Conditioned Taste Aversion as Instrumental Punishment
Kuang-Chu Li, Sigmund Hsiao, and Jay-Shake Li
Online First Publication, April 29, 2013. doi: 10.1037/a0031822

CITATION
BRIEF REPORT

Conditioned Taste Aversion as Instrumental Punishment

Kuang-Chu Li, Sigmund Hsiao, and Jay-Shake Li
National Chung Cheng University

Conditioned taste aversion (CTA) is traditionally viewed as an instance of Pavlovian conditioning. This interpretation rests on the lack of an instrumental contingency between the tastant and the gastric malaise in a standard procedure of CTA. To investigate a role for instrumental punishment in CTA, we present 2 tastants sequentially (“sucrose then NaCl” or “NaCl then sucrose”) in a daily alternating and counterbalanced order to rats with an explicit positive contingency between the dosage of the lithium chloride (LiCl) administered and the amount of 1 tastant drunk on that trial. In the beginning of experiment, rats suppressed their intake of both tastants. With the increase of conditioning trials, rats gradually learned to resume the intake of noncontingent solution while selectively suppressing the intake of LiCl-contingent solution. This selective suppression in CTA is the first report indicating that rats are sensitive to the subtle cues related to the covariations between the magnitude of stimulus and the magnitude of responses in a punishment paradigm involving a long delay between the gustatory stimulus of tastant ingestion and the aversive effect of LiCl injection.

Keywords: conditioned taste aversion, Pavlovian conditioning, instrumental conditioning, punishment

Learning the relationship between tastants and gastric illness is vital for surviving in a world full of poisonous compounds. In this study, we used a laboratory procedure named conditioned taste aversion (CTA) to model such learning. In the standard CTA procedure, a distinctive tastant, the conditioned stimulus is paired with an illness effect that is induced by drugs or exposure to certain physiologically noxious agents. Subsequently, following full recovery from acute physiological effects, when the tastant is presented again, its intake is reduced. A reduced intake indicates the formation of a CTA (Garcia, Kimeldorf, & Koelling, 1955; Nachman, 1970).

CTA is traditionally viewed as an instance of a classical conditioning (Garcia et al., 1955), with the tastant acting as the conditioned stimulus and the gastric malaise as the unconditioned stimulus. This interpretation rests on the fact that, in the standard procedure, there is no instrumental contingency between the amount of the tastant consumed and the dosage of toxin administered during a conditioning trial. However, based on the finding that the active consumption of the tastant established a stronger aversion than the passive administration, Fouquet, Oberling, and Sandner (2001) suggested that an instrumental process could contribute to the aversion.

Furthermore, there are often situations in nature in which more than one tastant is consumed but only one of which is poisonous. If the consumption of each of two tastants is equally contiguous with the toxic effect, simple Pavlovian conditioning will not differentiate the one that should be avoided from the one that can be safely consumed. It is likely that all tastants paired with a poisonous effect would be avoided initially, but at issue is whether the animals would later on learn not to avoid the safe tastant. In this report, we address this issue through an investigation of a role for instrumental punishment in CTA by arranging an explicit positive contingency between the amount of one tastant drunk on a conditioning trial and the dosage of the lithium chloride (LiCl) administered on that trial.

Rats were given two taste solutions to drink (“sweet then salty” or “salty then sweet”) daily in an alternating and counterbalanced order, and then injected with LiCl. On each trial, the dose of LiCl administered increased with the amount of the contingent tastant, either the “sweet” or “salty” solution, that the rat drank on that trial, but was unrelated to the amount of the noncontingent tastant, either “salty” or “sweet” solution, respectively, drunk. If rats were sensitive to this instrumental punishment contingency, they should have drunk less of the contingent than of the noncontingent solution. By contrast, if the resulting aversions were mediated by Pavlovian or classical conditioning, the aversions to the two tastants should have been similar. Because the order in which contingent and noncontingent tastants was alternated across the conditioning trials, on average, they had the same temporal contiguity with the administration of the LiCl.

Kuang-Chu Li, Sigmund Hsiao, and Jay-Shake Li, Department of Psychology, National Chung Cheng University, Chia-Yi, Taiwan.

This research was supported by Grant NSC100-2410-H194-038-MY2 and NSC100-2815-C-194-014-H from National Research Council of the Republic of China.

Correspondence concerning this article should be addressed to Jay-Shake Li, Department of Psychology, National Chung Cheng University, Chia-Yi 62102, Taiwan. E-mail: psyjsl@ccu.edu.tw

© 2013 American Psychological Association
Method

Subjects

Sixteen naïve male Sprague–Dawley rats (*Rattus norvegicus*; National Laboratory Animal Breeding and Research Center, Taiwan) served as subjects. All animals were housed individually in plastic chambers in a temperature-controlled (22 to 24 °C) animal care facility with a 12-hr light–dark cycle (lights on at 7:00 a.m.). Except where noted otherwise, the rats received distilled water (dH₂O) and Rat Chow (Fwusow Industrial, Taiwan) ad libitum. Each animal was handled daily for several minutes on 7 days prior to beginning the experiment. All procedures were conducted with the approval and under the supervision of the Committee on Use and Care of Laboratory Animals of National Chung Cheng University.

