Conditioning and extinction of taste aversions with variations in intensity of the CS and UCS in two strains of rats*

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One hundred and eighty male rats (90 Sprague-Dawley albinos and 90 Long-Evans hoodeds) were conditioned to avoid a distinctively flavored fluid by twice conditionally pairing the fluid with a drug-induced illness. The UCS (induced by injection of cyclophosphamide) followed the CS by 30 min. The CS and UCS were varied factorially at three levels of intensity. The results indicated that the strength of the aversion was both a function of the intensity of the CS and UCS and that the hooded animals developed stronger and more persistent aversions. The results suggest that conditioned taste aversions are similar to more conventional Pavlovian phenomena.

An interesting phenomenon of animal learning manifests itself in the form of what Barnett (1963) terms "bait-shyness." He describes how the unsuccessful poisoning of rats results in refusal to eat the toxic substance upon a subsequent encounter with it. Bait-shyness behavior has been subjected to experimental investigation in recent years, and the evidence indicates that the avoidance behavior is established by the pairing of an olfactory or gustatory stimulus with an internal visceral malaise (Garcia, Ervin, & Koelling, 1967). Research includes a number of experiments involving the acquisition of this avoidance response to chemical cues using drug-induced or radiation-induced illness as a reinforcing stimulus. A comprehensive review of this research is provided by Garcia & Ervin (1968), and the data reveal that the animal can acquire the aversion after a single pairing of the CS (taste or odor) and UCS (induced illness). Moreover, the aversion is acquired when the interval between the CS and UCS is greater than 1 h and even when potential mediators of contiguity such as aftertaste and vomiting are controlled (Garcia, Green, & McGowan, 1968). The acquisition of the aversion is readily acquired when the illness is conditionally paired with chemical cues, whereas rats exhibit great difficulty in associating exteroceptor stimulation with internal malaise (Garcia & Koelling, 1966). Garcia & Ervin (1968) have suggested that the learning of taste aversions can be conceptualized as Pavlovian conditioning, where the taste cue (CS) comes to elicit nausea previously elicited by the drug or poisoning (UCS).

Several studies (Garcia, Ervin, & Koelling, 1967; Revusky, 1968) have demonstrated that the strength of taste aversions is functionally related to the magnitude of the UCS, but McLaurin (1964) concludes that taste aversions do not fall within the classical conditioning paradigm because the learning is not impaired with prolonged delays between the CS-UCS presentation. However, Wright, Foshee, & McCleary (1971) obtained significant effects for this time delay. It is known that the intensity of the CS is an important variable in classical conditioning (Razran, 1957; Kimble, 1961), and one purpose of the present study was to ascertain the influence of this variable upon the acquisition and extinction of taste aversions and to replicate findings concerning the effects of UCS intensity. It is also known that there are strain differences in bait-shyness behavior (Rozin, 1968), and an additional purpose of the present study was to determine if the effect of this genetic variable on conditioned taste aversions extended across two common varieties of laboratory rats.

SUBJECTS

One hundred and eighty male rats (Sprague-Dawley albino and Long-Evans hooded), 80-100 days old at the beginning of the experiment, were employed as Ss. Differences in arousal, avoidance learning, and exploratory behavior are reported between these strains (Carr, 1957; Schaefer, 1959; and Foshee, 1960). The Ss were maintained and tested in individual wire mesh cages and fed Purina Laboratory Rat Chow ad lib.

EXPERIMENTAL DESIGN

The experimental design was a 3 by 3 by 2 factorial. CS and UCS intensity were each varied at three levels within both strains. All Ss were given two acquisition trials (CS-UCS pairings) and five extinction trials.

PROCEDURE

Ninety animals of each strain were assigned randomly to one of nine different treatment groups, making a total of 18 groups. The UCS was Cyclophosphamide (Cytoxan^R, Mead-Johnson Laboratories, Evansville, Indiana), employed for reasons discussed by Garcia et al (1967). Varying drug dosage (16, 33, and 66 mg/kg of S body weight) injected intraperitoneally provided three levels of UCS intensity. Each animal was weighed before each injection, and the dosage computed. The CS utilized was standard HCL (37%) diluted in distilled water. The three levels of intensity were .25, .50, and .75 ml HCL per liter of water. The medium level has previously been employed in aversion studies, and both the high and low levels were easily discriminated from the medium by humans, while the low was quite discernible from distilled water. The Ss were adapted to a water-drinking schedule of 10 min each day for 7 days. A 100-ml calibrated cylinder fitted with drinking tubes was used to measure fluid intake. On treatment day (TD_1, Day 8) the Ss were presented the appropriate HCL solution for 10 min, and the amount consumed was calculated and recorded. Thirty minutes following the removal of the HCL solution the Ss received an injection of the drug. Following this treatment, animals were allowed 2 recovery days with access to distilled water on the regular 10-min schedule. On the third day (TD_2, Day 11) following treatment, the animals were offered the CS a second time, the amount consumed was recorded, and again this presentation was followed by a Cyclophosphamide injection. The Ss were given 2 more recovery days on the distilled water schedule, and a third presentation of the CS was made—this time without the UCS. Four additional extinction trials were given to the Ss within the same paradigm. All Ss were run at approximately the same time each day.

