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AVOIDANCE LEARNING TO STIMULUS OBJECTS
PRESENTED FOLLOWING SHOCK

by

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Date: April 17, 1973

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Dissertation submitted in partial fulfillment of
the requirements for the degree of Doctor
of Philosophy in the Department of
Psychology in the Graduate School
of Duke University

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ABSTRACT

(Psychology--Natural-Science)

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An earlier informal experiment by Hudson (1950) in which rats learned to avoid a bundle of pipe cleaners presented only following shock is replicated and extended. Five groups of 20 Ss each received a single shock each while taking a sucrose pellet from a novel striped panel. A black-out period ranging from 1 to 40 sec. began with the onset of the 3/4 sec. shock. During the black-out the striped panel (forward-order CS) was removed; immediately following the black-out, a rubber toy hedgehog descended into the apparatus. Following a short exposure to the toy hedgehog and an intervening 24 hr. in the home cage, S was observed in the apparatus with the toy hedgehog at one end and the striped panel at the other. Control groups received either shock without the toy hedgehog or the toy hedgehog without the shock. All behavior was video recorded.

Significant differential avoidance of the toy hedgehog occurred in

the short interstimulus interval groups (1, 5, and 10 sec.), but not in the 40 sec. group or in the control groups. In further analyses, individual Ss were classified as differentially avoiding either the toy hedgehog, the striped panel, the shock location, the opposite end of the apparatus or no identifiable stimulus, according to two schemes. In the first, the basis of classification was differences in time spent in a normal posture at the two ends of the apparatus relative to a distribution of such differences in the unshocked control group. In the other, a combined score derived from differences in four other classes of behavior was the basis of classification. In both analyses, significant numbers of Ss from the 1, 5, and 10 sec. groups were identified as avoiding the toy hedgehog, while insignificant numbers of Ss from the 40 sec. and control groups did so. Only insignificant numbers of Ss avoided the striped panel.

The results demonstrate that the "backward" association of the toy hedgehog with the shock is a reliable and robust phenomenon that can occur despite a 10 sec. UCS-CS delay, a single trial procedure, a 24-hr. delay between shock and testing, and the availability of a potential forward-order CS. The results cannot readily be explained either in terms of an unconditioned response to the toy hedgehog or simple sensitization. Both logical considerations and experimental results in backward conditioning preclude describing these results in terms of stimulus cuing.

The results are interpreted as a demonstration of the ability of rats to perceive causal agent-effect relationships in certain specific situations.

Support for conclusions drawn from the inference that rats can make causal agent-effect connections is taken from the areas of belongingness, stimulus selection in avoidance learning, delayed taste-avoidance learning, novelty, reflexive aggression, and species-specific defense reactions. Theoretical literature relevant to this inference and the broader question of what is learned is discussed.

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T. K-L.

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INTRODUCTION

This paper reports a replication and extension of earlier experiments by Hudson (1950) and by the present author (Keith-Lucas, 1972) in what nominally may be termed backward conditioning. The experiment reported differs from experiments usually termed backward conditioning in that the conditioned stimulus presented to S following an aversive unconditioned stimulus is a stimulus object having roughly animate features, rather than a transient stimulus event such as a tone or flash of light. It is a basic premise of the current study that conditioning in this situation may involve the perception of a causal relationship between the conditioned stimulus and the unconditioned stimulus it follows, that is, of S treating the conditioned stimulus object as the causal agent responsible for the aversive unconditioned stimulus.

In a review of experiments in backward conditioning in which transient events served as conditioned stimuli, Cautela (1965) concludes that "only one study seems unquestionably to have fulfilled the criteria for the substitute-stimulus definition of conditioning (pp. 140-141)." Cautela goes on to hypothesize that reported instances of backward conditioning may be accounted for by simultaneous conditioning between the conditioned

stimulus and pain resulting from a noxious unconditioned stimulus.

Razran (1956), in his review, concludes that backward conditioning is a reliable learning phenomenon, but he accepts as examples of backward conditioning results that might be interpreted as unstable or due to pseudo-conditioning (Cautela, 1965). Barlow (1956) similarly concludes in his review that backward conditioning is a reliable phenomenon, but Barlow accepts as examples of backward conditioning conditioned responses which are opposite in valence (or algebraic sign) to that normally evoked by the UCS. These instances of conditioning may better be interpreted as forward order conditioning with the conditioned stimulus signalling termination of the unconditioned stimulus. Cautela justifiably considers only instances in which the response to the conditioned stimulus is of the same valence as the unconditioned response. It thus remains doubtful that there are reliable instances of backward conditioning that involve transient events as conditioned stimuli.

This conclusion is plausible on logical grounds as well. Within the theoretical framework associated with classical conditioning, learning is seen to be based on the association of transient events in close temporal-contiguity, with one stimulus signalling the impending arrival of another. In the forward conditioning case, conditioning may involve the formation of a purely temporal connection. The underlying association learned need only be that the first stimulus reliably precedes the second, not that the first stimulus caused the second. The first stimulus acts as a signal

for the second, without any other relationship between them. Indeed, since the conditioned stimulus is a transient event and has no observable physical or spatial relationship to the unconditioned stimulus, there is little basis on which the two could be associated other than the temporal relationship between them. Logically, then, if a response of the same valence as the response to the unconditioned stimulus is to be conditioned to a signalling conditioned stimulus, then the signalling conditioned stimulus will have to precede the unconditioned stimulus. Any signalling stimulus which follows the unconditioned stimulus signals termination of that unconditioned stimulus rather than its impending arrival.

Innumerable learning experiments (e.g., Tolman, 1932) have involved the learning of spatial relationships rather than temporal relationships. In these cases, the stimulus objects to be associated or integrated are present in the same spatial relationships throughout the learning process, so that the association made is independent of temporal factors. Another class of learning experiments do involve a temporal relationship between events, but in these cases S causes a certain result through its own behavior. Both Thorndike's (1911) puzzle box experiments and operant conditioning fall into this class. Köhler (1927) would say that in these experiments S has grasped the material, inner relationship between its behavior and the result. The same concept is expressed in saying that S attributes a causal relationship to exist between its behavior and the result.

Backward conditioning might occur in situations that involve an unconditioned transient stimulus event followed by the presence of a stimulus object, if S can associate the object with the event in the relationship of the object being the causal agent for the event. In this case, a causal relationship would be learned, as in the case of operant conditioning, but the causal agent would be an external object rather than S itself. S might attribute a causal role to the external object independent of the temporal relationship between the presentation of the UCS and the CS, just as Hudson (1950) suggests a rat might attribute the pain of an abortive attack to a predator seen only after the arrival of the pain. The experiments by Hudson and the present author fit into this category of learning situations.

Hudson found that rats shocked while eating would avoid a small bundle of wire pipe cleaners dropped into the experimental cage following the shock. This experiment was done informally, with few Ss and no control for the effect of the presence of the bundle of pipe cleaners independent of the shock. The present author replicated this work (1972), again using very few Ss, but including a "no-shock" control procedure. Successful conditioning in this case was dependent on the nature of the stimulus object used, since a striped panel on the side of the apparatus was not an adequate "backward" conditioned stimulus, and neither was a stuffed teddy-bear that was lowered into the apparatus. However, a toy rubber hedgehog, with many soft spikes radiating from its body, was an adequate conditioned stimulus.

This finding of conditioned stimulus specificity is compatible with a growing literature dealing with the constraints placed on the generality of principles of conditioning (Rozin & Kalat, 1971; Shettleworth, 1972). This literature supports the view that whether or not an organism can associate two stimuli is strongly dependent on the nature of the stimuli themselves and the nature of the organism. If the stimulus objects successfully used by Hudson and the present author, a bundle of wire pipe cleaners and a toy rubber hedgehog, are interpreted as having animate qualities of importance to this learning, then backward conditioning between these objects and aversive shock is not unreasonable. The ability to associate pain with an animate object present only immediately after that pain would contribute to the survival of that organism. This reasoning regarding stimulus specificity in learning is gaining current prominence in the learning literature, but may be traced with ease to Thorndike's "belongingness" concept (1932).

The present experiment is intended to meet several goals implicit in the preceding discussion. First, it will seek to establish the phenomenon of backward conditioning using an environmental stimulus object as the conditioned stimulus, and at the same time determine one set of stimulus conditions under which it will occur. It will seek to determine the robustness of the learning phenomenon in question through a parametric examination of the delay interval between the unconditioned stimulus and the presentation of the conditioned stimulus object, and by placing

Ss in a situation in which they may associate an aversive shock with any of several stimulus objects. Further, it will seek to support the theoretical position that learning may involve associations that are based on relationships in which a stimulus object is treated as a causal agent, independent of temporal relationships. It will attempt to add a supportive element to the literature on the constraints on learning. Finally, by making use of video recordings it will include an attempt to determine in some detail the behavior of rats in the presence of aversive stimulus objects.

Procedurally, rats are introduced to a novel stimulus object, a striped stimulus panel which serves as a forward-order CS, and are shocked while eating a sucrose pellet from its center. The chamber is darkened at the onset of shock and remains darkened for intervals of up to 40 sec., during which the panel is removed. Immediately following the black-out period, a toy rubber hedgehog, serving as a backward-order conditioned stimulus, is introduced into the apparatus for a short period. On the following day, S is returned to the apparatus, and is exposed to the striped panel, at one end of the apparatus, and the toy hedgehog, at the other end of the apparatus. After five minutes, the two stimulus objects are reversed, end for end, for another five minutes. The design of the test session permits the observation of S's behavior in the presence of the forward-order and a backward-order stimuli simultaneously. In addition, the location of the two conditioned stimuli is

counterbalanced in the test to control for the effects of S's possibly associating the shock with enduring stimuli in the location in which it was shocked. Control groups that are not shocked or are not presented with the toy hedgehog following the shock are also run.

METHOD

Subjects

Ss were 120 experimentally naive, mature female albino rats weighing about 250 grams each prior to food deprivation.

Apparatus

The apparatus used (see Fig. 1 for sketch) was a black Plexiglas chamber 46.6 cm. long by 25.4 cm. wide by 63.5 cm. high (18 in. by 10 in. by 24 in.). At each end, a 10.2 cm. (4 in.) diameter round hole permitted the display of stimulus panels. The chamber was lighted by two 40-watt incandescent bulbs placed on each side mid-way on the long dimension and near the top edge of the chamber. The floor, 12.7 cm. (5 in.) from the bottom, was composed of 3.2 mm. (1/8 in.) diameter brass rods, placed 9.5 mm. (3/8 in.) on centers. The interior surfaces were sanded to remove the reflective surface of the Plexiglas. The two ends of the apparatus were made as similar as possible.

At each end of the apparatus, and just to the left (as seen by S) of the stimulus panel openings, a thin, taut wire ran vertically from an overhead frame through the grid floor to the base of the apparatus. Strung on each wire was a red rubber toy hedgehog (Fig. 2), roughly

Figure 1. Apparatus in Plan, Side, and End Views.

Figure 2. Toy Hedgehog.

hemispherical in shape, and about 10 cm. in diameter. Each toy hedgehog had a large number of soft rubber spikes radiating from its body. The toy hedgehogs could be lowered into the chamber remotely via a string and pulley system. When not in use in the chamber, the toy hedgehogs were suspended at the top of their wires, so that they were well out of the effective visual range of Ss. Intervening equipment such as the board which supported an overhead television camera further obscured them from view.

The stimulus panels at each end of the apparatus traveled on horizontal tracks, with stops on each end of the tracks serving to position the appropriate stimulus panels before the holes in the ends of the apparatus. Each panel had in its center a small brass ring with its inside diameter bored so that it would firmly hold a Noyes 4.9 mm. diameter sucrose pellet. Pellets could be pushed into this ring from the outside so that they extended into the apparatus. Pellets could then be pulled out of the ring or bitten off by Ss. During the early part of the present experiment, both the stimulus panels and the toy hedgehogs were changed by hand. This resulted in many animals being discarded due to errors by the experimenter, so the manual system was replaced with a solenoid-operated system that was much more reliable, although slightly noisier.

