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INTRAGASTRIC REINFORCEMENT EFFECT[1]

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Conditions leading to the intragrastric (IG) reinforcement effect were investigated in a lever-pressing situation in which oral stimulation and IG injections of a liquid diet could be controlled independently. Rats lever pressed only when an oral stimulus (weak saccharin, temperature changes in the nasopharynx, or self-produced stimuli) was available to mediate the effects of food injections and did not lever press for the oral stimuli or injections alone. In another study using a two-bottle choice technique it was shown that the value of oral stimuli can be enhanced by liquid diet injections. It is concluded that IG injections of food have the power to enhance the value of oral stimuli but do not reinforce operant behavior directly as has been reported earlier.

The hypothesis of need reduction as a reinforcer originated an interest in the possibility of reinforcing operant behavior with some need reducing operation that would bypass the usual stimulus consequences and consumatory responses of eating or drinking. Direct intragastric (IG) or intravenous (IV) injections of food or water have been taken as at least approximations of such an operation.

Several studies (Borer, 1968; Coppock & Chambers, 1954; Epstein, 1960; Epstein & Teitelbaum, 1962; McGinty, Epstein, & Teitelbaum, 1965; Hull, Livingston, Rouse, & Barker, 1951; Miller & Kessen, 1952; Snowden, 1968; and Teitelbaum & Epstein, 1962) have used such injections as the outcome contingent upon some operant and have been interpreted as showing that the injections do act as reinforcers. However, unpublished experience with partial replications of some of these studies in this and other laboratories has indicated that IG or IV reinforcement effects are not so easy to produce as the literature suggests. For example, a partial replication of Miller and Kessen's study using identical techniques, but sucrose instead of milk, failed to show that IG injections were reinforcers. In addition, it was learned that rats frequently chewed through the supply tube going to their catheters and received some sucrose orally. These *S*s did learn the T maze and it could have been the case that Miller and Kessen's rats also received these accidental oral reinforcers.

Another approach to the problem of the behavioral consequences of internal events has been provided by research demonstrating the formation of conditioned aversions to oral stimuli (Garcia, Kimeldorf, & Hunt, 1961; Garcia & Koelling, 1966; Revusky & Bedarf, 1967; Rogers & Rozin, 1966; and others). These studies point out quite clearly that large changes in preferences among oral stimuli can be produced easily and quickly by aversive internal events and that it is extremely difficult for these internal events to become conditioned to external stimuli such as light or sound. Generalizing to the appetitive situation, it is possible that IG or IV injections of food or water could enhance the value of oral stimuli but not reinforce operant responses. Corbit (1965) presents data that indicate that IV injections of water may act as reinforcers only if they are accompanied by some oral stimulation appropriate to the injection, that is, a small amount of water.

A partial replication of Epstein and Teitelbaum's (1962) study by this author

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did not indicate that IG injections of sugar solutions would reinforce bar-pressing behavior. While many details of the experiments differed, the supposed essential condition of IG delivery of a food substance contingent upon a bar press was met. A close examination of both experiments led to two major hypotheses that could have explained the failure to replicate the effect. The first dealt with the length of experimental session. In the partial replication, rats were run for 1 hr. or 2 hr. per day, whereas Epstein and Teitelbaum ran their rats 24 hr. per day. The *S*s run continuously may have had more experience with the experimental conditions and IG injections allowing them to learn, perhaps in a sequence of events taking several hours, that the injections were reinforcers. The other hypothesis dealt with the path the IG catheters traced from the surface of the rat to its stomach and the possibility that the route used by Epstein and Teitelbaum could have resulted in their *S*s receiving unsuspected cues in the nasopharynx and esophagus along with the IG injections. Epstein and Teitelbaum used a catheter developed by Epstein (1960) that passed through their *S*'s nasopharynx and esophagus to the stomach. The *S*s in the partial replication had catheters similar to those of Miller and Kesson (1952) that ran from the back of a rat's neck, beneath its skin to its ventral surface, and then into the abdomen and stomach. If the fluid going through these plastic tubes was cooler than body temperature, then the rats could receive a sensation of coolness over the route of the catheter. Since Epstein and Teitelbaum kept their liquid diet in a bucket of chipped ice during the experiment it is virtually certain that their *S*s had a thermal cue in their nasopharynx and esophagus regions during injections that could have made the injections quite similar to normal ingestion.

