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Rats Learn to Like the Taste of Morphine

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When rats are forced to drink a morphine solution as their only source of fluid, they eventually reverse their initial preference and drink more morphine than water in a two-bottle preference test. The cause of this shift in preference was examined with the taste reactivity test which involves the analysis of fixed action patterns elicited by taste solutions infused into rats' mouths. Three morphine concentrations and two levels of motivation were studied. A greater percentage of ingestive taste reactivity responses occurred to the oral morphine infusion in morphine-raised rats than in water-raised rats. These data argue against the idea that enhanced morphine ingestion is caused by anticipation of positive consequences. Instead, they support the idea that rats come to "like" the flavor of the morphine solution; in other words, the palatability evaluation of the morphine changes, possibly through an association between the flavor and the hedonically positive effects of the morphine.

Morphine solution, which tastes bitter to humans, is avoided by rats in favor of water in two-bottle preference tests. However, when rats are forced to drink morphine solutions as their only source of fluid, they reverse their original preference and drink more morphine solution than water (Khavari & Risner, 1973; Kumar & Stolerman, 1972; Stolerman & Kumar, 1970; Ternes, 1975).

Two explanations could account for this positive shift in preference for the bitter morphine solution. One explanation is that rats continue to dislike the taste of morphine solution but drink more of it than water in order to obtain the drug's positive consequences. This view is consistent with the observation that opiates are potent reinforcers which increase the frequency of occurrence of behaviors that precede their administration in both humans and animals (Deneau, Yanagita, & Seevers, 1969; Thompson & Shuster, 1964; Weeks, 1962). This explanation is analogous to the human condition in which patients take medicines for the positive consequences they produce but never come to like their taste; for example, although human patients in treatment for opiate dependence regularly consume methadone mixed in an orange-flavored vehicle such as Tang, they do not develop a liking for the flavor of the Tang–methadone mixture (Pliner, Rozin, Cooper, & Woody, 1985).

An alternative explanation for the rats' shift in preference is that rats acquire a "liking" (i.e., a shift in palatability) for the taste of morphine possibly because of frequent pairings of the morphine flavor with the hedonically positive physiological effects of morphine. This type of conditioning effect, in which the hedonic value of a stimulus increases through association with a stimulus of greater hedonic value (either positive or negative) is called *evaluative conditioning* (Martin & Levey, 1978).

This is similar to the human condition in which increases in the liking of stimuli such as slogans and pictures occur after pairing of these stimuli with a free lunch

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that has positive hedonic value (Razran, 1938, 1940). It is also similar to the cases in which "liking" for a flavor increases following pairing of that flavor with sucrose (Zellner, Rozin, Aron, & Kulish, 1983) or calories in hungry subjects (Booth, Mather, & Fuller, 1982).

This distinction between increases in preference for flavors based primarily on anticipated beneficial consequence ("beneficial effects") and increases in preference based primarily on increases in palatability ("good taste") has been discussed concerning the acquisition of likes in humans (Rozin & Fallon, 1981). There are only a few reports of acquired preferences in rats (Booth, 1980; Fanselow & Birk, 1982; Holman, 1975; Mehiel & Bolles, in press); however, none of these distinguished between the two explanations proposed above. Perhaps this has resulted because there has been no technique available until recently to assess this distinction. Investigators generally have looked at intake in the form of preference data and assumed palatability changes; however, the same data could result from changes in anticipated consequences.

The taste reactivity test (Grill & Norgren, 1978b) is a recently developed technique which should discriminate between these two alternative explanations. It has been used in one study that examined the acquisition of *dislikes* in rats (Pelchat, Grill, Rozin, & Jacobs, 1983). This technique made it possible to demonstrate differences in dislikes for flavors caused by anticipated negative consequences or by shifts in palatability. Rats were either shocked or injected with LiCl following consumption of a sucrose solution. Both groups of rats subsequently avoided the sucrose solution to the same degree, but only those rats that had sucrose paired with LiCl showed shifts in their taste reactivity responses indicative of a decrease in palatability of the sucrose solution (distaste). The group having shock paired with sucrose avoided the solution in intake tests but showed no decrease in palatability in taste reactivity tests, that is, they appeared to avoid the solution because of anticipated negative consequences (danger).

