A within-event analysis of taste-potentiated odor and contextual aversions

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A series of experiments was conducted to examine the phenomenon of potentiation. Experiment 1 demonstrated potentiation of odor aversions by taste when morphine served as the unconditioned stimulus (US). Experiment 2 provided evidence that the observed potentiation was due to a within-event association between odor and taste stimuli, rather than reflecting an enhanced odor-morphine association. In Experiment 3, morphine supported place conditioning to contextual cues and aversive conditioning to a taste cue, but potentiation of place conditioning by a taste cue was not obtained. Apparently the absence of potentiation was due to the dual nature of the morphine US, as potentiation of a contextual aversion by taste was obtained in Experiment 4 when a strictly aversive US (lithium) was used. These data suggest that potentiation depends on (1) an initially weak association between the to-be-potentiated conditioned stimulus (CS) element and the US, and (2) the elicitation of qualitatively similar responses by the individual elements of the CS compound. Collectively, these results support an explanation of potentiation based on within-event learning.

When a compound conditioned stimulus (CS) composed of two or more elements is paired with an unconditioned stimulus (US), the elements of the CS are assumed to compete for associative strength. The typical finding is that the more salient element becomes conditioned, whereas remaining CS elements are overshadowed and elicit a weaker conditioned response (CR) (Kamin, 1969; Mackintosh, 1971). An exception to this finding is a situation in which some subjects are presented with an odor CS followed by an illness-inducing injection of lithium chloride (LiCl), whereas others are presented with a compound odor-taste CS followed by a LiCl injection. When subsequently tested with the odor stimulus alone, subjects conditioned with the compound odor-taste CS show a stronger aversion than those conditioned with the odor CS alone (Durlach & Rescorla, 1980; Lett, 1984a, 1984b; Palmerino, Rusiniak, & Garcia, 1980; Rescorla & Durlach, 1981; Rusiniak, Hankins, Garcia, & Brett, 1979; Rusiniak, Palmerino, Rice, Forthman, & Garcia, 1982). Therefore, in this situation the odor aversion is potentiated, rather than overshadowed, in the group conditioned with the compound CS.

To date, the majority of studies investigating potentiation have used LiCl as the US. It is not clear how alternative USs might function in this situation, particularly those agents, such as morphine, which have appetitive as

well as aversive properties. The aversive properties of morphine have been demonstrated using the conditioned taste aversion procedure (Bardo, Miller, & Risner, 1984; Cappell & LeBlanc, 1973; Farber, Gorman, & Reid, 1976; Riley, Jacobs, & LoLordo, 1978). Alternatively, morphine has been shown to function as a positive reinforcer in both the self-administration (Weeks, 1962; Weeks & Collins, 1979) and place-conditioning paradigms. In the self-administration situation, the subject is required to perform an operant response (e.g., leverpressing) to receive a drug infusion. In the place-conditioning paradigm, the US is administered in association with one distinct set of contextual stimuli, and saline is given in the presence of an alternative set of contextual stimuli. After these pairings, subjects are given an opportunity to spend time in either of the two contexts. The conditioned reinforcing properties of morphine are demonstrated as a preference for drug-associated stimuli. Using this procedure, a variety of agents have been shown to support a conditioned place preference, including amphetamine (Reicher & Holman, 1977; Sherman, Roberts, Roskam, & Holman, 1980), cocaine (Mucha, van der Kooy, O'Shaughnessy, & Bucenieks, 1982), and morphine (Bardo, Miller, & Neisewander, 1984; Blander, Hunt, Blair, & Amit, 1984; Katz & Gormezano, 1979; Rossi & Reid, 1976; Sherman, Pickman, Rice, Liebeskind, & Holman, 1980).

Experiment 1 of the present series investigated whether morphine-induced odor aversions are potentiated when a compound, rather than single-element, CS is used. Experiment 2 sought to determine whether potentiated odor aversions are due to an enhanced odor-morphine association or are the result of a within-event association between the two elements of the compound odor-taste CS.

