

Higher-order Conditioning of the Burying Response

by

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A thesis submitted in partial fulfillment of the
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Abstract

This research was designed to determine the mechanisms of response control in a burying paradigm. Learning theorists have proposed a variety of mechanisms for the determination of the topography of an associative response. Generally, the theories fall into two classes. The first class of theories focus on the acquisition of a response. The mechanisms for response control include: the response eliciting characteristics of the unconditioned stimulus; and, a combination of ethological constraints and experimental contingencies. The second class of theories propose the learning of an association, with the index of association determined by environmental variables. The proposed mechanisms of response control include: the evocation of the acquired response by predictive cues; an interaction of the response eliciting characteristics of unconditioned stimuli, predictive cues, and the context in which each occurs; and the constraints of the experimental environment itself.

In order to test the prediction of the two classes of theories, an adaptation of a higher-order conditioning paradigm was employed. In the first phase, a tone was paired with shock, and in the second phase, the tone was paired with a prod. Since shock has been found to elicit

freezing, theories focusing on the response eliciting characteristics of the unconditioned stimulus predict the acquisition of freezing to both the tone and the prod. And, since a prod has been found to elicit burying, theories whose focus is on the response evocative qualities of predictive cues predict the acquisition of burying to the prod. The results showed that both freezing and burying were acquired to the prod, suggesting that: first, higher-order conditioning occurred; and second, a single stimulus, a prod, controlled the occurrence of two distinct classes of behaviours. The present observations therefore support a combination of the classes of theories mentioned above.

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Table of Contents

LIST OF TABLES	vi
LIST OF FIGURES	vii
INTRODUCTION	1
METHOD	24
Subjects	24
Apparatus	25
Procedure	27
RESULTS	30
DISCUSSION	52
APPENDIX A	76
ANOVA's of Habituation Data.....	77
ANOVA's of Conditioning Data.....	78
ANOVA'S of Test Day Data.....	79
APPENDIX B	80
Subjects that Buried the Prod During Habituation, Conditioning, and Test Days.....	81

List of Tables

Table		Page
1	Experimental design.....	28
2	The number of subjects that buried in the area of the prod during Conditioning and Test days...	44

LIST OF FIGURES

Figures	Page
1	Mean frequency (Left Column), duration (Middle Column), and latency (Right Column) of freezing (Upper Row), and burying (Lower Row) over Habituation (Days 1 and 2), Conditioning (C), and Test (T) Days for the Prod-Tone, Tone-Alone, Prod-Shock and Notreatment Groups.....33
2	Mean heights of the pile on the prod (Upper Frame) and the largest pile in the chamber (Lower Frame) over Habituation (Days 1 and 2), Conditioning (C), and Test (T) Days for the Prod-Tone, Tone-Alone, Prod-Shock, and Notreatment Groups.....35
3	Frequency distribution (depicted on a log scale) of freezing bout lengths of: 0.1-5.0 secs; 5.1-10.0 secs; 10.1-25.5 secs; 25.6-51.1 secs; 51.2-102.3 secs; 102.4-204.7 secs; 204.8-511.9 secs; 512.0-900 secs; for the Prod-Tone, Tone-Alone, Prod-Shock, and Notreatment Groups.....40
4	Individual subjects' performance from the Prod-Tone (P-T), Tone-Alone (T), Prod-Shock (P-S), and Notreatment (N) Groups on Conditioning Day frequencies, durations, and latencies to bury; heights of the pile on the prod, and the largest pile in the chamber.....49
5	Individual subjects' performance from the Prod-Tone (P-T), Tone-Alone (T), Prod-Shock (P-S), and Notreatment (N) Groups on Test Day frequencies, durations, and latencies to bury; heights of the pile on the prod, and the largest pile in the chamber.....52

Higher-order Conditioning of the Burying Response

In the variety of existing learning models, the proposed impact of the conditioned and unconditioned stimuli on response topography differs across theories. Within a traditional classical conditioning framework, the US is thought to be the major determinant of the learned response (cf. Gormezano and Kehoe, 1975). Other perspectives have identified: the predictive stimulus as a major determinant of the learned response (cf. Holland, 1977); a combination of ethological constraints and implicit experimental contingencies interacting to produce the associative response (cf. Bolles, 1970); and the interaction of predictive cues and aversive stimulus characteristics with situational variables as determinants of the associative response topography (cf. Blanchard, Fukanaga, & Blanchard, 1976a). The following investigation sought to test the predictions of each of the models for responding in a burying paradigm (cf. Pinel & Treit, 1981). The burying paradigm was employed, since within the operations of the paradigm, there exists the potential for response control by all of the above mechanisms. The stimulus (McKim & Lett, 1979); the aversive event (cf. Pinel & Treit, 1981); the context in which both are presented (Moser & Tait, Note 1); and ethological constraints (Pinel & Treit, 1978) have all been implicated as important variables in response control

in the burying paradigm. None of the investigations thus far, however, have assessed the independent contributions of each of the variables. In the following experiment, an attempt was made to independently assess the controlling mechanisms in a burying paradigm, and each of the above theoretical positions were addressed.

Response Control in Classical Conditioning Paradigms

In the traditional classical conditioning paradigm, a conditioned stimulus (CS) and an unconditioned stimulus (US) are repeatedly presented to an organism in a given temporal order. The US refers to any stimulus which reliably elicits an unconditioned response (UR). The CS is any stimulus which initially does not elicit a response in the effector system of the US. After repeated presentation of the two stimuli to an organism in a fixed temporal order, a response within the effector system elicited by the US develops to the CS. This response is termed the conditioned response (CR). Initially, the CR was assumed to be an exact replica of the UR (cf. Hilard & Marquis, 1940). This notion appears to stem from two sources. First, expectations derived from the theoretical mechanisms posited by both response contiguity (Guthrie, 1933) and effect theories (Hull, 1943) of conditioning led to the belief that the response conditioned to the CS should at least be a component of the UR, if not a replica. And second, Pavlov (1927) only

measured responses that were similar to the UR. Although he acknowledged that responses other than the measured CRs could occur in the conditioning situation, Pavlov's (1927) empirical observations of conditioning did not focus on CRs which differed topographically from the UR. However, when a more global observation of the organism during conditioning was made (cf. Zener, 1937), it became apparent that responses other than those resembling the UR were conditioned. Consequently, the CR was proposed to be either a redintegrative response, a fractional component of the UR, or a preparatory response (Hilgard & Marquis, 1940). A redintegrative response is one which appears to be identical to the actual response elicited by the US; a fractional component response is one which resembles only one component of the complete UR; and a preparatory response is a behavioural sequence which appears to prepare the organism for the onset of the US. Accordingly, the sole criterion for selecting a CR is that the response appears in the same effector system as the UR (Gormezano & Kehoe, 1975). Such criterion would encompass the various classes of CRs described by Hilgard and Marquis (1940).

While the set of procedures and measurement techniques described by Gormezano and Kehoe (1975) are adequate for the assessment of classical conditioning processes, Rescorla (1975) has argued that the restrictions of classical conditioning are too limiting for the study of learning

processes in general. Initially, learning theorists assumed that an association involved the learning of a stimulus and a response (Guthrie, 1933; Hull, 1943; Pavlov, 1927). For Pavlov (1927) and Guthrie (1933), performance was a direct representation of the learning process; the response elicited by the US was associated with the CS, and resulted in a CR resembling the UR. For Hull (1943), the learning process was similar, but performance involved more than simply the association of a response. Rather, observed responding was a function of both the learned response and the organism's motivation level. Given the focus on the learning of a relationship between a stimulus and a response, classical conditioning methodology would appear to be appropriate. For if the association is between the stimulus and response, then the focus of measurement should be on a response similar to that elicited by the US. If, however, learning is thought to involve an association between two events (e.g., a CS and a US; cf. Rescorla, 1975; 1980), then the index of association could involve more than the measurement of a CR. Rescorla (1975; 1980) argues that if one accepts the view that learning is an association between events, then any behaviour change can serve as an index of learning. Thus within Rescorla's framework, classical conditioning methodology would be one alternative for the measurement of the learning process.

Based on an associative perspective in which events are thought to be the primary components, the traditional restrictions of conditioning methodology have been disengaged (Rescorla, 1975; 1980), and there is a tendency for investigators to specify classical conditioning paradigms solely on the basis of response-independent presentations of a CS and a US (Gormezano & Kehoe, 1975). While such procedures clearly represent a digression from the classical conditioning paradigm, there remains a tendency for theorists to interpret the obtained results within a classical conditioning framework (e.g., Moore, 1973; Holland & Rescorla, 1975). As examples of paradigms which address classical conditioning theory, and in which the possibility for classical-instrumental response interactions exists, Gormezano and Kehoe (1975) point to the commonly employed procedure of assessing the effects of CS-US pairings by superimposing the CS on a baseline of instrumental responding and observing changes in behaviour (cf. Rescorla & Solomon, 1967). Although this approach may be useful in exploring the laws of learning in general, it is an ineffective strategy for testing the laws of classical conditioning. For within paradigms employing nonclassical conditioning methodology, there exists the potential for a variety of response interactions (e.g., conditioned response-instrumental response interactions; conditioned response-ethological response interactions) which are not

described by classical conditioning theory (Gormezano & Kehoe, 1975; Overmier & Lawry, 1979; Trapold & Overmier, 1972). A more appropriate strategy for the study of these learning phenomenon would be to abandon the rubric of classical conditioning, and to begin to delineate the parameters of the response interactions.

Response Control in Operant-Pavlovian Paradigms

One body of literature in which associative and ethological response interactions have been investigated stems from Brown and Jenkins' (1968) identification of autoshaping, and from the broader conceptualization of sign tracking (cf. Hearst & Jenkins, 1974). Sign tracking refers to both behaviour that is directed toward stimuli predicting the imminent arrival of a reinforcer and behaviour that is directed away from stimuli predicting the absence of a reinforcer (Hearst & Jenkins, 1974), and therefore, would include such phenomenon as autoshaping (Brown & Jenkins, 1968). In the autoshaping paradigm, Brown and Jenkins (1968) found that upon repeated exposure to a keylight preceeding food presentations, pigeons began to peck the keylight. Since its initial demonstration, the origins of the autoshaped response have been attributed to the interaction of Pavlovian and ethological mechanisms. Pavlovian mechanisms have been proposed to regulate the acquisition of stimulus-reinforcer relationships, while

ethological mechanisms participate in generating goal directed behaviour (Hearst & Jenkins, 1974). Thus Moore (1973) has shown that the topography of the autoshaped response varies with the type of reinforcer used. While the autoshaped response of a pigeon is similar to that observed in pigeons pecking for food when grain is used as a reinforcer, the response is more similar to the pigeon's drinking behaviour when water is used as the reinforcer (Moore, 1973). The interactions, therefore, would be a function of the response-eliciting characteristics of the 'sign', or predictive cue, and the tracking response. Leyland (1977) and Rescorla (1980) have demonstrated the effects of the autoshaping stimulus on response topography in their use of a tone as the autoshaping stimulus. In contrast to observations of the autoshaping of a keypecking response when a light stimulus is employed, Leyland (1977) and Rescorla (1980) failed to observe the acquisition of the keypecking response when a tone stimulus was used in an autoshaping paradigm. In addition, Wasserman (1972) has suggested that the nature of a light stimulus employed may determine the topography of the observed autoshaping response. In his investigation, Wasserman (1972) examined the influence of the keylight stimulus localizability on the autoshaping response by varying the ambient illumination of the chamber in which keylight-grain pairings occurred. When the chamber was illuminated between pairings, keylight onset

was the sole predictor of grain presentations, and the autoshaped keypecking response emerged. When the chamber was darkened between trials and the houselight was illuminated during keylight-grain presentations, the predictive cue was more diffuse, consisting of both an ambient illumination change and keylight onset. With the more diffuse cue, head bobbing and cooing rather than keypecking emerged. Thus the reinforcer (Moore, 1973), stimulus modality (Leyland, 1977; Rescorla, 1980), and parametric variations within modalities (Wasserman, 1972) appear to determine the topography of the sign tracked keypecking response.

