JOHN GARCIA: CONDITIONED TASTE AVERSION

By the 1950s, Pavlov's discovery, classical or Pavlovian conditioning, had been extensively studied in laboratories all over the world. The laws it followed seemed well established.

In classical conditioning, some neutral stimulus (or CS), which did *not* elicit the response in question, is paired repeatedly with another stimulus, the UCS, which does. One then sees the gradual development of a new reflex, such that the CS now triggers the response where it did not do so before. That is classical conditioning.

Though dispute continued about just how it worked, three principles seemed so well established as to be beyond serious dispute. First, it doesn't seem to matter what CS, what UCS, or even what species is used. One can condition salivation in dogs (or humans) to the sound of bubbling water. One can pair a shock to the foot, or a shock to the finger, with a tone and see conditioned leg flexion in goats or conditioned finger flexion in humans. One can pair a clicking sound with a shock and see conditioned freezing in rats. Or one can pair a shock with the onset of a light and see a conditioned scrunching-up response in flatworms. It seems that *the specific choice of CS, UCS, and species is arbitrary.*

Second, *conditioning is a slow, gradual process*. Even in humans, it takes many pairings of CS and UCS before conditioning will be seen.

Third, *the interval between CS and UCS is quite critical, and must be short*. In many conditioning experiments, the procedure works best if there is an interval about half a second between the onset of the CS (like a tone) or the UCS (like a shock). Let the interval be much longer than that, and conditioning will not occur.

Then, in the 1960s, came the catastrophic experiments of John Garcia and his colleagues, showing that all of these "principles of conditioning" were really only "principles of *some* conditioning." In other cases, it was quite possible in some species to get a strong conditioned response after only *one* CS-UCS pairing with an interval between CS and UCS that was measured in hours! All of our "principles" turn out to hold for only some cases, not for all — and those cases might turn out to be the exceptional ones.

John Garcia (1917-) was born in Santa Rosa, California. After working on farms and in shipyards, he earned his B.A. in 1948 (at age 31), his M.A. in 1949, and his Ph.D. in 1965, all at the University of California at Berkeley. He worked at the U.S. Radiological Defense Laboratory and has taught in the Oakland, California, public schools; at the State University of New York at Stony Brook; and at the University of Utah. He returned to Berkeley in 1973 as a professor of psychology and psychiatry, and is now a professor emeritus there.

It was while working at the U.S. Radiological Defense Laboratory tat he noticed something strange. Radiation produces nausea in humans and behavioral signs of nausea in rats. Garcia noticed that after his rats got sick, they began rejecting their food — perfectly ordinary, harmless rat food. This was not just because they were feeling sick at the time. Even after they got better, they fed reluctantly. It was as if they blamed the food for their illness.

As a matter of fact, something very much like this is a quite common human experience, though neglected by learning theorists until recently. One psychologist realized that the rats' reactions closely matched his own on an occasion when he went out to eat, had a steak with béarnaise sauce, and then got violently ill. He learned the next day that stomach flu was sweeping the department, so his illness was almost surely produced by the flu and not the sauce. It didn't matter. He now had a violent dislike for béarnaise sauce, a dislike that lasted for years.

Might rats — and other omnivores, like humans — be particularly quick to form an association specifically between *taste* and *illness*? Garcia and his collaborators decided to find out.

In one of the early experiments (Garcia, Ervin, & Koelling, 1966), the procedure was as follows. Rats were allowed to drink something novel and tasty — a saccharin solution. Saccharin apparently tastes sweet to rats, as it does to humans; they drink it with great enthusiasm when it is offered, and they did so here.

Then, a half hour after that, Garcia's rats were made sick by X-irradiation. A separate control group of rats was made sick in the same way, but without having drunk saccharin first. In both cases this was done only once.

Three days later, the rats in each group were simply offered the saccharin solution to drink. The control rats, whose illness had not been paired with saccharin, drank copious quantities of it now. But the experimental rats, who had been made sick *after* having drunk the saccharin, now refused it, drinking very little.

In its framework, this conditioning experiment is analogous to Pavlov's experiments. The conditioned stimulus (CS) is the sweet saccharin solution; the unconditioned stimulus (UCS) is the illness-inducing agent. Then, if the animal later refuses the sweet solution, we say that i has formed a *conditioned aversion* to the sweet taste of the solution. So, in this case, the rats in the experimental group had formed such a conditioned aversion. The rats in the control group had not, because saccharin had not been paired with illness. (That control group was necessary to rule out the possibility that illness, all by itself, might lead the rats to reject all unfamiliar solutions or foods. Clearly it did not , for the control rats did accept the saccharin solution.)