Experiment 1

Due to the failure described above to obtain the IG reinforcement effect in a bar-press situation only roughly similar to that used by Epstein and Teitelbaum (1962), this first experiment was a replication of their procedures to insure that the IG reinforcement effect could be replicated in this laboratory with the minor variations in technique that are inevitable. In addition, length of session, temperature of injection, and route of catheter were varied to see if these variables were important determinants of the effect.

Method

Apparatus. The experimental chamber was a standard Gerbrands Skinner box 9½ × 8 × 7½ in. with a Gerbrands response lever (response pressure = 13 gm.) mounted 3 in. from the grid floor in the center of the front wall. Liquid reinforcers could be delivered into an aluminium drinking fountain ¾ in. in diameter and ½ in. deep mounted on the floor midway between the response lever and the left wall. All fluid deliveries, oral reinforcers as well as IG injections, were made by a Harvard syringe driver with a 50-cc syringe, driven by a Ledex Digimotor at a rate of 4 cc per min. Fluid injected intragastrically ran from the syringe driver through polyethylene tubing (PE 205) to a brass swivel that allowed *S*s to move freely without entangling the tubing. A 10-in. length of 22-gauge stainless-steel tubing led from the swivel to the *S*'s catheter through a slot (⅜ × 7 in.) in the Plexiglas top of the experimental chamber. The supply tube ran over a pulley above the experimental chamber and the weight of the brass swivel was carefully counterbalanced to allow *S* a maximum freedom of movement. The experimental chamber and the pumping equipment were housed in a sound-shielded chamber (Industrial Acoustics Company, Inc., model 400A type 3) and all control and recording equipment was outside. Responses and fluid deliveries were recorded on counters and on a cumulative recorder.

Two types of IG catheters were used. The first type followed the route described by Epstein (1960) from the top of a rat's head, under its skin to the superior border of the naris, into the nasopharynx, down the esophagus and into the stomach (nasal route). The only modification in Epstein's (1960) technique was the use of PE 50 polyethylene tubing in place of stretched PE 90. The second type of catheter followed the route described by Miller and Kessen (1952) from the back of a rat's neck, under its skin to its ventral surface, through the abdominal wall and into the stomach (Sub-Q route). This Sub-Q catheter was made of PE 60 and was reinforced at the distal end, where it was tied to the rat's neck muscles, with PE 190. All surgery was performed using Halothane anesthesia and in semisterile conditions. With either route, catheter failure was the most common cause of animal loss in the experiment.

TABLE 1
IG INJECTION CONDITIONS AND RESULTS: EXPERIMENT 1

Subject	Cool			Warm		Sub-Q
	2 cc	2 cc 50%	1 cc 50%	2 cc 50%	1 cc 50%	1 cc 50%
IGR 11[a]	+	+				
IGR 15	+	+				
IGR 16[a]	+	+	+		+	−
IGR 19	+	+		−		
IGR 22	+		+		+	+
IGR 25	+		+		−	
IGR 26					−	
IGR 28					−	
IGR 32						−

[a] Overnight sessions.

The food stuff used in training and for injection was a complete liquid diet based on the recipe of Epstein and Teitelbaum (1962). The following ingredients were blended in the indicated proportions: whole eggs, 100 cc; evaporated milk, 165 cc; 50% sucrose, 85 cc; Kaopectate 25 cc; Poly-Vi-Sol multiple vitamins, .25 cc; 10% formalin, 6 cc. This mixture was then strained through cheesecloth to remove any particles that might clog a catheter and was refrigerated until the time of use. The 50% liquid diet was made by mixing equal quantities of the above diet and tap water. The temperature of the injected diet was either warm (40° C.) or cool (10°–20° C.). When cool, the refrigerated diet was placed directly into the syringe driver and the syringe was packed in crushed ice. This procedure was intended to reproduce the condition of Epstein and Teitelbaum and others using their techniques. When warm, the diet was heated to 40° C. before being placed in the syringe driver, the syringe was covered with a hot-water bottle, and the last 2 ft. of the supply tube passed through a plastic tube ½ in. in diameter that was warmed with heating tape. While this procedure does not make the injections exactly rat body temperature it was thought that the match would be close enough to eliminate temperature changes as an important cue.

Subjects. Data are reported on nine male albino Wistar rats from the breeding colony at the University of Washington. The *Ss* were 4 mo. old at the beginning of the experiment.

