Learning and the persistence of appetite: Extinction and the motivation to eat and overeat

Mark E. Bouton *

Department of Psychology, University of Vermont, 2 Colchester Ave., Burlington, VT 05405-0134, United States

A R T I C L E   I N F O

Article history:
Received 15 September 2010
Received in revised form 31 October 2010
Accepted 19 November 2010

Keywords:
Eating
Overeating
Pavlovian and operant conditioning
Extinction

A B S T R A C T

The modern world is saturated with highly palatable and highly available food, providing many opportunities to associate food with environmental cues and actions (through Pavlovian and operant or instrumental learning, respectively). Basic learning processes can often increase the tendency to approach and consume food, whereas extinction, in which Pavlovian and operant behaviors decline when the reinforcer is withheld, weakens but does not erase those tendencies. Contemporary research suggests that extinction involves an inhibitory form of new learning that appears fragile because it is highly dependent on the context for expression. These ideas are supported by the phenomena of renewal, spontaneous recovery, resurgence, reinstatement, and rapid reacquisition in appetitive learning, which together may help explain why overeating may be difficult to suppress permanently, and why appetite behavior may seem so persistent.

Human food intake is influenced by a large and very complex set of factors (e.g., [1]). However, there is little doubt that learning and conditioning processes are important among them. As Stephen Woods and others have emphasized, conditioning can play a very important role in determining the onset or timing of meals, preferences and aversions for different foods, and other aspects of eating and appetite (e.g., [2–4]; see also [5–7]). The purpose of this article is to selectively review some basic research on learning with an emphasis on extinction, a major inhibitory process in conditioning, and discuss some of the possible implications for understanding the persistence of appetite, difficulties in losing weight and maintaining weight loss, and the contemporary obesity epidemic.

The modern world is saturated with food and with opportunities to consume it. As noted by Kessler [8], we are constantly exposed to highly palatable, high-calorie foods that have been engineered with multiple layers of sugar, salt, and fat. From the perspective of learning theory, the high abundance of such tasty foods means that the world is full of very effective conditioning trials, i.e., opportunities to associate the food with cues in the environment (through Pavlovian conditioning) or with voluntary actions that lead to it (through operant or instrumental learning). Table 1 illustrates some of the many cues and operant behaviors that are available for association with food. In the Pavlovian case, it seems hard to avoid exposure to colorful food packaging, advertising logos, and the sight, smell and taste of foods. Any or all such stimuli can serve as Pavlovian conditional stimuli (CSs), and as CSs, they would be expected to engage approach behavior (e.g., [9]) and any of a number of conditioned responses that function to get the system ready for the meal (e.g., [10]). They might also trigger eating, even when the individual is full or satiated (e.g., [11–15]). Table 1 also illustrates some voluntary, operant behaviors available for reinforcement by the pleasures of eating—choosing a restaurant at the mall, purchasing food, opening the packaging to get at the food, and of course handling and eating it. Presentation of a Pavlovian CS would further excite or motivate these behaviors through Pavlovian-instrumental transfer (e.g., [16,17]), for example, by eliciting the “wanting” of food (e.g., [18,19]). Given the abundance and high palatability of the food in the environment today, basic learning processes could easily support strong appetite and food-motivated behavior.

Table 1 also lists a few examples of the kinds of “contexts” in which food consumption occurs. Contexts are usually “background” cues in which Pavlovian CSs are presented and operant behaviors are emitted. Thus, as illustrated in Table 1, CSs and operant behaviors never occur in a vacuum; they always occur in a context like a shopping mall, an airport, the couch in front of the television, or a social event such as a Superbowl party. Contexts like these may be directly associated with food, and have all the behavioral consequences of CSs noted above. Contexts can also provide a kind of hierarchical control over behavior that occurs in them (e.g., [20]), as I will illustrate below. In that case, they can engage behavior not by directly eliciting it, but by signaling whether or not the CS or the operant behavior will be associated with food.