RESULTS AND DISCUSSION

In order to assess the effect of the conditioning procedure, the amount of fluid consumed by a S on the second conditioning trial and on subsequent extinction trials was expressed as a percentage of his consumption on the

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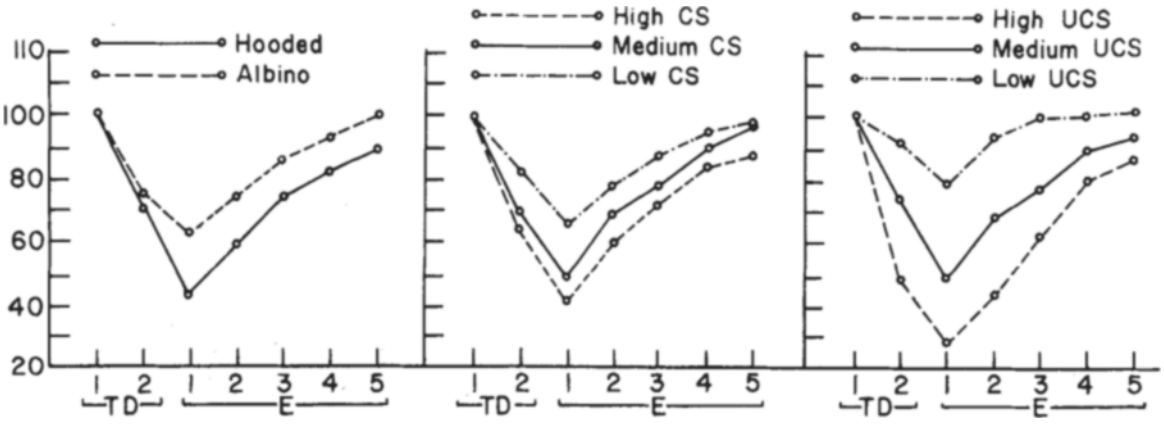

Fig. 1. LEFT: Strain differences during acquisition and extinction. Data points are plotted at first treatment day (TD_1), second treatment day (TD_2), and five subsequent extinction tests (E_{1-5}). MIDDLE: CS effect during acquisition and extinction. Data points are plotted at first treatment day (TD_1), second treatment day (TD_2), and five subsequent tests (E_{1-5}). RIGHT: UCS intensity effect during acquisition and extinction. Data points are plotted at first treatment day (TD_1), second treatment day (TD_2), and five subsequent tests (E_{1-5}).

first conditioning trial. Hence, all Ss score 100% on the first conditioning trial (TD_1). Separate analyses of variance were computed on the acquisition and extinction data. The particular computational procedure required that all cell Ns be equal, and nine animals died during the course of the experiment (autopsy revealed that five died of respiratory infection and it is likely the others from procedural stress). The cell Ns were made equal by discarding the partial data collected from the dead animals and by removing randomly the required number of Ss from the other groups. All groups were equalized at seven Ss per cell. In computing analyses on separate days, however, the computer program compensated for the missing data by assigning a harmonic mean to those cells where they occurred (Winer, 1962).

Figure 1 depicts the differences in performance between the two strains across treatment and testing days. Long-Evans Ss drank less of the sour fluid on all test presentations; however, the difference on the first test trial (TD_2) is not significant. The difference after two CS-UCS pairings (E_1) is significant with $p < .003$. The strain difference persists on the last four extinction trials, and on the final day (E_5) the Sprague-Dawley Ss have completely extinguished (mean consumption = 103%) while the Long-Evans animals are still significantly lower (mean consumption = 89%), $p < .01$. Several tentative hypotheses regarding the source of the strain differences can be made. Perhaps the strains are differentially sensitive to the gustatory cue and, as is discussed below, the intensity of the CS is an important variable. Perhaps equal doses of Cyclophosphamide produce different internal reactions in the two strains. It is also possible that the hypothesized central mechanism underlying this learning (Garcia & Ervin, 1968) has been differentially modified by the various breeding programs that have produced the strains. No firm conclusion can be reached concerning the source of the strain difference on the basis of the data provided by the present investigation.

CS intensity also proves to be an effective variable in this study. Figure 1 presents the mean percentage consumed by the three CS groups. The overall CS effect is significant during the acquisition and extinction ($p < .001$). However, the drinking scores of the medium- and high-CS groups do not differ reliably. Both do differ significantly from those of the low except for the last two extinction trials. The difference in performance produced by the variation in CS intensity is consistent with the findings in traditional studies of classical conditioning (Beecroft, 1966). How CS intensity affects response strength is usually explained in terms of its discriminative value. Contrast provided by greater intensities of the CS allows the animal to discriminate those situations in which it is present from those in which it is not. This is a plausible explanation for the data of this study.