Procedure. All *Ss* were placed on a limited daily supply of food (Purina lab chow) for approximately 10 days to reduce their weight to 70–80% ad-lib weight. After one session in the experimental chamber for adaptation to the new environment *Ss* were shaped to bar press for continuous reinforcement with .1-cc liquid diet, delivered to the fountain for oral consumption, as the reinforcer. In the next session the schedule was leaned out to a tandem FI 30-sec. FR 6 with the reinforcer increased to .5-cc liquid diet and training was continued for 4 or 5 days on this schedule. The tandem schedule was used throughout the rest of the experiment and is the same schedule used by Epstein and Teitelbaum (1962), Teitelbaum and Epstein (1962), and McGinty et al. (1965). Nasal-type stomach catheters were implanted under Halothane anesthesia and *Ss* were given about a week to recover from surgery before they were returned to the training regime. At the end of 4 or 5 days of additional training all *Ss* were abruptly switched to the injection phases of the experiment in which the diet was no longer delivered in the fountain for oral consumption but was injected directly into their stomachs via the nasal-type IG catheters. The injections were either cool or warm, consisted of liquid diet or 50% diet, and were 1 cc or 2 cc in amount. Epstein and Teitelbaum used either 1.25-cc or 2.50-cc injections in their earlier studies. Three *Ss* had 1-cc injections of warm 50% diet through Sub-Q catheters that were implanted in a second surgery after completion of the other conditions. The various injection conditions each *S* was exposed to are indicated in Table 1 by either + or −, were run for 4 or 5 days per *S*, and in order from left to right. For example, IGR 19 received 2-cc injections of cool diet for a few days, then 2-cc injections of cool 50% diet, then 2-cc injections of warm 50% diet. Two *Ss* were run overnight (18–20 hr/day) and seven *Ss* were run in 1- or 1½-hr. sessions each day. Those *Ss* on the overnight condition received all their food via the IG injections. Those *Ss* on the short-session conditions could not be expected to self-inject their daily food requirement in so short a time and were fed enough lab chow in their home cages 1 hr. after the experimental session ended to maintain them at 70–80% of their ad-lib weights.

Results and Discussion

Table 1 presents the major results with + indicating that *S* continued to lever press in a particular injection condition and − indicating that he extinguished. The two results, extinction or nonextinction, were clearly distinguishable since *Ss* that extinguished lever pressed only enough to receive one or two injections per session if they pressed at all. The *Ss* that did not extinguish continued to lever press and receive IG injections until they became satiated (20–30 cc liquid diet in a short session). The *Ss* that extinguished did so only when receiving warm injections or injections through a Sub-Q catheter instead of a nasal-type catheter. As the concentration and amount of injection was lowered, *Ss* in the overnight condition

increased their rate of self-injection to maintain a constant caloric intake and a stable or rising body weight. The *Ss* in the short session conditions also increased their rate of self-injection but could not always do so enough in so short a time to maintain a constant caloric intake.

Observation of *Ss* yielded some unquantified information. In the training phase *Ss* typically pressed the lever with their forepaws until the sound of the syringe driver signaled the delivery of diet in the fountain. They would then approach the fountain, lap up the diet, and return to the lever. When satiated they would groom and sleep. During the injection phases this behavior changed. The topography of the bar-press response changed from the normal forepaw press to licking and gnawing. At the sound of the syringe driver the empty fountain was frequently gnawed, and licking and gnawing of the lever increased. Frequently *Ss* were observed licking and gnawing the grid floor and the walls of the experimental chamber. This type of "oral" behavior is also reported by Snowden (1968) in rats with the nasal-type catheters receiving cool injections. The two *Ss* that continued to self-inject the warm diet and the *S* that did not extinguish when the Sub-Q catheters were used exhibited a stereotyped chain of these oral responses that included the response lever and that succeeded in operating it. They looked as if they were "eating the bar." The *Ss* that extinguished under the same conditions also exhibited a great deal of oral behavior but it was not directed in such a manner as to depress the lever; rather, it was directed toward the empty fountain, floor, and walls. Although this next observation was not confirmed by independent observation, it seemed as if the cool injections elicited oral behavior. That is, cool injections seemed to elicit movements of the mouth and swallowing and *Ss* would then frequently approach an object such as the fountain or lever and begin licking and gnawing.