Research in my laboratory and in others has discovered that contexts play an especially important role in extinction. In extinction, the reinforcer (food) is withdrawn, and the Pavlovian CS or the

---

Table 1

<table>
<thead>
<tr>
<th>Context Examples</th>
<th>Pavlovian CSs</th>
<th>Operant Behaviors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shopping mall</td>
<td>Item colors</td>
<td>Choosing a store</td>
</tr>
<tr>
<td>Airport</td>
<td>Airport view</td>
<td>Purchasing tickets</td>
</tr>
<tr>
<td>Couch in front of TV</td>
<td>TV ads</td>
<td>Handling food</td>
</tr>
<tr>
<td>Social events</td>
<td>Event context</td>
<td>Eating in public</td>
</tr>
</tbody>
</table>

---


E-mail address: mark.bouton@uvm.edu.

© 2010 Published by Elsevier Inc.
implications for the treatment and understanding of anxiety disorders

with food pellets (e.g., renewal in appetitive conditioning, where a CS like a tone is paired
techniques, where a tone is
extinction is at least partly a context-dependent form of learning.
responding. Something learned in, and speci
of extinction can be suf
and AAB renewals thus indicate that simple removal from the context
occurs in a context other than the original conditioning context. ABC
form, they are interesting because the
elicited by the CS again when it is returned to the original context (Context A).
behavior again when it is returned to the original context (Context A).
conditioning depends at least partly on the organism actively learning something
that inhibits performance based on the original learning. As I
illustrate below, the organism seems to learn that the CS or the
behavior is no longer paired with the reinforcer in the present context.
Behavior can thus return in other contexts, and this fact (among
others) makes extinguished behavior seem persistent and vulnerable
to relapse. I will illustrate the idea by reviewing several phenomena in
extinction. The phenomena and their implications have been
discussed elsewhere (e.g., [23,24]); what follows emphasizes recent
research with food reinforcers and attempts to develop some specific
implications for appetite and overeating.

1. Renewal of extinguished appetitive behavior

One phenomenon that is especially central to the contemporary
understanding of extinction is the renewal effect. Renewal has been
studied most extensively in Pavlovian learning. In its simplest form, if
a CS is associated with a reinforcer in one context (e.g., Context A),
and then extinguished in a second one (Context B), the CS elicits
behavior again when it is returned to the original context (Context A).
This is called ABA renewal. Renewal can also be observed if
conditioning, extinction, and testing respectively occur in Contexts
A, B, and C (ABC renewal) and A, A, and B (AAB renewal). Although
the latter forms of renewal are often somewhat weaker than the classic
ABA form, they are interesting because the final return of the behavior
occurs in a context other than the original conditioning context. ABC
and AAB renewals thus indicate that simple removal from the context
of extinction can be sufficient to cause a return of conditioned
responding. Something learned in, and specific to, the extinction
context inhibits or suppresses the conditioned response. Hence,
extinction is at least partly a context-dependent form of learning.

Many well-known studies of renewal used fear conditioning
techniques, where a tone is first paired with footshock and then
consequently evokes fear (e.g., [25,26]). The renewal of fear has
implications for the treatment and understanding of anxiety disorders
(e.g., [23,27]). However, we have also demonstrated various forms of
renewal in appetitive conditioning, where a CS like a tone is paired
with food pellets (e.g., [28–30]). In this case, food responding is
elicited by the CS again when it is removed from the extinction
context. The parallel between aversive and appetitive conditioning is
strong. In either case, there is often surprisingly little effect on the
strength of the response to the CS when the CS is switched from
Context A to Context B at the beginning of extinction. That is, the first
context switch has little influence on conditioned responding. Like the
ABC and AAB renewal phenomena themselves, this feature of
behavior suggests that conditioned responding can transfer surpris-
ingly well to new contexts, while extinction is more context-specific.
The asymmetry or imbalance may be fundamental to the persistence
of motivated behavior and appetite.