A more direct comparison of the effects of stimulus characteristics upon the conditioned response can be made in a within subject contrast using the second-order conditioning paradigm. In the second-order conditioning paradigm, a CS (S1), is repeatedly paired with a US until a CR develops to S1. Following this first-order conditioning phase, S1-US pairings are typically terminated, and second-order conditioning is commenced. In second-order conditioning, S1 is repeatedly paired with another stimulus (S2), with S2 presentations immediately preceeding the onset of S1. The result of this set of procedures is that the associational value of S1 that was acquired in first-order conditioning subsequently supports conditioning to S2 in second-order conditioning. When two qualitatively different

stimulus modalities are employed as CSs, then the unique effects of each of the stimuli on response topography can be determined. According to Rescorla (1980) these effects are most readily demonstrable in a second-order conditioning paradigm, because responding is not constrained by the elicitational properties of the US that is employed. In first-order conditioning, the effects of the nature of the predictive cue on response topography can be overshadowed by either immediate gross motor responses elicited by the reinforcer, or by its lingering after-effects (e.g., long duration freezing elicited by shock presentations). In second-order conditioning, the reinforcer is absent, and more subtle responses elicited by the predictive cue can be observed. In their adaptation of the second-order conditioning paradigm, Holland and Rescorla (1975) initially paired a flashing light with a food stimulus, and measured the rat's activity response. Subsequently, they paired the flashing light with an auditory clicker, with the clicker preceeding the light presentations. In accord with expectations derived from the second-order conditioning process, a response developed to the second-order stimulus, the tone. The finding of interest, however, was that the level of activity acquired to the tone CS was twice as high as the level of activity acquired to the light stimulus.

In an effort to identify the factors contributing to the performance difference noted in his initial study

(Holland & Rescorla, 1975), Holland (1977) directly observed the behaviour of rats during presentations of either a light or a tone paired with food. He observed that the most frequently occurring associative responses to the light were rearing and magazine behaviour (i.e., 'standing motionless in front of the food magazine with nose or head within the magazine', p. 80). In contrast, the most frequently occurring behaviours to the tone were head jerks and hind movements, thus supporting the assertion that topographically distinct associative responses are evoked in the appetitive conditioning of a visual and an auditory stimulus (Holland, 1977). From his observations, Holland (1977) concluded that the initial performance difference in activity was an artifact of the measurement techniques employed. That is, the stabilometer used to measure activity was more sensitive to head jerks and hind movements than rearing and magazine behaviour. It therefore appeared that the tone, which elicited head jerks and hind movements, supported higher levels of activity than the light, which elicited rearing and magazine behaviour.

In relating Holland's (1977) empirical observations to second-order conditioning processes, Rescorla (1980) argues that associations are formed between the S1 and US, and between the S1 and S2. The behavioural index of the association can be any response that reliably changes during conditioning. If different stimulus modalities have unique

response evocative characteristics, then learning may be reflected by changes in different classes of responses. Thus when Holland (1977) observed different types of responding to each of the stimuli he employed, the response classes represented indices of the same associative process.

While much of the groundwork for the delineation of response interactions lies in appetitive conditioning paradigms, similar lines of investigation have been pursued in the aversive conditioning literature since Bolles' (1970) derivation of a species-specific defensive reaction (SSDR) theory of avoidance responding. According to Bolles, all of the SSDRs in an organism's repertoire are elicited by an aversive stimulus. Like traditional theorists, Bolles assumes that the response that is conditioned as an avoidance response is similar in topography to one of the responses elicited by the aversive stimulus. Where Bolles differs from traditional theorists, however, is in the determination of which response is conditioned. While for Pavlov (1927), Guthrie (1935), and Hull (1943), the critical determinant of response selection is a temporal variable, for Bolles (1970), response selection is a function of the punishment process inherent in the acquisition of avoidance responding. That is, in an avoidance learning paradigm, the elicited SSDRs that fail to fulfill the experimental contingency are punished by further aversive stimulation, and thus decrease in frequency. An SSDR that does fulfill

the experimental avoidance contingency is not punished; instead, it is rewarded by successful avoidance, and thus increases in frequency. Because the response that fulfills the experimental requirement increases in frequency, and all others decrease, the successful response becomes the dominant response and is associated with the avoidance cue. Thus while the associative response assumes the form of one of the responses elicited by the aversive stimulus, its selection is not determined by temporal variables, but rather by implicit experimental contingencies.

In contrast to Bolles' (1970) SSDR model, the emphasis of Blanchard, Mast, and Blanchard's (1975; Blanchard, Fukanaga, & Blanchard, 1976a; 1976b) model of defensive responding is more heavily weighted on the elicitational properties of non-US variables such as contextual and discrete stimuli. For the Blanchards, the selection laws of both elicited and associative responses are similar. The topography of defensive responses elicited by aversive stimuli as well as by predictive cues are determined by biologically significant features of the threat source (i.e., the aversive stimulus or predictive cue), and the context in which the threat occurs. While they have not operationally defined the biologically significant features of the threat source, Blanchard, Fukanaga, and Blanchard (1976a; 1976b) have defined contextual features which are presumed to determine the topography of the elicited

response. Thus Blanchard et al. (1976a; 1976b) and Blanchard, Mast, and Blanchard (1975) have argued that when rats were familiar with an inescapable box and encountered a cat, dog, or grid shock, freezing replaced escape as the dominant defensive response. In contrast, when rats were not familiar with the inescapable box, escape-like behaviours initially predominated. Similar processes are implicated in the acquisition of defensive responses to predictive cues. Accordingly, when both the aversive stimulus and predictive cues are present, a response is elicited, and fear is acquired to the predictive stimulus (Blanchard & Blanchard, 1969; Blanchard, Fukanaga, & Blanchard, 1976a, 1976b; Blanchard, Mast, & Blanchard, 1975). In the absence of the response eliciting aversive stimulus, the behavioural referant of the fear is a function of both the response eliciting qualities of the predictive cues, and the context in which they are presented. The determinants of responding, therefore, are similar to those described by Rescorla (1980). In the presence of an aversive stimulus, response evocation is controlled, for the most part, by the aversive stimulus. In its absence, there is the potential for a variety of responses to index the association.

In support of their model of defensive responding, Blanchard, Fukanaga, and Blanchard, (1976a; 1976b) have shown that by varying the environmental context in which an

aversive stimulus was presented, the frequency of occurrence of freezing was altered. In addition, Blanchard and Blanchard (1969) have demonstrated that by manipulating the context in which the predictive cue is presented, the frequency with which active or passive avoidance responses are displayed can be varied. While they have pointed to the significance of the response evocative characteristics of conditioned stimuli (Blanchard & Blanchard, 1969), as yet, a formal analysis of the contribution of predictive stimulus characteristics to response control has not been undertaken.

Response Control in Burying Paradigms

Thus far, it has been argued that the index of association is constrained by: the nature of the unconditioned stimulus (Gormezano & Kehoe, 1975); the experimenter's response selection (Bolles, 1970; Rescorla, 1980); the nature of the predictive cues employed (Blanchard, Fukanaga, & Blanchard, 1976a, 1976b; Holland, 1977); ethological determinants and implicit experimental contingencies (Bolles, 1970); and, an interaction of the response eliciting features of the stimuli employed and the context in which they are presented (Blanchard, Fukanaga, & Blanchard, 1976a, 1976b; Rescorla, 1980). Similar to the Blanchards' focus on contextual variables, Pinel and Treit (1978) have suggested that the behavioural indices of learned associations in traditional learning paradigms are

constrained by the resources provided to the organism in its experimental environment. Pinel and Treit's (1978) assertions are based on the observation of the burying response. The burying response was originally identified by Hudson (1950) and has been theoretically interpreted by Pinel and Treit (1978) as an instance of the conditioning of an animal's defensive reaction to a neutral stimulus. Pinel and Treit's (1978) burying paradigm involved adapting rats to an experimental chamber that had a bedding material covered floor. After several adaptation sessions, a small wire-wrapped prod was introduced into the chamber. When subjects touched the prod, shock was delivered through the wires. Subsequently the rats, using their forepaws, pushed bedding material towards the prod and ultimately buried it. Pinel and Treit (1978; 1981) called the covering of the prod conditioned burying because only a prod associated with shock was buried. In extensions of the original paradigm, conditioned burying has been found to occur with a range of aversive stimuli (Terlecki, Pinel, & Treit, 1979; Wilkie, MacLennan & Pinel, 1979). In addition, burying has been observed to be directly controlled by unconditioned stimuli such as physical objects (e.g., mousetraps and flash cube assemblies; Terlecki, Pinel, & Treit, 1979) and odours and tastes (e.g., cadaverine; Pinel, Hoyer, & Terlecki, 1980).

To account for burying behaviour, Pinel and Treit (1981) have proposed two models: one for unconditioned

burying, and a second for conditioned burying. For unconditioned burying, it is proposed that novel stimuli produce a neophobic reaction that leads to burying. Presumably the steps involved in this process would be as follows: the novel stimulus elicits a fear reaction, and the fear reaction activates defensive responses, one of which, burying, is directed at the fear eliciting stimulus. For conditioned burying, very similar mechanisms are implied. When rats touch the prod and receive shock, it is assumed that due to spatial contiguity the prod is associated with the aversive event. Subsequently, the prod becomes a fear eliciting stimulus that activates defensive responses with the consequence that the subjects bury the prod. Central to both accounts is the assertion that burying is a defensive response. And critical to both models is the mechanism that activates burying as opposed to the other defensive responses. While Pinel and his colleagues (cf. Pinel & Treit, 1981) have collected evidence from the conditioned burying paradigm and from ethological observations on predator-prey interactions to support the claim that burying is a defensive response, they have not directly addressed the selective activation question. Instead, they have appealed to Bolles' model of avoidance behaviour (Bolles, 1970) to account for the elicitation of the burying response.

Bolles' (1970) SSDR model of avoidance responding is based on expectations derived from predator-prey interactions. Implicit in SSDR formulations is the assumption that there is a sequential order in which different defensive behaviours emerge. This is indicated by Bolles' (1975) assertion that a rat's predisposition when confronted with an aversive stimulus in an escapable environment is to first flee; if that fails, it freezes; if that fails and if confronted by a predator, it will fight. Somewhere, at the top of Bolles' (1970) list, Pinel and Treit (1978) would add burying. In applying Bolles' (1970) model to the burying response, Pinel and Treit (1978) abstract only that portion of the model dealing with the sequential activation of defensive responses. The punishment process advocated by Bolles (1970) is not applied to burying, since in the burying paradigm, only one shock is administered. Thus punishment of the shock elicited defensive responses is impossible. While Pinel and Treit (1978) categorize burying amongst defensive responses such as escaping and freezing, it has been empirically determined that some of the parameters of burying (e.g., latency) do not directly covary with those of freezing and escape (Moser & Tait, Note 1). This finding is inconsistent with the notion that burying is an SSDR like freezing and escaping. Instead, Moser and Tait (Note 1) proposed that burying may occur as a defensive response within the broader categorization advocated by Edmunds (1974).