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The remaining experiments examined potentiation of contextual associations, using morphine and lithium as unconditioned stimuli.

EXPERIMENT 1

The use of morphine and lithium as unconditioned stimuli has been shown to produce different outcomes in a variety of conditioning preparations. As mentioned above, a rat will readily self-administer morphine, a result that has not been demonstrated with strictly aversive agents, such as lithium. The pairing of a distinctive context with morphine results in a conditioned place *preference*, whereas the use of lithium produces a conditioned place *aversion*. Finally, although both agents serve as effective USs in the conditioned taste aversion situation, morphine-induced aversions are reduced in magnitude relative to lithium-induced conditioned taste aversions. Thus, it is difficult to predict, on the basis of previous studies that used lithium as the US, how morphine will function in a given conditioning preparation.

Therefore, we conducted the first experiment to determine whether the pairing of an odor CS (a weak cue, relative to taste, for lithium-induced toxicosis) with morphine would result in a conditioned odor aversion, and to determine whether taste would serve to potentiate a morphine-induced odor aversion.

Method

Subjects. The subjects were 20 Sprague-Dawley male albino rats weighing 300–350 g. The subjects were individually housed in a temperature- and humidity-controlled colony room. All testing was conducted during the light phase of a 14/10 h light/dark cycle. Purina rat chow was available in the home cage throughout the experiment.

Apparatus. All treatments took place in a row of cages located above the animals' home cages. Each treatment cage was equipped with a 100-ml drinking tube which measured consumption to the nearest milliliter. The odor and taste stimuli were those used by Durlach and Rescorla (1980). The odor stimulus was a 1.5% (v/v) solution of Durkee brand almond extract. The almond odor in combination with a .06% (w/v) sodium saccharin solution served as the compound CS.

Procedure. The experimental design was a 2×2 factorial. The subjects were presented with either an almond-saccharin compound (AS) or the almond odor alone (A) as the CS, and were injected subcutaneously with either morphine (10 mg/kg) or saline. All subjects were given 15 min access to water per day on Days 1–6. On Day 7, one group of subjects ($n = 10$) received 15 min access to the AS compound. A second group of subjects ($n = 10$) received 15 min access to A alone. Immediately following this CS exposure, half of the animals in each group were injected subcutaneously with morphine, whereas the remaining animals in each group were injected with saline. This conditioning procedure was repeated on Days 10 and 13. Each conditioning trial was followed by 2 recovery days (15 min access to water per day). In order to determine the degree of acquired odor aversion, all subjects were given 15 min access to the almond stimulus alone in a single-bottle test on Day 16.

Results and Discussion

The test data are presented in Figure 1. A 2×2 ANOVA indicated that subjects presented with the compound CS consumed significantly less of the almond so-

Figure 1. Mean consumption (in milliliters) of almond odor by subjects conditioned with either the almond odor alone (A) or the almond-saccharin compound (AS) and injected with morphine or saline.

lution on test day than did subjects presented with the almond CS alone [$F(1,16) = 11.66, p < .01$]. Subjects injected with morphine consumed significantly less of the almond solution on test day than did subjects injected with saline [$F(1,16) = 38.45, p < .01$]. The interaction was also significant [$F(1,16) = 23.11, p < .01$]. Subsequent comparisons indicated that subjects in Group AS-Morphine consumed significantly less of the almond solution on test day than did subjects in Group A-Morphine [$t(8) = 5.22, p < .01$], demonstrating potentiation of odor aversion by the taste cue. Subjects in Group AS-Morphine also consumed significantly less of the almond solution than did subjects in the appropriate control group, Group AS-Saline [$t(8) = 6.93, p < .01$]. However, a similar comparison between Group A-Morphine and the relevant control group, A-Saline, revealed that this difference was not significant, indicating that there was no evidence of conditioning when odor alone served as the CS. Finally, the two saline control groups did not differ significantly in the amount of the almond solution consumed on the test day.