The data clearly indicate that the results of Epstein and Teitelbaum (1962) are replicable if one uses the nasal-type catheter and cool injections as they did. It is also apparent that length of session is not a major variable affecting the IG reinforcement effect since the effect was observed in sessions as short as 1 hr. The data from the warm injection and Sub-Q catheter phases are more difficult to interpret. For *Ss* in these conditions, it would appear that the oral cues provided by the cold injections were necessary for the IG injections to act as reinforcers, since in the absence of any oral stimulation they extinguished. In apparent contradiction to these data are the *Ss* that did not extinguish in the absence of the stimuli from cool injections through the nasal-type catheters. However, these *Ss* seemed to rely heavily on self-produced oral stimuli derived from licking and gnawing the response lever and fountain in a stereotyped chain that resulted in continued self-injections. If this was the case then none of the *Ss* found the IG injections of liquid diet to be reinforcers in the absence of oral stimuli.

Further observations of this type seemed inefficient since oral behavior could not be controlled and its role in providing oral stimuli to accompany IG injections could not be determined conclusively. Experiment 2 was designed to provide better control of oral behavior, especially that part of it directed toward the bar, so that the functional significance of oral stimuli (whatever their origin—taste, temperature changes, or self-produced), in mediating the IG reinforcement effect could be determined.

Experiment 2

Method

Apparatus. The apparatus used in this experiment was the same as that used in Experiment 1 with a few modifications. A retractable response lever (Hawley Mfg. Co.) replaced the Gerbrands lever and was mounted just above the floor in an attempt to minimize bar-biting. The lever was withdrawn during the FI 30-sec. portion of the FI 30-sec. FR 6 tandem schedule when injections or oral reinforcer deliveries were being made. In addition, a second fluid delivery system (gravity feed with electric valve) was used to feed the drinking fountain in some phases of the experi-

ment, so that fluid could be delivered simultaneously and independently to the fountain and to the IG catheter. The drinking fountain was remounted so that it could be easily removed and reinstalled for various experimental conditions.

Subjects. Nine male albino Wistar rats, 4 mo. old at the start of the experiment, served as *S*s.

Procedure. The *S*s were deprived and shaped to lever press in 1-hr. sessions as in Experiment 1. After initial shaping *S*s were trained on a tandem FI 30-sec. FR 6 schedule in which the lever was withdrawn during the FI 30-sec. portion. After a few days training on this schedule Sub-Q catheters were implanted and *S*s given 3–4 days recovery before continuing training for 3 more days. The experimental conditions began immediately.

Phase 1. The *S*s were exposed at least once to each of the following three conditions which were presented in mixed order and for 2–5 days apiece. In Condition I (injection) the outcome for lever pressing was a 1-cc IG injection of warm 50% diet over a 15-sec. period through the *S*s' Sub-Q catheters. The drinking fountain was not present in the experimental chamber. In Condition S (saccharin) the outcome for lever pressing was the presentation of .1 cc of .01% saccharin solution in the fountain delivered over 15 sec. It was expected that this small amount of very weak saccharin delivered so slowly would not be reinforcing. No injection was given but the syringe driver was run to provide an auditory cue signaling the saccharin delivery. In Condition I-S (injection and saccharin) the outcome for lever pressing was the simultaneous delivery of saccharin (as in Condition S) and an IG injection of food (as in Condition I). It was anticipated that Condition I would be a condition in which *S*s would receive only IG injections of food for lever pressing without any oral stimulation from normal consumption, temperature changes in a nasal-type catheter, or even self-produced stimuli from licking and gnawing the lever or fountain. Condition S was to be a condition in which *S*s received only an oral stimulus for lever pressing without IG injections. Condition I-S was to be a condition in which *S*s received both an IG injection of food and an oral stimulus for lever pressing.

Phase 2. Five of the nine *S*s in Phase 1 had nasal-type IG catheters implanted in a second surgery at the completion of Phase 1 and were returned to the experiment after a few days recovery. In Condition W (warm) the outcome for lever pressing was a 1-cc IG injection of warm 50% diet, as in Condition I, through their nasal-type catheters. In Condition C (cool) *S*s received 1-cc injections of cool 50% diet. Condition C was identical to Condition W except for the temperature of the IG injections. It was anticipated that Condition W would be similar to Condition I with the injections being the only outcome for lever pressing and no oral stimuli available. Condition C was to be similar to Condition I-S in that *S*s would receive both an injection of food and an oral stimulus, temperature changes along the route of the nasal-type catheters. Each condition was run for 4 or 5 days and in the order W-C-W.