The stimulus panels themselves were of two types. One type was of the same sanded black Plexiglas as the chamber walls. Hereafter this type of panel will be called "blank." The over type was of sanded white

Plexiglas with two vertical black stripes, each $3/4$ in. wide, made of plastic electrical tape. These panels will be called "striped."

The grid floor was wired to a BRS-Foringer Model SG-901 shock generator and a Model SC-901 scrambler supplying 1 ma. of current. A single switch supplied foot shock for $3/4$ sec., turned off the apparatus lights for the prescribed interval, and later in the experiment controlled the stimulus panel change and the release of the toy hedgehog as well.

The experiment was run in a darkened, sound-attenuated room, with the apparatus shielded from stray light by a large black paper hood. An overhead television camera connected to a Concord Model 820 video recorder allowed the recording of all experimental sessions. A television monitor permitted the experimenter to observe the animal in the apparatus without looking into the top of the chamber. Two "dummy" apparatuses, internally similar to the working apparatus, were also used for habituating Ss.

Pre-shock procedure

All Ss were food-deprived on a 23-hr. schedule for at least 3 days prior to running. Each animal spent at least 10 hr. in one of the chambers prior to being run. While each S was in a chamber for habituation, both panels were blank and sucrose pellets were available from the center rings. If eaten, these pellets were replaced every few hours. In all cases, the Ss were left in a chamber until they showed no hesitancy

in moving about the chamber and until they readily went to the blank stimulus panels at either end to collect sucrose pellets immediately following their presentation. If an animal was habituated in one of the "dummy" apparatuses, it was transferred to the working apparatus at least 15 min. before being run, and the same behavioral criteria were applied again. In order to determine whether an animal was ready to be run, it was felt that a fixed habituation period would be less appropriate to the purpose of the experiment than meeting certain behavioral criteria. All Ss were run approximately 20-24 hr. after their last food other than sugar pellets received in the chamber. No water was available in the chamber.

When each S had met the behavioral criteria for being run, it was attracted to the right end of the apparatus with a sucrose pellet. While S ate that pellet, the blank panel at the left end was replaced with a striped panel. No pellet was placed in the ring in this panel. Using a stopwatch, the experimenter then accumulated the total time that S spent exploring this completely novel stimulus panel. Time was counted only if S was near the panel and was oriented toward it. Time spent in behaviors such as grooming was not counted, even if the other criteria were met. In all cases, Ss explored the striped panel extensively soon after it was inserted.

When S had spent at least one cumulative minute exploring the striped panel, it was attracted to the right end of the apparatus with a

sucrose pellet. While S ate this pellet, a pellet was inserted through the striped panel for the first time. S was allowed to return to the left (panel) end of the apparatus and was allowed to grasp this pellet with its mouth. At the moment that S grasped the pellet, the experimenter pressed the shock switch. It should be emphasized that Ss were shocked while taking a pellet from this striped panel for the first time, and that no S had seen this striped panel prior to the few minutes before it was shocked. All animals in this experiment were run with this pre-shock procedure.

Post-shock procedure

The 120 Ss used in this experiment were divided into four experimental groups and two control groups of 20 animals each. In each experimental group, the chamber lights went out as the shock began, the shock lasted $3/4$ sec., and the chamber lights remained out for a fixed interval following the onset of shock. At the end of the shock period, the striped panel was replaced by an empty blank panel. At the end of the black-out period, the lights were turned on and the toy hedgehog at the left end was released from above, to slide down the wire into the apparatus. After the end of the black-out period, the toy hedgehog remained in the apparatus for 1 min. and S was left in the apparatus for an additional minute. S was then returned to an individual cage and allowed access to food for 1 hr. The black-out periods for the experimental groups, as measured from

the onset of shock, were 1 sec., 5 sec., 10 sec., and 40 sec.; these groups are referred to by the duration of their black-out periods hereafter.

One control group, called the H-No S group hereafter, was identical in procedure to the experimental groups except that it was not shocked. The shock apparatus was disconnected at the grid floor so that the same shock scrambler noises were maintained. Within the H-No S group, five Ss received each of the four (1 sec., 5 sec., 10 sec., and 40 sec.) black-out periods. The other control group, called the S-No H group hereafter, was shocked but was not exposed to the toy hedgehog during the post-shock period. The toy hedgehog was tied in place above the apparatus so that the same solenoid noises were maintained. As in the CS group, five Ss from the S-No H group received each of the four black-out periods.

Test procedure

The test procedure was identical for all Ss. Approximately 20 hr. after being run, each S was returned to the apparatus for 10 min. During the first 30 sec., blank panels without sucrose pellets were present at both ends of the apparatus. Then, a striped panel without a sucrose pellet was inserted at one end and a toy hedgehog was lowered into the apparatus at the other end. Immediately thereafter, sucrose pellets were inserted in the striped panel and in the blank panel beside and behind the

toy hedgehog. If collected by S, these pellets were not replaced. After 5 min. (from the time at which S was placed in the apparatus) the toy hedgehog and the striped panel were reversed end-for-end and new sucrose pellets were inserted. At the end of 5 more min., S was removed from the apparatus. This ended the experiment for each S.

Half (approximately) of each group was tested with the toy hedgehog first at the left end, and half with the toy hedgehog first at the right end to counterbalance any effect of extinguishing learned behavior during the course of the test (Appendix I). This test design permitted observation of the behavior of each S relative to the striped panel, which was present only prior to the shock, and the toy hedgehog, which was present only following the shock, independent of the left and right ends of the apparatus, and behavior relative to the ends of the apparatus independent of the pre- and post-shock stimulus objects. In discussing test results, the left end of the apparatus will be referred to as the "shock" end, while the right end will be called the "safe" end. The test session, like the pre- and post-shock sessions, was video recorded for later analysis.

Order of animal running

The order of running Ss from various groups was not totally counterbalanced, since an interest in establishing that backward-order associations could be obtained, prior to a large investment in research time, dictated the running of more 5 sec. group animals early in the

experiment. The original experimental design included only the 1 sec., 5 sec., 10 sec., and S-No H groups. The 40 sec. group was added fairly late in the experiment after it became apparent that some Ss in each of the shorter delay groups avoided the toy hedgehog on the test. The S-No H control group was also added later in the experiment.

Data reduction and extraction of behavioral measures

The video recording of each experimental session was scanned both for S's location in the apparatus and for each of seven classes of behavior. Data were compiled with the aid of an encoding device, such that the experimenter could view each recording, press designated keys on an organ keyboard as each change in location or as each behavior occurred, and thereby produce an eight-channel punched paper tape. These tapes included a separate punched code for each location or class of behavior, plus another code indicating each 1-sec. interval. The paper tapes were then analyzed on a Digital Equipment Corporation PDP-8L computer, which compiled the number of incidents of various classes of behavior and changes in location, the time at which each event occurred, the sum of the durations of each class of behavior, and the sum of the time spent in each location. Further data analysis was carried out on these compiled records of the behavior of individual Ss.

Measures of behavior. First the video records were scanned for the location of S, which is defined by the position of the top of the S's

head, in quarters of the apparatus, from left to right. Then each record was rescanned and seven classes of behavior were recorded for each S in each half of the apparatus.

The classes of behavior recorded were:

Normal Approach (NA), which is defined by forward movement toward one end of the apparatus by walking or running with the body as long as is typical for these rats, or about 7 1/2 in. Unlike most other measures, NA was allotted to a given end of the apparatus as soon as S started in that direction, even if S had not yet left the near half of the apparatus.

Elongated Approach (EA), defined as planting the rear feet on the grid floor and then extending the body without moving the rear feet in that direction, to the point that the rear feet were visible behind S's body as seen from above. The fact of the rear feet being visible was used to distinguish EA from NA. The extension of the body was obvious in cases of EA, with body lengths commonly reaching 10 in. All movements toward an end of the apparatus were counted as either NA or EA, and both were recorded as soon as movement began, even if S had not yet entered that half of the apparatus.

Retraction (RE), which is defined as movement away from one end of the apparatus by contracting the body and moving backward. This is a rapid movement and its occurrence obviously is facilitated by prior elongation of the body, although retraction can occur without a prior EA.

Hudson used as a measure of avoidance the combination of elongated approach and retraction, defined as "the animal first stretching out its body in the direction of the food, then following this with a quick withdrawal (1950, p. 107)."

Freezing (FR), which is defined as not visibly moving any part of the body for 5 sec. or longer. Immobility of less than 5-sec. duration was scored as CP or BTP (see below).

Eat Pellet (EP), which is simply the behavior of taking a sucrose pellet from a pellet holder in an end panel. Ss were not scored as remaining in the EP class after collecting a pellet from a holder, even if S was indeed eating the pellet. Instead, EP was used simply to indicate that the pellet was removed at that time. If an S bit off the exposed end of a pellet, the rest of the pellet was pushed through into the apparatus, so that a single S could be scored for only one event of EP per end of the apparatus in each half of the test.

Back-to-Panel (BTP), which is defined as sitting in one half of the apparatus, with the back to the stimulus object at that end, such that the stimulus object is presumed to be outside the visual range of S.

Compact Posture (CP), which is defined as being present in one end of the apparatus without being in any of the other classes of behavior defined above. Observable classes of behavior such as grooming, rearing against the walls, and consuming pellets are included in CP. However, classes of behavior which are not normally observed among Ss

which have habituated to their environment and which have not been shocked are not included in CP.

Use and interpretation of measures

Both the location data recorded for four quarters of the apparatus and the seven classes of behavioral data defined above represent exclusive and in one sense exhaustive descriptions of the behavior of individual Ss in the apparatus. Both categorizations are exclusive, inasmuch as an S could be recorded as being within only one class of behavior and one location at any one time. No two classes of behavior were recorded simultaneously. They are exhaustive, inasmuch as all of the S's time in the apparatus was recorded with the seven behavioral classes, including the CP class which aggregates several other observable classes of behavior, and S's location at all times was recorded with one of the four classes. Operationally, this meant that the computer program used to compile data accumulated time for one class of behavior or location until a code punch indicated the beginning of a new class, at which point it began accumulating time in that class.

Of the available classes of behavior, time spent in CP in the presence of a particular stimulus object, as opposed to in the presence of another stimulus object available at the same time at the other end of the apparatus, is used as a basic inverse measure of avoidance throughout this report. Time spent away from an available location, when S is not

restricted as to his choice of location, is clearly avoidance of that location. Preference for one location over another involves avoidance of the less-preferred location, at least within the context of the available alternatives.

However, simple time in quarters of the apparatus, an available measure here, has certain deficiencies. First, it includes time spent traversing from one location to another and time engaged in behavior such as REs which may not represent nonavoidance of the location in which S is present. In terms of time in the test for 20 randomly selected Ss (four from each of the 1, 5, 10, 40, and S-No H groups), these other classes of behavior take up 7% of the total time of the average S. Second, the remaining 93% of these Ss' test time was taken up with time in CP and time in FR. While time spent in CP appears to represent the behavior of a nonavoiding rat, as might be observed in H-No S group Ss during the test, time spent in FR is more difficult to interpret. Ss which froze during the post-shock period and during the test often did so without any seeming order in location. An S might freeze at the far end of the apparatus from the toy hedgehog when it was inserted at the start of the test, and stay frozen in that same location when the stimuli were reversed and the toy hedgehog was placed directly beside S. Another S might freeze in one location, then move to the other end of the apparatus and freeze there, both within one half of the test.