Weight loss is notoriously difficult to maintain after clinical
treatment, and Wilffley et al. [31] have recently noted how renewal
effects might contribute to making maintenance difficult. The renewal
effect might also work in more natural settings, outside the domain of
clinical treatment. For example, a friend of mine was able to eat
sensibly and extinguish a number of habitual appetitive behaviors
while she was at school for several months, away from a home
environment in which the family often gathered socially with great
quantities of food. At school, she stopped shopping for (and cooking)
large amounts of food when she was expecting guests, and refrained
from over-indulging at potlucks and dinner parties. On return home to
the family over the holidays, however, all the original behaviors
returned. In a similar way, those of us who feel cravings in the
presence of the odor of cinnamon buns may learn to suppress the urge
to eat in their presence when we visit the shopping mall. But the odor
may trigger the desire again when we encounter it at the airport.

The renewal effect is clearly evident in operant as well as Pavlovian
conditioning. Interestingly, its importance in operant learning has
been a focus of several behavioral pharmacology laboratories
investigating drug self-administration. The "compulsion" that some
individuals have to take drugs might bear some resemblance to the
"compulsion" that others have to eat food.ABA renewal effects have
now been documented after extinction when rats have been
reinforced for lever pressing with injections of heroin (e.g., [32]),
cocaine (e.g., [33]), a mixture of heroin and cocaine (e.g., [34]), or oral
delivery of ethanol (e.g., [35,36]). Specifically, when the rat learns to
take the drug via lever pressing in one context and then is
extinguished in another, drug seeking returns when the animal is
simply returned to the original context. ABA renewal has also been
demonstrated in operant experiments in which rats have learned to
leaver press for food pellets instead of drugs (e.g., [37,38,76]).
Nakajima et al. [37] also found the renewal effect in discriminated
operant conditioning, where rats first learned to perform the operant
response in the presence of a light discriminative stimulus. In this
case, renewal took the form of increased responding in the presence of
the light in Context A after it had been fully extinguished in Context B.
The context thus controlled the tendency of the light to instigate food-
seeking behavior.

Most of the initial operant work focused on ABA renewal, ignoring
the ABC and AAB forms. In fact, there were a number of failures to
produce the AAB renewal effect [32,34,37]. This created a puzzle,
because as noted above, ABC and AAB renewals are important in
suggesting that removal from the extinction context is sufficient to
renew behavior. However, my colleagues and I have recently
produced good evidence of each of the renewal effects in free operant
learning [39]. For example, in one experiment rats were first trained
to lever press in Context A on a variable-interval (VI) 30-s schedule of
food-pellet reinforcement. After several daily sessions, they received
four sessions of extinction training in either Context A, the same
context, or Context B, a second context. After extinction was complete,
the rats were tested in extinction in both Contexts A and B
counterbalanced). As shown in Fig. 1, when the rats extinguished
in Context B were tested in Context A (the ABA renewal condition),
there was a robust return of extinguished lever pressing. And when
the rats extinguished in Context A were tested in Context B (the AAB
renewal condition), there was also an increase in responding.
Although the AAB effect was significantly weaker than the ABA effect,

Table 1

| Table 1 Some natural conditioning events available for association with food. |
|-------------------------|-------------------------|
| Conditional stimuli (CSs) | Advertising logos |
|                         | Food packaging |
|                         | Sight of food |
|                         | Smell of food |
|                         | Taste of food |
| Operant (instrumental) actions | Approaching food court or restaurant |
|                         | Purchasing food |
|                         | Handling food |
| Contexts: | Airports |
|                         | Shopping malls |
|                         | Sporting events |
|                         | Superbowl parties |
|                         | Couch in front of the television |
100% of the animals in either condition responded more in the renewal context than in the extinction context. In another experiment, we found that tripling the amount of extinction in the AAB design did not weaken the strength of the AAB renewal effect. And in a third experiment, we found evidence of ABC renewal—when operant conditioning occurred in Context A, extinction occurred in B, and testing occurred in B and C, the rats recovered some responding in C. In this case, 94% of the subjects showed more responding in the nonextinction context than in the extinction context. Thus, there is no doubt that mere removal from a context of extinction can be sufficient to cause recovery of an extinguished appetitive operant. The extinguished craving for a cinnamon bun, and the urge to get up and buy one, can be renewed at the airport even if I've never eaten a cinnamon bun there. One does not have to return to the original context in which the operant behavior was learned.