The UCS effect proved to be significant on all test days. Figure 1 depicts these data. All F ratios produce probabilities of less than .02—which was the largest and occurred on the last extinction day. Intensity of the UCS has previously been related to strength of conditioned taste aversions. The agreement between the data presented by Garcia, Ervin, & Koelling (1967) and that of the present study is good. In the overall analyses of acquisition data, the only significant interactions are Trial by Strain and Trials by UCS Level. In extinction data, only the Trial by UCS Level interaction is significant. All of these reflect differences in rate of learning and are readily discernible from the graphed main effects.

In conclusion, the experiment provides data which indicate that the strength of conditioned taste aversions is a direct function of the intensity of both the CS and UCS. The data are interpreted as supporting the contention that taste aversions are indeed a form of associative learning similar, in many respects, to more conventional Pavolvian phenomena.

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Response-reinforcement interactions in multiple interval schedules

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After responding was maintained on multiple variable-interval schedules of reinforcement, a limited-hold requirement was added to one component. Each scheduled availability of reinforcement terminated if no response occurred within a 1-sec period of time. Response rate increased and reinforcement rate decreased in the limited-hold component. Response rate in the unchanged VI component increased. When responding was extinguished in the changed component, positive behavioral contrast was observed in the unchanged VI component.

In variable interval (VI) schedules of reinforcement, changes in reinforcement rates produce direct changes in response rates. When two VI schedules alternate in a multiple schedule, changes in reinforcement rate in one component, while producing direct changes in that component, produce inverse changes in responding in an unaltered component. These opposing changes in response rates have been termed behavioral contrast (Reynolds, 1961). It has since been demonstrated (Hughes, 1970) that these changes in response rates will occur in the absence of large changes in responding in the component in which reinforcement rate is varied. The importance of reinforcement rate in these interactions has been stressed by Bloomfield (1967). Arranging multiple schedules with a constant VI 1-min schedule in one component, S1, and either a fixed ratio (FR) schedule or a DRL schedule in the other component, S2, Bloomfield demonstrated that equivalent changes in the frequency of reinforcement in S2 resulted in similar effects on response rate in S1, regardless of whether the schedule in S2 led to high rates of responding on FR or to low rates on DRL.

Reynolds & Limpo (1968) have reported that positive behavioral contrast will occur in multiple DRL schedules when, upon the addition of an added "clock" to one DRL component, responding is reduced and reinforcement frequency simultaneously increased in that component. While cited as support of a reduction in responding as a factor in producing positive contrast, a reinforcement interpretation can be saved if one chooses to treat the reinforced response as pausing rather than keypecking. Thus, the increased pausing that develops in the component with the added clock is contrasted (negative contrast) with the occurrence of shorter pauses (resulting in higher response rates) in the unchanged DRL component.

Reynolds & Limpo (1968) have pointed to the lack of data on a potentially fundamental case of contrast in multiple schedules: the effect on responding in an unchanged component produced by a substantial increase in response rate together with a substantial decrease in reinforcement rate. These conditions were satisfied in the present experiment by the addition of a limited hold requirement to one component of a multiple variable-interval schedule of reinforcement. The primary observation was the rate of responding in the unchanged variable-interval component.

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SUBJECTS

Two adult Silver King pigeons with previous experimental histories were maintained at approximately 80% of their free-feeding weights. Animals were housed in individual cages with free access to water. Daily experimental sessions were run.

APPARATUS

A standard two-key experimental chamber for pigeons similar in design to that described by Ferster & Skinner (1957) was used. The right key was covered throughout the experiment. The left key could be transilluminated with either a red or green light, and was effectively operated by a force of 15 g. No feedback relay was used. White noise masked extraneous sounds. Reinforcement consisted of a 4.5-sec access to mixed grain. Reinforcements were programmed by variable-interval tapes consisting of 13 intervals arranged in an irregular order. Standard relay programming equipment was located in an adjoining room.

PROCEDURE

Two pigeons were initially exposed to multiple variable-interval schedules of reinforcement, in which 3-min components of red regularly alternated with 3-min components of green illumination of the response key. Responding was reinforced in each component according to identical arithmetic VI 1-min schedules, a daily session consisting of 10 presentations of each schedule component. When responding was approximately equal in both components, a limited hold 1-sec requirement was added to the red component. Each scheduled availability of reinforcement terminated if no response occurred within a 1-sec period of time. Bird RH-1 was exposed to this condition for 14 daily sessions and Bird RH-3 for 10 daily sessions. No changes were made in the regularly alternated green component. The limited hold requirement was then removed and the schedule in the red component changed to VI 2 min. This condition was in effect for 9 sessions for RH-1 and 9 sessions for RH-3. Responding was then extinguished in the red component.

RESULTS

Figure 1 shows the response rates in each schedule component for each of the experimental conditions. Table 1 gives the obtained mean rates of reinforcement in the red component for each experimental condition. Panel A of Fig. 1 shows the rate of responding in each VI component for the five sessions preceding the