The taste reactivity test analyzes the pattern of highly stereotyped fixed action patterns (FAPs) or consummatory responses that are evoked by the infusion of taste solutions directly into the mouths of rats. These responses are very sensitive to the palatability evaluation elicited by the solution's taste (Grill & Berridge, in press). Certain flavors, such as the taste of sugar, reliably elicit ingestive fixed action patterns, such as rhythmic mouth movements, rhythmic tongue protrusions, discrete lateral tongue protrusions, and paw licking. Other flavors, such as the taste of quinine, reliably elicit aversive FAPs, such as gapes, chin rubs, face washing, forelimb flailing, head shakes, and active locomotion. Tastes that are perceived as simultaneously both palatable and unpalatable may elicit both sets of responses in alteration (Berridge & Grill, 1983). It should be noted that two patterns of taste reactivity responding can accompany both ingestion and rejection. A taste can be ingested, accompanied solely by mouth movements, or ingestion can be accompanied by tongue protrusions, lateral tongue protrusions, and paw licking. The latter type of response is considered to be the hallmark of a palatability response, whereas the former could be considered more neutral. Likewise, a taste can be rejected passively, with passive dripping of the solution the only taste reactivity response displayed or, alternatively, actively rejected by the execution of aversive taste reactivity responses such as gaping, chin rubbing, and head shaking (Berridge & Grill, 1983).

Human perceptions of palatability are influenced by internal states, such as satiety (Booth et al., 1982; Cabanac, 1971), and classical conditioning, such as conditioned taste preferences (Zellner et al., 1983). In a similar manner, the taste reactivity responses of rats to oral infusions of specific taste solutions are sensitive to internal states, such as satiety (Flynn & Grill, 1983; Grill & Norgren, 1978a) and sodium balance (Berridge, Flynn, Schulkin, & Grill, 1984), and classical conditioning, such as conditioned taste aversions (Berridge, Grill, & Norgren, 1981; Grill, 1975; Pelchat et al., 1983). The various FAPs are not

elicited separately by diverse properties of the taste stimulus. Rather, they reflect specific decisions about palatability and are temporally clustered into two distinct groups of ingestive and aversive response patterns. Even when both patterns of FAPs are elicited in the same minute by the same taste, the responses generally occur in clusters: Ingestive FAPs follow other ingestive FAPs, and aversive FAPs follow other aversive FAPs (Berridge, 1983). This sensitivity to palatability makes the measure an excellent tool for examining the role of palatability in consummatory behavior.

In the following studies, we used the taste reactivity test to examine the role of palatability in the preference for morphine solutions in morphine-raised rats. If morphine is ingested because the flavor has become hedonically positive (increase in palatability), ingestive responses should occur to infusions of morphine solutions in rats preexposed to oral morphine. On the other hand, if morphine is ingested only for its anticipated positive consequences, the flavor of the morphine should remain hedonically negative (i.e., no change in palatability should occur), and aversive responses should continue to occur despite the fact that rats will consume the solution.

Experiment 1

Method

Subjects. Six male Holtzman rats, approximately 9 months old at testing, were maintained on ad-lib access to food and fluid (tap water or morphine solutions) throughout the experiment. All animals were maintained on a 12:12 hr light/dark cycle for the duration of the experiment. They were housed in individual wire mesh cages. Each rat was implanted with two oral cannulae by the procedure of Grill and Norgren (1978b). Briefly, with the rats under anesthesia, a polyethylene tube was inserted just rostral to the first molar on each side of the mouth. Metal tubing was inserted into the exposed end of the polyethylene tubing and anchored to the skull with dental acrylic.

Apparatus. The testing chamber consisted of a transparent plastic chamber positioned over a mirror which reflected a ventral view of the rat for videotaping. The rats' oral cannulae were attached to stimulus delivery tubes, which allowed remote infusion of taste stimuli (morphine, sucrose, or quinine solutions) into the rat's mouth. All taste chemicals were reagent grade, and the solvent was distilled water.

Procedure. Rats in Group M ($n = 3$) were raised for 9 months (from weaning) with 0.3 mg/ml (0.0004 M) morphine sulfate solution as their only source of fluid. Rats in Group W ($n = 3$) were raised with access to tap water for the same period.

Following this 9-month phase of constant exposure to the morphine solution (0.3 mg/ml), rats in Group M were given a 48-hr two-bottle preference test between 0.6 mg/ml (0.0008 M) morphine and water. All subjects were then transported to a different building and allowed to adjust to their new environment. When daily consumption of their respective drinking solutions returned to baseline, all rats were implanted with two oral cannulae under Ketamine/acepromazine anesthesia. Following recovery from surgery, when drinking had returned to baseline levels, taste reactivity testing began. Each rat was tested twice with five different taste solutions: three concentrations of morphine sulfate (0.3 [0.0004 M], 0.6 [0.0008 M], and 1.5 [0.002 M] mg/ml) in ascending order, quinine HCl (0.5 mg/ml [0.0013 M]), and sucrose (10.27 mg/ml [0.03 M]). In addition, rats raised on the morphine solution were tested for their taste reactivity response to 0.6 and 1.5 mg/ml morphine solutions two additional times following a 72- and a 96-hr morphine abstinence period during which only water was available. Water-raised controls were also retested on these test days with the same solutions.