Edmunds (1974) catalogued defensive responding into either primary defenses or secondary defenses. Primary defenses function continuously and serve to decrease the probability of encountering a predator. Included within this category would be the mechanisms of anachoresis, crypsis, aposematism, and Batesian mimicry. Secondary defenses refer to responses which appear when the primary defenses fail, and predator confrontation occurs. Secondary defensive responses include withdrawal to a prepared retreat; the elicitation of deimatic, or frightening behaviours such as piloerection; thanatosis, the feigning of death; or, if the predator is very close or actually attacking the prey, the prey will either deflect the attack to a non-vital portion of its body, or retaliate. Various sequences of these responses are thought to comprise the innate defensive network of a given species. Since the secondary defensive behaviours are believed to emerge in a sequential order, with movement through the order depending on the success or failure of a given defensive response, Edmunds' (1974) secondary defensive behaviours are equivalent to Bolles' (1970) SSDRs.

While burying was originally thought (Pinel & Treit, 1978) to be a secondary defensive response, it now appears that burying may be a laboratory analogue to the rat's primary defensive behaviour of burrowing (Moser & Tait, Note 1). The frame of reference provided by Moser and Tait (Note

1) suggests some of the processes determining stimulus control of the burying response. The model should be able to predict those classes of stimuli which support burying and those which cannot. And, in fact, there exists some empirical data which can be applied to the model. Hudson (1950), Pinel, Treit, and Wilkie (1980), and Silverman (1978) have reported that rats bury openings through which aversive events have entered experimental chambers. This observation is similar to naturalistic observations (Calhoun, 1962) of rats covering over entrances to their burrow systems to prevent access by intruders. Both the burying of the holes in the experimental chambers, and in the burrows would serve to decrease the probability of future encounters with aversive stimuli, and as such, would be considered primary defensive behaviours.

The model would also predict those classes of stimuli which would not be buried. If, for example, burying is a primary defensive response, then one would not expect to observe burying in predator-prey interactions. Edmunds (1974) suggests that an organism's initial response to a predator may be an exaggeration of a primary defensive response, but that subsequently, secondary defensive responding is initiated. Thus in the laboratory, stimuli which closely mimicked a predator would not be expected to support either the elicitation or the conditioning of prolonged burying, since primary defensive responses are

supplanted by secondary defensive responses when a predator is encountered. One parameter of stimuli used in the laboratory that is assumed to closely mimic a predator is stimulus movements (Blanchard, Mast, & Blanchard, 1975). Moser and Tait (1981) observed that when rats were presented with a moving prod associated with shock, they did not subsequently bury the prod. These observations are consistent with the primary defensive response hypothesis. For secondary defensive responses such as freezing and escaping were observed in face of a stimulus which closely resembled a predator, while primary defensive responses such as burying, were not. However, as Moser and Tait (1981) point out, in the paradigm employed there existed the possibility for interactions between the response eliciting properties of the prod, and those of the shock. Accordingly, the observations of Moser and Tait (1981) were unable to address the problem that was initially proposed, that is, the mechanisms underlying the emergence of the burying response.

In order to address the question of the mechanisms underlying burying, the present investigation examined the effects of stimulus characteristics on the emergence of burying. Specifically, the unique effects of qualitatively different stimuli, a tone and a prod, on responding in a burying paradigm was determined. In order to separate the elicitational properties of aversive stimuli from the

elicitational properties of predictive cues, an adaptation of a second-order conditioning paradigm was employed. It was necessary to eliminate the effects of the shock in order to determine the effects of the tone and prod, since shock has been shown to elicit long durations of freezing in a burying paradigm (Moser & Tait, 1981). Long durations of freezing are incompatible with the response of burying, and could, therefore, obscure any effects that the prod and tone would have in the absence of the shock. According to Rescorla (1980), the use of a second-order conditioning paradigm should eliminate the potential confounding of US-elicited responding. In the following experiment, a tone (S1) and shock were paired in a primary conditioning phase. In the higher-order conditioning that followed, the tone was employed in lieu of the electric shock that is typically employed in a burying paradigm (cf. Pinel & Treit, 1978). That is, upon a rat's contact of its forepaw with the prod, the S1 tone was presented. It was expected that the manipulations of the primary conditioning to the tone would render the tone as a conditioned elicitor of the freezing response. This expectation was derived from Nicholaichuk, Quesnel, and Tait's (1982) demonstration that a tone paired with shock becomes a reliable elicitor of freezing. The consequences of higher-order conditioning, however, were not unequivocally predictable; each of the theoretical positions predicts a different outcome.

According to Pavlov (1927), higher-order conditioning processes parallel the processes involved in primary conditioning. Thus it would be expected by traditional theorists (Guthrie, 1933; Hull, 1943; Pavlov, 1927) that the response acquired to the primary conditioned stimulus would be conditioned in the higher-order conditioning phase. Therefore, it would be predicted that both the tone and the prod acquire conditioned freezing. Similar outcomes would be predicted from SSDR theory, since the associative response is presumed to take the same form as the unconditioned SSDR that ultimately predominates (Bolles, 1970). That is, the response that is not punished remains as the associative response throughout primary and higher-order conditioning, since no punishment is administered in higher-order conditioning. In contrast, theoretical positions emphasizing the influence of stimulus modality on conditioned response topography (e.g., Holland, 1977) would make differential outcome predictions for response acquisition to the tone and prod employed in primary and higher-order conditioning. Since it has been empirically determined that a tone associated with shock supports freezing (Nicholaichuk, Quesnel & Tait, 1982), and that a prod associated with shock supports burying (Pinel & Treit, 1978), Holland (1977) would expect the acquisition of freezing and burying in primary and higher-order conditioning, respectively. Similar predictions would be

derived from a response elicitation perspective based on the adaptive interaction of the organism with its environment (e.g., Blanchard, Fukunaga, & Blanchard, 1976a, 1976b; Blanchard, Mast, & Blanchard, 1975), as well as from Pinel and Treit's (1978; 1981) model of burying based on ethological analogy. From Nicholaichuk et al.'s (1982) results, it would be expected that freezing would be acquired to the tone in primary conditioning. And if, in higher-order conditioning the prod was established as a predictor of aversive stimulation, then it would be expected that burying would be conditioned to the prod. For given Moser and Tait's (Note 1) ethological analysis of conditioned burying, it would be expected that burying would be an efficient response in decreasing the probability of encounter with the threat source, while freezing would not. Therefore, higher-order conditioning would result in the acquisition of the burying response.

In order to establish that the response conditioned to the prod during higher-order conditioning is a function of the aversive properties that were acquired by the tone during primary conditioning, a no-treatment control group was employed. This group was merely placed in the apparatus during primary conditioning and was subsequently exposed to a prod-tone pairing. In addition, a group receiving tone-shock pairings followed by the prod-shock pairing employed by Pinel and Treit (1978) was used as a reference group.

Since the presently employed procedures deviated from the standard burying paradigm, it was necessary to demonstrate that conditioned burying would occur to a prod paired with an aversive stimulus, given prior experience with tone and shock stimuli. And finally, a group receiving tone-shock presentations followed by a tone alone presentation was used to assess the magnitude of conditioned freezing that would occur to the tone, in the absence of the opportunity to bury a prod.

Since it has been shown that a single tone-shock pairing can evoke freezing behaviour which lasts for over fifteen minutes, it is possible that the present paradigm would be vulnerable to the same confounds described by Rescorla (1980). That is, the effects of the prod would not be observed if the tone-elicited freezing lasted the entire session in higher-order conditioning. Therefore, a test day following the second phase was implemented. In order to determine the contribution of the prod itself to the emergence of burying, the prod alone was presented on the test day.

Method

Subjects. Forty naive male adult hooded rats weighing approximately 250 grams were purchased from the University of Manitoba vivarium and, upon their arrival, were individually housed and given free access to food and water.

Apparatus. The experimental apparatus consisted of two chambers: one chamber was used for primary conditioning and another for higher-order conditioning. Primary conditioning took place in a brushed aluminum Coulbourn Instruments Inc. operant chamber equipped with a house light, a grid floor, and a 4.5 cm diameter 8 ohm speaker. The grid floor was composed of 7 mm diameter steel bars 1.8 cm apart (centre to centre). Scrambled shock was delivered to the floor of the chamber by a Coulbourn Instruments Inc. Solid State Shock Generator.

The higher-order conditioning chamber was a flat-black wooden box measuring 30x30x20 cm on the interior. The floor of the chamber was uniformly covered with 5 cm of finely cut sawdust. During conditioning, the same speaker that was used in primary conditioning was attached to the end wall of the chamber. Immediately below the speaker, a wooden prod (6 x .5 x .5 cm) was affixed at a 90° angle midway along the end wall of the chamber, 2 cm above the level of the sawdust. The prod consisted of a balsa wood dowel around which two uninsulated wires were wrapped. The prod wires were connected to a Coulbourn Instruments Inc. Solid State Shock Generator, which was situated in an adjoining room. The adjoining room also contained: a white noise generator, which operated to provide continuous white noise at 70 db in the experimental room; a T.V. monitor; and a Southwest Technical Products M6800 microcomputer. The T.V. monitor

was connected to a Sony Videocamera that was suspended above the experimental chamber and allowed the experimenter to unobtrusively observe a subject's behaviour. By observing the monitor, the experimenter was able to encode mutually exclusive behavioural classes on a keyboard. Every ten milliseconds, the computer software scanned the keyboard for depressions and accumulated the frequency and duration of the key depressions. Since each key defined a particular behaviour, the computer tabulated the frequency and duration of the measured behaviours.

Dependent Measures. The responses that were measured during habituation and during higher-order conditioning were identified and recorded according to the following schema:

Burying was characterized by a forward shovelling movement of the rat's forepaw.

Freezing was defined as a complete absence of movements characterized by abruptness of onset, wide open eyes, and muscular rigidity.

Throughout habituation and at the end of both the higher-order conditioning and test sessions, additional dependent variables were collected. These include the height of the pile on the prod, or during habituation, the height of the pile where the prod would have been placed, and the height of the largest pile in the chamber. In addition, because it has been suggested (Moser & Tait, 1981) that the duration of freezing bouts varies with the type of aversive conditioning paradigm employed, the frequency with

which a number of bout durations were observed was collected. That is, each freezing bout was classified by the computer into one of seven categories: a bout of 0.1-5.0 seconds in length; 5.1-10.0 secs; 10.1-25.5 secs; 25.6-51.1 secs; 51.2-102.3 secs; 102.4-204.7 secs; 204.8-511.9 secs; or, 512.0-900.0 secs.

Procedure. The experimental protocol for each subject lasted five days. On each of the first two days, the subjects were individually habituated to the higher-order conditioning chamber for 15 minutes. On the third day, the subjects were randomly assigned to one of the four groups ($n=10$) depicted in Table 1. As can be seen from the table, the Experimental Group (Prod-Tone) received tone-shock pairings in primary conditioning, and a prod-tone presentation in higher-order conditioning; a Tone-Alone Group received tone-shock pairings in primary conditioning and a tone presentation in the higher-order conditioning phase; a Prod-Shock Group was presented with tone-shock presentations in primary conditioning, and a prod-shock pairing in higher-order conditioning; and finally, a Notreatment Group received no programmed stimuli in primary conditioning, and were subsequently presented with a prod-tone pairing. In the test session that followed, all groups received prod alone presentations.

On the day following the last day of habituation, primary conditioning was initiated. Three groups received 8 pairings of a 10 sec, 1000 Hz, 75 db tone, with a .5 mA, 1.0

Table 1. Experimental Design.