EXPERIMENT 2

At least two explanations have been offered for the potentiation phenomenon. The first, referred to as the *synergistic* (Rusiniak et al., 1979) or *associative* (Lett, 1984a, 1984b) theory of potentiation, suggests that the taste cue serves to enhance or strengthen the odor-US association. This view assumes that the enhancement of the odor aversion observed in potentiation should be independent of the conditioned taste aversion. Alternatively, Durlach and Rescorla (1980) suggested that potentiation is due to an interaction of odor-US and odor-taste (within-event) associations. This explanation assumes that the odor becomes aversive not only by virtue of an association with the US, but, primarily, because of an association with the aversive taste cue. Accordingly, potentiation is said to be

critically dependent on the formation and maintenance of a conditioned taste aversion.

Experiment 2 sought to differentiate between these alternative accounts of morphine-induced potentiation by extinguishing the taste aversion in subjects conditioned with the compound odor-taste CS prior to the assessment of odor aversions. As Lett (1984a) has pointed out, if potentiation reflects an enhanced odor-US association, the degree of acquired odor aversion should be unaffected by extinction of the taste aversion. However, if potentiation is due to a within-event odor-taste association, extinction of the taste aversion should also attenuate the conditioned odor aversion.

Method

Subjects. The subjects were 24 male Sprague-Dawley albino rats weighing 200–240 g. Housing conditions were as described in Experiment 1.

Apparatus. The treatment cages and compound odor-taste stimulus were as described in Experiment 1.

Procedure. All subjects were given 15 min access to water per day on Days 1–6. On Day 7, all subjects were given 15 min access to the almond-saccharin (AS) compound CS. Immediately following CS consumption, one group of subjects ($n = 12$) was injected subcutaneously with morphine (10 mg/kg), whereas the remaining group of subjects ($n = 12$) was injected with an equal volume of saline. This conditioning procedure was repeated on Days 10 and 13. Each conditioning trial was followed by 2 recovery days (15 min access to water each day). On Days 16–19, half of the subjects in each group received 15 min access to the saccharin solution in order to extinguish the conditioned aversion to the taste cue. The remaining subjects received 15 min access to water on Days 16–19. On Days 20 and 21 all subjects received 15 min access to water to ensure that varying levels of fluid deprivation would not affect test day consumption. On Day 22, all subjects received 15 min access to the almond stimulus alone in order to assess the degree of acquired odor aversion in each group. In summary, the experimental design was a 2×2 factorial in which subjects receiving the compound odor-taste CS were injected with either morphine or saline and were given postconditioning exposures to saccharin (extinction) or water (no extinction).

Results and Discussion

Analysis of CS consumption data from the final conditioning trial indicated that subjects injected with morphine consumed significantly less of the AS compound than did saline-injected subjects [$F(1,22) = 36.4, p < .01$], demonstrating a morphine-induced aversion to the odor-taste CS. During extinction, the morphine-treated subjects consumed significantly less of the saccharin solution on the first two extinction trials [$F(1,10) = 24.6$ and 39.8 , respectively; $p < .01$ for both comparisons]. However, this difference was not significant on the third [$F(1,10) = 4.15$] or fourth [$F(1,10) = .71$] saccharin exposure, demonstrating extinction of the morphine-induced taste aversion. Mean consumption by morphine- and saline-injected subjects on the final extinction trial was 14.67 ml and 15.33 ml, respectively.