Results and Discussion

Without exception, *S*s extinguished in Conditions I, S, and W, in which they received either IG injections of food with no correlated oral stimulus or an oral stimulus (saccharin) without injections. All *S*s continued lever pressing, or, if extinguished, returned to lever pressing in Conditions I-S and C in which the IG injections of food were correlated with oral stimuli (saccharin or temperature change in the nasopharynx or esophagus). Figure 1 presents the data for a single *S*, IGR 35. IGR 35 was in no way exceptional; all *S*s just as clearly found the injections paired with oral stimuli to be reinforcers and just as clearly extinguished on injections or saccharin alone. The *S* was judged "extinguished" if his rate of self-injection had dropped from the usual reinforcement level of 25 cc or more per hr. session to 5 cc or less. When returned to reinforcing conditions (I-S or C) *S*s would begin lever pressing at a high rate within 5–10 min. of the first injection. Table 2 presents the data for all nine *S*s with + indicating continued lever pressing and − indicating extinction.

As in Experiment 1, licking and gnawing behavior was observed in *S*s with the nasal-type catheters. The oral behavior was first noted in Condition C and again seemed to be elicited by the cool injections. Since the response lever was retracted during the injections and the drinking fountain was not in the experimental chamber the oral behavior was directed diffusely toward the walls and grid floor and no chain of oral behavior developed that succeeded in pressing the lever. The oral behavior continued into the following Condition W but extinguished in two or three sessions.

The data demonstrate that neither the oral saccharin nor the IG injections were sufficient reinforcers to maintain lever pressing, but that if used together, they were. They also demonstrate that cool injections through the nasal-type catheters (the technique used by Epstein & Teitel-

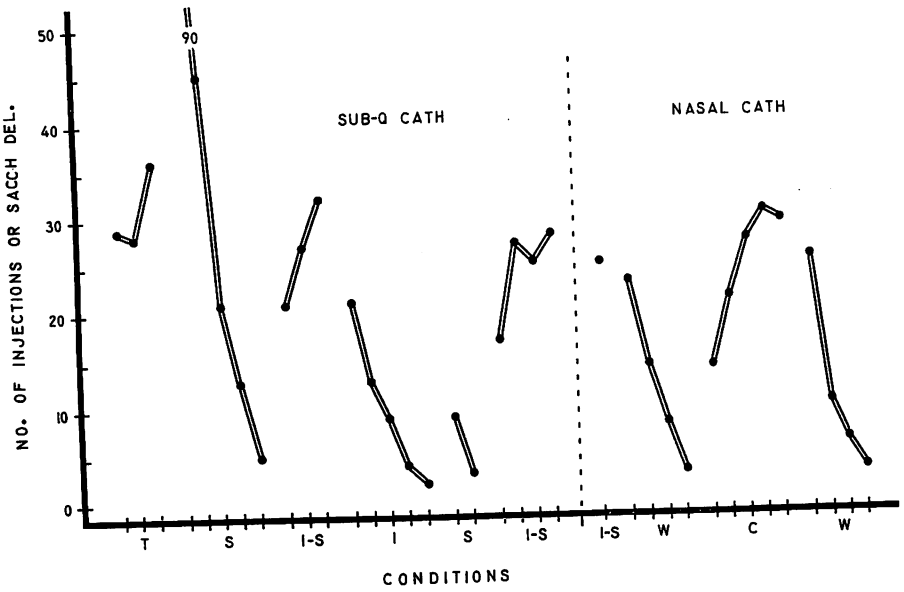

FIG. 1. Performance of *S* IGR 35 in both phases of Experiment 2. (The data for each point was gathered in a 1-hr. session, 1 session per day. T = training; S = saccharin only; I = injection only; I-S = injection and saccharin; W = warm injection; C = cool injection.)

baum, 1962) provide enough oral stimulation to make the injections reinforcing in the same way the oral saccharin did. Furthermore, the effect of self-produced oral stimuli could be destroyed by removing the drinking fountain and response lever during the injection, thereby preventing the development of chains of behavior in which licking and gnawing the lever was a prominent feature and which also served to press it.