Since data were recorded in this experiment in terms of classes of

behavior at one end of the apparatus or the other, it is impossible to determine how to use time spent in FR as a measure of avoidance. Time in FR at one end of the apparatus might indicate avoidance of that end or the other, with no strong argument available to support either interpretation. For this reason, time spent in FR is not used as a measure of avoidance in the remainder of this report. Therefore, time spent in CP in one location seems the best measure of avoidance of the stimuli available in another location, given that the two locations may be reached with equal ease. The measure of time in a particular location is used in this report only in reference to behavior prior to the shock when no FR responses were observed.

NA, EP, and BTP were chosen as classes of behavior which might be inversely related to avoidance of the end of the apparatus in which they occur. NA responses suggest nonavoidance, since they involve an approach of the type observed in habituated and nonshocked Ss moving about the apparatus. Instances of EP suggest that S does not associate aversive consequences with taking sucrose pellets from that location. Instances of BTP suggest that S does not fear any aversive consequences of sitting near a particular stimulus object with that object outside S's visual range.

EA and RE were chosen as classes of behavior probably related to avoidance. Instances of EA suggest hesitancy on the part of S in approaching a particular location, coupled presumably with preparation for a

rapid withdrawal. RE bears a logical relationship to avoidance, since it is a rapid withdrawal from a particular location.

Data reported in this experiment are analyzed on the basis of differences in total responses to each stimulus complex (shock end, safe end, toy hedgehog, and striped panel) without regard for the other stimulus complex present at the same end at the time of the response. For example, consider an S tested with the toy hedgehog at the shock end during the first half of the test. S makes five NAs to the shock end (with the toy hedgehog) and two NAs to the safe end (with the striped panel). In the second half of the test, S makes three NAs at the shock end (with the striped panel) and six NAs at the safe end (with the toy hedgehog). The total number of NAs at the shock end is eight; at the safe end, eight; at the toy hedgehog, eleven; and at the striped panel, five. Therefore, S made six more NAs at the toy hedgehog than at the striped panel, and an equal number of NAs at the safe and shock ends.

Objectivity and reliability

The reliability with which events could be placed in the classes of behavior used here, with a few minor definitional changes, was examined in the pilot work preceding this experiment (Keith-Lucas, 1972). During 1 1/2 min. of observation for each rat, the experimenter reported 61 incidents of the classes NA, EA, RET, CP, or BTP. The second observer reported 60 incidents, with two differences from the record

made by the experimenter. The experimenter recorded one CP which the second observer did not, and the experimenter classified one approach as EA while the second observer classified it as NA. Thus there are grounds for concluding that the present method of classification is objective and reliable. Within the present experiment, an attempt was made to avoid experimenter bias in the scoring of the video records by the experimenter's concealing from himself the group from which each S came when running the test sessions and when transcribing data from the video recordings. This concealment was not complete, particularly toward the end of the experiment when Ss from particular groups were needed to complete the project. On the whole, it was too successful an effort, since several animals were run in excess of those needed, and unequal numbers of animals were run in each of the two test directions in two groups. Equal groups of 20 Ss were achieved by discarding randomly selected Ss from some groups.

RESULTS

Pre-shock behavior

Since all Ss were exposed to the same procedure prior to shock, their pre-shock behavior is described here on the basis of a sample of 20 Ss from the 1 sec., 5 sec., and 10 sec. groups for which there were extensive video recordings. Location and behavior data were recorded for each S for approximately 2 min. prior to the insertion of the striped panel into the chamber and for the entire period during which the striped panel was present prior to the shock.

This sample group of Ss is shown to not avoid either end of the apparatus prior to the insertion of the striped panel by the equal percentages of time spent in each end of the apparatus (Fig. 3) and by the equal distribution of percent time spent in CP at each end of the apparatus before the insertion of the striped panel (Fig. 4). Differences in time spent in halves of the apparatus and in time spent in CP in halves of the apparatus are not significant (Appendix II, lines 1 and 2). Further, Ss in this sample did not engage in any instances of FR, EA, or RE (Fig. 5A), the behavior classes hypothesized to represent avoidance. Figure 5A also indicates that there was no preference for one end over the other in

Figure 3. Percent time in quarters of the apparatus before and after insertion of the striped panel.

Figure 4. Percent time in CP at ends of apparatus before and after insertion of the striped panel.

Figure 5A. Mean NA, FR, EA, and RE responses at ends of apparatus before insertion of the striped panel.

terms of number of incidents of NA (Appendix II, line 3). All available evidence supports the claim of little or no explicit avoidance prior to the insertion of the striped panel.

Figures 3 and 4 suggest that, following insertion of the striped panel, the percent time spent in CP and the percent time spent in quarters of the apparatus were greater for the right than for the left end of the apparatus. These differences are not significant, and may be attributed to a few Ss remaining in the right end of the apparatus for periods of several minutes after taking the sucrose pellet at that end. Note also that there are 18 incidents of EA and even 3 of RE to the left panel end of the apparatus among this sample of 20 Ss during the period in which the striped panel was present (Fig. 5B). These incidents of EA and RE occurred when Ss first approached the novel striped panel. The observations suggest that EA and RE are representative of hesitant approach and withdrawal relative to a novel stimulus. In all, the introduction of the novel striped panel resulted in several EAs and REs suggestive of avoidance, but not in significant changes in other classes of behavior.

Post-shock behavior

Avoidance of the shock end of the apparatus following the shock is conspicuously demonstrated for the shocked groups of Ss by the strong shift in time spent in CP to the safe end of the apparatus in the 2 min. after the black-out periods (Figure 6). This shift in time spent

Figure 5B. Mean NA, FR, EA, and RE responses at ends of apparatus following insertion of the striped panel.

Figure 6. Mean differences in time in CP by interstimulus interval groups following shock. In this and all subsequent figures, mean difference refers to mean difference at ends of apparatus, and HSD refers to Honest Statistical Difference (Winer, 1962) at the $p=.05$ level.

in CP did not occur in the H-No S group, which actually spent slightly more time in CP at the "shock" end which contained the novel toy hedgehog than at the safe end. Statistically, in terms of mean differences in time spent in CP at each end for each group, the H-No S group differs from all other groups at beyond the $p = .01$ level (Appendix II, line 6), while the shocked groups are not statistically separable.

Avoidance of the shock end of the apparatus is further demonstrated by the occurrence of EA and RE at the shock end but not at the safe end (Figs. 7B and 7C). Some incidents of EA and RE at the shock end did occur in the H-No S group. This result may be interpreted as avoidance of the toy hedgehog due to its novelty, just as incidents of EA and RE to the striped panel prior to shock may be interpreted. To the extent that the frequencies of EA and RE at the shock end among the shocked groups exceeds those among the H-No S group, such differences may be considered representative of avoidance due to the shock.

There is a suggestion within the post-shock results of differential avoidance of the shock end of the apparatus across delay groups, but this suggestion must be treated with great caution. There are more incidents of NA and fewer incidents of EA and RE to the shock end in the longer delay groups than in the shorter delay groups (Figs. 7A, 7B, and 7C), and these differences are in all cases significant beyond the $p = .05$ level (Appendix II, lines 7-9). This may suggest more avoidance of the shock end by the shorter delay groups than by the longer. However, this result

Figure 7A. Mean NA responses by interstimulus interval groups following shock.

Figure 7B. Mean EA responses by interstimulus interval groups following shock.

Figure 7C. Mean RE responses by interstimulus interval groups following shock. No RE responses were observed at the safe end.

might simply represent differences in time following shock at which the observation of behavior began for the different delay groups, which varied from 1 sec. to 40 sec.

In summary, the shock had the clear and not unexpected result of causing Ss to avoid the shock end of the apparatus. H-No S Ss did not avoid the "shock" end of the apparatus in terms of time spent in CP, but did so to some degree in terms of incidents of EA and RE. These incidents probably are responses to the novelty of the toy hedgehog.

Test results

The behavior of Ss during the test session will be treated in several ways. The first analysis will be at the level of the average behavior across Ss for various experimental conditions. This analysis will be used to demonstrate changes in behavior relative to the toy hedgehog as a result of shock, and differences in these changes across experimental conditions. Several classes of behavior will be used to demonstrate these changes, so as to extract as much evidence as possible given the single-trial design of this experiment.

Since the analysis of results across Ss by experimental conditions necessarily describes the behavior of groups at the expense of not describing individual behavior, a second form of analysis will be used as well. Individual Ss will be classified as predominately avoiding one of four stimulus elements (toy hedgehog, striped panel, shock end, or safe

end) or none of these on this basis of test behavior, and then the number of Ss in each avoidance class from each experimental condition will be compared.

This analysis is motivated by the hypothesis that each experimental group may include several smaller groups of Ss having entirely different patterns of avoidance behavior to particular stimulus elements. If this is the case, then it is more reasonable to determine the number of animals from a group that avoided a particular stimulus element and to compare this number with that obtained from another experimental group, than it is to attempt a single description of all Ss from an experimental group.

The determination of classes of avoidance for individual Ss will be carried out in two ways. In the first, Ss will be classified on the basis of differences in time spent in CP at the ends of the apparatus. In the second, Ss will be classified on the basis of composite differences in NA, EA, RE, and EP. In both cases, the number of Ss from each experimental condition classified as avoiding particular stimulus elements will be determined, so as to demonstrate changes in behavior as a function of the interstimulus interval.

Differences in the behavior of inter-stimulus interval groups

Backward conditioning of avoidance to the toy hedgehog following short UCS-CS delays is demonstrated by the significant differences between the mean differences in time spent in CP at the toy hedgehog and

striped panel ends of the apparatus for each of the 1 sec., 5 sec., and 10 sec. groups and for each of the control groups (Fig. 8A; one-way analysis of variance, $F = 4.31$, critical F for $p = .01 = 3.20$). The 1, 5, and 10 sec. groups are statistically indistinguishable from each other; on the average, Ss from these groups spend far more time in CP at the striped panel end of the apparatus than at the toy hedgehog end of the apparatus (Appendix II, line 10; note also the honest statistical differences indicated in Fig. 8 and the means from which these differences are derived, which are compiled in Appendix III). Ss in the 40 sec., S-No H, and H-No S groups spent more time in CP at the toy hedgehog end than at the striped panel end of the apparatus and are statistically inseparable from each other.

Backward conditioned avoidance of the toy hedgehog occurs in this experiment when the unconditioned stimulus-conditioned stimulus interval is less than 40 sec. Avoidance of the toy hedgehog is not caused by unconditioned effects of shock or by the toy hedgehog independent of shock since neither the S-No H nor the H-No S Ss avoid the toy hedgehog. Nor is it reasonable to conclude that Ss in the 40 sec. and S-No H groups avoid the striped panel in favor of the toy hedgehog as a result of the shock, since Ss in the H-No S group were not shocked and still spent an equal or greater amount of CP time at the toy hedgehog end of the apparatus than did Ss in the 40 sec. and S-No H groups. Finally, it is not clear from these data that there are any orderly effects of the different black-out

Figure 8A. Mean differences in time in CP by interstimulus groups, toy hedgehog minus striped panel.

periods on differential avoidance of the shock and safe ends of the apparatus, since the differences in time spent in CP at the shock and safe ends (Fig. 8B) are not significant (Appendix II, line 11). The failure to find an orderly relationship here is not crucial to the main purposes of the experiment since the shock and safe ends were constant parameters in this experiment, but the disorderly nature of these data is mildly surprising.