The data of primary interest are from the odor aversion test, and these are presented in Figure 2. A 2×2 ANOVA indicated that subjects injected with morphine consumed significantly less of the almond solution than

Figure 2. Mean consumption (in milliliters) of almond odor by subjects that received pairings of the almond-saccharin compound and morphine or saline, followed by postconditioning exposures to saccharin (EXT) or water (NO EXT).

saline-injected subjects [$F(1,20) = 23.31, p < .01$]. Subjects not given extinction training consumed significantly less of the test solution than subjects given extinction training [$F(1,20) = 9.82, p < .01$]. The interaction was also significant [$F(1,20) = 13.26, p < .01$]. Subsequent comparisons indicated that subjects in the morphine-no-extinction group consumed significantly less of the almond solution than subjects in the saline-no-extinction group [$t(10) = 7.67, p < .01$]. However, a similar comparison between morphine- and saline-injected subjects given extinction training was not significant [$t(10) = .71$]. Thus, a conditioned odor aversion was evident only in subjects not given extinction training. A comparison between the two conditioned groups indicated that subjects in the morphine-no-extinction group consumed significantly less of the odor test solution than subjects in the morphine-extinction group [$t(10) = 7.07, p < .01$], providing additional evidence that extinction of the taste aversion attenuated the conditioned odor aversion. The two saline control groups did not differ in the amount of the almond solution consumed on the test day.

The results indicate that subjects conditioned with the AS compound acquired an aversion to the almond odor cue. The aversions were somewhat weaker than those observed in Experiment 1, presumably due to the longer interval between conditioning and testing used in the present study. However, subjects that received AS-morphine pairings but were given postconditioning exposures to the taste cue showed no evidence of an acquired aversion to the almond odor stimulus. These results provide strong support for an explanation of potentiation based on a within-event association between the odor and taste cues.

EXPERIMENT 3

When potentiation is assessed in a learned taste aversion paradigm, it is clear that morphine serves as an aversive US, in a manner similar to that shown with lithium. In contrast to lithium, however, morphine functions as an appetitive stimulus when used as the US in the place-conditioning procedure. Experiment 3 investigated whether the morphine-induced conditioned place prefer-

ence could be potentiated by presentation of a taste cue in the morphine-associated context at the time of conditioning.

Method

Subjects. The subjects were 28 Sprague-Dawley male albino rats weighing 300–400 g. Housing was as described in Experiment 1.

Apparatus. Place conditioning was conducted in a rectangular chamber with three different compartments separated by guillotine doors. The two end compartments measured $22 \times 26 \times 30$ cm. One end compartment had white walls, and sawdust beneath a wire mesh floor; the other had black walls, with pine chips beneath a metal grid floor. A 100-ml drinking tube could be mounted inside each end compartment. The middle chamber measured $22 \times 14 \times 30$ cm and had gray walls and a solid wood floor which was also gray.

Procedure. On Days 1–7, to establish a stable drinking baseline, all subjects were given 10 min access to water in the row of cages located above the animals' home cages. Beginning on Day 8, subjects were placed in the white chamber once every other day for 10 min, during which time liquid was present in the chamber. For one group of animals, the liquid available was a .06% saccharin solution (S); for the remaining group, water (W) was available. After this 10-min period, the liquid was removed and consumption was recorded. Half of the subjects from each group were then given a subcutaneous injection of 10 mg/kg morphine and returned to the same chamber for an additional 30 min with no liquid present. The remaining subjects from each group were treated similarly, except that injections were saline.

On alternate days during conditioning, all subjects were placed in the black chamber for 10 min with water available. After this 10-min period, the water was removed and consumption was recorded. The subjects then received a saline injection and were returned to the black chamber for an additional 30 min with no water present. This treatment continued until all subjects had received three exposures to each chamber in a counterbalanced order. In summary, these treatments comprised a 2×2 factorial design in which subjects were conditioned with either a compound (context-taste) or elemental (context alone) CS in combination with injections of either morphine or saline.

On the day following the final conditioning trial, all subjects were tested for place conditioning. Each animal was placed in the gray middle compartment with the guillotine doors open. An observer, who was unaware of the animals' individual treatment, recorded the time spent in each compartment during a 15-min test period.