During the taste reactivity tests, rats were transported to the testing room in a plastic holding bin. A rat's oral cannula was attached to a stimulus delivery tube, and the rat was placed in the testing apparatus. After approximately 5 min of habituation to the testing chamber, a 1-ml volume of solution was infused over a 1-min period into the rat's mouth. Percentage of consumption was recorded, and the taste reactivity responses to the infusion were videotaped. Videotapes were later analyzed in slow motion or single frame.

Consummatory response criteria. Using a slow-motion videotape analysis, we scored each rat for the occurrence of ingestive and aversive FAPs. Ingestive response components are mouth movements—low-amplitude, rhythmic openings of the mandible (6.6 Hz); tongue protrusions—rhythmic protrusions of the tongue on the midline (8.8 Hz), with the tongue visibly emerging beyond the plane formed by the incisors; lateral tongue protrusions—nonrhythmic extensions of the tongue on either side of the mouth, with the tongue pushing the lip laterally as it moves forward, with duration of 85–215 ms; and paw licking—persistent direction of the ingestive response toward the rat's forepaws, with the paws held close to the mouth and lapped for some seconds. Aversive response components are gaping—rapid large-amplitude opening of the mandible with concomitant retraction of the corners of the mouth to reveal the internal oral labia and retraction of the lower lip, lasting approximately 150 ms; chin rubbing—bringing the mouth into direct contact with a substrate (i.e., floor or wall) and projecting the body forward by flexion of the dorsal neck and by pectoral and forelimb musculature; head shaking—rapid side-to-side movements of the head at a rate faster than 60 Hz; forelimb flailing—rapidly shaking both forelimbs in the vertical plane with a frequency greater than 60 Hz; face washing—the unilateral downward movement of either forepaw across the face (face washing can occur as a single movement or as a group of several wipes with the same paw). Fluid

ejection, if the solution was not entirely consumed, and the amount of time within the minute during which the stimulus was ingested was recorded. In addition, instances of fluid ejection were classified as either passive drip or active rejection. In passive drip, fluid simply accumulated along the tip of the lower mandible and dropped off onto the floor. The rat might or might not simultaneously ingest part of the solution. In active rejection, the fluid was expelled from the mouth during the display of aversive components.

Videotape analysis. Using slow-motion videotape analysis, we scored each 1-min trial for the occurrence of ingestive and aversive fixed action patterns. When necessary, frame-by-frame analyses were made. Behavior was analyzed in slow motion, at speeds ranging from 1/10 of normal speed down to stopped individual fields (which allow 1/60 second resolution). A cyclic behavior that appears blurred on a stopped field can thus be judged to be moving at a cycle greater than 60 Hz (e.g., headshaking and forelimb flailing). The same observer scored all rats in all conditions.

Discrete FAPs such as lateral tongue protrusions, gapes, chin rubs, and bouts of face washing, forelimb flailing, headshaking, and locomotion (usually rearing) were recorded each time they occurred. Continuous responses such as paw licks, mouth movements, and passive drips were recorded in bins or units of 5-s duration. A rat had to perform one of these behaviors continuously for 5 s before it was recorded, and every 5-s bin was counted as one occurrence. A rat that showed paw licking continuously for 20 s, for example, was scored as showing four paw lick bins. Rhythmic tongue protrusions were scored in the same way, but in 2-s bins.

Results

All data were analyzed by the Fisher randomization test (Marascuilo & McSweeney, 1977). The variable used in the analyses was the percentage of total responses that were ingestive for each animal combined over the two similar tests. The results of all statistical tests are reported by a probability value.

By the end of the 9-month ingestion period, morphine-raised rats (Group M) were drinking as much, or more, morphine than water-raised rats (Group W) were drinking water. Figure 1 shows morphine preference data for the three morphine-raised rats prior to taste reactivity testing. All of these rats preferred 0.6 mg/ml morphine to water ($p = .05$). Figures 2, 3, and 4 show the distribution of ingestive and aversive fixed action patterns of both groups of rats during the taste reactivity tests. The response profiles of these two groups were completely different. Water-raised rats actively rejected (with gapes, headshakes, etc.) all

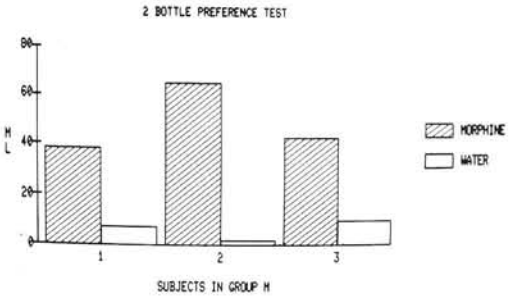

Figure 1. Consumption of 0.6 mg/ml morphine sulfate and water (in ml) of each animal in morphine-raised Group M in a 48-hr two-bottle preference test.