Apparatus

Adaptation and conditioning were conducted in stainless steel hanging cages with a drinking tube (a 30-ml plastic burette with 0.1-ml graduations fitted with a stainless steel spout) mounted on the front wall of the cage with the tip located 7 cm above the floor. Sucrose (Taiwan Sugar Corporation), NaCl (Taiwan Salt Industrial Corporation), and LiCl (Sigma Chemical) were dissolved in dH₂O before experiments and presented at room temperature.

Procedure

**Pretraining.** The rats were maintained on a water deprivation schedule of 30-min access per day to dH₂O in the home cages every afternoon throughout the experiment. After 7 days, they were placed into the experimental cage once per day from 10:00 to 14:00 h. All rats received 30-min access to dH₂O on the first day and thereafter two periods of 3-min free access to dH₂O. The rats were then placed back in their home cages before they received 30-min access to dH₂O 6 h later. This pretraining phase lasted for several days until drinking volume and behavior became stable.

**Conditioning.** All rats received two sequential periods of 3-min free access to 4% (wt/wt) sucrose and 0.9% (wt/wt) NaCl solutions, separated by a 5-min interval. The order of the two solutions alternated across days with the initial order counterbalanced across rats. That is, one half of the animals drank sucrose and the other half drank NaCl solutions first on the first day of conditioning. On the second day, the order of the solutions was reversed, with this alternation continued until the end of the conditioning phase.

On the first day of the conditioning phase, approximately 5 min after drinking the second solution, all rats received an injection of 4 ml/kg 0.15 M LiCl. On the second and subsequent days, the rats received two injections. The first injection was 0.15 M LiCl, with a dose calculated individually for each animal according to the following equation:

\[ BW \times \frac{VC_r}{VC_1} \times 4 \]

where \( BW \), \( VC_r \), and \( VC_1 \) are the body weight (kg), intake volume of the contingent solution on that day, and the intake volume of contingent solution on Trial 1, respectively. Therefore, the dose of LiCl was proportional to the amount of the contingent solution drunk on that trial. The second injection was 0.15 M saline with a volume that made up the total daily injection to 4 ml/kg. As a result of the counterbalancing, half of the rats’ dosages of LiCl were contingent to their sucrose intake and the other half were contingent to their NaCl intake. A total of 14 conditioning trials were conducted once per day.

Results

Figure 1A shows the mean intake volume of contingent and noncontingent solutions across 14 conditioning trials. The initial conditioning trial produced a comparable and substantial reduction in consumption of both solutions. Importantly, thereafter, the consumption of the noncontingent solution recovered to the initial level, whereas that of the contingent solution remained suppressed. A 2 (contingent vs. noncontingent solution) × 14 (conditioning trials) two-way repeated measures ANOVA revealed significant main effects of solutions, \( F(1, 15) = 36.75, p < .001 \), and conditioning trials, \( F(13, 195) = 15.14, p < .001 \), and a significant interaction, \( F(13, 195) = 7.64, p < .001 \). The post hoc Tukey’s HSD test indicated that intake of noncontingent solution were significantly higher than that of the contingent solution on Trials 4 and 6 through 14, with \( p < .05 \).

To investigate whether this effect of contingency was confounded by any of the counterbalancing factors, we conducted separate analyses of the intake as a function of the type of solution and the order of the solution on a trial (first or second). Figure 1B shows the overall intakes of the sucrose and NaCl solutions was similar, \( F < 1 \). However, although the interaction between solutions and conditioning trials was not significant, \( F(13, 195) = 1.53, p > .05 \), a post hoc Tukey’s HSD test indicated that intake volume of sucrose solution was significantly higher than that of NaCl solution on Trial 1.

Finally, Figure 1C shows that the rats drank slightly more from the first bottle than the second, \( F(1, 15) = 7.73, p < .05 \), although this effect did not interact significantly with trials, \( F < 1 \).

Discussion

Our rats were sensitive to the instrumental contingency between the volume of drinking a particular flavored solution and the magnitude of the consequent gastric illness, in that, after an initial general reduction, they gradually increased and resumed drinking the noncontingent solution while the intake of the contingent solution remained reduced. This profile is similar to that observed in operant punishment procedures. For example, Bolles, Holtz, Dunn, and Hill (1980) trained hungry rats to push up and press down a lever for a food reinforcer on a concurrent reinforcement schedule before punishing one of these two responses, either pushing or pressing, with a fixed-ratio contingent footshock. Initially, the introduction of punishment suppressed both responses equally, but with further training, the unpunished response recovered, whereas the punished one remained suppressed, a profile that is similar to that displayed in Figure 1A. However, there is a key difference between our experiment and Bolles et al.’s. In the experiment of Bolles et al., the footshock punishment immediately followed the contingent response, while the sickness effects of LiCl had a more than 5-min delay to the drinking of contingent taste.
Furthermore, before concluding that the differential consumption of the contingent and noncontingent solutions was mediated by the instrumental contingency, we should consider a potential artifact identified by Church (1964) in contrasting performance under a response contingency with that under a noncontingent schedule, especially within the context of punishment. Due to normal biological variations, the contingent solution would have been more salient, and therefore more associative, with the gastric malaise than was the noncontingent solution for certain rats, with the reverse being true for others. Considering the rats for which the contingent solution was the more salient, simple Pavlovian conditioning predicts that the consumption of the contingent solution should have been more suppressed than that of the noncontingent solution due to their differing salience. By contrast, for the rats for which the contingent solution was less salient, these animals should have continued to self-administer LiCl by drinking the contingent solution until resulting aversive Pavlovian conditioning suppressed its intake. However, because the noncontingent solution was more salient for these rats, this amount of Pavlovian conditioning should have been more than sufficient to suppress the intake of this solution as well. Therefore, according to this artifactual Pavlovian account, the effect of the contingency should have been entirely carried by the rats for which the contingent solution was the more salient, with complete suppression of the intake of both solutions being observed in rats for which the noncontingent solution was the more salient.