Figure 3. Mean time spent in the white chamber by subjects given saccharin (S) or water (W) and injected with morphine or saline during conditioning.

Figure 4. Mean consumption (in milliliters) of saccharin during the final conditioning trial by subjects for which saccharin was paired with morphine (MOR) or saline (SAL).

Results and Discussion

The data for the place-preference test are presented in Figure 3. Animals injected with morphine spent significantly more time in the white chamber than animals injected with saline [$F(1,26) = 17.86, p < .01$], indicating that conditioned place preference was obtained. Regardless of drug treatment, subjects given saccharin in the white chamber did not differ significantly from subjects given water in time spent in the white chamber (data not shown). The drug $\times$ taste interaction was not significant. Nevertheless, subjects in the morphine group consumed significantly less saccharin solution during the final conditioning trial than did subjects in the saline group [$F(1,12) = 6.17, p < .05$], demonstrating morphine-induced taste aversion (see Figure 4). Thus, subjects injected with morphine in association with the white chamber acquired a preference for the white chamber, but developed an aversion to the saccharin taste cue presented in that chamber. This paradoxical conditioning to contextual and taste cues, using morphine, has been reported previously by Sherman, Pickman, et al. (1980). More importantly, pairwise comparisons (see Figure 3) indicate that although both elements of the compound (taste-context) CS were associated with the US, potentiation of the conditioned place preference did not occur. In fact, there was a non-significant trend toward overshadowing, as subjects in the W-morphine group spent slightly more time in the white chamber than subjects in the S-morphine group. The difference between the two saline control groups in time spent in the white chamber was also not significant.

EXPERIMENT 4

According to one explanation of potentiation (Durlach & Rescorla, 1980; Rescorla & Durlach, 1981), the formation of a within-event association between gustatory and contextual stimuli would be a prerequisite for potentiation of an acquired contextual preference by a taste cue. Previous research in our laboratory (Scott, Miller, McCoy, & Bardo, 1985) has demonstrated that subjects are able to form a within-event association between a taste cue and the context in which it is presented. Therefore,

it is unlikely that the absence of potentiation in Experiment 3 was due to a failure of within-event learning.

Alternatively, it is possible that when incompatible responses are elicited by the individual elements of a compound CS, potentiation may not occur. In Experiment 3, for example, an approach response was elicited by the morphine-associated context, whereas an avoidance or withdrawal response was elicited by the morphine-associated taste cue. Thus, despite the formation of a within-event association between these two CS elements, the incompatibility of the associated responses may have prevented the potentiation of conditioning to the morphine-associated context. This suggests that if the responses elicited by the individual elements (taste and context) of the compound CS are compatible (e.g., avoidance or withdrawal) then it would be possible to demonstrate potentiation of place conditioning by a taste cue. Previous research has shown that subjects learn to avoid a taste (Garcia & Koelling, 1966; Nachman & Ashe, 1973) or context (Mucha et al., 1982) that has been paired with lithium administration. Therefore, the final experiment investigated whether the presence of a taste stimulus at the time of conditioning would serve to potentiate lithium-induced conditioned place aversion.

Method

Subjects. The subjects were 18 Sprague-Dawley male albino rats weighing 300–400 g. Housing was as described in Experiment 1.

Apparatus. The apparatus was that described in Experiment 3.