concentrations of morphine (0.3, 0.6, and 1.5 mg/ml). Morphine-raised rats, on the other hand, typically consumed large portions of all infused morphine solutions and showed predominately ingestive responses (mouth movements, tongue protrusions, lateral tongue protrusions, etc.) both while having morphine as their drinking solution or after 3 days of drinking only water (morphine abstinence).[1]

The percentage of ingestive responses to morphine was significantly greater for morphine-raised rats (Group M) than water-raised controls (Group W; $p = .05$ for all comparisons). There were no significant differences in percentage of ingestive responses between the three concentrations of morphine tested in morphine-raised rats, ($p > .05$). Finally, the response of the rats in Group M to morphine appeared to be independent of their physiological state at testing because their ingestive responses were not significantly different after either 72 or 96 hr of morphine abstinence (see Figures 3 and 4).

There were no significant differences between groups in their response to the weak (0.03M) sucrose solution, with both groups showing predominantly ingestive responses (see Figure 5, upper panel). There were also no significant differences between the groups in their percentage of aversive responses to the 0.5 mg/ml solution of qui-

[1] Seventy-two and ninety-six hours following termination of access to morphine were chosen as times for testing during morphine abstinence because these times are the times when withdrawal responses have been noted (Martin, Wikler, Eades, & Pescor, 1963).

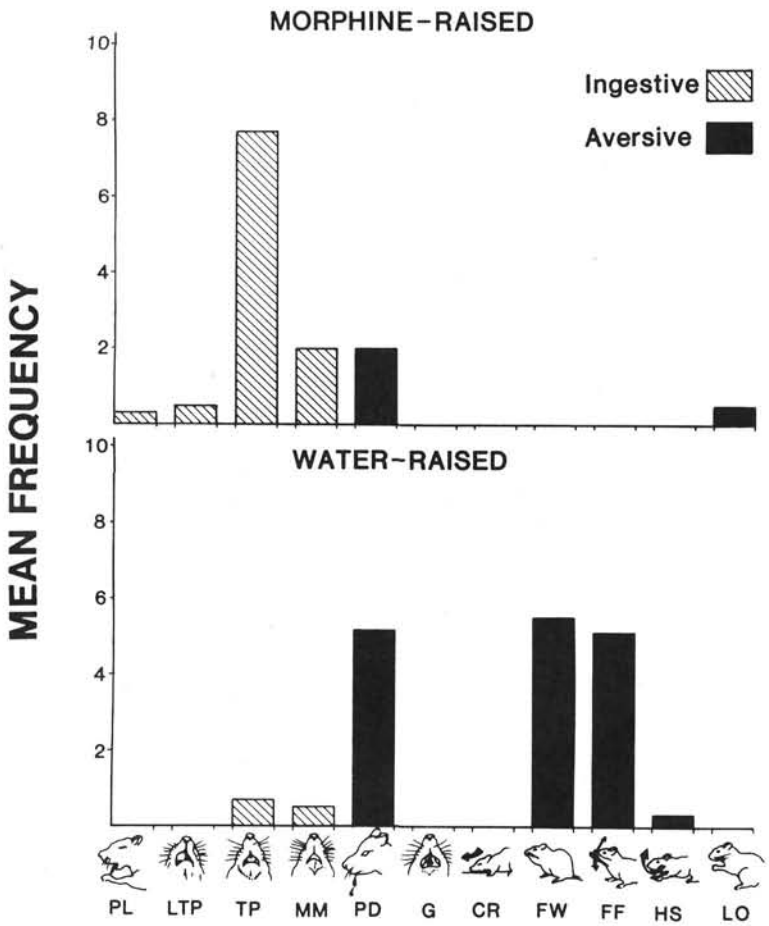

Figure 2. Mean frequency of ingestive and aversive fixed action patterns of morphine-raised (Group M) and water-raised (Group W) rats to infusions of 0.3 mg/ml morphine sulfate while on ad-lib access to 0.3 mg/ml morphine sulfate solution. (Drawings along the x-axis illustrate [from left to right] the ingestive fixed action patterns [FAPs]—PL [paw-licking], LTP [lateral tongue protrusion], TP [tongue protrusion], and MM [mouth movements]—and the aversive FAPs—PD [passive dripping], G [gaping], CR [chin rubbing], FW [face washing], FF [forelimb flailing], HS [head shaking] and LO [locomotor activity].)

nine HCl. The quinine HCl solution was rejected by both morphine-raised and water-raised rats. However, it should be noted that the morphine-raised rats had a tendency (not statistically significant) to show more ingestive responses than the water-raised rats (see Figure 5, lower panel).