To examine this account, we assessed the relative salience of the contingent and noncontingent solutions by measuring how much the intake decreased from the first to the second trial. By this measure, there were nine rats for which the contingent solution was the more salient with the remaining seven showing a greater reduction for the noncontingent solution. However, when consumption was assessed on the last conditioning trial, there was no indication that the magnitude of the contingency effect varied with the relative salience of the two solutions. The intakes of the contingent solution were effectively completely suppressed in both groups, whereas the intakes of the noncontingent solutions were similar for the two groups. The mean (±SEM) intake volumes of contingent and noncontingent solutions were 0.01 (±0.01) and 3.87 (±0.64) ml for the rats for which the contingent solution was more salient, and 0.07 (±0.03) and 3.47 (±0.85) ml when the noncontingent solution was more salient. The absence of a relative effect of salience is confirmed by a 2 (contingent solution was the more salient or not) × 2 (contingent vs. noncontingent solution) two-way repeated measures ANOVA, with only a significant main effect of solutions, $F(1, 14) = 48.88$, $p < .01$. Assuming that the individual differences in the relative saliences of the two solutions were stable across conditioning, this analysis provides no evidence that the effect of the instrumental contingency was an artifact of Pavlovian conditioning.

Despite the fact that our instrumental CTA procedure generates a response profile similar to that observed with conventional operant punishment (Bolles et al., 1980), there are important differences. Whereas delaying the punisher for more than a few seconds severely attenuates its effectiveness in conventional operant punishment (e.g., Camp, Raymond, & Church, 1967), the impact of the LiCl was delayed by more than 5 min in this study, and, in this respect, our punishment CTA paradigm is similar to the standard Pavlovian CTA procedure. Although conventional instrumental conditioning can be observed when the reinforcer is delayed for a number of minutes, the sources of relevant interference must be minimized (e.g., Lett, 1975). In our study, on the contrary, animals had to differentially suppress one of two operant behaviors with a long delay of punishment. That is, there is a lot of interference between punishment and the contingent behavior. How did our animals overcome this obstacle and learn the contingent relationship between tastant and sickness?

Facing a situation in CTA learning when intake of Tastant A and Tastant B are followed by a toxic effect, animals may reduce or avoid the intake of (a) both A and B, or (b) reduce the intake of A

Figure 1. (A) Mean 3-min intake volume (±SEM) of the LiCl-contingent solution and LiCl-noncontingent solution for a total of 14 conditioning trials. The asterisk (*) indicates a significant difference between LiCl-contingent and LiCl-noncontingent solutions, $p < .01$. (B) Mean 3-min intake volume (±SEM) of 4% sucrose solution and 0.9% NaCl solution for a total of 14 conditioning trials. The pound sign (#) indicates a significant difference between sucrose and NaCl solutions, $p < .05$. (C) Mean 3-min intake volume (±SEM) of the first and second bottle solutions for 14 conditioning trials.
but not B. In this experiment, both (a) and (b) occurred—of course, not simultaneously, but (a) is followed by (b). So, apparently, two learning processes were involved. Initial avoidance of intake of both solutions in the trials immediately following the pairing between the tastes and toxicosis indicates that two associations, CS1-US and CS2-US, like classical conditioning, had formed resulting in CS1 avoidance as well as CS2. But then in the later trials, why did animals learn to gradually increase the intake of one tastant but suppress the other? The tastant that was kept suppressed was the one that the intake volume was related to the injection volume of LiCl such that the response magnitude mattered; but to the subject that resumed drinking, it did not matter. Apparently, the magnitude of response needs to be associated to the magnitude of the outcome to “win” over the one without this association. This effect occurs in an instrumental conditioning where response magnitude determines the outcome (reward or punishment). This effect of covariation between response and outcome is observed only under a competitive situation when there is a contrast between response–outcome contingency against non-contingency. This selective suppression in CTA is the first report indicating that rats are sensitive to the subtle cues related to the covariations between the magnitude of stimulus and the magnitude of responses in a punishment paradigm involving a long delay between the gustatory stimulus of tastant ingestion and the aversive effect of LiCl injection.

References


Received July 31, 2012
Revision received December 6, 2012
Accepted January 9, 2013