Group Designation	Primary	Higher-Order	Test
Prod-Tone	Tone \rightarrow Shock	Prod \rightarrow Tone	Prod
Tone-Alone	Tone \rightarrow Shock	Tone	Prod
Prod-Shock	Tone \rightarrow Shock	Prod \rightarrow Shock	Prod
Notreatment	Notreatment	Prod \rightarrow Tone	Prod

sec, scrambled foot shock at a forward interstimulus interval of 10 seconds, and an intertrial interval of 5 minutes. It was expected that eight pairings would support asymptotic performance, since Rizley and Rescorla (1972) have demonstrated reliable acquisition of primary and higher-order associative responses with eight pairings of a tone and shock in a conditioned emotional response paradigm. A fourth group was placed in the experimental apparatus but received no stimulus presentations. On the following day, the Prod-Tone Group was placed in the higher-order conditioning chamber. Upon the subject's first contact of its forepaw with the prod, a 10 second presentation of the tone was initiated. During the 15 minutes that followed, the subject's behaviour was recorded. The Tone-Alone Group received a 10 second tone presentation in the absence of the prod. The Prod-Shock Group received a presentation of the prod, paired with shock in a manner typical of the standard burying paradigm. That is, upon the subject's first contact of its forepaw with the prod, a 7.9 mA shock, initiated by the experimenter and terminated by the subject's withdrawal, was administered. And finally, the group that received no treatment during primary conditioning was presented with the same prod-tone pairing as the Prod-Tone Group; upon the first contact of a subject's forepaw with the prod, a 10 second tone was presented. For all groups, the 15 minute period following stimulus presentation served as the time

period during which the dependent variables were recorded. On the following day, a test session was employed. In the test session, the prod was presented in the higher-order conditioning chamber, but neither the tone nor the shock were delivered. The subject's behaviours were recorded for the 15 minute period following their placement in the chamber.

Results

The results were divided into three sections: the first one dealing with habituation data; the second one dealing with conditioning data; and, the third one dealing with test day data. Four x Two (Groups x Days) repeated measures Analyses of Variance (ANOVA's) were applied to the habituation data while Multivariate Analyses of Variance (MANOVA's) were used to analyze both conditioning and test day data. Univariate breakdowns were followed by a priori orthogonal contrasts which compared the Prod-Tone and Prod-Shock Groups with the Tone-Alone and Notreatment Groups; the Prod-Tone with the Prod-Shock Group; and the Tone-Alone with the Notreatment Group. In addition, a separate analysis was applied to those subjects that evidenced burying of the prod on conditioning and test days. For clarity of discussion, only significant ($\alpha=.05$) F-statistics will be reported. For further reference, the global ANOVA's for habituation, conditioning, and test days can be found in Tables 1, 2, and 3 of Appendix A.

Responding During Habituation. The first two points on the abscissas of each of the panels in Figure 1 represent the mean group frequencies (Left Column), durations (Middle Column), and latencies (Right Column) of freezing (Upper Row), and burying (Lower Row) across the two habituation days. As can be seen from the Upper Row, over the two days of habituation, both the frequency and duration of freezing increased [$F(1,36)=54.55$, $p<.001$, and $F(1,36)=21.83$, $p<.001$, respectively] while the latency decreased, [$F(1,36)=4.36$, $p<.05$]. There were no significant Group or Group x Days effects on freezing measures in habituation, thus indicating that the freezing effects were similar in each group.

The Lower Row of Figure 1 represents the mean frequency, duration, and latency of burying, and shows that over days of habituation, both the frequency and duration of burying decreased [$F(1,36)=17.55$, $p<.001$, and $F(1,36)=14.58$, $p<.001$, respectively], while the latency to bury increased [$F(1,36)=16.50$, $p<.001$].

The first two points on the abscissa of each panel in Figure 2 depicts the mean group heights of the piles where the prod was to be placed during conditioning (Upper Panel), as well as the mean group heights of the largest piles in the chamber (Lower Panel). As can be seen from the figure, both the pile in the area where the prod was to be placed and the height of the largest pile in the chamber decreased over habituation days [$F(1,36)=7.80$, $p<.025$, and

Figure 1. Mean frequency (Left Column), duration (Middle Column), and latency (Right Column) of freezing (Upper Row) and burying (Lower Row) over Habituation (Days 1 and 2), Conditioning (C), and Test (T) Days for the Prod-Tone, Tone-Alone, Prod-Shock, and Notreatment Groups.

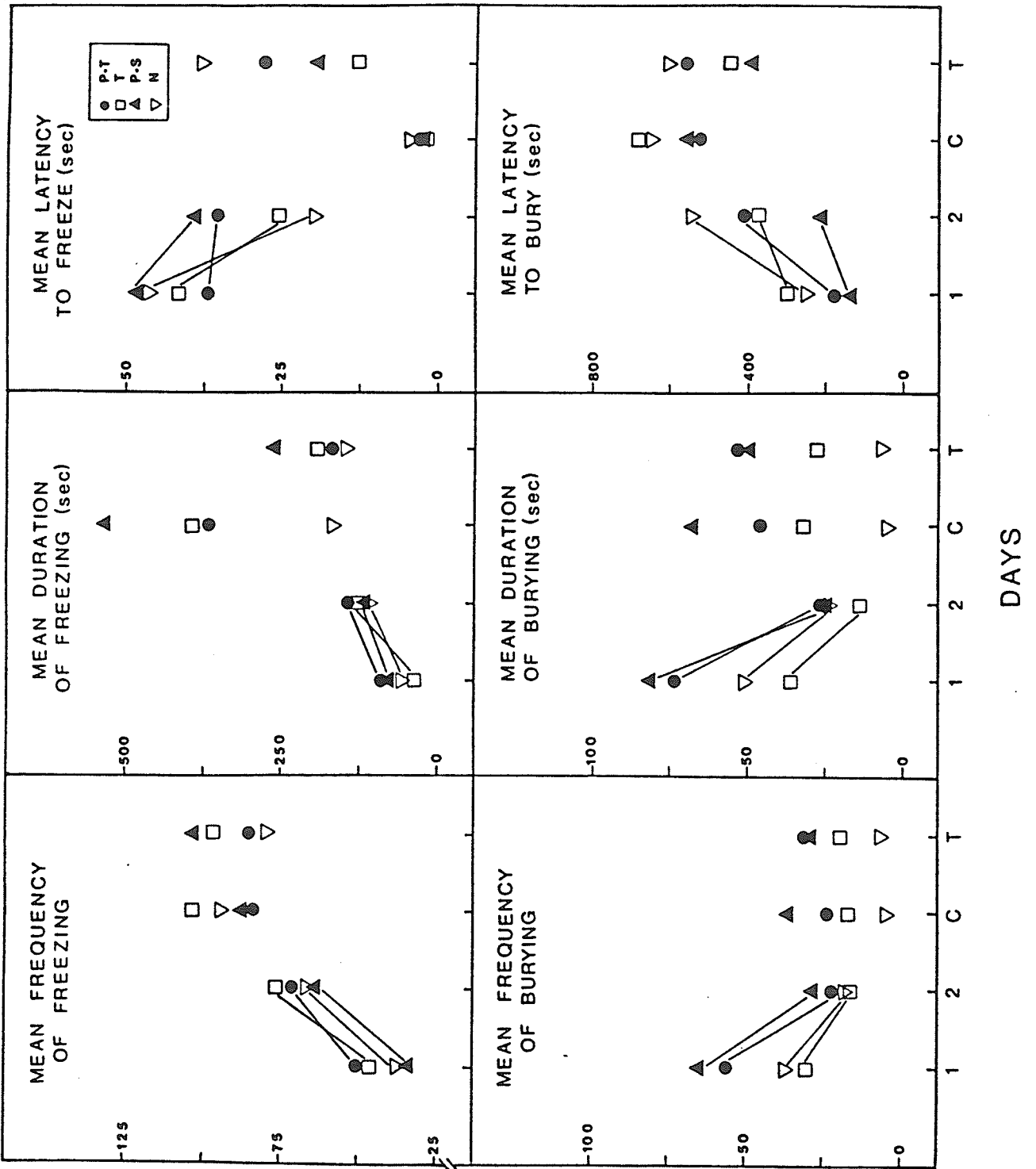
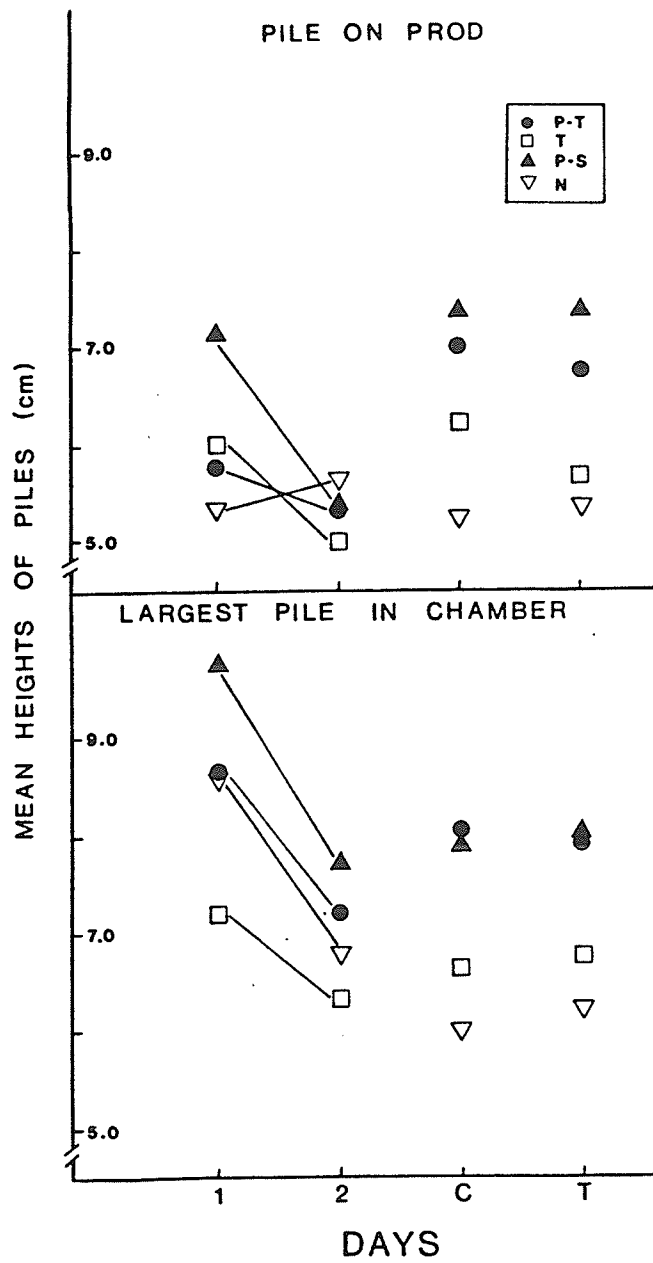


Figure 2. Mean heights of the pile on the prod (Upper Frame) and the largest pile in the chamber (Lower Frame) over Habituation (Days 1 and 2), Conditioning (C), and Test (T) Days for the Prod-Tone, Tone-Alone, Prod-Shock, and Notreatment Groups.



$F(1,36)=12.69$, $p<.025$, respectively]. There were no significant Group or Group x Days interactions for the frequency, duration, latency to bury, or heights of piles measures. The failure to find significant interactions suggests that the observed adaptation in burying indices was constant across groups.