The data are interpreted to indicate that the internal effects of IG injections of food alone have little or no power to reinforce operant behavior, but do enhance the value of an oral stimulus, itself not a reinforcer, associated with such injections. That is, the IG injections of food may enhance the reward value of a "neutral" oral stimulus so that the oral stimulus becomes an effective reinforcer as long as it is paired with the injections, but when such pairing is stopped the oral stimulus loses its reinforcing properties. This is similar to the effect observed by Garcia et al. (1961) and others in which oral stimuli have been

TABLE 2

SUMMARY OF CONDITIONS AND RESULTS: EXPERIMENT 2

Subject	Conditions[a] and Results[b]								
IGR 34	T+	S−	I-S+						
IGR 35	T+	S−	I-S+	I−	S−	I-S+	W−	C+	W−
IGR 36	T+	S−	I-S+	I−	S−				
IGR 37	T+	I-S+	I−	S−	I-S+		W−	C+	W−
IGR 38	T+	I-S+	I−	S−	I-S+		W−	C+	W−
IGR 39	T+	I-S+	I−	S−	I-S+		W−	C+	W−
IGR 40	T+	I−	I-S+	S−	I−				
IGR 41	T+	I−	I-S+	S−	I−	I-S+	W−	C+	W−
IGR 42	T+	I−	I-S+	S−	I−				

Note.—*S*s were run in these conditions from left to right, 3–5 days per condition.

[a] T = training; I = diet injection; S = oral saccharin; I-S = diet injection and oral saccharin; W = warm diet through Nasal-type catheters; C = cool diet through Nasal-type catheters.

[b] + indicates a high rate of lever pressing, − indicates extinction.

given negative values if associated with aversive internal events. Garcia et al. (1966) have also shown that noxious internal events can be conditioned to oral stimuli but not (or with great difficulty) to external stimuli in much the same way the internal consequences of an IG injection of food became attached to oral stimuli but not to external events such as the lever-press response or the sound of the syringe driver. A more recent study (Garcia, Ervin, Yorke, & Koelling, 1967) has demonstrated that oral stimuli can also be given enhanced positive value if paired with the positive internal events of relief of vitamin deficiency, but no study has independently demonstrated that IG food injections can enhance the value of oral stimuli. Experiment 3 was designed to provide such an independent demonstration.

Experiment 3

Method

Apparatus. Training and testing were done in the *S*s' individual home cages (7 × 9½ × 7 in. with ½-in. wire-mesh floor and front). All fluids to be tasted were presented in 8-oz. bottles equipped with Girton sipper tubes hung on the front of the cages.

Taste substances. Taste substances were chosen that were distinctively different, almost equally acceptable, and nonnutritive. One solution was sour (HCl: .0025 N HCl, .005% lemon extract [Schilling], .2% saccharin) and the other was bitter (SOA: .02% sucrose octaacetate, .005% anise [Schilling], .2% saccharin), with distinctive olfactory cues added. Both solutions were made slightly sweet with saccharin to insure their acceptability.

Subjects. The *S*s were 20 female albino Wistar rats, 4 mo. old at the beginning of the experiment. Due to catheter failure in two *S*s at the beginning of the taste-injection training phase, data are reported on only 18 *S*s.

Procedure. The *S*s were placed in individual cages and given limited amounts of food (Purina lab chow) once a day for 9–10 days, to reduce their weights to approximately 80% ad lib. Sub-Q IG catheters were then implanted under Halothane anesthesia and *S*s were given 5–6 days for recovery. The *S*s were trained to approach the front of the cage and drink at their usual mealtime for 3 days by presenting a bottle of liquid diet for 30 min. the first day, 15 min. the second day and 5 min. the third day. On the fourth day the 6 days of taste-injection training began. Each *S* had a daily exposure of 5 min. to one of the two taste substances and these were alternated daily so that each taste substance was presented three times in three 2-day cycles. For each *S* one taste substance was followed immediately by an IG injection of liquid diet and the other taste substance was followed immediately by an IG injection of water. In the first cycle the injections were 7 cc and in the last two cycles they were 10 cc. One hr. after the injections *S*s were given enough additional food to maintain their 80% body weight. Pairing of taste substance and injection substance and order of presentation were counterbalanced. The day following the last taste-injection training session *S*s were presented both taste substances simultaneously for 140 min. and consumption was measured at 20 min., 80 min., and 140 min.