Discussion

In the present study, we observed differences in taste reactivity to oral infusions of morphine between the morphine-raised and water-raised rats. The morphine-raised subjects showed predominately ingestive responses to the taste of morphine, whereas water-raised subjects showed predominately aversive responses. The positive reaction of the morphine-raised subjects to morphine infusions persisted across drug-replete and drug-withdrawal states. In contrast, the increase in palatability of concentrated NaCl solutions shown by Berridge et al. (1984) is present only during Na depletion. The fact that the increase in palatability of morphine is not dependent on need state lends support to the idea that the taste

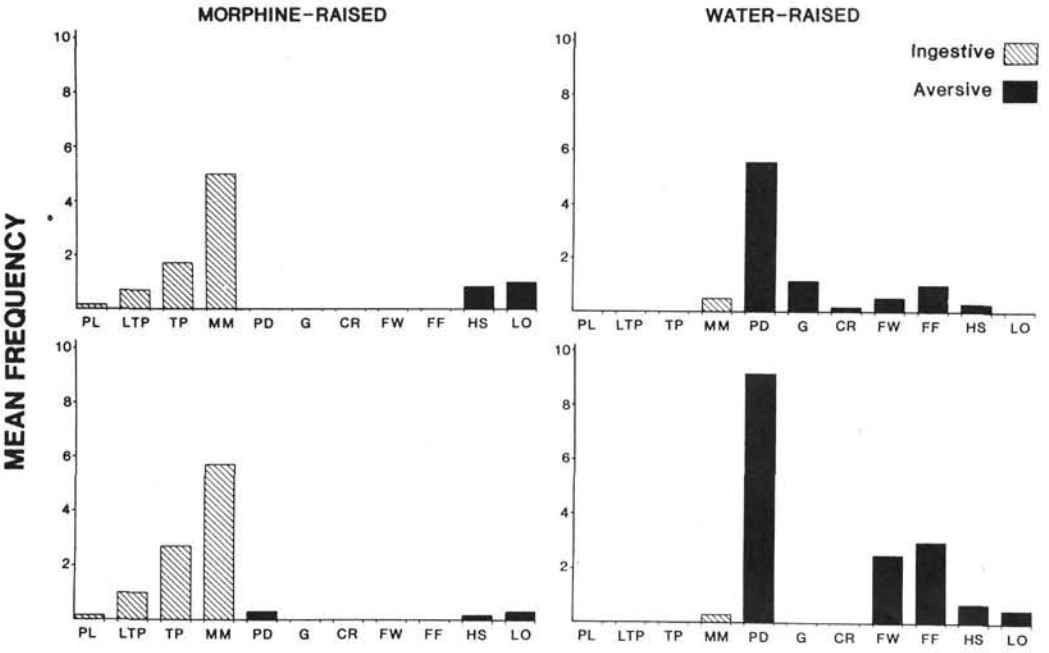

Figure 3. Mean frequency of ingestive and aversive fixed action patterns of morphine-raised (Group M) and water-raised (Group W) rats to infusions of 0.6 mg/ml morphine sulfate while on ad-lib access to 0.3 mg/ml morphine sulfate solution (top panel) and following 72-hr access to water (bottom panel). (See caption of Figure 2 for meanings of abbreviations.)

of the morphine gains positive hedonic value (increases in palatability) through association with positive postingestional consequences of the morphine. In this case, the positive hedonic value gained by the association appears to be independent of the rats' drug state at the time of testing. We believe these data provide strong support for increase in palatability as the explanation for the observed shift in preference.

The morphine-raised rats showed both ingestive and aversive responses to quinine, whereas controls showed only aversive components. These data suggest that the flavor of the morphine solution attained reinforcing properties which may have generalized to the quinine solution. An alternative to the explanation that increases in palatability have occurred might suggest that morphine-raised subjects were simply habituated to the bitter taste of the morphine during their 9 months of exposure. According to this explanation, repeated habituation to the bitter flavor of morphine caused the flavor to be less aversive.

In order to investigate whether habituation contributed to the results of Experiment 1, two additional groups of rats were examined. These rats were maintained on quinine HCl as their only source of fluid and subsequently were tested to determine their responses to infusions of quinine, both immediately following quinine maintenance and after 72- and 96-hr quinine-free periods. If the increase in palatability that we obtained to the morphine solutions by the morphine-raised rats was due to habituation to the taste, the responses to quinine in quinine-raised subjects should be similar to those of the morphine-treated rats both during the initial tests (during maintenance) and during the tests conducted after 3 and 4 days of quinine abstinence.