Responding During Conditioning. The third point on the abscissas of each of the panels in Figures 1 and 2 depict levels of post prod-tone and prod-shock responding. A MANOVA was applied to the conditioning frequencies and durations of freezing and burying as well as to the heights of piles measures. The results revealed that when combined across all dependent variables, there were significant group differences [$F(24,85)=2.13$, $p<.025$]. Simple MANOVA contrasts revealed that the Notreatment Group differed from: the Prod-Tone, [$F(8,29)=2.46$, $p<.05$]; the Tone-Alone, [$F(8,29)=3.63$, $p<.025$]; and, the Prod-Shock, [$F(8,29)=6.60$, $p<.001$] Groups. The Prod-Tone, Prod-Shock, and Tone-Alone Groups did not differ from each other. Univariate breakdowns that were provided by the MANOVA described the individual dependent variables that differentiated groups, and are presented as follows.

Freezing During Conditioning. The Upper Left Panel of Figure 1 presents the mean group frequencies of freezing, and shows that there were no major differences between groups. However, as can be seen from the Upper Middle Panel

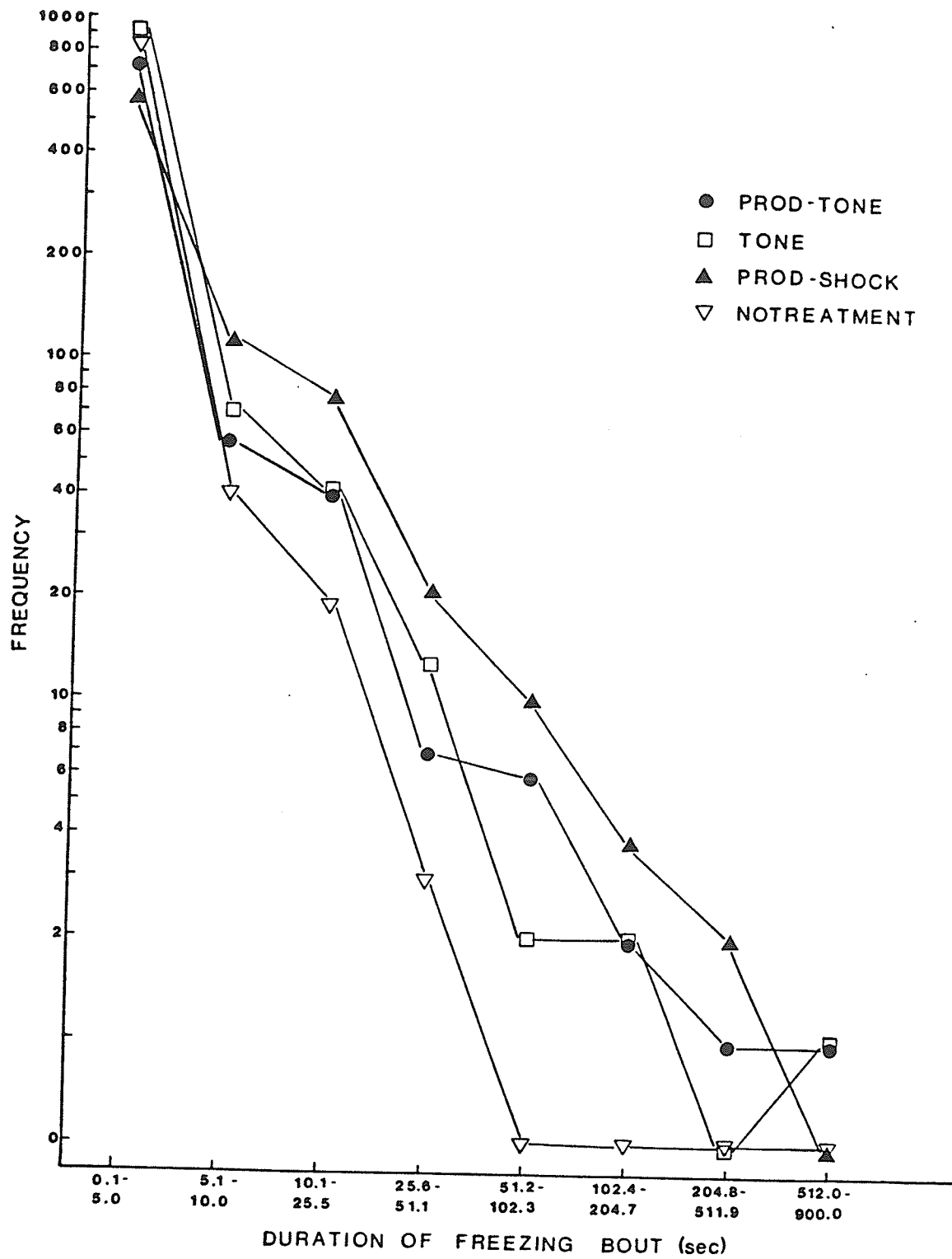
of the figure, the Notreatment Group froze for shorter durations than the Prod-Shock, Tone-Alone, and Prod-Tone Groups. An ANOVA confirmed the graphical depiction of group differences in freezing durations [$F(3,36)=4.69$, $p<.025$]. Orthogonal contrasts showed that: the Prod-Tone and Prod-Shock Groups froze for longer durations than the Tone-Alone and Notreatment Groups [$F(1,36)=5.22$, $p<.05$]; the Tone-Alone Group froze for longer durations than the Notreatment Group [$F(1,36)=6.35$, $p<.05$]; and, the freezing durations of the Prod-Tone and Prod-Shock Groups were not statistically different. The Upper Right Panel of Figure 1 depicts the mean latencies to freeze for the Prod-Tone, Prod-Shock, Tone-Alone, and Notreatment Groups, and shows very small differences in latencies, with the Notreatment Group having the longest latency to freeze. The ANOVA suggested that group differences for the latency to freeze approached significance [$F(3,36)=2.43$, $p=.08$]. Orthogonal comparisons showed that: the latencies to freeze for the Prod-Tone and Prod-Shock Groups were not statistically different than the latencies to freeze for the Tone-Alone and Notreatment Groups; the Tone-Alone Group had a significantly shorter latency to freeze than the Notreatment Group, [$F(1,36)=5.00$, $p<.05$]; and, the latencies to freeze for the Prod-Tone and Prod-Shock Groups were not statistically different.

Since there were group differences for the duration of freezing, but not for the frequency of freezing, it is clear

that the duration of freezing bouts were different across groups. Figure 3 depicts the frequency distribution of each of the groups for freezing bout lengths of: 0.1-5.0 seconds in length; 5.1-10.0 secs; 10.1-25.5 secs; 25.6-51.1 secs; 51.2-102.3 secs; 102.4-204.7 secs; 204.8-511.9 secs; and, 512.0-900.0 secs. A Chi-square analysis, comparing the frequency distribution of each of the four groups with each other, was applied to the frequency distribution of freezing bouts, and significant group differences were found, [$\chi^2(3)=189.01, p<.001$]. As can be seen from Figure 3, the frequency distribution of the Notreatment Group was clearly different than the other groups, with the Notreatment Group having both fewer shorter and fewer longer duration freezing bouts than the Prod-Tone, Tone-Alone, and Prod-Shock Groups. The Chi-Square analysis suggested that amongst the Prod-Tone, Tone-Alone, and Prod-Shock Groups, the Prod-Shock Group had more bouts of greater durations and fewer shorter duration bouts than either the Prod-Tone or Tone-Alone Groups [$\chi^2(1)=60.40, p<.001$, and $\chi^2(1)=80.36, p<.001$, respectively]. As well, the Prod-Tone Group had a larger number of long duration bouts and fewer short duration bouts than the Tone-Alone Group [$\chi^2(1)=6.78, p<.05$].

Burying During Conditioning. The third point on the abscissa of the Lower Left Panel in Figure 1 presents the mean group frequencies of burying during conditioning and shows that there are no group differences in burying

Figure 3. Frequency distribution (depicted on a log scale) of freezing bout lengths of: 0.1-5.0 secs; 5.1-10.0 secs; 10.1-25.5 secs; 25.6-51.1 secs; 51.2-102.3 secs; 102.4-204.7 secs; 204.8-511.9 secs; 512.0-900.0 secs; for the Prod-Tone, Tone-Alone, Prod-Shock, and Notreatment Groups.



frequencies. The Lower Middle Panel of the figure represents the durations of burying and suggests that the Prod-Shock, Prod-Tone, and Tone-Alone Groups buried for longer durations than the Notreatment Group, with the Prod-Shock Group evidencing the longest durations of burying. The graphical impressions were not, however, confirmed statistically. Similarly the graphical representation of burying latencies in the Lower Left Panel suggests that the Prod-Tone and Prod-Shock Groups had lower latencies to bury than the Notreatment and Tone-Alone Groups. However, these impressions were not statistically confirmed by the ANOVA.

The third point on the abscissas of the Upper and Lower Panels in Figure 2 depict the conditioning day heights of the piles on the prod and of the largest pile in the chamber, respectively. While from the graph it appears as though the Prod-Shock and Prod-Tone Groups buried higher piles than the Tone-Alone and Notreatment Groups, no statistical differences were found.

Since no statistical group differences on any of the burying measures were found, it would appear as though the present investigation failed to demonstrate reliable conditioned burying. However, it should be noted that in the standard burying paradigm (Pinel & Treit, 1978), only a prod-shock and notreatment control group are employed. In contrast, the analyses described above were applied to four groups, which received either prod-shock, prod-tone, tone-

alone, or no stimulus presentations. In order to determine whether or not the present investigation replicated Pinel and Treit's (1978) initial demonstration of conditioned burying, an analysis between the Prod-Shock and Notreatment Groups alone was applied to the presently measured variables that are typically utilized in the burying paradigm (Pinel & Treit, 1978; 1979; 1980); these are the durations of burying, and the heights of the piles on the prod. When the Prod-Shock and Notreatment Groups were compared on these measures, significant group differences were found for both of the variables, with the Prod-Shock Group burying for longer durations and accumulating higher piles on the prod than the Notreatment Group [$F(1,18)=5.52$, $p<.05$, and $F(1,18)=6.14$, $p<.025$, respectively]. From the observations of the Prod-Shock and Notreatment Groups, it is thus apparent that reliable conditioned burying (cf. Pinel & Treit, 1978) occurred following the prod-shock pairing.

Responding on the Test Day. The last point on the abscissas of each of the panels in Figures 1 and 2 represent levels of test day responding. A MANOVA was applied to the test day frequencies, durations, and latencies to bury and freeze, as well as to the heights of piles measures. The MANOVA revealed that there were no group differences when combining across variables. Univariate statistics showed that no group differences existed for any of the individual freezing, burying, or height of pile measures, thus

suggesting that the effects observed during conditioning may have extinguished.

Subjects that Buried During Conditioning. While no significant effects were found for the four groups on any of the burying measures, an examination of the individual subject's data revealed some important patterns of responding that were not described by the analyses. Table 2 presents the number of subjects that buried the prod on each of the habituation, conditioning, and test days, as well as the number of subjects that buried on conditioning and test days that had also buried on the last day of habituation. A more complete description of the individual subjects that evidenced burying of the prod can be found in Table 1 of Appendix B. As can be seen from the first two data columns of Table 2, with the exception of the Notreatment Group, the number of subjects that buried decreased over habituation days. On the conditioning day, the number of subjects that buried in the Prod-Tone, Tone-Alone, and Prod-Shock Groups increased, while the number of subjects that buried in the Notreatment Group decreased. From a comparison of the number of subjects that evidenced burying on the last day of habituation in the area where the prod was to be placed, with the number of subjects that buried the prod during conditioning, it can be seen that: following a prod-tone pairing, there was an increment of three subjects ($5-2=3$) that buried during conditioning, and which had not buried on

Table 2. The number of subjects that buried in the area of the prod during Habituation and on Conditioning and Test Days. Bracketed figures show the number of subjects on the Conditioning and Test Days that had also buried on the second day of Habituation.

