjects in group 1A had their highest rates during this part of Test 4.

The second CS onset in Test 4 (after 290 seconds from start) produced almost complete suppression of CS rates for all subjects in group 1A, for three subjects in group 2, and one subject in group 3; it produced suppression of CS rates below overall rates for one subject in group 1B and one subject in group 3; and it produced no suppression of CS rates for the rest. This onset occurred only 10 seconds later than the usual onset time for training conditions for groups 1A, 1B, and 3. There was no discrepancy between the results of this part of Test 4 and CS rates during training conditions for all subjects in group 1A and for two of the three rats in group 3 that experienced Test 4. There is a marked discrepancy between the results of this part of Test 4 and CS rates during training conditions for all subjects in group 1B. Test 4 produced a very slight decrease in overall session response rates for one subject in group 3, and it produced some depression of overall rates for one subject in group 1B.

Angerami (1976) did not find evidence of temporal discrimination when the CS was continuously present during the session. The lick rate

at the point where the CS had been presented during training was not suppressed. The results of Test 1 for group 1A replicated some of Angerami's findings, utilizing the same procedure and parameters. There was no suppression of CS response rates, except for one subject, and there was no suppression of overall session rates, except for one subject. The first part of Test 4 consisted on the same conditions and there was no suppression of CS or of overall session rates. Two subjects during Test 1 and one subject during Test 4 completely suppressed licking within 20 seconds of the usual CS onset. This finding is in discrepancy with Angerami's results.

When the CS was presented from the start of the session (Tests 1 and 4), CS response rates were very high for the groups with a usual onset at the middle of the session. When the CS was presented at some point after the session had started, CS rates were usually not so high for the groups with a usual onset at the middle of the session. When the onset was very close to the usual time of CS onset, either before or after it, CS rates were almost completely suppressed (Tests 1, 2, and first part of 4 for group 2; and second part of Test 4 for all other groups). These results seem to indicate that subjects were responding to a complex stimulus comprised of CS onset and time elapsed since the start of the session, although in some occasions passage of time alone seemed to be sufficient to cause suppression of responding at the usual time of CS onset. All subjects showed this marked decrease in responding during some test days, even in the absence of the CS, as in Test 3, indicating some temporal discrimination. Most of this suppression occurred within 20 seconds of the usual CS onset time, usually prior to it.

It would seem that the CS onset once the session had started was more effective in suppressing responding during the first 10 seconds than when it was presented from the start, in view of the results obtained for the second part of Test 4 for three of the subjects in group 2 and for Test 3 for all groups. Also, Test 2 usually resulted in lower CS rates than Test 1 or first part of Test 4.

A crucial variable that seems to be confounded with passage of time in this experiment is deprivation. At the beginning of the session deprivation is very high and it may over-ride the suppressive effects of the CS. Towards the end of the session subjects have been drinking at high rates for some time and deprivation is reduced, a fact indicated by the low and variable rates found for most subjects during the last 40 seconds of the session. The suppressive effects of the CS may depend to a great extent upon the immediate deprivation condition of the organism, which is decreasing as the session progresses. Low deprivation levels could explain the results of Test 3 for all groups.

It is possible that the presentation of the CS so early in the session for group 2 during training conditions made this stimulus relatively more aversive for this group than for the other groups, due to the high levels of deprivation at that point in the session. The fact that the subjects in group 2 delayed the start of the session while the other subjects did not, seems to support the assumption of greater aversiveness of the early CS. This assumption could also explain the findings during the second part of Test 4 for the subjects

in group 2. Although this CS was presented at the middle of the session, and these subjects never had experienced the CS onset at this time, there was almost complete suppression of responding for three of the subjects during the first 10 seconds of the CS. Further support for the assumption of greater aversiveness of the CS for group 2 is found in the fact that the subjects in this group were, in the average, the most successful avoiders of shocks.

Some of the results are puzzling and do not seem to be explained by the interaction of deprivation level and CS suppressive effects. The second part of Test 4 for group 1B did not result in suppression of CS rates, even though this onset was only 10 seconds after the usual CS presentation. All the subjects in the group suppressed consistently during training conditions, and it can be assumed that deprivation levels were similar for Test 4. One possible explanation is that the termination of the CS for 10 seconds in the middle of the session and its second presentation was less salient for this group, due to the visual nature of the CS. Subjects in group 1B were, in the average, the worst avoiders of shocks, and this could also be explained by the lack of salience of the CS for this group, in comparison with the groups that had an auditory CS.

Another puzzling result was found during Test 2 for two of the subjects in group 2. Although this CS was presented at the exact moment of usual CS onset for training sessions, there was an appreciable amount of responding during the first 10 seconds of the CS for these two subjects. It can be assumed that deprivation levels were the same for this test and for training sessions. One of the subjects had

very variable CS rates throughout the experiment, but the other subject had very low CS rates. Both subjects suppressed almost completely during Test 1 and first part of Test 4, where the CS onset was only 10 seconds prior to the onset in Test 2.

When the CS consisted of turning off a tone (group 3) the results did not differ markedly from those found when the CS was the tone on, except for an increase in variability. Disregarding the data for R816, whose CS rate was very variable, the results of the second part of Test 4 for the remaining two subjects that experienced this test were completely opposite. One subject had a CS rate as high as during the first onset, while the other completely suppressed licking. It is difficult to explain these results.

Angerami (1976) found suppression of responding during the post-CS period during training conditions, a phenomenon also found in the present experiment. Angerami also observed that the subjects often made one or two responses at the very beginning of the CS period during training conditions, possibly as a carry-over from a burst of licks that had started before the CS, followed by suppression for the rest of the CS. This was also observed in the present experiment, via an interface panel that indicated responses and stimuli conditions in the chambers, although as responses were collected in 10-second bins, it was impossible to objectively determine at which point during the 10 seconds the responses had occurred, and no data are presented regarding this observation.

In summary, the results of this experiment suggest that the greater the level of deprivation when the CS is presented during training

conditions, the greater the aversive properties the CS will acquire, producing greater suppression of responding when the CS is presented in test conditions, causing more successful avoidance of shocks in a discriminative punishment procedure. On the other hand, the results indicate that given a certain aversiveness of the CS, the earlier it is presented in the test session, when deprivation levels are very high, the less suppression it will cause; while the later the CS is presented in the session, when deprivation levels are low, the more suppression it will cause.

The visual CS utilized in this experiment resulted in the least amount of shock avoidance, possibly because it was less salient for the species.

It will be necessary to separate the effects of temporal discrimination from those of deprivation. This could be accomplished by the use of a reinforcer which effectiveness does not depend upon deprivation level, like intra-cranial shock (ICS). Another way to separate these variables would be by utilizing an intermittent schedule of reinforcement delivery that would still maintain licking without significantly decreasing the deprivation level of the organism.

It would be interesting to test this procedure with other temporal locations of the CS onset, both during training and testing. It is suggested to utilize a within-group design, so that every subject serves as control for itself and individual differences would not obscure the results. It would be also necessary to attempt to replicate these results utilizing an instrumental response instead of a consummatory one.

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