Procedure. On Days 1–6, to establish a stable drinking baseline, all subjects were given 10 min access to water in a row of cages located above the animals' home cages. Beginning on Day 7, subjects were placed in the white chamber once every other day for a 10-min period, during which time liquid was available. For two groups of animals ($n = 6$ per group), the liquid was water (W); a third group of animals ($n = 6$) was given access to a .06% saccharin solution (S). After this 10-min period, the liquid was removed from the chamber and consumption was recorded. The subjects given access to S were injected immediately with lithium carbonate (LI, 10 mg/kg, ip). One group of subjects given access to W in the white chamber was injected with LI (10 mg/kg, ip), whereas the remaining subjects given access to W were injected with an equal volume of saline (SAL). After receiving an injection, each subject was returned immediately to the white chamber for an additional 30-min period. On alternate days, all subjects were given 10 min access to water in the black chamber. Following this 10-min period, the water was removed and consumption was recorded. All subjects were then given an ip injection of SAL and returned to the black chamber for an additional 30 min. This treatment continued until all subjects had received three exposures to each chamber in a counterbalanced order. On the day following the final conditioning trial (Day 13), all subjects were tested for place conditioning as described in Experiment 3.

Results and Discussion

The place-conditioning data are presented in Figure 5. Subjects in the W-LI group did not differ significantly from those in the W-SAL group in time spent in the white chamber on test day. Thus, conditioned place aversion was not obtained when context alone served as the CS. This failure to obtain conditioned place aversion using 10 mg/kg lithium carbonate contrasts with the place aver-

Figure 5. Mean time spent in the white chamber by subjects given saccharin (S) or water (W) and injected with lithium (LI) or saline (SAL) during conditioning.

sion reported previously by Mucha et al. (1982), who used 60 mg/kg LiCl as the US. However, with our relatively weak US, subjects in the S-LI group did spend significantly less time in the white chamber than did subjects in the saline control group [$F(1,10) = 6.59$, $p < .05$], thus indicating potentiation of place aversion by the taste cue. Typically, the place-conditioning procedure involves the comparison of a drug-treated group with a saline control group, as was shown above. However, it could be argued that the proper comparison to demonstrate potentiation involves a compound CS group tested against a single-element CS group (in this case, group S-LI vs. W-LI). When this comparison was made in the present experiment, it did not reach statistical significance. This was due to the fact that one animal in the W-LI group simply "froze" in the black chamber during the test period. When this subject was omitted from the analysis, the comparison was significant ($p < .05$). Furthermore, a dependent measures t test indicated that subjects in the S-LI group showed a significant decrease in saccharin consumption from initial exposure ($x = 14.66$) to final exposure during the last conditioning trial ($x = 8.83$) [$t(5) = 2.61$, $p < .05$], demonstrating a lithium-induced taste aversion.

As shown in Experiment 3, taste did not potentiate the reinforcing properties of morphine, as assessed by the place-conditioning procedure. However, in the present experiment, the same procedure resulted in potentiation of conditioned place aversion by the taste cue when lithium was used as the US. These results suggest that potentiation may occur when similar responses (e.g., both avoidance) are elicited by the individual elements of the compound CS.

GENERAL DISCUSSION

Experiment 1 demonstrated potentiation of a morphine-induced odor aversion by a taste cue. Experiment 2 provided evidence that potentiation of the aversive properties of morphine was dependent on a within-event odor-taste association. Experiment 3 indicated that, although morphine produced a preference for drug-associated con-

textual cues and an aversion for the taste cue, potentiation of conditioned place preference by the taste cue did not occur. Experiment 4 demonstrated potentiation of a lithium-induced contextual aversion by the taste cue.

Potentiation of both odor (Experiment 1) and contextual (Experiment 4) aversions was obtained when there was little evidence of a direct association between the potentiated CS element and the US. These results agree with previous findings of taste potentiation of visual aversions in rats (Galef & Osborne, 1978), pigeons, and quail (Lett, 1980), without significant conditioning to the visual CS element when it is presented alone (without a taste cue). The absence of conditioning of the potentiated CS element when it is presented alone does not allow a choice between the alternative accounts of potentiation. However, the results of Experiment 2, in which extinction of the conditioned taste aversion resulted in a corresponding extinction of the acquired odor aversion, provide strong support for an explanation of potentiation based on within-event learning. These results suggest that potentiation resulted from an association between odor and taste cues, rather than reflecting an enhanced odor-morphine association.