Group	Day 1	Day 2	Condit- ioning	Test
Prod- Tone	5	2	5 (2)	6 (2)
Tone- Alone	4	1	2 (0)	3 (0)
Prod- Shock	9	4	5 (3)	7 (2)
Notreat- ment	2	3	2 (2)	2 (2)

the last day of habituation; following either the tone alone or prod-shock presentation, there was an increment of 2 subjects that buried; while no increment in the number of subjects that buried occurred following the prod-tone pairing in the Notreatment Group. Thus it appears that the pairing of a prod with either a shock or an aversive tone, or the presentation of an aversive tone alone, led to an increase in the number of subjects that buried the prod, while the presentation of an innocuous prod and tone did not.

Given the varying numbers of subjects who buried in each of the groups, it was felt that a mean group score for burying measures would not adequately reflect the magnitude of burying observed in each of the groups, since the scores of the subjects that buried in each of the groups would be averaged with differing numbers of zero scores of the non responders. In the ANOVA, the combination of high scores with zero scores would have resulted in high levels of error variance, resulting in nonsignificant results. Accordingly, an analysis of only those subjects that buried was applied to the frequencies, durations, and latencies to bury, as well as to the heights of piles measures. Nonparametric statistics were used to assess the reliability of between group differences; Kruskal-Wallis oneway analyses of variance of ranks ($\alpha=.05$) were used to test for overall group differences, followed by Mann-Whitney tests to

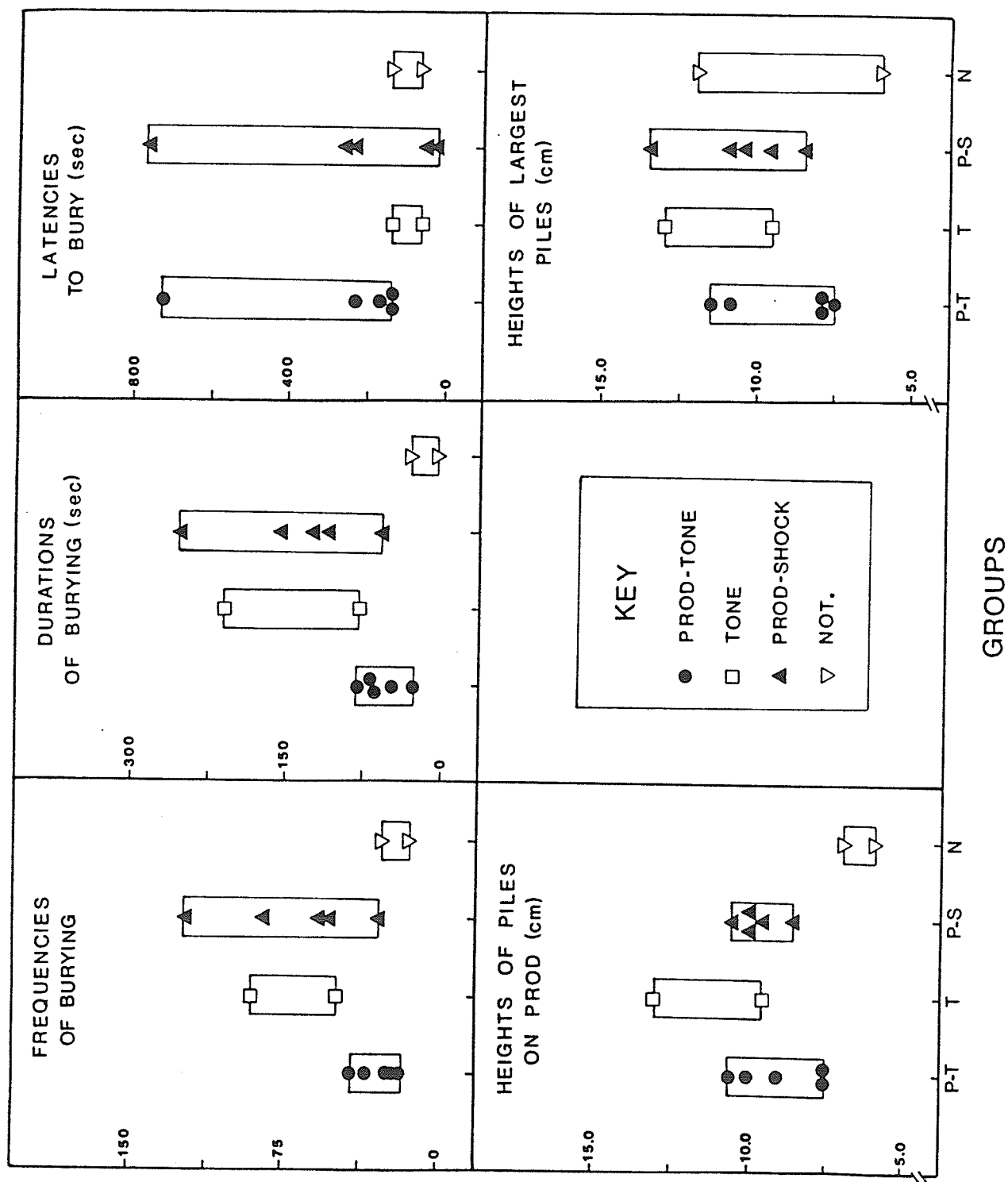
determine where individual group differences lay. The individual contrasts compared those groups that were exposed to the prod (Prod-Tone and Prod-Shock) with those that did not experience the prod (Tone-Alone and Notreatment). As well, the Experimental Group (Prod-Tone) was compared with the Prod-Shock Group. Due to the small number of subjects that buried in the Tone-Alone and Notreatment Groups, direct comparisons with either one of these groups alone could not be made.

During conditioning, group differences were found for both the frequencies and durations of burying [Kruskall-Wallis $H=8.41$, $df=3$, $p<.05$, and $H=7.52$, $df=3$, $p<.05$, respectively]. Mann-Whitney contrasts showed that the Prod-Tone and Prod-Shock Groups buried more frequently and for longer durations than the Tone-Alone and Notreatment Groups. However, there were no differences in either the frequency or duration of burying between the Prod-Tone and Prod-Shock Groups. As well, there were no group differences in the latencies to bury. In contrast, the differences in heights of the piles on the prod approached significance [$H=6.10$, $df=3$, $p<.10$]. Mann-Whitney contrasts showed that while the Prod-Tone and Prod-Shock Groups buried higher piles on the prod than the Tone-Alone and Notreatment Groups, there were no differences in the heights of the piles of the Prod-Tone and Prod-Shock Groups.

Figure 4 depicts the performance of each of the subjects that buried in the Prod-Tone, Prod-Shock, Tone-Alone, and Notreatment Groups, for the frequency (Upper Left Panel), duration (Upper Middle Panel), and latency to bury (Upper Right Panel), as well as the heights of the pile on the prod (Lower Left Panel) and the largest pile in the chamber (Lower Right Panel). From the Upper Left and Middle Panels, it appears that there is little variability in the frequencies and durations of burying for the Prod-Tone Group as compared to the Prod-Shock, Tone-Alone, and Notreatment Groups. In addition, the frequencies and durations are generally lower for the Prod-Tone Group than for the Prod-Shock and Tone-Alone Groups, suggesting that the effects of pairing a prod with an aversive tone are not simply a combination of the processes derived from pairing a prod with shock, and of presenting an aversive tone by itself. From the Upper Right Panel, it appears that the presentation of a prod with an aversive stimulus had similar effects on latencies to bury in the Prod-Tone and Prod-Shock Groups as compared to the latencies to bury of subjects who were not exposed to the prod (Tone-Alone Group) or a prod paired with an aversive stimulus (Notreatment Group).

The Lower Left Panel of Figure 4 depicts the heights of the piles on the prod for each subject, and shows that subjects in the Prod-Tone and Prod-Shock Groups accumulated

Figure 4. Individual subjects' performance from the Prod-Tone (P-T), Tone-Alone (T), Prod-Shock (P-S), and Notreatment Groups (N) on Conditioning Day frequencies, durations, and latencies to bury; heights of the pile on the prod, and the largest pile in the chamber.



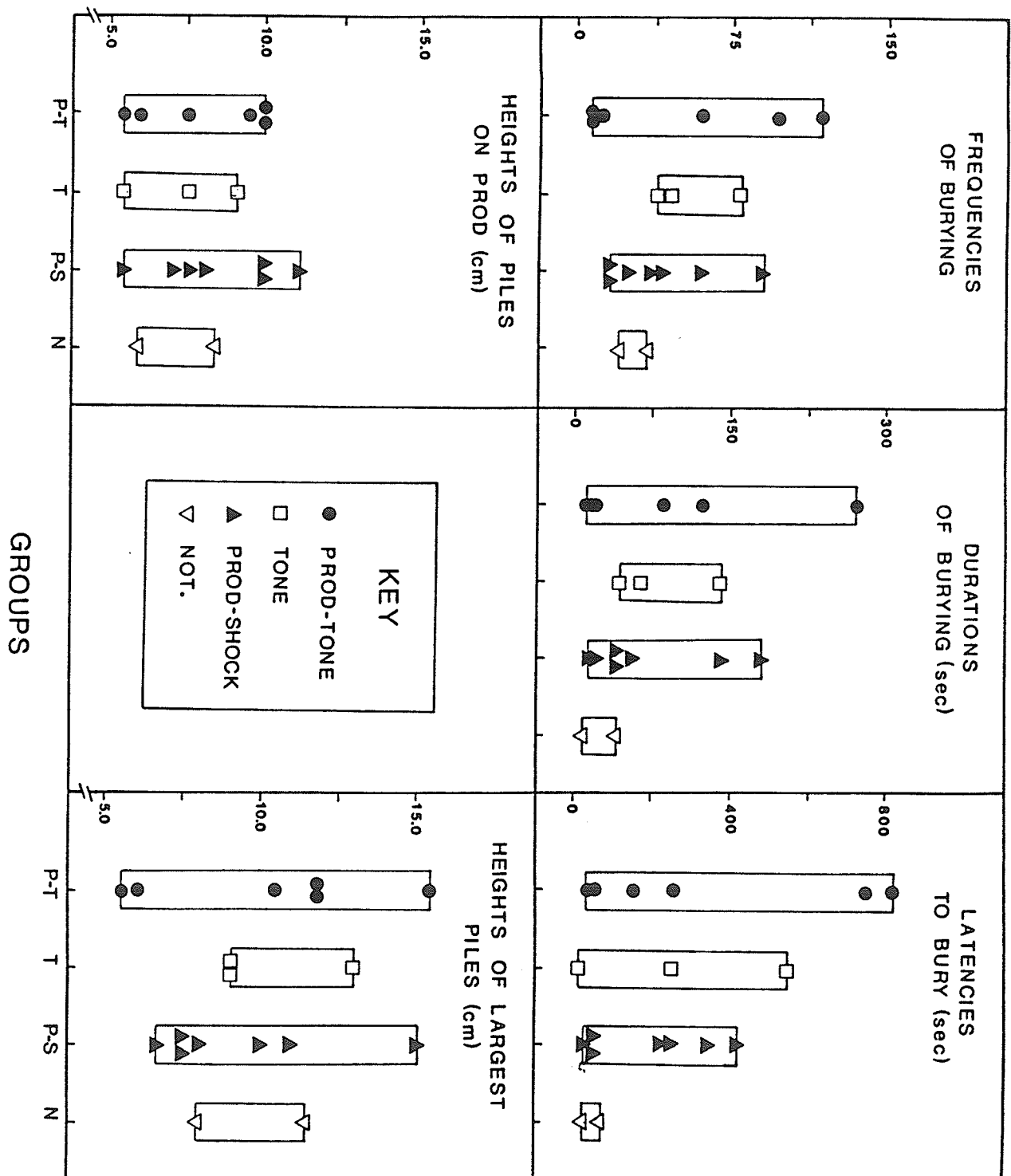
piles on the prod, that were, for the most part, lower than the Tone-Alone Group, and higher than the Notreatment Group. In contrast, the range of the heights of the largest pile in the chamber were similar across groups.