Experiment 2

Method

Subjects. Seven naive male Holtzman rats, approximately 1 year old at testing, were maintained on ad-lib access to food and fluid (quinine HCl or water)

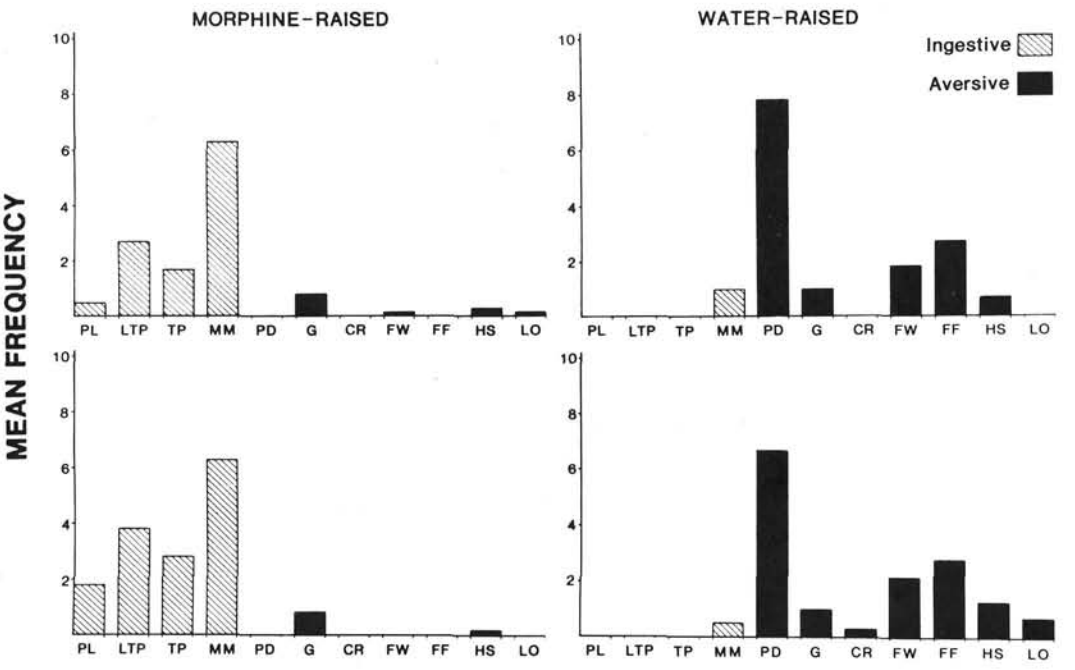

Figure 4. Mean frequency of ingestive and aversive fixed action patterns of morphine-raised (Group M) and water-raised (Group W) rats to infusions of 1.5 mg/ml morphine sulfate while on ad-lib access to 1.5 mg/ml morphine sulfate solution (top panel) and following 72-hr access to water (bottom panel). (See caption of Figure 2 for meanings of abbreviations.)

throughout the experiment.[2] They were housed under conditions identical to those for subjects in Experiment 1.

Apparatus. The apparatus was the same as in Experiment 1.

Procedure. The rats in Group Q1 ($n = 4$) were preexposed for 3 months to 0.5 mg/ml (0.0013 M) quinine HCl solution and then implanted with two oral cannulae while under Ketamine/acepromazine anesthesia. Following surgery, however, animals in this group refused to drink the 0.5 mg/ml solution. Because of their reluctance to drink, the quinine concentration was reduced to 0.25 mg/ml (0.00063 M) quinine HCl for the duration of the experiment. After 2 weeks on this concentration, taste reactivity testing began. In order to avoid the disruption of drinking that was produced by surgery in Group Q1, the rats in Group Q2 ($n = 3$) were implanted with oral cannulae prior to 3 months of exposure to a 0.25 mg/ml (0.00063 M) concentration of quinine HCl (see Footnote 2).

Following quinine exposure, all subjects were tested twice for their taste reactivity to 1 ml/1 min infusion of 0.25 mg/ml quinine HCl while having it as their only source of fluid. They were tested twice more on the same solution following 72 and 96 hr with water as their only source of fluid. The testing procedure was the same as in Experiment 1.

Results

Subjects in Group Q1 showed almost all ingestive and no aversive responses to infusions of quinine when they were tested while drinking quinine as their only source of fluid. However, when tested with the same concentration of quinine following 3 days of drinking only water, they exhibited far more aversive responses than ingestive responses (see Figure 6). The two conditions produced significantly different percentages of ingestive responses to the quinine ($p = .02$).

Subjects in Group Q2 rejected orally infused quinine but showed almost no active responding (either ingestive or aversive) to quinine infusions while having quinine as their only source of fluid (i.e., they allowed the solution to passively drip from their mouths). There was no change in this pattern of responding after 3 days of access to water (quinine abstinence; see Figure 6). All subjects in this group allowed the solu-

[2] The concentrations of 0.5 and 0.25 mg/ml quinine HCl were chosen as the solutions used in this experiment because they appear to be approximately equally aversive as 0.6 and 0.3 mg/ml morphine in other studies (Nichols, 1965; Stolerman & Kumar, 1970).