Although the confirmation of operant ABC and AAB renewal is important, there is little doubt that ABA is a stronger effect than either AAB or ABC. One obvious reason is that testing in the ABA design occurs in a context (Context A) that has been directly associated with food during the original operant training. Thus, the rat is returned to a food-associated context that can motivate responding (through Pavlovian-instrumental transfer) via its direct Pavlovian association with food (e.g., [17]). To test this idea, we ran an experiment in which two groups of rats received operant lever press-food training in Context A before receiving extinction (lever press-no food) in Context B. A control group received the same training that the ABA group in Fig. 1 had. But in an experimental group, the rats were returned to Context A (with response lever removed and unavailable) four times (30-min sessions each) after every extinction session in Context B. This treatment created substantial exposure to the food-associated box without food. Although all that exposure should have weakened the influence of the context-food association through extinction, as shown in Fig. 2, it had no discernible impact on the strength of the renewal effect that occurred there during a final test. Although we know that a direct association between a context and a reinforcer can in fact augment extinguished operant responding ([40], see below), the role of Context A in the ABA renewal experiment may depend on another mechanism. It seems likely that the context is playing the role of an occasion setter, a stimulus that signals that the response–reinforcer association is now in force, rather than simply that the context means food. In Pavlovian experiments, such occasion setting is not diminished by simple exposure to the occasion setting stimulus itself (e.g., [41]), but instead requires disconfirmation of a target CS–reinforcer relation in the presence of the occasion setter in order to extinguish it. In the analogous operant case, simple passive exposure

![Fig. 1](image1.png)

**Fig. 1.** The renewal effect after the extinction of operant conditioning. Left: Mean lever-press responding in rats for a food-pellet reinforcer during each 30-min session of acquisition (Context A) and extinction. Right: Mean responding during two 10-min test sessions in the extinction context and the non-extinction (renewal) context (counterbalanced; note change in the y axis). AAB = renewal in Context B after extinction in Context A (n = 16); ABA = renewal in Context A after extinction in Context B (n = 16). Both groups increased responding when moved to the nonextinction context (p < 0.005); there was significantly more responding in the renewal context in the ABA condition than in the AAB condition (p < 0.005).

From Bouton et al. [39], Experiment 1. Reprinted with permission.

![Fig. 2](image2.png)

**Fig. 2.** Lack of an effect of exposure to Context A on the ABA renewal effect in operant conditioning. Left: Mean lever-press responding during each 30-min session of acquisition (Context A) and extinction (Context B). Right: Mean responding during the 10-min test sessions in the extinction context (Context B) and the non-extinction (renewal) context (Context A; note change in y axis). EXP = extra exposures to Context A (n = 16) during the extinction phase; NoEXP = no such exposures (n = 16). There was a reliable increase in responding in either group in Context A (p < 0.005), and no difference between the groups or group × test session interaction (Fs < 1).

From Bouton et al. [39], Experiment 4. Reprinted with permission.
to the cues of a fast food restaurant might not be as good at weakening operant food-seeking as extinction of at least one operant behavior in that context. We need more basic research on how to get rid of occasion setting in both Pavlovian and operant learning.

It is worth explicitly summarizing what renewal might suggest for our understanding of overeating. First, the renewal effect tells us that extinction is not unlearning. The potential for old behaviors may remain, perhaps indefinitely, in the memory system. Second, it illustrates and supports the idea that extinction depends on learning about the extinction context. Thus, as the overeater learns not to eat in the presence of a trigger cue, he or she really learns not to eat in the presence of the trigger cue in that context. Third, the ABC and AAB effects further tell us that removal from the extinction context is sufficient to cause a return of the behavior—it is not necessary to return to the context in which indulgence has occurred in the past. Finally, although a return to the original context (ABA) does produce the strongest renewal effect, simple exposure to the context without omission of the operant behavior (as in the experiment shown in Fig. 2) is not sufficient to eliminate the renewal effect. This might be one reason why simple exposure to cues associated with drugs and perhaps food might be ineffective at reducing appetite (see [42]). More research is needed to further understand how to eliminate behavioral control by occasion setting.