Subjects That Buried on the Test Day. The fourth data column of Table 2 displays the number of subjects that buried the prod on the test day, and the portion of those subjects who had buried on the last day of habituation. As can be seen from the table, more subjects in the Prod-Tone, Prod-Shock, and Tone-Alone Groups buried the prod on the test day than had on the last day of habituation. In contrast, fewer subjects in the Notreatment Group buried the prod on the test day as compared to the last day of habituation. Furthermore, from a comparison of columns 3 and 4, it appears that more subjects in the Prod-Tone, Prod-Shock and Tone-Alone Groups buried the prod on the test day as compared to the conditioning session.

While the numbers of subjects who buried the prod differed across groups, these differences were not reflected in the magnitude of burying indices. Kruskal-Wallis analyses showed that there were no group differences in the frequencies, durations, and latencies to bury, or the heights of piles.

Figure 5 depicts the individual subjects' performance on frequency (Upper Left Panel), duration (Upper Middle Panel), and latency to bury (Upper Right Panel), as well as

Figure 5. Individual subjects' performance in the Prod-Tone (P-T), Tone-Alone (T), Prod-Shock (P-S), and Notreatment Groups (N) on Test Day frequencies, durations, and latencies to bury; heights of the pile on the prod and the largest pile in the chamber.



the heights of the piles on the prod (Lower Left Panel) and of the largest pile in the chamber (Lower Right Panel). As can be seen from the figure, there is considerable overlap between levels of performance of the subjects in each of the four groups. Such overlap may have accounted for the failure to find significant group differences on burying indices.

Discussion

Empirical Outcomes. Over days of habituation, indices of freezing increased while indices of burying decreased. This finding is consistent with previous reports of habituation performance in burying paradigms showing increases in freezing and decreases in burying across habituation (Moser & Tait, 1981; Note 1). During conditioning, the Prod-Shock Group buried for longer durations and accumulated higher piles on the prod than the Notreatment Group, thus replicating the initial demonstration of conditioned burying (Pinel & Treit, 1978). As well, the Prod-Shock Group froze for longer durations than the Notreatment Group. While the observation of long durations of freezing is inconsistent with Pinel and Treit's (1979) casual observation that 'only small amounts of freezing are observed', Peacock and Wong (1981) and Moser and Tait (1981; Note 1) have measured freezing durations in burying paradigms, and have found them to exceed burying durations. Thus the performance of the Prod-Shock Group is

in agreement with previously measured observations of freezing in burying paradigms.

The freezing durations of the Notreatment Group during conditioning were shorter than the durations of freezing observed in the Prod-Shock, Prod-Tone, and Tone-Alone Groups. As well, the Tone-Alone Group had a shorter latency to freeze than the Notreatment Group. Together, the freezing latencies and durations suggest that primary conditioned freezing was acquired in the Tone-Alone Group. This finding is in agreement with previous observations of freezing and crouching following the pairing of an auditory stimulus with shock (Bindra & Palfai, 1967; Nicholaichuk, Quesnel, & Tait, 1982). Since it was established that primary conditioned freezing occurred following the tone-shock pairings presently employed, it was possible for the tone stimulus to support higher-order conditioning when the tone was paired with a prod. During conditioning, the Prod-Tone Group froze for longer durations than the Notreatment Group. While the average freezing bout duration was longer in the Prod-Tone Group as compared to the Tone-Alone Group, the total amount of time spent freezing was similar in the Prod-Tone and Tone-Alone Groups. Together, these results suggest that higher-order conditioned freezing may have been acquired to the prod in the Prod-Tone Group. However, when the prod was presented alone, on the test day, reliable differences in freezing durations of the Prod-Tone, Prod-

Shock, Tone-Alone, and Notreatment Groups, were not observed. Because of the extinction in freezing, it cannot be determined whether the tone-elicited freezine was acquired to the prod itself during higher-order conditioning, or whether the observed freezing was simply elicited by the tone itself. Further investigation would be necessary to determine if, in fact, freezing was acquired to the prod during conditioning. In order to do this, it would be necessary to prevent extinction from occurring prior to the presentation of the prod alone. This could be accomplished by: pairing a prod with the aversive tone; immediately removing the animal from the experimental environment to prevent responding; and, testing on the following day with the prod alone.

While it cannot be unequivocally determined that the freezing observed in the Prod-Tone Group was acquired to the prod, there was some indication, from the data, that higher-order conditioned burying was acquired to the prod. First, there was an increase in the number of subjects in the Prod-Tone Group that buried during conditioning as compared to the last day of habituation. And second, of the subjects that buried during conditioning, subjects in the Prod-Tone and Prod-Shock Groups buried more frequently, for longer durations, and accumulated higher piles on the prod than the Tone-Alone and Notreatment Groups. While no reliable differences were found between the Prod-Tone and Prod-Shock

Groups, the individual subjects' data suggested that for the most part, the frequencies and durations of burying were smaller for the Prod-Tone Group than for either the Prod-Shock or Tone-Alone Groups. However, there was less variability in the frequencies and durations of burying in the Prod-Tone Group than for either of the other two groups. In addition, more than twice as many subjects in the Prod-Tone Group buried the prod as compared to subjects in the Tone-Alone Group. These results suggested that first, higher-order conditioned burying did occur in the Prod-Tone Group, and second, some unpredicted effects may have occurred in the Tone-Alone Group. That is, while no prod was present during conditioning, in the Tone-Alone Group, two of the ten subjects engaged in burying. Although it is possible that this burying was an artifact of habituation behaviour, two observations suggest that the burying of the subjects in the Tone-Alone Group was not artifactual. First, neither of the two subjects had buried piles in the chamber on the last day of habituation. And second, observations of the areas in which the piles were accumulated suggested that the burying was directed toward the area in which the speaker was situated. Thus the subjects that buried in the Tone-Alone Group may have been attempting to bury the source of the aversive tone.

On the test day, no reliable group differences were found for any of the burying measures, thus suggesting that the strength of burying indices decremented as a function of

the unreinforced presentations of the tone during conditioning and on the test day. One interesting finding, however, was that there was an increase in the number of subjects in the Prod-Shock, Prod-Tone, and Tone-Alone Groups that buried on the test day as compared to the number of subjects that buried during conditioning. This increase may have occurred as a result of the extinction in freezing on the test day. That is, during conditioning, some subjects froze for almost the entire session length, thus limiting the amount of time that was available for burying. On the test day, these subjects froze for a shorter duration, thereby increasing the amount of time that they could engage in burying. Hence burying may have increased as a function of a reduction in the competing response of freezing.

Theoretical Considerations. From the description of the empirical findings presented above, it appears that primary conditioning rendered the tone as a conditioned elicitor of freezing, and that higher-order conditioning of the prod and tone resulted in both freezing and burying. These observations address theoretical accounts of conditioning emphasizing both the acquisition of elicited responses as well as positions emphasizing the learning of an association, the index of which is determined by environmental variables.

Theoretical positions emphasizing the acquisition of a response during conditioning (Bolles, 1970; Guthrie, 1933;

Hull, 1943; Pavlov, 1927) focus on the response elicitation properties of unconditioned stimuli as determinants of the index of association. For Pavlovian theory (Pavlov, 1927), primary conditioning occurs when a neutral stimulus (CS) is presented in temporal contiguity with a US that elicits a reliable observable response (UR). The response that is acquired to the neutral stimulus (CR) is assumed to be in the same effector system as the UR. Similar processes occur in the higher-order conditioning of a response. In the case of higher-order conditioning, the primary conditioned stimulus acts as a US, and supports the conditioning of a response that is in the same effector system as the CR, and therefore, that of the initial UR. Hence, the response that is initially conditioned chains through to the higher-order conditioned stimulus. Given these notions, Pavlovian theory would expect that in the present study, the response that is elicited by the shock US would be acquired to the tone CS. Generally, two types of unconditioned responses to grid shock have been documented: active responses such as jumping, running, or prancing (Kimble, 1955; Trabasso & Thompson, 1962); and passive, or immobility responses such as standing, crouching, or freezing (Blanchard & Blanchard, 1969; Blanchard, Dielman & Blanchard, 1968). From a description of the studies in which these responses have been observed, it appears that active responses occur shortly after shock onset (Kimble,

1955) and that immobility occurs shortly following shock offset, and is the predominant response for at least one half hour following shock (Blanchard, Dielman & Blanchard, 1968). Within a Pavlovian framework, each of these responses could be classified as fractional components of the UR, and each could be conditioned to a neutral stimulus (Hilgard & Marquis, 1940). In the present investigation, jumping was not observed upon the presentation of a tone that had previously been paired with shock. Rather, the predominant response following the presentation of the tone CS was freezing. Hence, in accord with Pavlovian theory, a fractional component of the response to shock (i.e., freezing) was conditioned to the tone stimulus. Given the primary conditioned response of freezing, Pavlovian theory would expect the freezing response to chain through and be acquired to a higher-order conditioned stimulus. Thus the present observation of freezing during higher-order conditioning is consistent with Pavlovian theory. However, in addition to freezing, burying was also observed to occur upon the prod-tone presentation. Since burying was not an unconditioned response to grid shock during the primary conditioned pairings of tone and shock, burying would not be expected to be elicited by the tone upon its presentation with the prod. Thus, while Pavlovian theory would have predicted the observed acquisition of freezing in both primary and higher-order conditioning, it cannot account for the observation of burying during higher-order conditioning.

Like Pavlovian theory, Bolles' (1970) SSDR theory focuses on the acquisition of a response to stimuli paired with aversive events. According to Bolles (1970), an aversive event elicits all of the SSDRs in an organism's repertoire. Those responses that fail to prevent further aversive stimulation are punished, and so decrease in frequency; the response that succeeds in preventing further contact with the aversive event remains in the animal's repertoire, and occurs as the response that is conditioned when a neutral stimulus is paired with the aversive event. In the present study, shock was delivered every five minutes. Since shock has been shown to elicit freezing which lasts for up to one half-hour (Blanchard, Dielman, & Blanchard, 1968), it is likely that subjects were freezing at the onset of each shock presentation following the first trial. Accordingly, freezing would have been punished, and it would be expected to decrease in frequency and duration. In contrast to expectations derived from SSDR theory (Bolles, 1970), the present investigation documented increases in freezing following tone-shock presentations. However, since Bolles' initial derivation of SSDR theory, he has suggested that shock-elicited freezing may be a respondent which is unmodifiable by instrumental contingencies (Bolles & Riley, 1973). If this is true, then the punishment process would not be expected to decrease freezing behaviours, and thus freezing would be conditioned

to the tone. It should be noted that Bolles and Riley's (1973) observation that freezing is an unmodifiable respondent lies in contradiction to SSDR theory. For the SSDR conditioning process rests on the premise that SSDRs are modifiable through punishment. It is possible that freezing is a unique defensive response, in that freezing behaviours have no consequence on the environment of the organism. In contrast, fleeing, fighting, and burying directly impact on either the threat source itself or the environment in which the threat occurred. It may therefore be the case that SSDRs other than freezing both modify and are modified by environmental variables, while freezing cannot. Accordingly, it is possible that SSDRs other than freezing are modifiable by punishment. In order to be tenable, Bolles' (1970) SSDR theory would require such a demonstration.