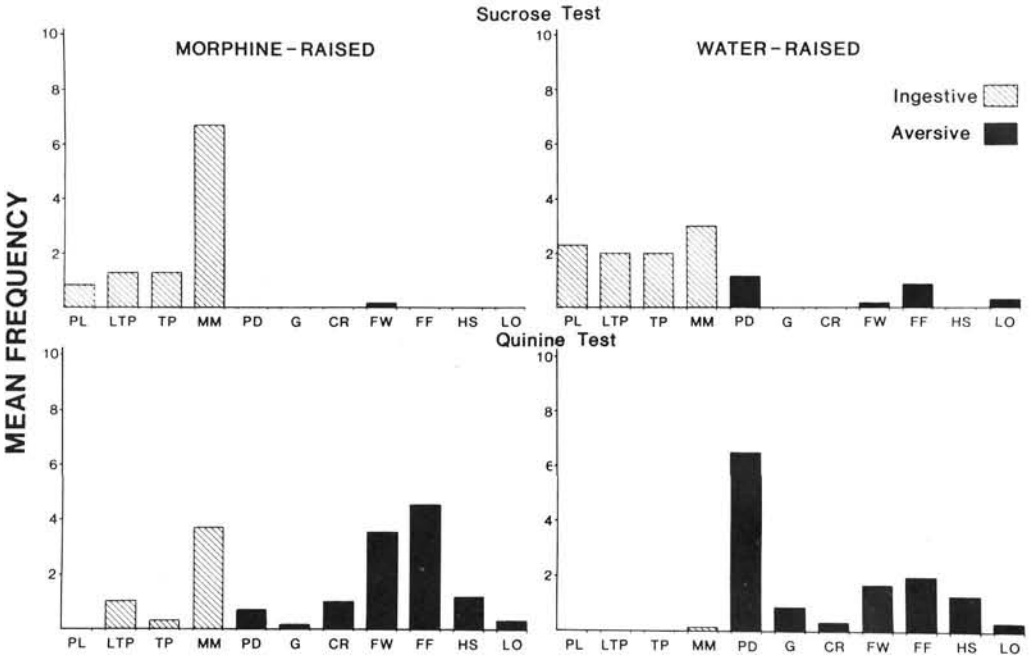

Figure 5. Mean frequency of ingestive and aversive fixed action patterns of morphine-raised (Group M) and water-raised (Group W) rats to infusions of 0.03 M sucrose and 0.5 mg/ml quinine HCl. (See caption to Figure 2 for meanings of abbreviations.)

tion to passively drip out of their mouths while consuming only 0%–7% of the 1-ml infusion.

Discussion

The responses of both quinine-raised groups were very different from those of the morphine-raised group to morphine infusions in Experiment 1. Group Q1 showed ingestive responses for the taste of the quinine when that was their only source of fluid. However, these animals quickly shifted to aversive responses after having 3 days of access to water. This pattern differs from that shown by the morphine-raised rats to morphine in Experiment 1 in which morphine elicited ingestive responses when the rats were tested on ad-lib morphine *and* following 3 days of access to water. Although the ad-lib data appear to fit a habituation interpretation, it is also possible that the reason this group initially exhibited ingestive responses to the quinine was the contrast between the original training solution (0.5 mg/ml) and the weaker test solution (0.25 mg/ml).

Group Q2, which was given experience only with the 0.25 mg/ml test solution, never actively ingested the quinine under either condition. Rather, unlike morphine-raised rats in Experiment 1, which exhibited active ingestion of morphine, these rats passively rejected the quinine solution on both occasions. Thus both of these quinine-exposed groups behaved differently from the morphine-raised group.

General Discussion

When rats are forced to consume bitter morphine solutions as their only source of fluid, they eventually come to prefer the initially aversive morphine solution over water in a two-bottle preference test (Ternes, 1975). Two explanations for this shift in preference have been suggested. One is that rats acquire a "liking" for the flavor of the morphine through association with the positive drug effects. The other is that rats drink more of the morphine for its positive consequences but continue to dislike the flavor. In the present studies, we investigated which of these alternative ex-