Mean differences in the number of incidents of NA, EA, RE, and EP between the toy hedgehog and the striped panel ends suggest that differences in incidents of some of these classes of behavior vary with the interstimulus interval (Figs. 9A, 9B, 9C, and 9D). More EA and RE responses occur at the toy hedgehog than at the striped panel in the 1, 5, and 10 sec. groups. The reverse is true in the 40 sec. and the S-No H groups. More EP are made at the striped panel than at the toy hedgehog in the 1 and 5 sec. groups; while in the 10 sec., 40 sec., and S-No H groups, more pellets are eaten at the toy hedgehog end than at the striped panel end. All these functions contain significant differences between groups at the $p = .01$ level (Appendix II, lines 13, 14, and 15). The mean differences in incidents of NA to the toy hedgehog and the striped panel (Fig. 9A) include no significant differences among groups (Appendix II, line 12). In terms of mean differences in incidents of NA, EA, RE, and EP for the shock or safe ends, there are no statistically significant differences among experimental groups (Figs. 10A, 10B, 10C, and 10D;

Figure 8B. Mean differences in time in CP by interstimulus interval groups, shock minus safe.

Figure 9A. Mean differences in NA responses by interstimulus interval groups, toy hedgehog minus striped panel.

Figure 9B. Mean differences in EA responses by interstimulus interval groups, toy hedgehog minus striped panel.

Figure 9C. Mean differences in RE responses by interstimulus interval groups, toy hedgehog minus striped panel.

Figure 9D. Mean differences in EP responses by interstimulus interval groups, toy hedgehog minus striped panel.

Figure 10A. Mean differences in NA responses by interstimulus interval groups, shock minus safe.

Figure 10B. Mean differences in EA responses by interstimulus interval groups, shock minus safe.

Figure 10C. Mean differences in RE responses by interstimulus interval groups, shock minus safe.

Figure 10D. Mean differences in EP responses by interstimulus interval groups, shock minus safe.

Appendix II, lines 16, 17, 18, and 19). Again, there is no reason to believe that avoidance behavior to the shock and safe ends of the apparatus should vary as a function of the interstimulus interval. The possibility that avoidance of the shock and safe ends varies with individual Ss will be explored in later analyses of these data.

In summary, differences in time spent in CP, and incidents of EA, RE, and EP at the toy hedgehog and the striped panel vary with the interstimulus interval and are the result of the shock manipulation. Therefore, such differences are indices of differential avoidance of the stimulus elements available in this experiment. As a general case, Ss which spend more CP time at one end of the apparatus than at another also eat more pellets at that end (EP) and make more EAs and REs to the other end of the apparatus.

Avoidance patterns of individual Ss

The test session was designed to determine the avoidance of each S relative to several stimulus elements. It is hypothesized that individual Ss may differentially avoid different stimulus elements, with some Ss avoiding one stimulus and other Ss other stimuli. Therefore, it is more reasonable to speak of an individual avoiding, say, the toy hedgehog, or of a certain number of Ss from an experimental group avoiding the toy hedgehog, than it is to speak of the combined behavior of all Ss from one experimental group representing more avoidance of the toy hedgehog than

of the striped panel.

Comparison of differences in
compact posture time

The central goal of this analysis of the test data is to classify Ss into groups according to the type of stimulus element predominantly avoided, as based on differences in time spent in CP at the various ends of the apparatus. The categories available are avoiding the toy hedgehog (H group), avoiding the striped panel (P group), avoiding the shock end (SH group), avoiding the safe end (SF group), and not predominantly avoiding any of the above stimulus elements (O group). The procedure of classification is described below.

The two distributions of differences in time spent in CP at the toy hedgehog and the striped panel ends and at the shock and safe ends within the H-No S group were obtained and the mean and standard deviations of each were computed. These distributions represent the behavior of 20 Ss which were not shocked, but which were exposed to the same test procedure as the shocked Ss. If a difference of time spent in CP on one of the two dimensions (toy hedgehog-striped panel or shock end-safe end) for an individual shocked S exceeded ± 2 standard deviations from the mean of the distribution of differences in the corresponding dimension for the H-No S group, then S was classified as belonging to the appropriate avoidance group. The criterion difference of ± 2 standard deviations from the mean for the H-No S group was somewhat arbitrary but reasonable since

under this criterion less than one in 20 Ss would be classed as avoiding a particular stimulus when, in fact, the behavior of these Ss did not differ from that of the H-No S group. Ss which did not exceed ± 2 SD from the mean for the H-No S group in either dimension were placed in the O group. Ss which exceeded the criterion in both dimensions were not classified into any groups and were not included in the remainder of this analysis. This occurred in the cases of 12 Ss which froze through most of one half of the test and remained in CP at one end of the apparatus through most of the other half of the test. It was not possible to determine which of two stimulus elements these Ss avoided. Of the 100 shocked Ss, 17 were classified as being in the H (avoiding) group, 4 in the P group, 31 in the SH group, 13 in the SF group, and 23 in the O group.

The number of Ss from each experimental group that were classified in each avoidance group (Figs. 11A and 11B) demonstrates that the probability of Ss avoiding the toy hedgehog is a function of the interstimulus interval. While 6, 4, and 6 Ss fall into the H group from the 1, 5, and 10 sec. groups, respectively, no Ss from the 40 sec. group are found in the H category. One S from the S-No H group was placed in the H category, but there is no statistical significance to finding 1 S in 20 which departs ± 2 SD from the mean of a control group. In fact, 1 S from the H-No S group does exceed the criterion and would be classed in the SF group were these Ss included in this analysis.

In terms of significance, 4 or more of 20 Ss avoiding a particular

Figure 11A. Number of S_s from each interstimulus interval group in H and P groups.

Figure 11B. Number of Ss from each interstimulus interval group in SH, SF, and O groups.

stimulus is significantly different from 0 of 20 Ss from the H-No S group avoiding that stimulus at the $p = 0.5$ level by Fisher's exact probability test. However, care must be taken in applying that criterion repeatedly, since the number of Ss avoiding a particular stimulus necessarily affects the number available to avoid another stimulus.

Within Figs. 11A and 11B, it is of interest to note that the number of Ss classified in the O group seems to increase with the interstimulus interval, and so does the number of Ss in the P group. Neither increase is statistically significant ($p > .05$) according to Fisher's exact probability test, however. If these functions do have any meaning, they might suggest that avoidance of the striped panel and the toy hedgehog have a reciprocal relationship, and that total differential avoidance decreases with longer interstimulus intervals. The striped panel may serve as a reasonable choice for S, which is prepared to associate shock with an external stimulus element, but which does not have access to the toy hedgehog shortly following shock due to the black-out. The number of Ss from each experimental group in the SH and SF classes does not appear to be an orderly function of the delay interval.

It is in no way surprising that there are large differences in the differences in the mean time spent in CP at the toy hedgehog, striped panel, shock and safe ends of the apparatus for animals classed in the H, P, SH, and SF groups (Figs. 12A and 12B; Appendix II, lines 20 and 21) since these differences are the basis of the classification system. The

Figure 12A. Mean differences in time in CP for H, P, SH, SF, and O groups, toy hedgehog minus striped panel.

Figure 12B. Mean differences in time in CP for H, P, SH, SF, and O groups, shock minus safe.

differences in time spent at the toy hedgehog and at the striped panel (H-P) for both the H and P groups differ significantly from the same differences for the O and H-No S groups by a Scheffé contrast ($p < .05$; Appendix II, line 20). The same is true for the SH and SF groups in terms of the differences in time spent at the shock and safe ends (Appendix II, line 21). Note, however, that the difference in mean time spent in CP at the toy hedgehog and striped panel ends by the SH, SF, and O groups is not statistically separable from the difference in mean time spent in CP at the toy hedgehog and striped panel ends by the H-No S groups. The same is true of all other inappropriate combinations of avoidance groups and stimulus elements, such as the H group on the SH-SF stimulus dimension (Appendix II, lines 20 and 21). These results demonstrate that Ss which are classified as avoiding one stimulus element do not systematically avoid any other stimulus element, even at levels of avoidance below the criterion for classification.

The mean differences in the number of incidents of NA, EA, RE, and EP at each end of the apparatus for Ss classified in H, P, SH, SF, and O groups (Figs. 13A through 13D and 14A through 14D) suggest but do not conclusively demonstrate that differences in these classes of behavior are related to differences in time spent in CP. Ss in class H seem to make far fewer NAs, more EAs, more REs and fewer EPs at the toy hedgehog than at the striped panel. These correlations with time in CP are similar to those noted between these classes of behavior and the

Figure 13 A. Mean differences in NA responses by H, P, SH, SF and O groups, toy hedgehog minus striped panel.

Figure 13B. Mean differences in EA responses by H, P, SH, SF and O groups, toy hedgehog minus striped panel.

Figure 13C. Mean differences in RE responses by H, P, SH, SF and O groups, toy hedgehog minus striped panel.

Figure 13D. Mean differences in EP responses by H, P, SH, SF and O groups, toy hedgehog minus striped panel.

Figure 14A. Mean differences in NA responses by H, P, SH, SF, and O groups, shock minus safe.

Figure 14B. Mean differences in EA responses by H, P, SH, SF, and O groups, shock minus safe.

Figure 14C. Mean differences in RE responses by H, P, SH, SF and O groups, shock minus safe.

Figure 14D. Mean differences in EP responses by H, P, SH, SF, and O groups, shock minus safe.

interstimulus interval, except that NA seems here to bear inverse relationship to avoidance. The P group makes more NAs and more EAs to the toy hedgehog end than to the striped panel end, but the relationship does not hold in the EA and RE classes. The SH group makes fewer NAs, more EAs, more REs, and fewer EPs to the shock end than to the safe end. The R group makes more NAs, less REs, less EAs, and more EPs to the safe end than to the shock end. The overall differences between groups in NA and EP for both the toy hedgehog-striped panel and shock-safe dimensions and for EA in the shock-safe dimension are significant beyond the $p = .01$ level for a one-way analysis of variance (Appendix II, lines 22 through 29). The differences between the mean differences for NA for the H group and for the H-No S group on the toy hedgehog-striped panel dimension are significant beyond the $p = .05$ level by the quite conservative Scheffé contrast test. The differences between the mean differences for the H group and the O group for EP in the toy hedgehog-striped panel dimension are also significant beyond the $p = .05$ level by the Scheffé contrast test. Significant Scheffé contrast differences are listed in Appendix II, lines 22 through 29. Some instances of statistical insignificance, despite large mean differences, may be due to the very small number of Ss in the P (four) group. As well, it should be remembered that Ss were classified here by differences in time spent in CP, and S which demonstrates avoidance by a strong bias in time spent in CP is necessarily not available to express that avoidance through these other classes

of behavior. This fact in no way suggests that changes in the frequency of these classes of behavior attributable to shock do not indicate avoidance.

These data give the impression that certain classes of behavior are related to differences in time spent in CP. An S which avoids a certain stimulus element, as defined by time spent in CP elsewhere, most probably will make less NAs, more EAs, more REs, and less EPs to that stimulus complex than to whatever stimuli are available at the other end of the apparatus. The difference in total incidents of a single class of behavior between ends of the apparatus for a single S would not reliably predict the differences in CP time for that same S to the same ends of the apparatus or reliably indicate the overall mode of avoidance of S following shock. However, the consensus of differences in incidents of the classes of behavior recorded here probably would predict the behavior of an individual in terms of time spent in CP at a particular end of the apparatus. Moreover, the consensus of differences in these classes of behavior might quite accurately reflect the overall mode of avoidance for each S. Both of these conjectures will be explored in the following section.

The central conclusions from this analysis of the test data are two. First, if individual Ss are classified as avoiding particular stimulus elements on the basis of difference in time spent in CP at each end of the apparatus, then there are substantial numbers of Ss from 1, 5, and 10 sec. groups, but not from the 40 sec. and S-No H groups, that are

classified as avoiding the toy hedgehog. Second, there appear to be fairly reliable relationships between differences in time spent in CP at different ends of the apparatus and differences in the frequencies of other behaviors in the same ends of the apparatus.

Classification of Ss by incidents of NA, EA, RE, and EP

Given the results of the preceding analysis, it may be possible to devise a way of separating individual Ss into classes of avoidance on the basis of differences in the incidence of certain classes of behavior alone, and then find that these classifications resemble those based on differences in the time spent in CP before the various stimulus elements. In other words, if we know something of an Ss behavior in terms of the frequency of NA, EA, RE, and EP, then it should be possible to predict the differences in time spent in CP before various stimuli by the same S. These classifications may also represent coherent descriptions of the avoidance behavior of individual Ss.