Because Bolles' (1970) SSDR theory was formulated prior to Pinel and Treit's (1978) identification of burying as a defensive response, burying was not included in Bolles' list of the rat's defensive repertoire. However, SSDR theory could be adapted to account for the observed burying in the present study. The Prod-Shock Group first received eight tone-shock pairings in one environment, and were subsequently exposed to a single prod-shock pairing in a different environment. Since the contexts in which subjects received the two types of pairings were different, the

punishment processes that occurred during tone-shock presentations would not be expected to greatly influence the behaviours that were elicited by the shock during the prod-shock pairing (cf. Bolles, 1970). For the Prod-Shock Group, only a single shock was delivered in the presence of the prod. Therefore, all of the defensive responses in the animal's repertoire would have been expected to occur. Because no further aversive stimulation was presented, none of the responses would have been punished, and all would have been expected to persist. Since the opportunity to flee the experimental environment was physically prevented, freezing and burying would be expected to be the dominant defensive responses in the Prod-Shock Group. Likewise, for the Prod-Tone Group, no burying materials were available during primary conditioning of the tone and grid shock. Hence, the response of burying was prevented from occurring and could not have been punished. During higher-order conditioning, the aversive tone would be expected to elicit all of the defensive responses in the animal's repertoire that were not previously punished, one of which, would be burying. Hence if Bolles accepts that burying is a defensive response, burying would be expected to occur following the presentation of the aversive tone in both the Prod-Tone and Tone-Alone Groups. While burying was observed in both these groups, substantially higher levels of burying were found in the Prod-Tone Group. Since punishment was not

administered in the Tone-Alone Group during the tone presentation, the mechanisms of SSDR theory cannot account for the elevated levels of burying in the Prod-Tone Group as compared to the Tone-Alone Group. Because the only difference in manipulations applied to the Prod-Tone and Tone-Alone Groups was the presentation of the prod, some mechanism focusing on the elicitational properties of the prod would be required to account for the observed differences in outcome.

An alternative to theories that emphasize the US as the determinant of conditioned response topography, are theories which focus on the response eliciting characteristics of conditioned stimuli (Blanchard, Fukanaga & Blanchard, 1976a; 1976b; Holland, 1977; Rescorla, 1980). According to Holland (1977), conditioned stimuli elicit orienting responses which are subsequently augmented during conditioning. In his study, Holland (1977) observed the orienting response to a tone stimulus, and found that head jerks, or a startle response, occurred immediately following tone presentations. Accordingly, Holland would expect the conditioning of a startle response to a tone paired with shock. In the present study, freezing was observed to occur to the tone in the Tone-Alone Group. One of the defining characteristics of freezing is the abruptness of onset. Essentially, the abrupt onset of freezing occurs as a startle response, or a head jerk, which is then followed by muscular rigidity.

Thus it is possible that the conditioned response to the tone paired with shock was simply an enhancement of the startle response which Holland (1977) described. Similarly, since a prod has been shown to elicit burying (McKim & Lett, 1979), Holland would expect the higher-order conditioning of burying to a prod stimulus paired with an aversive tone. Consistent with expectations derived from Holland (1977), burying was found to be acquired to the prod in the Prod-Tone Group. However, Holland's position cannot explain the finding that substantially higher levels of freezing than burying were observed in the Prod-Tone and Prod-Shock Groups. Moser and Tait (Note 1) found that the presentation of a prod alone did not enhance freezing levels above an habituation baseline. If, as Holland argues, the conditioning process is an enhancement of the orienting response to conditioned stimuli, then one would expect the Prod-Shock and Prod-Tone Groups to engage in burying, which has been shown to be elicited by a prod (McKim & Lett, 1979), but not freezing. The present observations of high levels of freezing in the Prod-Tone and Prod-Shock Groups is thus unpredicted by theoretical positions emphasizing conditioned stimulus characteristics as the sole determinants of response topography.

Another theoretical framework that addresses the issue of stimulus determinants of response form, and which may contribute to an understanding of the data, is an

ethological analysis of burying (Moser & Tait, Note 1; Pinel & Treit, 1978). Moser and Tait (Note 1) proposed that burying may occur as an expression of the rat's primary defensive response of burrowing. According to Edmunds (1974), primary defensive responses serve to decrease the probability of encountering a threat source, while secondary defensive responses occur when the threat source is encountered. In the present study, primary defensive responses would be expected to be elicited by predictive cues, in order to decrease the probability of encountering the threat source which the cues predict. In contrast, secondary defensive responses would be expected to be elicited by the threat source itself, in this case, the shock. Applying this analysis to the present body of data, for subjects in the Prod-Shock Group, burying the prod would cover the shock source, and thus serve as an effective response in preventing encounter with the shock. Hence the observation of high levels of burying in the Prod-Shock Group is consistent with the ethological analysis proposed above. In contrast, in the Tone-Alone Group, the threat source (i.e., the speaker) was situated high in the chamber, out of the subjects' reach. Pushing sawdust in the direction of the speaker would not readily cover and remove the threat source. Accordingly, burying would be expected to be a low probability behaviour. And, in fact, only two of the ten subjects in the Tone-Alone Group buried in the

area of the speaker. For subjects in the Prod-Tone Group, the prod predicted aversive events, both the tone and shock. If the prod did, in fact, predict shock indirectly, then burying the prod could have served to prevent contact with the threat which it predicted. Accordingly, subjects in the Prod-Tone Group engaged in burying.

One observation which cannot be accounted for by an ethological analysis alone is the finding of high levels of freezing in both the Prod-Tone and Tone-Alone Groups. For these Groups, the shock was not delivered during the conditioning session. Since the threat source itself was not present, secondary defensive responding such as freezing would not be expected to occur. However, long durations of freezing were observed in both these groups. The most parsimonious explanation for the observation of freezing in these groups would be to invoke the mechanisms of conditioning. That is, shock evoked freezing, a response which was subsequently conditioned to the predictive cues both in primary and higher-order conditioning. Thus it would appear that an interaction of ethological and conditioning processes functioned to determine the present observation of both burying and freezing. The rules governing the interaction as yet remain unknown. It may be the case that secondary defensive responses are readily conditioned to environmental stimuli, and subsequently function as primary defensive responses. In the present

instance, the response of freezing was conditioned to the tone during primary conditioning, and then occurred as an acquired primary defensive response during higher-order conditioning, even in the absence of the threat source itself (i.e., the shock). Alternatively, the conditioning of responses may occur as an entirely separate process, irrespective of the defensive response elicitation properties of threat stimuli. In such a case, the observed behaviour will typically reference the dominant process. The critical theoretical question, then, is what determines the dominance of processes.

In conclusion, the present results suggest that in the burying paradigm presently employed, no one mechanism by itself can account for the observed topographies of responding. Pavlovian theory could account for the acquisition of conditioned freezing, but not for the observation of burying; SSDR theory could account for the observations of both freezing and burying, but not for the differential acquisition of burying in the Prod-Tone and Tone-Alone Groups; and finally, positions which focused on the characteristics of conditioned stimuli, and the ethological background of the organism in determining response topography, could account for the acquisition of freezing in the Tone-Alone Group and burying in the Prod-Tone Group, but not for the observation of freezing in the Prod-Tone Group. Instead, a complete understanding of the

data can only be derived from a combination of conditioning mechanisms together with an ethological analysis that incorporates a response elicitational model of both conditioned and unconditioned stimuli.

Reference Notes

1. Moser, C.G., & Tait, R.W. Environmental control of multiple defensive responses in a conditioned burying paradigm. Manuscript under review, 1982.

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Appendix A

TABLES OF ANOVA'S FOR HABITUATION, CONDITIONING, AND TEST DAYS

Table 1. ANOVA's of Habituation Data.

Dependent Variable	Sources of Variance	df	Mean Sq. Error	F
Freezing-frequency	Days	1	16102.81	54.55****
	Days x Group	3	93.94	0.32
	Error	36	295.19	
Freezing-duration	Days	1	68872.70	21.83****
	Days x Group	3	2382.70	0.76
	Error	36	3154.69	
Freezing-latency	Days	1	3408.66	4.36**
	Days x Group	3	567.42	0.73
	Error	36	781.65	
Burying-frequency	Days	1	12675.61	17.55****
	Days x Group	3	724.94	1.00
	Error	36	722.11	
Burying-duration	Days	1	30666.19	14.58****
	Days x Group	3	1414.98	0.67
	Error	36	2103.19	
Burying-latency	Days	1	582342.96	16.50****
	Days x Group	3	62253.17	1.76
	Error	36	35286.97	
Pile on prod	Days	1	10.51	7.80***
	Days x Group	3	2.91	2.16
	Error	36	1.35	
Largest pile	Days	1	45.75	12.67***
	Days x Group	3	1.04	0.29
	Error	36	3.61	

*p<.10, **p<.05, ***p<.01, ****p<.001

Table 2. ANOVA's of Conditioning Data.

Dependent Variable	Sources of Variance	df	Mean Sq. Error	F
Freezing-frequency	Groups	3	800.29	0.65
	Error	36	1224.44	
Freezing-duration	Groups	3	239762.26	4.69****
	Error	36	51121.23	
Freezing-latency	Groups	3	4.97	2.43*
	Error	36	2.04	
Burying-frequency	Groups	3	1670.09	1.90
	Error	36	877.57	
Burying-duration	Groups	3	6926.30	1.87
	Error	36	3694.29	
Burying-latency	Groups	3	63731.92	0.50
	Error	36	127449.86	
Pile-on Prod	Groups	3	8.07	1.65
	Error	36	4.89	
Largest Pile	Groups	3	8.67	1.07
	Error	36	8.12	

*p<.10, **p<.05, ***p<.01, ****p<.001

Table 3. ANOVA's of Test Day Data.

Dependent Variable	Sources of Variance	df	Mean Sq. Error	F
Freezing-frequency	Groups Error	3 36	1006.56 727.50	1.38
Freezing-duration	Groups Error	3 36	26569.12 15582.68	1.71
Freezing-latency	Groups Error	3 36	1194.49 467.97	2.55*
Burying-frequency	Groups Error	3 36	1159.37 918.86	1.26
Burying-duration	Groups Error	3 36	4581.45 3512.79	1.30
Burying-latency	Groups Error	3 36	86995.60 125917.32	0.69
Pile-on Prod	Groups Error	3 36	8.62 3.34	2.58*
Largest Pile	Groups Error	3 36	9.41 9.49	0.99
*p<.10, **p<.05, ***p<.01, ****p<.001				

Appendix B
SUBJECTS THAT BURIED THE PROD

Table 1. Subjects that Buried the Prod During Habituation, Conditioning, and Test Days.

Group	Day 1	Day 2	Condition- ioning	Test
Prod- Tone	1			
	2			2
			3	3
			4	4
	6	6	6	6
			7	7
	8			
	9			
		10	10	10
Tone- Alone			2	
				4
	5	5		
	7		7	7
	8			
	10			10
Prod- Shock	1		1	1
	2		2	2
				3
	4	4	4	
	5			5
	6	6	6	6
	7	7		
	8			8
	9			
	10	10	10	10
No- treatment		1		
	6	6	6	6
	9			
		10	10	10