2. Spontaneous recovery of extinguished appetitive behavior

Spontaneous recovery, another post-extinction behavior recovery phenomenon, was first described by Pavlov ([43], e.g., p. 58). In either Pavlovian or operant learning, allowing time to elapse after extinction has occurred can allow the behavior to at least partially return. In the animal lab, the CS elicits responding again, or the subject now returns to the lever and emits some responding. Extinguished appetitive behavior can thus return after a delay.

Several explanations of spontaneous recovery are available (e.g., [44]). One idea is that the organism pays less and less attention to the CS (or perhaps its own behavior) as extinction training continues, and this attention recovers spontaneously over time (e.g., [45]). However, spontaneous recovery also occurs after counterconditioning, where a CS associated with food is associated with a qualitatively different event (e.g., footshock) in the second phase [46]. The subject shows, by its appropriate shock-related behavior when the CS is presented, that it is still attending to the CS during Phase 2. My students and I have instead emphasized that time may be part of the context. Just as the organism might learn that the CS or operant response is no longer paired with food here, it might learn that the CS is no longer paired with food now. Spontaneous recovery is essentially the renewal effect that occurs when testing occurs in a temporal context that is different from the temporal context of extinction. Consistent with this view, we have recently shown that temporal intervals can indeed play the role of context and control performance to CSs embedded in them.

It has recently been shown that temporal intervals can indeed play the role of context and control performance to CSs embedded in them. We need more basic research on how to get rid of occasion setting in both Pavlovian and operant learning.

The general implication for appetite is that the urge to eat or seek food may return sometime after the temptation has been successfully suppressed. Once again, the conditioning processes that trigger motivated behavior seem to generalize better across contexts than the extinction process that suppresses them.

3. Resurgence of extinguished appetitive behavior

Another post-extinction phenomenon is worth addressing at this point, because it seems especially relevant to the issue of overeating. In resurgence, an organism first learns one operant response (e.g., pressing a lever in a Skinner box) and then, while that behavior is being extinguished, a second “replacement” behavior is reinforced (e.g., pressing a second lever in the box). In a third phase, the second behavior is then extinguished, and the first response recovers (e.g., [51–53]). Once again, extinction—in this case coupled with the explicit reinforcement of a new behavior—does not erase the original memory, but only suppresses it. An example of resurgence is presented in Fig. 3 (Winterbauer and Bouton, unpublished). Rats were first trained to press on a lever (Lever 1) reinforced on a VI 30 schedule (Panel A). Then, presses on Lever 2 were extinguished while presses on a second lever were reinforced (or, in a control group, ignored; Panel B). When responses on Lever 2 were then in turn extinguished, responses on Lever 1 returned in the experimental group (Panel D at right in Fig. 3). New experiments (in progress) have found that resurgence is even stronger when the first response receives more training than the rather minimal amount shown. The phenomenon also has some generality. For example, a number of different schedules of reinforcement on Levers 1 and 2 support the effect [53], and resurgence has also been shown to occur in rats reinforced in Phase 1 with other reinforcers, like alcohol [55].

In the world outside the laboratory, reinforcement of other behaviors during extinction of a target behavior is probably the rule rather than the exception. A dieter who is reducing his or her calorie intake might be encouraged to take up new behaviors, such as walking or running or playing volley ball. Any such replacement behavior has its own payoff according to its own natural schedule of reinforcement. Extinction of the new behavior could allow the bad habits to resurge. In the clinic, weight loss and self-regulatory behaviors can be explicitly reinforced via social contact with a clinician, or even more effectively, with money (e.g., [56]). Although the evidence suggests that such strategies help with weight loss, the implication of resurgence is that the extinguished appetitive behavior should be expected to lapse to some extent if the new behavior is put on extinction. Consistent with this, weight is regained at least partially in the first few months after monetary incentives are withdrawn (e.g., [56]).

