TRANSFER FROM EXTERO- TO INTEROCEPTIVE REINFORCEMENT IN THE COURSE OF INSTRUMENTAL CONDITIONING IN RATS

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Abstract. The possibility of maintaining an ingestive instrumental reflex following the transfer from oral food reinforcement to different kinds of intragastric reinforcements (liquid food, water, hypertonic NaCl and morphine) was investigated. The experiment carried out on male hooded rats with previously implanted nasopharyngeal gastric tube showed that in all but the morphine reinforced group the performance gradually decreased showing a pattern of extinction similar to nonreinforced control group. Instrumental response was maintained in morphine reinforced rats although they were not drug addicted. The results obtained contradict the possibility of instrumental conditioning of ingestive reflexes reinforced interoceptively. They also question the drive-reduction hypothesis of instrumental conditioning, supplying further evidence in favor of the hedonistic view.

INTRODUCTION

Up to now, the instrumental reflexes reinforced with infusions of nutrients or water directly into the stomach (14, 15, 18, 21, 22, 28, 29) or introduced intravenously (6, 23–25, 27) seemed to be a crucial support for the drive-reduction hypothesis postulated earlier by Hull (17). In our laboratory, however, we had no success in establishing the ingestive instrumental reflex reinforced with direct intragastric infusions of nutrients (9–11). The failure in conditioning might result from two procedural differences. First, we tried to establish the instrumental reflex without the transfer from oral to intragastric reinforcement, commonly
practiced in this kind of experiment. Second, we kept intragastric infusions within the limit of body temperature. The nasopharyngeal gastric tube, usually applied in experiments with direct intragastric self-administration of nutrients, does not completely eliminate all exteroceptive information from the upper part of the alimentary canal. When a refrigerated liquid diet was used as an intragastric reinforcement, animals could utilize the thermal cue. Indeed, the rats do press the bar if pressing is reinforced with direct intragastric infusions of liquid food paired with either cold or warm stimulation of the pharynx and esophagus (8, 16).

While the contribution of thermal stimulation to the process of intragastric conditioning is already clear, the mechanism of transfer of instrumental reflex reinforced orally to that reinforced intragastrically still requires further investigation. Having eliminated the thermal cue, we were able to maintain bar-pressing reinforced with intragastric infusions of nutrients only after a transfer from oral reward (9-11). We noticed, however, that this performance was characterized by a diminishing trend. This made us assume that it was not a true instrumental reflex but rather a peculiar instance of its extinction which had been difficult to identify during the 5-day experiment. In this paper we checked this assumption using rats previously trained to press the bar for oral food reinforcement and later transferred to intragastric reinforcement with liquids of various properties.

MATERIAL AND METHOD

The experiment was carried out on 25 male hooded rats weighing 250–350 g, with a previously implanted nasopharyngeal gastric tube of Epstein and Teitelbaum (15) according to the procedure described elsewhere (12). The experiment started after 1 week's convalescence on rats maintained at a steady level of food deprivation corresponding to 85% of initial body weight. Animals were placed for at least 15 successive days twice daily for 1 h (at 9 a.m. and 4 p.m.) in the apparatus for investigation of instrumental reflexes, having access to the bar which, when pressed, delivered through a microdose pump 0.5 ml of fluid reinforcement heated to body temperature in a water bath. Readings of the counter connected with the contacts on the micro-dose pump, i.e., the number of reinforced responses, were averaged to obtain daily performance.

At the first stage of the experiment, lasting 5 days, each bar-pressing delivered the reinforcement into the fountain opposite the bar.
After the orally reinforced instrumental reflex was elaborated, 5 groups of 5 rats each were assigned at random for the next stage.

At the second stage of the experiment rats previously reinforced orally with liquid food were now given various fluids intragastrically. Particular groups differed with respect to intragastric reinforcement: liquid food (group F), 0.05% aqueous morphine hydrochloride solution (group M), water (group W) and hypertonic 1 M sodium chloride solution (group S). The control group subjected to acute extinction received no reinforcement (group E). The second stage of the experiment lasted at least 10, and on some rats 15 days.

RESULTS

At the first stage of the experiment, when the food reinforcement was delivered into the fountain, the number of responses gradually increased, indicating learning. The instrumental reflex reinforced orally was easily established, and on the 5th day the performance evaluated as median ranged from 23 to 34 responses per hour in different groups (Fig. 1 — oral food reinforcement).

![Graph showing the effect of transfer from oral to intragastric reinforcement.](image)

Fig. 1. Effect of transfer from oral to intragastric reinforcement.

In the second stage of the experiment the animals were transferred to different kinds of intragastric reinforcements. The performance of all but the morphine reinforced group rapidly decreased, and within 4–5 days became equal with that of the control group. The lowest level of performance was observed in the group reinforced with hypertonic saline intragastrically. The group reinforced with liquid food and water in-
gastrically did not differ from the control group subjected to the acute extinction (Fig. 1 — intragastric reinforcement).

The performance of groups F, M and S on the 1st day of transfer experiment was at level of the last day during oral reinforcement, while performance of group W, and especially of group E greatly exceeded it.