A number of classification schemes were attempted. Those schemes based on fewer than the four classes of behavior (NA, EP, RE, and EP) are effective in predicting time spent in CP for some of the Ss but leave so many Ss unclassified as to be unsatisfactory. This occurs simply because many Ss did not engage in a particular class of behavior often enough to allow classification, or do not make more instances of a particular class of behavior at one end of the apparatus than at the other during

one half of the test. As an example, if Ss were classified only on the basis of differences in the incidents of RE at each end, 42 of 60 Ss from the 1, 5, and 10 sec. groups and 32 of 40 Ss from the 40 sec. and S-No H could not be classified, even if the criterion for classification were simply more REs at one end than the other. By contrast, classifying Ss on the basis of incidents of all seven classes of behavior described earlier in this report (incidents of NA, EA, BTP, CP, FR, RE, and EP) results in a number of Ss from the H-No S group being classified as avoiding one stimulus element or another, largely due to the inclusion of the BTP measure. This method also has the distinct disadvantage of including the frequency of CP measure, which is redundant with time spent in CP.

A minimum criterion of difference between the number of instances of a certain class of behavior at each end of the apparatus, given that the difference is to be used as an index of avoidance, is desirable. For example, if simply more instances of NA to one end than to the other is considered relevant to predicting avoidance, then slight differences in the number of NAs at each end would result in many H-No S Ss being classified as avoiding certain stimuli.

The scoring procedure chosen incorporates the following elements. Each class of behavior is given equal weight as an indicator of avoidance, with the consensus of these classes being the basis of the final categorization. The classes NA and EP are taken as inverse indices of avoidance, while the classes EA and RE are taken as direct measures. A two-to-

one minimum ratio of instances of one class of behavior at each end of the apparatus is used in deciding whether a particular difference in behavior is relevant to differential avoidance. It is not possible to choose a criterion here based on the frequency distribution of behavior for the H-No S group, as was done in the preceding analysis, because the H-No S Ss engaged in no EA or RE responses whatever and ate every available sucrose pellet (EP) during the test.

It must be understood that this means of classifying Ss is somewhat arbitrary and is done after the fact, with full knowledge of the behavior of each S in terms of CP time before various stimulus elements, but without actually taking CP into account in making the categorization on the basis of the other measures. The goal is to demonstrate that knowledge of some aspects of behavior that bear no prima facie relationship to avoidance can be used to place individual Ss in groups which represent their individual modes of avoidance.

The procedure of classification finally chosen is as follows: In the first half of the test, the number of instances of each of four classes of behavior (NA, EA, RE, and EP) at each end of the apparatus is noted. If for a particular class of behavior there are twice as many or more instances at one end as at the other, then this class of behavior is taken to indicate avoidance of one end and the stimulus object paired with it. REs and EAs at a particular location are taken to indicate avoidance of that location, while NAs and EPs at one end indicate avoidance of the other

end and the stimulus object paired with it.

If, after following this procedure for one half of the test, avoidance of one end-stimulus object combination is indicated by more classes of behavior than indicate avoidance of the other, then S is taken to avoid that combination. However, since the apparatus during one half of the test contains two stimulus elements, both an end (shock or safe) and a stimulus object (striped panel or toy hedgehog), data from one half of the test are not adequate to indicate avoidance of a single stimulus element. Therefore, the process is repeated for the second half of the test, when the striped panel and the toy hedgehog are reversed.

If more of the classes of behavior indicate avoidance of one end of the apparatus than the other in the second half of the test, and avoidance was indicated for one end or the other in the first half as well, then a consistent image of avoidance of a particular stimulus element emerges. If S avoids the shock end of the apparatus in both halves of the test, independent of the stimulus object (toy hedgehog or striped panel) placed in the shock end, then S is classified as avoiding the shock end. If S avoids one end during the first half of the test and the other during the second half of the test, then S is classified as avoiding either the toy hedgehog or the striped panel, depending on which was present at the end for which avoidance is indicated in each half of the test. If a particular S is not indicated as avoiding one end of the apparatus or the other during one or both halves of the test, S is not classified in the H (toy hedgehog), P

(striped panel), SH (shock end), or SF (safe end) groups, but rather in the O (no identifiable avoidance) group. The mechanics of this classification scheme are presented in Appendix IV.

By this procedure, 25 Ss from the shocked groups were classified in the H group, 5 in the P group, 17 in the SH group, 8 in the SF group, and 45 in the O group. Ten of the Ss in the O group might have been classified in the SH or SF groups, but by remaining at one end of the apparatus throughout at least one half of the test did not engage in any of the behavior used in this classification procedure. All H-No S Ss would fall into the O group by this scheme.

The validity of the foregoing method of classification may be examined with a contingency table (Table 1) relating the classification of each S on the time in CP to the classification obtained by the present method. For the purposes of this table, the 12 Ss which were not classified on the basis of differences in CP time because they exceeded the criterion on two dimensions are counted as "half" Ss in each of the two classes of avoidance for which they exceed the criterion. With five possible classes for each S, 48.5 of 100 Ss fall into the same class by both means of classification. This result exceeds by seven standard deviations the mean of a binomial distribution based on the null hypothesis that the probability of agreement between the two schemes in any one case is $p = .20$. Only one S that was classified in one avoiding class on the basis of differences in time in CP is classified in the opposite class on the same

Table 1

Contingency Table for Ss Classified in H, P, SH, SF, and O
Groups on the Basis of Differences in Time in CP
and by NA, EA, RE, and EP Responses

Sorted by NA, EA, RE, and EP
Responses

		H	P	L	R	O
Sorted by Time in CP	H	15	0	1	0.5	5
	P	0	1	0	0	4
	L	5	1	13	0	14.5
	R	2	0	1	5.5	7.5
	O	3	3	2	2	14

avoidance dimension (H and P or SH and SF) by the present scheme.

Since both means of classification involve arbitrary minimum criteria, any S which barely exceeded the criterion for being placed in a particular avoidance class by one method and falls just short of the criterion for being placed in the same class under the other would be counted as a "miss" in Table 1. Therefore, it is worthwhile to examine the mean differences in time spent in CP at each end of the apparatus by Ss in the groups formed by the present classification method, in order to determine whether these groups resemble those formed on the basis of differences in time in CP. As shown in Figs. 15A and 15B, Ss in the H group spend less time at the toy hedgehog end of the apparatus than at the striped panel end. Conversely, Ss in the P group spend less time at the striped panel end than at the toy hedgehog end. Ss in the SH group spend less time at the shock end than at the safe end, and, conversely, Ss in the SF group spend less time at the safe end of the apparatus than at the shock end. The overall differences apparent in Figures 15A and 15B are significant far beyond the $p = .01$ level (Appendix II, lines 30 and 31). However, the differences between the P group and the H-No S group on the H-P dimension, and between the R group and the H-No S group on the SH-SF dimension, are not significant at the $p = .05$ level on the basis of the conservative Scheffé contrast test. This may in part be due to the very small number of Ss in the P (five) and SF (eight) groups. In all cases, the differences in time spent by Ss in the O and H-No S groups and by Ss

Figure 15A. Mean differences in time in CP for H, P, SH, SF, and O groups, toy hedgehog minus striped panel.

Figure 15B. Mean differences in time in CP for H, P, SH, SF, and O groups, shock minus safe.

in other groups before inappropriate stimuli (H group at the shock end, etc.) lie between the extremes in differences in time spent in CP before the appropriate stimuli for all groups and do not differ significantly (Appendix II, lines 30 and 31) from each other.

Mean differences in the number of incidents of NA, EP, RE, and EP between end of apparatus for the various groups of Ss may well be expected to conform to the differences found when Ss were classified on the basis of time spent in CP, since in this analysis these scores were used as the basis for grouping (Figs. 16A through 16D and 17A through 17D). For the most part, this is the case. However, the means of classifying Ss used here does not directly correspond to these data, since all differences above a certain minimum criterion were treated alike and all classes of behavior were given equal weight in this classification procedure. Indeed, more EPs (Fig. 14D, p. 66) were made by Ss in the SH (avoiding) group at the shock end of the apparatus than at the safe end. In all cases, the differences in the difference in the number of instances on the H-P dimension for the H and H-No S or O groups were significant beyond the $p = .05$ level by the Scheffé contrast test (Appendix II, lines 32 through 35). However, while all classes of behavior yielded significant overall differences between groups for both the H-P and SH-SF dimensions, except class EP in the SH-SF dimension (Fig. 17D), not all appropriate differences were significantly different from those for the H-No S or O groups (Appendix II, lines 32 through 39).

Figure 16A. Mean differences in NA responses by H, P, SH, SF, and O groups, toy hedgehog minus striped panel.

Figure 16B. Mean differences in EA responses by H, P, SH, SF, and O groups, toy hedgehog minus striped panel.

Figure 16C. Mean differences in RE responses by H, P, SH, SF and O groups, toy hedgehog minus striped panel.

Figure 16D. Mean differences in EP responses by H, P, SH, SF, and O groups, toy hedgehog minus striped panel.

Figure 17 A. Mean differences in NA responses by H, P, SH, SF, and O groups, shock minus safe.

Figure 17B. Mean differences in EA responses by H, P, SH, SF and O groups, shock minus safe.

Figure 17C. Mean differences in RE responses by H, P, SH, SF and O groups, shock minus safe.

Figure 17D. Mean differences in EP responses by H, P, SH, SF and O groups, shock minus safe.

The central result of this analysis is that on the basis of this scheme of classification employing four behavioral measures, 6 Ss from the 1 sec. group, 11 from the 5 sec. group, 8 from the 10 sec. group, and none from the 40 sec., S-No H, and H-No S groups avoided the toy hedgehog (Figs. 18A and 18B). Again, differential avoidance of the toy hedgehog is demonstrated to be limited to Ss with interstimulus intervals of less than 40 sec. Other orderly changes in avoidance patterns at various interstimulus intervals are evident. The number of Ss avoiding the striped panel increases with the interstimulus interval in a manner virtually identical to that found when Ss were classified by differences in CP time (Fig. 11A, p. 53). Again, the number of animals involved is too small to permit a strong conclusion from this trend, but the extreme orderliness of the function on the basis of both methods of classification is intriguing. If this relationship has any meaning, it suggests that, as association of shock with the toy hedgehog becomes less likely, forward-order association with the striped panel becomes more likely, as though the striped panel were a reasonable second choice for an S that is prepared to associate the shock with an environmental stimulus object.

Another trend is obvious in Fig. 18B, more so than in Fig. 11B. In terms of differences in incidents of behavior, far more Ss from the 40 sec., S-No H, and H-No S groups simply do not differentially avoid any of the available stimulus elements. While 6 Ss from each of the 1, 5, and 10 sec. groups are not classified into avoiding groups by this method,

Figure 18A. Number of $\underline{Ss}$ from each interstimulus interval group in H and P groups.

Figure 18B. Number of S_s from each interstimulus interval group in SH, SF, and O groups.

12 from the 40 sec. group and 14 from the S-No H group are not classified as differentially avoiding any particular stimulus. The fact that more Ss in the 40 sec. and S-No H groups than in the 1, 5, and 10 sec. groups do not differentially avoid any stimulus element must be attributed to the inavailability of the toy hedgehog and not the length of the black-out period per se, because the S-No H group, with 1, 5, 10, and 40 sec. black-outs, has the largest number of O group Ss. If it were the case that the lack of visual stimuli following shock prevented the association of shock with environmental stimuli, then the 40 sec. group could be expected to have the largest number of Ss in the O group. Instead, a lack of availability of the toy hedgehog following shock results in less differential avoidance of environmental stimuli in general. The only environmental stimulus for which there is an increase in differential avoidance with a decrease in the availability of the toy hedgehog is the striped panel. This result strengthens the evidence for the earlier hypothesis that the striped panel is a reasonable second choice for Ss prepared to associate shock with an environmental stimulus element but deprived of the toy hedgehog.