The finding encountered vigorous protest. This is not surprising, for it flew in the face of everything scientist thought they knew about conditioning. Suppose that Pavlov had sounded a bell to a dog, and then came back hours later and popped some food in the animal's mouth. Would he have seen conditioned salivation — after one such experience? Of course not!

But Garcia was showing something that very much like that could happen, if one chose the *right* CS-UCS combination. The conditioned aversion was formed with a *single* pairing of the saccharin taste with illness, even though they were separated by a full 30 minutes. Later experiments showed that they could be separated by many hours and conditioning would still occur — in one trial.

A typical reaction was that of a professor who, hearing of Garcia's findings, is aid to him: "Young man, that is completely impossible. The animal does not get sick from radiation until half an hour or more after it tastes the saccharin, and you cannot get any learning with such a big delay of the consequence, certainly not in one trial" (Bolles, 1993, p. 334). Conditioning just is not like that!

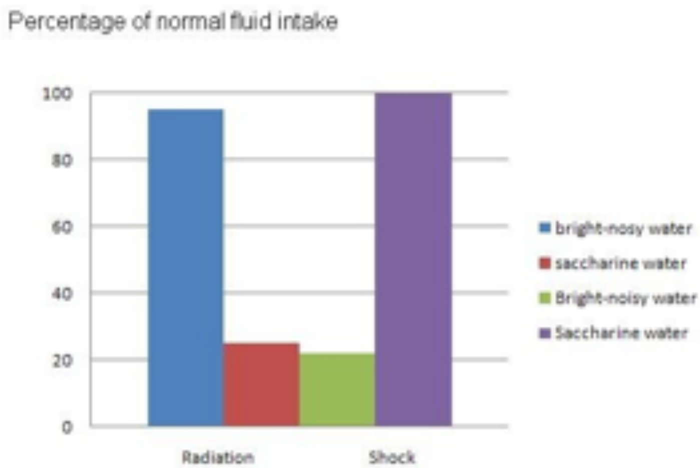
So strong was this kind of reaction that Garcia and his colleagues initially had a great deal of trouble getting their results published. Researchers in the field did not believe them. But Garcia persisted, and the experiments were replicated, and the results held.

Even so, one could have lingering doubts. Saccharin has a strong aftertaste that lasts for some time. It might last for hours, some argued; in which case maybe the aftertaste was still there when the illness came on. The reaction of the aversion might be conditioned to the *aftertaste* of saccharin, and it might have generalized to the taste of saccharin itself when the test was conducted later. Or another possibility: perhaps nausea is such a very potent stimulus that a conditioned connection between nausea and *any* arbitrary CS would form especially rapidly.

But all this is not so, and was ruled out by a particularly elegant experiment, again by Garcia and his colleagues (Garcia & Koelling, 1966). To anticipate: What this experiment showed is that there is nothing special about saccharin as a CS or about illness as a UCS. It is the *combination* that counts: rats are particularly good at learning the *relation between* tastes and nausea.

Garcia and his colleagues reasoned as follows. A saccharin solution is really just water with a sweet taste added. One could add different stimuli to water just as well. So, in one group of thirsty rats, water was offered to drink, and an electronic sensing define was set up so that when the rat lapped at the water, lights flashed and bells rang. Instead of sweet water, these rats were drinking “bright noisy water.” Under another condition, rats drink the saccharin-flavored “sweet water” as before. The point is that in both cases, something is being added to the plain water: a sweet taste in one case, lights and noises in the other.

In addition to this, the investigators compared the two different UCSs: illness and mild electric shock. In other words, some rats were made sick after they drank their fluid; but others were shocked instead. So we have four possible combinations of the two CSs and the two UCSs.



What happened? The conditioned avoidance response (refusal of the drinking fluid) depended on the combination of the CS and UCS that was used. If the rats were drinking sweet water, then nausea was much more effective than shock in producing a conditioned taste aversion. But if they were drinking bright noisy water instead, then the reverse was true: shock was more effective than shock across the board; it led to rejection only if it was paired with nausea. Therefore, it is the *combination* that counts. Rats are particularly good at learning a connection between taste and nausea, but not so good at learning a connection between light-and-sound and nausea. With shock instead of nausea, the reverse is true.

A large number of studies have since been conducted in a number of species, including humans. In the human case, an elegant set of experiments by Ilene Bernstein (1978) took advantage of a kind of natural experiment. Teenage children who had cancer were receiving chemotherapy, which produces nausea. Bernstein arranged for them to taste a new and unfamiliar flavor of ice cream (Maple Toff) a few hours before the scheduled chemotherapy. After *one* such pairing of the novel taste with illness, the children rejected the new ice cream when offered it. Control groups, which had the ice cream without the illness or the illness without the ice cream, showed no such rejection.