Resurgence can result from several behavioral processes. An early idea [57] was that the reinforcement of the replacement behavior might reduce the frequency of the behavior it is replacing so radically that the individual has fewer opportunities to learn about extinction. The replacement behavior, or the availability of the incentive motivating it, suppresses the original response so much that the subject insufficiently samples the new extinction contingency. We have recently shown, however, that resurgence readily occurs even when the new behavior is reinforced on a reinforcement schedule that is lean enough so that it does not suppress the original behavior beyond the suppression that occurs through extinction alone [53]. As an alternative, we have therefore proposed that resurgence can be considered a subtle example of the renewal effect (see also [58]). The original behavior is extinguished in the “context” of the new one being reinforced. Then, when reinforcement of the new behavior is discontinued, and its frequency begins to decline, the context changes again. Resurgence might thus be interpreted as another example of the ABC renewal effect—conditioning generalizes more than extinction does to the new context.

Perhaps the most straightforward implication of this contextual analysis of resurgence is that it highlights the importance of the transition between the extinction plus replacement behavior training and the test in which the replacement is put on extinction. A procedure that makes the transition less abrupt, e.g., by fading in the extinction phase so that the new reinforcer gradually becomes less...
frequent, would produce a less salient context change and ultimately allow extinction to be connected with contexts beyond the artificial one in which monetary incentives are earned. We are currently running experiments in the animal laboratory that investigate such methods.

4. Reinstatement of extinguished appetitive behavior

We also know that extinguished behavior can readily return if the organism is exposed to the reinforcer itself again after extinction. In Pavlovian learning, the food reinforcer can be presented and consumed again, independently of the CS, after extinction. When the CS is then tested, it can trigger responding again [28,59,60]. Reinstatement also occurs after operant extinction. If the reinforcer is simply presented after lever pressing has been extinguished, the rat may return to lever pressing [40,61,62]. In the laboratory, the reinstating reinforcers are usually presented somewhat artificially; they are delivered freely, that is, not contingent on a particular behavior. Humans probably rarely receive rewards that are truly free and noncontingent. But we have recently shown that reinforcers presented contingent on a second behavior also reinstate a separate extinguished operant [54]. Because of reinstatement, it is easy to see why an overeater might begin binging again if he or she eats some tasty guacamole at a Superbowl party. The presentation of the reinforcer would increase Pavlovian responding as well as voluntary, food-seeking operant behavior.

There are several mechanisms underlying reinstatement. In the drug self-administration literature, the operating assumption is usually that presentation of the drug primes neural reward circuits [but see 63]. A mechanism we have emphasized is the fact that presentation of the reinforcer allows it to be associated with the context, and this contextual conditioning triggers the extinguished response. Consistent with a role for context conditioning, in both Pavlovian and operant learning, presentation of the reinforcer in a different context has very little impact on the extinguished response in the context where it has been extinguished (e.g., [26,28,40,59,64]). Similarly, extended exposure to the context after presentation of the reinforcer can reduce its reinstating impact [40,64]. Theoretically, a context made “hot” by recent association with the reinforcer might motivate and invigorate the Pavlovian or instrumental response (exposure to the context without the reinforcer would effectively “cool” the context down). Or a hot context might set the occasion for the response, because the context was also hot when the response was originally reinforced, and thus provides a kind of contextual stimulus for another ABA renewal effect.

Another mechanism behind reinstatement, though, is direct occasion setting by the reinforcer itself. When the rat lever presses in an operant conditioning session, or the human takes a tasty chip from the bag, the taste and feel of the reinforcer provide a stimulus that is associated with reinforcement of the next response: The rat therefore returns to the lever, and the human reaches into the bag again. Presentation of food reinforcers after extinction might reinvigorate appetitive behavior because they are thus part of the context that supported them. One implication is that providing occasional reinforcers during extinction, so they are now decoupled from reinforcement of the next response, can reduce the reinstatement effect (e.g., [54,62]). I will return to this somewhat paradoxical idea in the next section.
5. Rapid reacquisition of extinguished appetitive behavior

We (e.g., [23]) have previously noted that the phenomena discussed above can cause extinguished behavior to lapse or "slip." But one very important feature of eating and appetitive behavior in the natural world is that the act of eating during a lapse will inevitably bring the stimuli and behavior into contact with the reinforcer again. Response recovery by renewal, spontaneous recovery, resurgence, or reinstatement will bring the individual back in contact with new CS–reinforcer or action–reinforcer pairings.