DISCUSSION

Summary of results

Three analyses of the same data have demonstrated that significant numbers of Ss from the 1, 5, and 10 sec. delay groups avoid the toy hedgehog during the test session. First, Ss in the 1, 5, and 10 sec. groups spend on the average far less time in CP at the toy hedgehog end of the apparatus than at the striped panel end. Ss from the 40 sec., S-No H and H-No S groups spend more time in CP at the toy hedgehog than at the striped panel. Avoidance of the toy hedgehog by Ss from the 1, 5, and 10 sec. groups is further demonstrated by the tendency for Ss from these groups to make more EAs and REs to the toy hedgehog than to the striped panel while the remaining groups show the reverse tendency. Ss from the 1 and 5 sec. groups made more EPs at the striped panel than at the toy hedgehog, and the reverse was true for the 40 sec., S-No H and H-No S groups.

Significant numbers of Ss from the 1, 5, and 10 sec. groups were shown to avoid the toy hedgehog when the criterion for avoidance was the difference in time spent in CP before hedgehog and panel. By this criterion, no Ss from the 40 sec. and H-No S groups and one from the

S-No H group were classified as avoiding the hedgehog. The classes of behavior NA, EA, RE, and EP were shown to be related fairly reliably to differences in time spent in CP. Ss classified as avoiding one stimulus element on the basis of time spent in CP tended to make fewer NAs, more EAs, more REs, and fewer EPs to that element than to any other element.

When Ss were classified as avoiding certain stimulus elements on the basis of NA, EA, RE, and EP responses, significant numbers of Ss from the 1, 5, and 10 sec. groups were found to avoid the hedgehog. No Ss from the 40 sec., S-No H, and H-No S groups were found to avoid the hedgehog on this basis.

Strength of evidence for backward conditioning

The results reported above convincingly demonstrate that an association between the hedgehog and the shock is found in significant numbers of Ss in the 1 sec., 5 sec., and 10 sec. groups. Certain aspects of these results indicate the full strength of this demonstration. First, conditioning is found here despite a 10 sec. UCS-CS delay, which indicates that not only is this a robust phenomenon but also that it can be expected to occur in a variety of stimulus conditions. If conditioning were found in only the 1 sec. group, then these results might be thought of as uniquely dependent on the use of the toy hedgehog as a conditioned stimulus object. Given that conditioning is obtained here with yet longer delays, it is

likely that various changes in the experimental conditions, such as the shock magnitude, the stimulus objects, or the running procedure, would not eliminate the basic phenomenon.

This conditioning occurred despite both a single-trial procedure and a 24-hr. trial-to-test delay. The single trial severely limits the opportunities for S to make any association with the shock, and the 24-hr. delay before testing decreases the probability that S will retain what has been learned and demonstrate that association during the test. For these reasons it is remarkable that conditioning of any sort was obtained.

The opportunities for forward conditioning included in this experiment also suggest that the conditioning found here with the CS following the UCS is a strong phenomenon. The panel, a novel stimulus until a few minutes before the shock, served as a conspicuous forward conditioning CS. Ss were shocked while taking the first sucrose pellet made available in the striped panel and that panel then disappeared with the beginning of the shock. The same panel has served as a successful forward conditioning CS in a similar experiment by the present author (1972). Ss might also associate shock with enduring stimuli present both before and after shock, such as those indicating the shock location. Indeed, Ss which avoided the hedgehog did so in one half of the test in preference to avoiding both the panel and the shock end of the apparatus, arranged in the identical stimulus array present immediately prior to shock.

Avoidance of the hedgehog cannot be attributed to an unconditioned

avoidance response since Ss in the H-No S did not avoid the hedgehog during the test. In this respect, the toy hedgehog may virtually be considered a neutral stimulus. The response of the H-No S group to the hedgehog during the test involved slight attraction and in no way suggested avoidance.

Simple sensitization resulting from the shock is apparently not responsible for the conditioning to the toy hedgehog observed here, since S-No H Ss did not avoid the toy hedgehog during the test. In general, Ss from the S-No H and 40 sec. groups slightly preferred the toy hedgehog to the striped panel. However, it should be noted that in one operational respect backward conditioning and sensitization are identical. Both involve S responding to a stimulus that follows the UCS with a response of the same valence as the UCR. The failure of the S-No H and 40 sec. groups to avoid the hedgehog demonstrates that this novel stimulus object will not elicit a response of the same valence as the UCR after intervals of 40 sec. or longer. If avoidance of the toy hedgehog were found among Ss from the S-No H group, an associative explanation of this result might be unconvincing, regardless of the operational similarities to backward conditioning.

Finally, given the opportunities for forward conditioning and the finding of conditioning to the hedgehog following a 10 sec. UCS-CS delay, Cautela's "duration of pain" (1965) hypothesis seems an unlikely explanation of these results. Cautela suggests that reported instances of

backward conditioning using aversive UCSs and short UCS-CS intervals may be forward conditioning between the CS and a pain trace from the UCS. Obviously, some sort of trace, but not necessarily a sensory one, must follow the UCS for backward conditioning to occur in any case. While Cautela's hypothesis might also be applied to pleasurable UCSs, and reduce to a denial of the possibility of backward conditioning in any situation, it is adequate at this time simply to answer his more narrow objection. If pain is the aspect of the UCS most important to conditioning, then it is logical to predict conditioning to objects present just before or concurrently present with the shock when the pain is maximal, not conditioning to an object first present 10 sec. following shock.

Stimulus cuing

It is logically implausible to conclude that backward conditioning can occur in any situation through the association of stimuli on the basis of the temporal cuing of one stimulus by another. The second stimulus, the CS in the case of backward conditioning, cannot cue the arrival of the first but instead cues its termination. A CS which follows a UCS will elicit a response opposite to that of the UCS if indeed any conditioning between the UCS and CS does occur.

Both Pavlov and Hull reached the conclusion that backward conditioning does not occur. Pavlov (1927, p. 27) denied the possibility on empirical grounds, since his students had failed to find any backward

conditioning. Innumerable backward conditioning articles (e. g., Cautela, 1965) begin with saying that Pavlov later reversed his position (Pavlov, 1928, p. 381), but a careful reading of Pavlov's statement does not clearly show that this is the case. Hull (1943, pp. 170-172) predicts weak and unstable backward conditioning at short UCS-CS intervals, on the basis of habit strength being a symmetrical decreasing function on either side of an interstimulus interval of .44 sec.

The backward conditioning experiments reported in the literature have been nearly universally unsuccessful. In the most complete available review, Cautela (1965) is able to find only one study in the American and Russian literature that satisfies the stimulus substitution definition of backward conditioning. Both Kimble (1961) and Osgood (1953) can find no reliable cases of backward conditioning, and both Kalish (1954) and Spence and Runquist (1958) go so far as to use backward conditioning as a control condition for forward conditioning. After a review of the available American literature, the present author can find no reason to doubt these conclusions. All of the studies known to this author employed transient events such as tones or flashes of light as conditioned stimuli. Since there is little basis other than temporal contiguity on which a tone and a shock might be associated, and backward conditioning is not a reasonably predicted outcome on the basis of cuing alone, it is not surprising that these efforts have met with failure.

The results of this present experiment may not reasonably be

described as the result of association by cuing alone, for several reasons. For the toy hedgehog to cue the impending arrival of shock, Ss would have had to confuse the order of occurrence of two events separated by up to 10 sec. This seems most unlikely. Further, if cuing was the only factor involved in the associations found in the present results, then forward-order conditioning to the striped panel is the more likely outcome for this experiment. Ss which avoided the toy hedgehog did so at the expense of not avoiding the forward-order conditioned stimulus panel.

Finally, there are excellent reasons for believing that the nature of the CS used here is of central importance to the association found in this experiment, not simply time order or temporal contiguity. Earlier attempts by the present author (1972) at using the striped panel as a backward-order CS were unsuccessful, while this experiment using the hedgehog was successful. As well, conditioning was found in this experiment following a UCS-CS delay of 10 sec., a longer interval than is usually attempted in either forward or backward conditioning. If the use of a hedgehog as the conditioned stimulus results in successful conditioning here, while the use of transient stimuli as CSs elsewhere has resulted in no reliable conditioning, then the nature of this stimulus and the assumptions that led to its use are important to our understanding of animal learning.

The heuristic value of an anthropo-
morphic assumption

If a rat can associate an aversive stimulus with a stimulus object under some conditions in a relationship of the form "that object causes that aversive stimulus," rather than only in a relationship of the form "that object immediately precedes that aversive stimulus," then the results of this experiment are quite reasonable. In fact, exactly this anthropomorphic assumption led to the design of the present experiment.

Several conclusions follow from the assumption that a rat can perceive a causal agent-effect relationship. First, there must be some situations in which a rat will make this attribution rather than the attribution of a purely temporal relationship. In turn, the stimuli present must determine whether the rat makes one attribution or the other, so the important element in finding a situation in which the causal attribution will be made will be the stimuli used in conditioning. Varying the temporal relationship between stimuli is likely to result in no conditioning, not backward conditioning, as innumerable experimenters have discovered. Finally, if the UCS is a painful (and novel) shock, then a highly likely stimulus for a rat is an animate object presumed to have attacked and caused pain. Transient stimulus events and inanimate objects are less likely to be treated as the cause of pain.

Auxiliary support from the
experimental literature

The conclusions reached from the assumption that rats can associate stimuli via a causal relationship are supported by a broad literature in conditioning. At the most general level, Shettleworth (1972) concludes, on the basis of a review of the literature, that the associability of stimuli is dependent on the causal relationships among similar stimuli in the natural environment of the animal. Rozin and Kalat (1971) take the somewhat broader view that the learning abilities of an animal are an expression of evolutionary adaptation to its environment. If this is the case, then the perception of a threatening, animate stimulus object as the causal agent for noxious stimulation is probable in the case of rats, which are threatened in their natural environment by predators and antagonists. It would be adaptive for a rat to be able to associate sudden pain with a predator seen only following the pain, a hypothesis made by Hudson (1950) in reference to the study replicated by the present experiment.

A number of specific experimental results lend more direct support for the conjectures made in designing this experiment. First, rats readily associate aversive stimuli with selected aspects of the environment, not with all stimuli present at the time of the aversive stimulus, just as did Ss in this experiment. Moreover, the stimuli avoided depend upon the modality of the aversive stimulus. Barnett (1963) reports that rats poisoned with food will thereafter avoid the food but not the location

in which they were poisoned. Garcia and Koelling (1967) induced nausea with radiation in rats that were drinking vinegar-flavored water in the presence of strong olfactory and visual and auditory location cues, and then separated the stimulus components in extinction tests. The rats strongly avoided the vinegar taste, somewhat avoided the smell, but did not avoid the combined location cues. Garcia and Koelling (1966) also shocked or poisoned (x-ray or LiCl) rats which were licking a salty solution from a spout while a light flashed and a relay clicked. Both shocked and poisoned Ss learned to avoid, but the shocked group avoided the audio-visual location stimuli and the poisoned group avoided the taste. This essential result has been replicated by Garcia and Ervin (1968).