It should be noted that these data are in contrast with a recent report in which extinction of the conditioned taste aversion in subjects conditioned with an odor-taste CS did not attenuate the magnitude of the conditioned odor aversion (Lett, 1984a). Although the reasons for this discrepancy are not clear, several procedural differences between the studies are evident. The studies differ in the method of odor presentation. More importantly, they differ in the method used to assess the conditioned odor aversion, and in the US that was used. Lett recorded consumption of unflavored water in the presence of the odor, whereas the present study used direct consumption of an almond solution to assess the degree of acquired odor aversions. Additionally, Lett used LiCl as the US, whereas the present study used morphine, an agent that supports weaker taste aversion, as the US. Consistent with the idea that the effect of US presentation is to break down within-event associations (Rescorla & Durlach, 1981), it is likely that the contribution of within-event associations would be more evident in our study, which used the weaker US.

A within-event analysis does not imply that CS-US relationships are not important in the potentiation situation. In Experiment 3, taste did not potentiate morphine-induced conditioned place preference. This was apparently due to the dual nature of morphine as a US. The context and taste stimuli were associated with the reinforcing and aversive properties of morphine, respectively. This differential association of the CS elements with the US led to the elicitation of opposing responses (approach vs. avoidance) by the individual elements of the CS compound. Elicitation of qualitatively similar responses by the individual elements of the compound CS may be a prerequisite for potentiation to occur. The results of Ex-

periment 4 provide support for this idea. When a strictly aversive US (lithium) was used, conditioning procedures identical to those used with morphine resulted in potentiation of the conditioned place aversion.

The finding that taste potentiates lithium-induced conditioned place aversion (Experiment 4) is consistent with the findings of Best, Brown, and Sowell (1984). In their study, rats were injected with lithium following consumption of saccharin, water, or no liquid in a distinctive context. Subjects given access to saccharin in the lithium-associated context acquired stronger contextual aversions than did subjects in either the water or no-liquid groups. Best et al. used suppression of water consumption in the drug-associated context as an index of conditioning, whereas the present research utilized a noningestional choice procedure to assess place conditioning. More recently, Best, Batson, Meachum, Brown, and Ringer (1985) found that exposure to the potentiating taste cue prior to (Best et al., 1985, Experiment 2) or following (Best et al., 1985, Experiment 4) conditioning significantly attenuated potentiation of conditioned contextual aversions. These results are consistent with an explanation of potentiation based on within-event learning, as potentiated contextual aversions were dependent on the formation and maintenance of a conditioned taste aversion.

It should be noted that our finding that taste potentiates lithium-induced conditioned place aversion (Experiment 4) contrasts with two previous studies that reported overshadowing of contextual aversions by taste (Best, Best, & Mickley, 1973; Taukulis & St. George, 1982). A number of procedural differences may account for these discrepant results. For example, Taukulis and St. George used a dose of lithium 10 times higher (as base) than that used in the present study. The use of such a potent US resulted in strong conditioning to the "to-be-potentiated" CS element when it was conditioned alone. However, in Experiment 4, a US was used that did not result in conditioning of the potentiated CS element. It is possible that potentiation occurs only when the association between the to-be-potentiated CS element and the US is relatively weak. Consistent with this idea, evidence presented by Rescorla and Durlach (1981) indicated that presentation of a US interferes with the formation of within-event associations, and thus, by implication, potentiation may be attenuated. From their results one might conclude that there is an inverse relationship between US intensity and the magnitude of potentiation. If this is the case, then the use of unconditioned stimuli such as morphine and other psychoactive drugs, which have weak aversive properties, might be expected to optimize the likelihood of obtaining potentiation. Collectively, our results with morphine and low doses of lithium suggest that, when compatible responses are elicited by the elements of a compound CS, procedures that support the formation and maintenance of within-event learning also maximize the likelihood that potentiation will occur.

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