Results and Discussion

During the first training phase in which the *S*s were given liquid diet for 3 days (30 min., 15 min., and 5 min. on succeeding days) they consumed means of 7.3 gm., 11.7 gm., and 10.0 gm., respectively. On the last day they approached the drinking tube immediately after it was inserted in their cages. During the first two cycles of taste-injection training, there was a small but insignificant preference for the taste solution paired with diet injections, and for the SOA. In the last taste-injection training cycle there was a marked preference for the diet-paired taste solution. All 18 *S*s consumed more of the diet-paired taste solution (M = 2.9 gm.) than of the water-paired taste solution (M = 1.1 gm.). In the two-bottle choice given the day after the taste-injection training was completed the bottles were weighed at 20 min., 80 min., and 140 min. Table 3 shows that in the first 20 min., 17 of the 18 *S*s preferred the diet-paired taste solution to the water-paired taste solution. In the following hour this preference extinguished with only eight *S*s drinking more of the diet-paired solution compared to the water-paired solution and this changed but little during the next hour. Unlike the training data, however, there was a mild preference for the HCl over the SOA such that at the end of the 140-min. test period the mean consumption of HCl was 9.3 gm. and of SOA was 6.8 gm.

The data indicate that IG injections of diet have the effect of enhancing the value of taste substances they are paired with. The opposite conclusion, that water injec-

tions are aversive, is rejected on the basis of the quick extinction of the observed effect. Similar aversive effects usually take several days to extinguish (Garcia et al., 1961) and the preference here extinguished in less than 80 min. It is also unlikely that *Ss* would have consumed an average of 16 gm. of solution in the choice test if 10 gm. of water in the stomach was aversive. Therefore, the effect is attributed to the positive characteristics of the liquid diet injections.

While the effect extinguished rapidly it should not be considered small or unimportant. The preference for the diet-paired taste substance was quite clear in all *Ss* in the last training cycle and in 17 of the 18 *Ss* in the first 20 min. of the two-bottle test session. The two-to-one preference for the diet-paired taste substance measured at 20 min. may not be a true indication of the original preference. The *Ss* may already have started extinguishing and the 20-min. measure may be an underestimate of the original preference. The fact that the effect extinguished rapidly indicates that rats are very sensitive to their internal state (which is also indicated by the fact that they learned this discrimination in only two trials) and can discriminate with high accuracy the internal consequences of eating. Some data from Experiment 2 shows that rats can discriminate a diet injection from no injection in much less than 20 min. When switched from Condition S (saccharin only) to Condition I-S (diet injection and saccharin) the *Ss* would return to lever pressing at a high rate within 5–10 min. of receiving the first reinforcer. This indicates that the value of the saccharin had been enhanced by the diet injection within that amount of time even though the injection would not reinforce lever pressing by itself (Condition I). If the presence of food in the stomach can affect behavior within 5–10 min. it is reasonable to assume that the absence of food could also affect behavior that quickly. Therefore the rapid extinction observed is just what one should expect under these conditions.

TABLE 3
MEAN INTAKE AND PREFERENCE IN TWO-BOTTLE CHOICE TEST: EXPERIMENT 3

Test period (in min.)	*Ss* with diet-paired HCl			*Ss* with diet-paired SOA		
	Intake of diet-paired HCl (gm.)	No. of *Ss* preferring HCl (n = 9)	Intake of H_2O-paired SOA (gm.)	Intake of diet-paired SOA (gm.)	No. of *Ss* preferring SOA (n = 9)	Intake of H_2O-paired HCl (gm.)
0–20	4.7	9	2.1	2.4	8	1.6
20–80	3.4	5	2.3	1.9	3	2.7
80–140	3.9	5	2.4	2.6	5	2.4

GENERAL DISCUSSION

Experiments 1 and 2 demonstrated that it is very unlikely that IG injections of liquid diet reinforce operant behavior directly, but instead control the reinforcing characteristics of oral stimuli associated with them. In the lever-pressing situation explored here the oral stimuli were a weak saccharin solution, temperature changes in the nasopharynx and esophagus, and the stimulation derived from licking the response lever. Note also that the sound of the syringe driver signaled the delivery of all fluids in the fountain and was present at all injections, but did not acquire any reinforcing characteristics attributable to the injections. If the injections had given this sound reinforcing properties, *Ss* would not have extinguished in the conditions in which they received injections and the sound, but no oral stimuli. This result parallels that of Garcia and Koelling (1966).

Experiment 3 independently demonstrated that IG injections of food could control the reward value of oral stimuli. The effect was easily observable in one bottle test during the third training cycle and was confirmed in a two-bottle choice test after the third training cycle. The speed with which this learning occurred and the magnitude of the effect also parallels the results of conditioned aversions to oral stimuli (Garcia et al., 1961). In addition, the ease of learning demonstrated in Experiment 3 supports the notion that the lever-pressing behavior observed in Experiments 1 and 2 was controlled by variations in the reward value of oral

stimuli rather than by the IG injections alone.