Hudson (1950) found that following shock rats avoided the single stimulus object (a striped panel) that was recently introduced into their home cages, not other aspects of the shock location, and that the avoidance behavior began only following a short period of post-shock non-avoidance behavior. This gradual orientation to one aspect of the environment, followed by specific avoidance of that stimulus in later tests, was also found by the present author (1972). Tolman, in interpreting Hudson's results, said that it "reinforces the notion of the largely active selective character in the rat's building up his cognitive map. He often has to look actively for significant stimuli in order to form his map and does not merely passively receive and react to all the stimuli which are physically present (1948, p. 201)." All of these results support the expectation that

Ss in the current work would associate shock with specific aspects of the environment, and that the aspects chosen would be appropriate to the nature of the aversive stimulus. This expectation may be contrasted with that of Spence (1950), who interpreted Tolman's "looking actively for the significant stimuli" in terms of receptor orientation and stimulus intensity only.

The novelty of the conditioned stimulus, whether the UCS is shock or nausea, is of importance to the formation of an association. Galef (1970b) found that shocked rats would attack a novel hardwood ball in a familiar chamber, but would not attack a familiar ball under the same circumstances. Galef (1970a) also found that spontaneous aggressive behavior in wild rats to novel stimuli such as handlers, mice, and other rats could be reduced by gentling, but that the gentling affected only the response to a narrow class of stimuli without reducing aggression to other novel stimuli. In other words, the fact of novelty was adequate to elicit unconditioned aggression, and the effect of gentling was not to reduce this general tendency. Barnett (1958) found unconditioned avoidance behavior in wild rats following novel stimulus changes as slight as moving the location of the food tray in their cages. Within the delayed taste-avoidance literature, several authors (e.g., Revusky & Bedarf, 1967) have demonstrated the greater tendency of rats to associate novel foods than familiar foods with delayed induced nausea. Within the present experiment, the toy hedgehog is the most novel available stimulus object temporally

contiguous with the shock. The striped panel is present for several minutes prior to shock, and has some similarities with familiar blank panels.

The fact that the toy hedgehog used in the current research is roughly animate in its features, as well as being novel, greatly increases the probability that it will be associated with shock. O'Kelly and Steckle (1939) shocked both individual rats and a group of six rats in a bare apparatus. They found that rats in the group attacked each other during and after shock whenever they came in contact with each other. In contrasting individual behavior with behavior in a group, they say,

consider the behavior of the isolated rat in a shock situation. When there is no means of ready escape the animal attacks the side of the cage, the grid, and any other object in the environment indiscriminately. When, however, more than one animal is being shocked at the same time the behavior rapidly narrows down into a definite aggressive relationship between animals, with no further attempt at the random attack of other aspects of the environment (pp. 129-130).

Similar fighting was found among paired rats by Ulrich and Azrin (1962), but in addition they found that individual rats would not attack dolls or dead rats when shocked. Presumably, there is a hierarchy of stimuli to which a rat is likely to attribute painful shock, and presumably the term "animate" refers to the essential feature of that hierarchy. Hudson (1950) found that a small bundle of pipe cleaners having roughly animate features was an adequate backward CS, while the present author (1972) has found that a striped panel is an adequate forward CS but not an adequate backward CS. Nor was a toy teddy bear that looked more like a

pillow than an animal an adequate backward CS.

Studies of delayed taste avoidance, reviewed by Rozin and Kalat (1971), clearly indicate that close temporal contiguity is not essential to all forms of learning in rats. In a prototypical experiment, Smith and Roll (1967) fed rats novel fluids (sucrose and saccharin) and then induced nausea with x-radiation several hours later. In tests still later, Ss avoided drinking the novel fluids involved. This basic result has been replicated many times. While the mechanism for this learned avoidance may be far different from that involved in the current research, it is clear that there is no a priori reason to assume that close temporal contiguity will be a necessary element in any particular type of learning in rats. Therefore, that the 10 sec. interstimulus interval is effective in the current research is not in itself surprising.

Finally, the species-specific defense reaction hypothesis of Bolles (1970) suggests that the present procedure may be particularly well suited to the detection of avoidance learning. Drawing on the work of others, Bolles describes the varying difficulty in teaching avoidance responses to rats as a function of the response required. Rats may learn to avoid a shock in a shuttlebox in 100 trials, by running in a wheel in 40 trials, or by running down an alley in 12 trials. Bolles then hypothesizes that the ease of learning an avoidance response is a function of the similarity between the required response and S's species-specific defense reaction. Of all the responses that might be required of a rat as evidence of

avoidance, the current experiment, in Bolles' terms, uses the most easily learned. In this experiment all differences in observed behavior of shocked and unshocked rats are taken as being evidence of avoidance, not simply an arbitrary contingent response.

In summary, a diverse literature supports the hypotheses that led to the design of this experiment. The evolutionary adaptation of the species, the tendency to associate noxious stimuli with specific, novel, and animate aspects of the environment, the evidence that temporal contiguity is not essential to all forms of avoidance learning in rats, and the inclusion of all observed changes in behavior following shock in this experiment as evidence of avoidance are all congruent with the hypotheses used in designing this experiment.

Problems in inferring "what is learned"

The avoidance learning observed in this experiment is hypothesized to involve a mechanism intervening between the stimulus and the response, the ability of Ss to infer causal-agent-effect relationships. Kendler (1952) objects to making conclusions about what is learned in cases such as this, because such intervening variables cannot be operationally defined, they are inferred from responses, and two different intervening variables might result in the same response. But Kendler ignores, as Campbell (1954) points out, that two intervening variables may predict different responses, as in this experiment where the learning of cuing predicts

forward conditioning and the learning of agent-effect relationships at least allows for backward-order associations. The fact that the inferred ability of S is difficult to define operationally does not reduce the heuristic value of that inference in predicting behavior, and neither does the fact that it is inferred on the basis of responses. Instead, a concern for the inferred ability leads to the conduction of experiments such as the present one in which the possible interpretations of what is learned are separated.

Kendler's further insistence, with the support of Campbell, that learning theories be based on precise operational definitions of stimulus and response unduly restricts the study of learning. Campbell points out that lack of careful operational definition of a response can lead to the same experiment supporting two theories. A rat may learn to make certain movements that result in a bar being depressed, or it may learn the causal relationship between pressing a bar and getting food, depending on the point of view of the experimenter. However, prior specification of the response that will be taken to indicate learning restricts our understanding of learning in rats to the rat's ability to learn responses we devise, a definitely anthropomorphic view of learning. By contrast, the present experiment considers all changes in behavior, with the possibility of discovering more about what is learned than would be discovered if a response were specified in advance.

The heuristic value in inferring the ability to make attributions of causal agents by rats is evident, but is it acceptable to take the next step

of inferring that this truly is an ability of rats? There are several arguments which suggest that it is.

Morgan (1899) states his famous canon in the following terms. "In no case may we interpret an action as the outcome of the exercise of a higher psychical faculty, if it can be interpreted as the outcome of the exercise of one which stands lower in the psychological scale." The present inference satisfies this requirement, in that the association of stimuli by temporal cuing does not adequately describe this learning. The inference proposed would seem the simplest one to describe the present results. However, there is a distinct difficulty in applying Morgan's canon in this situation or any other as Adams (1928) explains. How do we know which of two psychical faculties here "stands lower in the psychological scale"? There is no a priori reason to suppose one represents a simpler mental process than the other. For these reasons we need to look farther for justification for inferring this particular ability in rats.

Krechevsky (1932), in discussing his inference that rats make systematic hypotheses about solutions of a problem before actually arriving at a solution, uses the criterion that any such term may be applied to an animal as long as the meaning of the term does not exceed the description of certain behavior that it labels. Lashley (1923) used approximately the same criterion in defining consciousness. There is considerable validity to this method, since it describes the same inference by analogy which

we make whenever we infer that a mental capacity we have exists in another person. Krechevsky says, "When the human individual behaves in such and such a way we say he has an 'hypothesis'; when a rat behaves in the very same such and such way we must also say that he has an 'hypothesis' (1932, p. 529)."

However, this method of inference is at the one hand too meager, since it simply labels the behavior observed, without inferring an ability that will result in similar behavior in a variety of situations. This essentially is operationism taken in the narrow sense of the operations being the phenomenon, rather than the operations being examples of a phenomenon which may also be observed in other operations. At the other hand, Krechevsky's method of inference is too broad, since it implies that if we are to infer an ability in a rat it will be the same ability at the same cognitive level that we perceive in ourselves. To make Krechevsky's criterion more satisfactory, it needs to be modified in two ways. First, further restrictions suggested by Adams (1928) should be added, and, second, we need to be aware critically of the anthropomorphic pitfalls present in any inference of animal cognitive abilities and in any description of behavior. Adams (1928) proposes the following rule:

Any experience or mental process in another organism can be inferred from structure, situation, history, and behavior only when a similar experience or mental process is or has been invariably associated with similar structure, situation, history, and behavior in oneself; and the probability of the inference will be proportional to the degree of the similarity (pp. 243-244).

Adams, then, broadens the basis for making such an inference to

include other aspects of similarity between man and beast, and adds a probabilistic notion to the inference once it is made. However, this probability is in terms of the truth or falseness of the inference, not the degree of similarity of experiences in rat and man. The present author is satisfied with this criterion only if it is kept in mind that the inference of the ability to attribute causal-agent relationships to external stimulus objects does not mean that a rat perceives such a relationship as a human being might. The mental process of the rat in this situation, given his differences from a human being in structure, situation, history, and behavior, may have only superficial similarities to human mental processes. Certainly, this inference does not imply a similar human reaction to the same stimuli, since a human being would not be likely to associate a toy hedgehog with being shocked.

Inferences such as the one adopted here are often rejected out of hand on the grounds that they are anthropomorphic, but this objection itself can be answered on the grounds that virtually all descriptions of behavior such as "the rat pressed the bar" contain the assumption of intention or a goal, such as that the rat acted with the intention of lowering the bar, rather than that the rat fell on the bar or backed into it. A description of behavior that did not involve this anthropomorphism would reduce to a description of movements in space; "the rat's left forepaw descended 2.1 cm. from a position just above the bar to a position approximating the maximum downward movement," a decidedly clumsy

and largely useless description, at best. Even Guthrie and Horton (1946), who recorded movements of cats escaping a puzzle box, described behavior in an anthropomorphic manner. Adams (1928) confronts the issue of anthropomorphism in the description of behavior squarely by saying, "Man is the measure of all things, and his effort completely to avoid anthropomorphism in describing the behavior of other animals is just as successful as his effort to lift himself by his own bootstraps. . . . the whole method of psychology is anthropomorphic, or more properly auto-morphic (p. 248)."

Future experiments

Further research is required if we are to understand more fully the results of the present experiment. Three elements of the present experiment, the UCS, the interstimulus interval, and the CS, are particularly attractive as areas of experimental exploration, since they undoubtedly are central to the results obtained here. The interstimulus interval has been varied in this experiment but a black-out has been used for the entire interval in every condition. This black-out may extend the interstimulus interval over which Ss will associate the toy hedgehog with the shock by depriving Ss of other visual stimuli during the interstimulus interval. As well, given the effectiveness of the toy hedgehog as a backward conditioned stimulus, it is reasonable to hypothesize that the toy hedgehog could serve as a forward conditioned stimulus over considerable interstimulus intervals.

It is interesting to speculate that different UCSs would be more or less effective than the present footshock in the formation of backward associations. If these associations are based on the defensive tendencies of S, then UCSs more closely resembling attack would be more effective. However, it is difficult to devise noxious UCSs other than shock that do not include clues as to their true origin. A physical blow, for instance, might be a very effective UCS, but aside from the difficulty of hitting each S in a uniform manner, physical blows require objects like hammers, and the association may then be between the blow and the hammer, not the blow and the delayed CS. On the other hand, it is reasonable to hypothesize that some aversive UCSs would be ineffective. A sudden fall, for instance, is an unlikely outcome of attack by another animal.

A conclusive demonstration of the importance of the "animate" nature of the backward CS in this situation would both support the interpretation offered for the present experiment and better integrate this research with the literature describing reflexive aggression and species-specific defense reactions. This could best be done by substituting other CSs, such as balls and stuffed rats, for the toy hedgehog with the hope of determining a hierarchy of associability.