What is most striking about these findings is this: The children *knew perfectly well* that what had made them sick was the chemotherapy, not the ice cream. They said so when asked. It didn’t matter. They just didn’t like that flavor of ice cream anymore! Apparently, here, as in the bearnaise-sauce phenomenon, conscious knowledge has very little to do with conditioned taste aversions.

The conclusion is now well established: a number of species, including rats and humans, are particularly talented at learning a connection *specifically between taste and illness*.

The implications of this are considerable. The Lockean “blank slate” conception of mind implies the following: We should be able to learn that “*this* goes with *that*” for any pair of *this*-es and *that*-s with equal ease. But that is just not so. Certain stimuli “go with” certain others, so that, as one writer put it (Seligman, 1970), we are *prepared* to connect with one the other. Thus we are prepared to connect taste with nausea. As a result, we learn the taste-nausea connection very quickly. But we are not prepared to connect taste with pain — or, for that matter, bells with food in the mouth! These connections are “unprepared” — we learn them slowly if we learn them at all.

It used to be popular to distinguish “innate” and “acquired” responses to stimuli, or “instinctive” and “learned.” These experiments, and many others, show that that division has to be reconsidered. *The ability to learn certain things can itself be instinctive.* What we have, in taste-aversion learning, is an *instinctive readiness to* *learn* certain sorts of things. If rats and humans are "prepared" to associate taste with illness, there must be a reason for this. The most likely reason is that both rats and humans are omnivores, capable of eating almost anything, and so they face the problem of distinguishing what is edible from what is dangerous. A mechanism for associating taste with illness, rapidly and with only one experience, would be very useful in our learning to avoid poisonous substances. And it would seem that we humans, along with rats and other species, evolved just such a mechanism.

But not all species have done this. If all this is so, it would follow that animals who do not identify food by taste, but in some other way, might be especially good at associating *different* sensations with nausea. This seems to be the case. For example, many birds — quail, for example — choose their foods on the basis of vision, not taste. And, sure enough, quail quickly learn to avoid a food with a certain characteristic *color* if it makes them sick after they eat it. They are not so good at avoiding foods that have a characteristic *taste* under such conditions.

In short, specific learning mechanisms, or "preparednesses," are themselves products of evolution. We can't draw a line and say, "This behavior is instinctive and that behavior is learned." Instead, we seem to have *instinctive* tendencies to *learn* some things, but not others.

How general is this conclusion? It may be very general indeed. To this point, we have been talking about the pairing of one event with another - that is, classical or Pavlonian conditioning. But once alerted to the importance of preparedness, researchers began looking for it in other contexts too, and found it. Take, for example, operant conditioning and the reinforcement principle. Stated abstractly: If a response (any response) is followed by a reinforcer (any reinforcer), the frequency of that response increases. Therefore, any reinforcer should strengthen any response. But this is not so. Some reinforcing events work very well with some responses, but not with others. Some responses are easily strengthened by one reinforcer, but not by another that may be very effective with a different response (Shettleworth, 1987). As with taste-aversion learning, some combinations work well, others poorly or not at all.

One further example. Something that human beings are surely prepared for is the learning of language (Rozin, 1976). Consider this apparent paradox: A child hears the spoken language of its community under what should be very poor conditions for learning — the child hears the grown-ups speak in fragmented sentences, interspersed with "uh" and "ah" and with parts inaudible, and all the while great deal else is going on. Yet virtually all children learn to speak, and they learn it rapidly, effortlessly, and joyfully. But what happens when they must learn to read? Logically, this should be a far easier task. They should only have to memorize the sounds that letters represent and presto! they should be fluent readers. But this is not what happens. This "unprepared" task is learned relatively slowly and, for many, with great difficulty — or not at all.

Aside from specific instances, these findings and ideas may lead us to rethink some fundamental issues about what the mind itself is like. John Locke compared the mind to a blank tablet on which experience writes. This idea assumes that experience is free to write down a record of whatever "happens to happen." But this may not be true. Rather than Locke's blank tablet, we might think of the mind as something like a Swiss Army knife. It may be a set of tools, each one specialized for dealing with certain kinds of problems — problems like determining what events lead to pain, in one case, or what events lead to nausea, in another. These problems will be the sorts of problems that our remote ancestors encountered during prehistory, so that we may have evolved specialized cognitive tools designed specifically for each such set of problems.

At this point, it may seem that we've moved a long way away from rats and saccharin solutions! We have. But as is so often the case, little findings can bear on very large issues. Garcia's experiments are not "about" rats and saccharin solutions. They are "about" what learning is like, and whether the principles we once thought we had in hand are really as solid as we thought. And they are about what the *mind* is like, even for the lowly rat. Lockean blank slate, or Swiss Army knife (reminding us of the Kantian machine shop)? The pendulum is moving toward the latter. Garcia's experiments have given it a vigorous push in that direction.