The group reinforced intragastrically with morphine differed from all the others. During the whole second stage of the experiment the performance in this group was maintained on the response level reached by all groups on the last day of oral food reinforcement. The performance in this group always considerably exceeded the performance in all the other groups except the first posttransfer day when the performance level of groups E and W was much higher.

**DISCUSSION**

Data collected by different authors on intragastric and intravenous self-administration of nutrients strengthened the view that ingestive instrumental response reinforced interoceptively can be learned and that nutrient related interoceptive stimuli have reinforcing properties. However, since interoceptive information is always poorly defined and scarcely reach the level of consciousness this view seems to be quite obscure. Bulygin and Katchuro (5) showed that interoceptive stimuli produced by stimulation of the stomach or the small intestine wall did not generate evoked potentials in the cortical associative regions. The electrocortical responses to exteroceptive stimulation were quite different. Their physiological properties were different as well. With the exception of nociceptive stimuli interoceptive stimulation seems to have no reinforcing property in Pavlovian conditioning. Bulygin and Itina (4) failed to establish a classical conditioned inhibition of gastric motility when reinforced interoceptively with intraintestinal delivery of glucose, whereas the same reflex was easily formed when reinforced exteroceptively with oral administration of glucose. Melnikova, who tried to condition the decrease of gastric secretion (19) and liver function (20) using the same extero- and interoceptive reinforcement, obtained identical results. Antal (1) also could not obtain a conditioned response of blood pressure increase even after 100 combinations of conditioned signal with the carotid clamping which served as an unconditioned stimulus.

While classical conditioned reflexes in many instances can be unconscious, every instrumental response is always a conscious act. That is why the existence of ingestive instrumental reflexes reinforced interoceptively seemed obscure to us. The only explanation why animals make a conscious response in order to receive a reward which is below the
level of consciousness is that they receive some uncontrolled exteroceptive cues. In the light of our results (8) and those of Holman (16), this seems to be the matter.

The results of present experiment show that this exteroceptive cue is indispensable not only for the formation of an instrumental reflex, but even for the maintenance of instrumental responding after the transfer from oral to intragastric reinforcement. In all but the morphine group direct intragastric reinforcements are ineffective, resulting in the extinction of the bar-pressing.

The typical course of extinction can be seen in the case of the non-reinforced control group. On the first day of extinction the rats, receiving no food in the fountain, performed the trained movements with high frequency and rapidity. Their performance was much higher than that of the food, saline and morphine reinforced groups, because it was not limited by post-ingestional effects of the infused fluids. The group receiving intragastric infusions of water instead of oral reinforcement behaved midway in this respect.

The results of the group which received intragastric infusions of liquid food instead of food taken orally are of special interest, because of their implications for the theory of learning. They seriously contradict the drive-reduction hypothesis postulated by Hull (17). Just after the transfer to intragastric reinforcement, animals performed several bursts of trained movements, similarly as in the group subjected to acute extinction. This responding resulted in massive intragastric infusions of food. Despite the reduction of alimentary drive due to reinforcement, the reflex gradually extinguished demonstrating that reduction of drive had no reinforcing property.

The group which received hypertonic saline intragastrically, instead of orally delivered food, always had the lowest performance. Hypertonic saline is aversive even delivered intragastrically. Rabe and Corbit (26) showed that rats avoid drinking any fluids when combined with direct intragastric infusions of sodium chloride approaching 1 M concentration. Bulygin and Itina (4) who failed to establish a classical conditioned reflex reinforced with intestinal delivery of glucose, succeeded in formation of a conditioned reflex when they applied hypertonic saline to the same receptive area. Bulygin (2, 3) claims that information from receptors may be divided into three main categories: (i) exteroceptive information transmitted along somatic fibers can be easily conditioned; (ii) the majority of interoceptive information transmitted mainly along sympathetic fibers engaged in adaptative and trophic effects cannot be conditioned; (iii) some interoceptive information, mainly nociceptive, transmitted along somatic fibers may be conditioned, but not so easily
as an exteroceptive one. In our experiments the performance of rats reinforced with intragastric infusion of hypertonic saline, probably a nociceptive stimulus, was the lowest presumably due to active avoidance of aversive interoceptive reinforcement.

The only group without any distinct fall in bar-pressing performance after transfer from oral to intragastric reinforcement was the morphine one. In addicted rats morphine delivered intragastrically has a reinforcing property (7); this appears to be true for unaddicted animals as well. The morphine administered intragastrically was the only substance maintaining the performance at the level of exteroceptive food reinforcement. It should be stressed that the main action of morphine as a reinforcer is rather central than peripheral. It evokes a centrally induced state of pleasure certainly not only in humans.

The results of these experiments agree with our view (13) that stimuli which produce a state of pleasure possess a reinforcing property for instrumental approach reflexes. The food has this feature only when ingested by mouth, i.e., with the engagement of taste, smell and somatic sensations, whereas when infused intragastrically, i.e., when signaled by interoceptors, it is quite ineffective. Morphine has an aversive taste, and therefore cannot be used as a reinforcer when taken orally, but because of its central action appears to be a potent reinforcer when infused directly into the stomach.

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