CONCLUSION

Tolman cites five types of experiment in "Cognitive Maps in Rats and Men" (1948) which he believed "seem especially important in reinforcing the theoretical position I have been presenting (p. 193)." This position incorporates two assumptions: "First, that learning consists not of stimulus-response connections but in the building up in the nervous system of sets which function like cognitive maps, and second, that such cognitive maps may be usefully characterized as varying from a narrow strip variety to a broader comprehensive variety (p. 193)." Of the five types of experiment that Tolman used in his support, "latent learning," "vicarious trial and error," "hypotheses" (Krechevsky, 1932) and "spatial orientation" have all been explored at length and reported in the literature. Each has altered in some way our understanding of animal learning. "Searching for the stimulus," the remaining type of experiment, refers to the work by Hudson (1950) on which this work is based. It is clear now that this area of research can join the others cited here as a contribution to our knowledge of cognitive structure in animals.

It is not intended that this work support all of Tolman's theoretical position. It is intended that this work support the notion that animals

such as rats have rich and complicated cognitive abilities, that the structure of their cognitions is open to experimental exploration, and that the results of the present experiment are an example of such a cognitive structure in a rat.

Appendix I

Number of Ss from Each Experimental Group and Control Group Tested with the Toy Hedgehog
at the Left (Shock) End of the Apparatus in the First Half of the Test

Inter- stimulus Interval	Experimental Groups		H-No S Group		S-No H Group	
	# <u>Ss</u>	# Tested with Hedge- hog Left 1st	# <u>Ss</u>	# Tested with Hedge- hog Left 1st	# <u>Ss</u>	# Tested with Hedge- hog Left 1st
1 sec.	20	8	5	1	5	2
5 sec.	20	10	5	4	5	2
10 sec.	20	10	5	2	5	2
40 sec.	20	9	5	3	5	3

Appendix II

Compiled Statistical Analyses of Results

Wilcoxon Signed-Ranks

<u>Line</u>	<u>Fig.</u>	<u>Behavior</u>	<u>p</u>
1	3	Time in halves	p > .05
2	4	Time in CP	p > .05
3	5A	NA	p > .05
4	3	Time in halves	p > .05
5	4	Time in CP	p > .05

One-Way ANOVA

<u>Line</u>	<u>Fig.</u>	<u>Behavior</u>	<u>Groups Compared</u>	<u>Degrees of Freedom</u>	<u>WMS</u>	<u>Crit. F</u> p = .05	<u>F</u>	<u>HSD</u> p = .05
6	6	Time in CP	1, 5, 10, 40, S-No H, H-No S	5;114	2450	2.30	5.61	32
7	7A	NA	"	"	1.36	"	15.1	0.75
8	7B	EA	"	"	2.28	"	4.0	0.98
9	7C	RE	"	"	2.01	"	3.4	0.29
10	8A	Time in CP	"	"	26300	"	4.3	105
11	8B	Time in CP	"	"	58100	"	1.2	-
12	9A	NA	"	"	4.20	"	1.3	-
13	9B	EA	1, 5, 10, 40, S-No H	4;95	10.80	2.47	4.6	2.12

Appendix II (continued)

Line	Fig.	Behavior	Groups Compared	Degrees of Freedom	WMS	Crit. F p = .05	F	Scheffe p < .05
14	9C	RE	1, 5, 10, 40, S-No H	4;95	7.90	2.47	4.7	1.82
15	9D	EP	"	"	0.63	"	3.4	0.32
16	10A	NA	1, 5, 10, 40, S-No H, H-No S	5;114	3.84	2.30	0.6	-
17	10B	EA	1, 5, 10, 40, S-No H, H-No S	4;95	10.79	2.47	0.4	-
18	10C	RE	"	"	9.26	"	0.3	-
19	10D	EP	"	"	0.63	"	0.4	-
20	12A	Time in CP	H, P, SH, SF, O, H-No S	5;102	8272	2.30	56.4	H - H-No S, P - H-No S
21	12B	Time in CP	"	"	11912	"	77.7	SH - H-No S, SF - H-No S
22	13A	NA	"	"	3.13	"	8.0	H - H-No S
23	13B	EA	H, P, SH, SF, O	4;83	9.59	2.48	1.5	-
24	13C	RE	"	"	8.40	"	1.5	-
25	13D	EP	"	"	0.40	"	16.4	H - H-No S
26	14A	NA	H, P, SH, SF, O, H-No S	5;102	3.41	2.30	4.2	-
27	14B	EA	H, P, SH, SF, O	4;83	9.02	2.48	4.1	-
28	14C	RE	"	"	8.82	"	2.4	-
29	14D	EP	"	"	0.54	"	3.8	-
30	15A	Time in CP	H, P, SH, SF, O, H-No S	5;114	17961	2.30	16.8	H - H-No S
31	15B	Time in CP	"	"	44617	"	8.5	SH - H-No S
32	16A	NA	"	"	3.19	"	9.0	H - H-No S
33	16B	EA	H, P, SH, SF, O	4;95	9.28	2.47	9.1	H - O
34	16C	RE	"	"	7.07	"	8.0	H - O, P-O
35	16D	EP	"	"	0.47	"	12.3	H - O
36	17A	NA	H, P, SH, SF, O, H-No S	5;114	3.17	2.30	5.5	-

Appendix II (continued)

37	17B	EA	H, P, SH, SF, O	4;95	8.24	2.47	9.6	SH - O
38	17C	RE	"	"	7.79	"	4.8	SH - O
39	17D	EP	"	"	.59	"	2.0	-

Appendix III

Mean Time in CP and Mean NA, EA, RE, and EP
Responses, by Interstimulus Interval Groups
and Groups Classified by Behavior

<u>Interstimulus Interval Groups</u>					
Group	Behavior	Hedgehog End	Panel End	Shock End	Safe End
1 sec.	Time in CP	162	253	213	202
	NA	4.30	4.10	4.00	4.40
	EA	1.80	1.60	2.10	1.30
	RE	1.85	1.00	1.75	1.10
	EP	0.45	0.90	0.50	0.85
5 sec.	Time in CP	150	228	114	265
	NA	3.55	4.40	3.65	4.30
	EA	2.75	0.35	1.70	1.40
	RE	2.25	0.40	1.40	1.25
	EP	0.70	1.20	0.85	1.05
10 sec.	Time in CP	165	231	167	230
	NA	2.50	3.00	2.75	2.75
	EA	2.80	0.80	1.70	1.90
	RE	1.40	0.70	1.35	0.75
	EP	0.90	0.80	0.85	0.85
40 sec.	Time in CP	225	221	182	241
	NA	4.35	4.20	4.35	4.20
	EA	0.65	0.85	1.05	0.45
	RE	0.60	1.15	1.45	0.30
	EP	1.10	1.05	1.05	1.10
S-No H	Time in CP	269	197	183	291
	NA	7.25	6.90	7.10	7.05
	EA	0.50	1.90	1.65	0.75
	RE	0.45	2.10	1.80	0.75
	EP	1.30	1.10	1.10	1.30
H-No S	Time in CP	283	205	244	260
	NA	14.9	14.4	14.8	14.6
	EA	0.00	0.00	0.00	0.00
	RE	0.00	0.00	0.00	0.00
	EP	2.00	2.00	2.00	2.00

Appendix III (continued)

<u>Groups Classified by Differences in Time in CP</u>					
Group	Behavior	Hedgehog End	Panel End	Shock End	Safe End
H	Time in CP	59	389	208	240
	NA	1.82	3.82	2.94	2.71
	EA	2.24	0.47	1.29	1.41
	RE	1.65	0.24	0.82	1.06
	EP	0.24	1.35	0.65	0.94
P	Time in CP	386	93	221	259
	NA	8.00	6.25	7.75	6.50
	EA	0.75	0.75	0.50	1.00
	RE	1.00	0.25	1.00	0.25
	EP	1.75	1.25	1.50	1.50
SH	Time in CP	253	204	54	404
	NA	4.55	4.71	3.97	5.29
	EA	1.68	1.42	2.71	0.39
	RE	1.19	1.55	2.32	0.42
	EP	1.16	0.97	0.74	1.39
SF	Time in CP	221	195	370	46
	NA	3.38	3.69	3.77	3.31
	EA	1.31	0.92	0.54	1.69
	RE	0.69	0.69	0.46	0.92
	EP	1.00	0.54	1.00	0.54
O	Time in CP	188	159	167	175
	NA	7.00	5.65	6.61	6.04
	EA	1.04	1.65	1.43	1.26
	RE	1.13	1.87	1.83	1.17
	EP	0.96	0.96	1.00	0.91

Appendix III (continued)

Groups Classified by Differences in NA, EA,
RE, and EP Responses

Group	Behavior	Hedgehog End	Panel End	Shock End	Safe End
H	Time in CP	109	330	191	249
	NA	2.76	4.72	3.76	3.72
	EA	3.72	0.32	1.76	2.28
	RE	2.56	0.20	1.48	1.28
	EP	0.48	1.40	0.92	0.96
P	Time in CP	307	171	235	243
	NA	9.80	7.00	9.20	7.60
	EA	0.80	5.00	2.80	3.00
	RE	0.40	3.40	1.80	2.00
	EP	1.40	0.80	1.00	1.20
SH	Time in CP	221	213	664	368
	NA	3.94	3.47	2.94	4.47
	EA	2.06	2.23	4.00	0.12
	RE	1.65	2.29	3.65	0.29
	EP	1.78	1.00	0.65	1.53
SF	Time in CP	181	172	305	48
	NA	3.75	3.38	4.38	2.75
	EA	1.50	1.00	0.13	2.38
	RE	0.63	1.50	0.63	1.50
	EP	0.75	0.75	0.50	0.38
O	Time in CP	221	186	174	233
	NA	4.98	4.76	4.73	5.00
	EA	0.58	0.69	0.76	0.51
	RE	0.73	0.67	0.87	0.53
	EP	0.98	0.87	0.91	0.98

Appendix IV

Method of Classifying $\underline{S}$ s on Basis of NA, EA,
RE, and EP Responses

We define: $R_{X, T}$ = number of responses of class R at end X for test half T, for a given $\underline{S}$, where R can take values of NA, EA, RE or EP, X can take values SH or SF, and T can take values 1 or 2.

$$1. \quad \text{If } \frac{R_{SH, T}}{2} \geq R_{SF, T} \quad \text{then} \quad A_{SH, R, T} = -1, \quad \text{then}$$

$$\frac{R_{SF, T}}{2} \geq R_{SH, T} \quad \text{then} \quad A_{SH, R, T} = 1$$

$$\text{otherwise,} \quad A_{SH, R, T} = 0.$$

$$2. \quad \text{Determine } A_{SH, R, T} \text{ for all values of R and T,}$$

$$\text{and } \sum A_{SH, R, 1} \text{ for all values of R} = C_1 \quad \text{and}$$

$$\sum A_{SH, R, 2} \text{ for all values of R} = C_2.$$

$$3. \quad \text{If } C_1 > 0 \quad \text{and} \quad C_2 > 0, \text{ place } \underline{S} \text{ in class SH, or}$$

$$\text{if } C_1 < 0 \quad \text{and} \quad C_2 < 0, \text{ place } \underline{S} \text{ in class SF, or}$$

$$\text{if } C_1 > 0 \quad \text{and} \quad C_2 < 0, \text{ place } \underline{S} \text{ in class H or P, whichever was paired with the shock end in the first half of the test, or}$$

$$\text{if } C_1 < 0 \quad \text{and} \quad C_2 > 0, \text{ place } \underline{S} \text{ in class H or P, whichever was paired with the safe end in the first half of the test, or}$$

$$\text{if } C_1 = 0 \text{ and/or } C_2 = 0, \text{ place } \underline{S} \text{ in class O.}$$

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