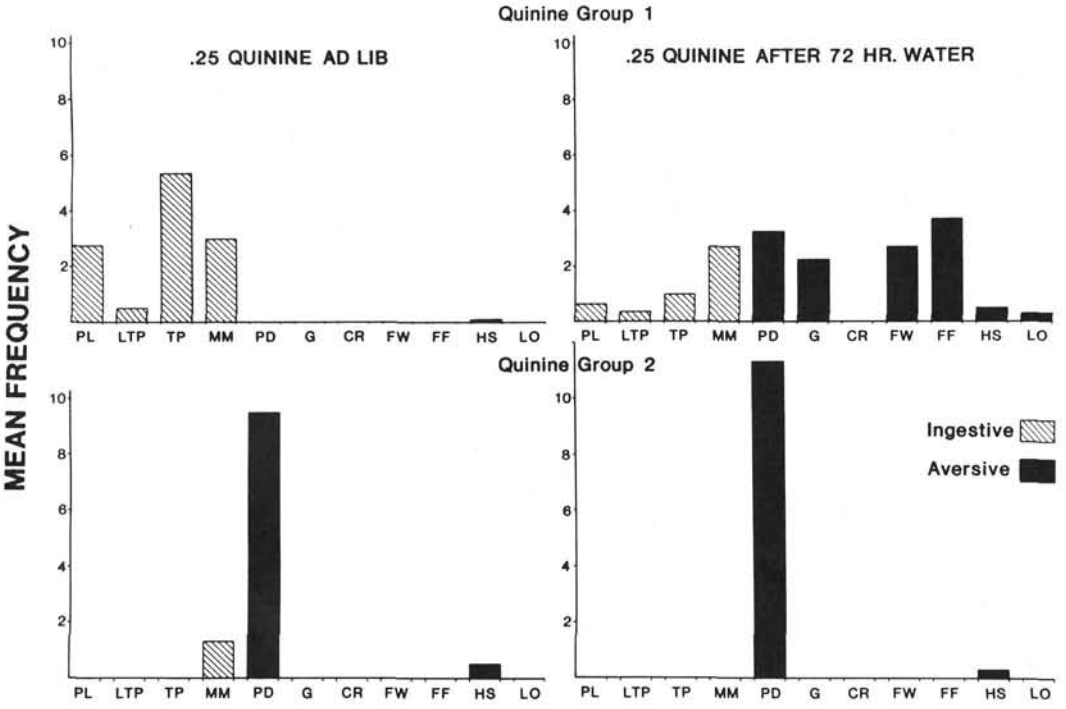

Figure 6. Mean frequency of ingestive and aversive fixed action patterns of quinine-exposed Group 1 (top panel) and Group 2 (bottom panel) to infusions of 0.25 mg/ml quinine HCl while on ad-lib access to quinine solution and following 72-hr access to water. (See caption to Figure 2 for meanings of abbreviations.)

planations best accounts for the data. It appears that an actual increase in palatability of the morphine flavor occurs in these rats. The taste reactivity test showed more ingestive than aversive responses to infusions of morphine in morphine-raised rats, a result indicating that they found the taste of the bitter morphine hedonically positive. The water-raised animals, on the other hand, exhibited predominately aversive responses to the same solution, which indicates that the taste of the morphine was hedonically negative.

The possibility that this effect might be due to habituation to the bitter flavor of morphine appears unlikely. In Experiment 2, rats raised on quinine and subsequently tested on quinine showed either passive rejection of the quinine solution or an initially positive response to quinine which changed to active rejection of the taste after 3 days of access to water.

An alternative explanation would suggest that the increase in palatability is due to an association of the bitter flavor of morphine (conditional stimulus) with one of two hedonically positive effects. One is the positive physiological effects of morphine as a drug; the second is the positive physiological effects of rehydration in an animal that may be drinking when osmotically challenged. However, the results of the quinine experiments argue against the second alternative. In the associative interpretation the flavor acquires positive hedonic value of its own, which results in the rats' developing a "liking" for the bitter taste of the morphine.

Shifts in preference from positive to negative as a result of conditioning have been fairly easy to demonstrate in rats with the use of the conditioned taste aversion paradigm (see Riley & Clarke, 1977). Pelchat et al. (1983) gave evidence that this change in preference is actually caused by a decrease in palatability when the unconditional stimulus was a nausea-producing agent. Conditioned increases in palatability ap-

pear to be more difficult to obtain although a few instances have been found by pairing a fairly neutral flavor with a greatly preferred flavor in rats (Fanslow & Birk, 1982; Holman, 1975). In these studies hedonic shifts were inferred by measuring intake. There is no evidence to indicate what the cause of increases in intake is due to in rats (see Pelchat et al., 1983, for details of this issue). The present study is the first clear demonstration of a shift in palatability from negative to positive in rats.

The present studies show that rats can develop "likings" (the solution becomes more palatable) for flavors of solutions that produce positive consequences (what humans call medicines). These results in rats are in contrast with similar data obtained with human patients on methadone maintenance, which show that although humans consume unpalatable solutions that produce positive consequences (such as medicines), they do not develop a liking for the taste of the medicine. Unlike humans, rats ingest opiate solutions because the flavor becomes hedonically positive (palatable), rather than because it is "good for them."

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