It is easy to see that if an oral stimulus was made contingent upon lever pressing and that if the subjective value of this stimulus was enhanced by being paired with IG injections, then the oral stimulus could reinforce lever pressing. The contingencies between lever pressing and the saccharin and temperature changes accompanied by injections were real, and under these circumstances lever pressing was reinforced. However, in Experiment 1 the contingencies between lever pressing, the oral stimuli of licking the lever, and injections of diet were partially adventitious and did not always result in continued lever pressing. In the cases in which lever pressing was maintained, licking and gnawing the lever served to press it and resulted in an injection which seemed to have the effect of enhancing the flavor of the lever and led to the continued licking and gnawing of the lever. The conditions of Experiment 1 may have favored the development of such a chain of events in that the cool injections seemed to elicit oral behavior that tended to be directed toward objects in the chamber, such as the fountain and lever. When *Ss* were then given warm injections or injections through a Sub-Q catheter, the lever licking-pressing response was already established and the events outlined above could proceed. The relationship seemed somewhat tenuous, however, because if the oral behavior is not directed predominately toward the response lever the injections may enhance the stimuli from licking other parts of the chamber and *Ss* spend less time licking-pressing the lever. This results in fewer injections and therefore an extinction of the oral stimuli enhancement effect and any behavior reinforced by this oral stimulation.

While this explanation is speculative, it is supported by several observations. The *Ss* in Experiment 2, Phase 2, did not engage in oral behavior during their first exposure to warm injections but did develop oral behavior during the cool injections that continued into the following sessions of warm injections. Since the response lever was retracted for 30 sec. at the beginning of the 15-sec. injections the oral behavior was directed diffusely and did not enter into a chain of events involving the lever. It was also noted in Experiment 1 that *Ss* that extinguished in the warm injection or Sub-Q catheter conditions did not direct most of their oral behavior toward the lever, whereas *Ss* that continued to press did. Furthermore, *Ss* that received warm or Sub-Q injections without having experienced cool injections did not develop oral behavior and extinguished.

In relating the results of the present studies, especially Experiment 2, to other reports of the IG reinforcement effect, it should be noted that all conditions were not identical. *Ss* in Experiment 2 were run in 1-hr. sessions, rather than 24 hr. per day and this may have some effect on the results despite the fact that Experiment 1 indicated that this was not an important variable. Also in Experiment 2 all IG injections were of 1 cc rather than the 1.25 cc or 2.5 cc used in much of the earlier work (Epstein & Teitelbaum, 1962; and others). However, it is believed that this difference is insignificant since in the present conditions the *Ss* self-injected the liquid diet at a high rate and slowed lever pressing only after receiving 20–30 cc in the first 10–15 min. of a session. Had the injections been of a different volume (larger or smaller) self-injections would probably have been the same except for the number of lever presses before satiation; fewer for larger injections and more for smaller injections. This was the case in Experiment 1 where two injection sizes were used. It should also be noted that on the first session of Conditions I and W, in which *Ss* extinguished, *Ss* lever pressed to satiation. This being the case it seems unlikely that larger injections would prove to be reinforcers.

While it is impossible to state with certainty that previous studies using IG injection through nasal-type catheters (Borer, 1968; Epstein, 1960; Epstein & Teitelbaum, 1962; McGinty et al., 1965; Snowden, 1968; and Teitelbaum & Ep-

stein, 1962) as reinforcers are plagued with unsuspected stimulation in the nasopharynx and esophagus, it is highly probable that this is the case. The replications of their conditions (nasal-type catheters and cool injections as in the first part of Experiment 1 and in Condition C in Experiment 2) yielded similar results; the *Ss* seem to lever press for IG food injections. However, as these experiments demonstrate, this result is not attributable to the injections alone since the *Ss* extinguish in the absence of an oral stimulus (weak saccharin, temperature changes, or self-produced) paired with the injections. It is probably the case that the reinforcement effects observed in these earlier studies were produced by the enhancement of temperature cues resulting from the IG injections rather than by the injections alone. It is also possible that the *Ss* in these earlier studies developed the type of oral behavior described here and supplemented the temperature cues with self-produced oral stimuli. This kind of oral behavior is reported by Snowden (1968) but he does not relate it to stimulation from the nasal-type catheters.

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