This observation is important, because we know that behaviors that have received extensive training, like those presumably involved in overeating, are quick to return to full force when the CS or the operant behavior is paired with the reinforcer again [65]. Such a return to the full-blown, reinforced, behavior would be the start of true relapse. Many investigators have been satisfied to assume that rapid reacquisition is merely evidence that the original learning is "saved" or retained after extinction. But this doesn't really explain why the behavior rapidly returns. Instead, at a more mechanistic level, the reintroduction of the CS–reinforcer or action–reinforcer contingency may return the subject to the original acquisition context, because conditioning originally occurred in the presence of a memory of recent reinforced trials. In this sense, rapid reacquisition may be an ABA renewal effect [65–67].

An important implication of this analysis is analogous to one we discussed a few paragraphs ago. If we are to protect an individual from relapse via rapid reacquisition, it is best to try to associate the renewing cues—CS–reinforcer or action–reinforcer pairings—with extinction. One can do this by inserting occasional CS–reinforcer or action–reinforcer pairings into an extinction procedure. In Pavlovian experiments [66], rats received extensive extinction in which the CS was paired with the reinforcer very infrequently, in the midst of many extinction trials. The idea was to associate the reinforced trials with ensuing extinction trials. Consistent with our hypothesis, the treatment slowed down the reacquisition that occurred when CS and US were again paired relative to a group that had received simple extinction. The new pairings were a feature of extinction. Fig. 4 shows the results of a test phase in an analogous experiment done in operant conditioning [67]. Here, after initial reinforcement of lever pressing with food pellets on a VI 30 schedule, the rats received either simple extinction or extinction with occasional response–reinforcer pairings (the reinforcement schedule was gradually made leaner, until the rats were responding on a VI 32-min schedule). Responding declined with either method, although the occasional response–reinforcer pairings led to less complete decline (as illustrated by “before” at left in Fig. 4). Importantly, when the response was then paired with the reinforcer again in a reacquisition phase, the partial reinforcement procedure reduced the impact of each new pairing. That is, while rats that had received simple extinction increased their responding during the minutes after each new action–reinforcer pairing, the partially reinforced rats did not. In this way, occasional reinforcement of the action during extinction may slow down relapse when the action regularly leads to the reinforcer again.

The implications for overeating (and for drug taking) are interesting. If a person has learned to eat unhealthy foods (or take drugs) repeatedly in binges, then eating a snack (or taking a drink) becomes a cue for reinforcement of the next one. A snack is a stimulus for additional intake. Therefore, an extinction procedure that includes the consumption of occasional snacks in a way that allows them to be associated with an overall reduction in intake may help reduce the risk of a lapse becoming a relapse.

6. Discussion and conclusion

Each of the phenomena described above illustrates at least three points. First, extinction is not the same as erasure; the tendency to respond can readily return. Second, each phenomenon suggests a possible mechanism or lapse and/or relapse. And third, the overall message is that extinguished responding is highly sensitive to manipulations of the context. In this regard, it is worth noting that our discussion of “context” has assumed that the concept is very broad. Although many experiments in the animal learning literature define context as the box or immediate environment in which learning and remembering take place, I have discussed the role of a number of possible background stimuli as part of the context, including time (in explaining spontaneous recovery), other behaviors and their reinforcement (in explaining resurgence), presentations of the reinforcer or context–reinforcer associations (in explaining reinstatement), and CS–reinforcer and action–reinforcer pairings (in explaining rapid reacquisition). Other research indicates that emotions and drug states can provide contexts too (e.g., see [23]). And it is noteworthy that Davidson [68,69] has argued that the state of food deprivation can also provide a contextual stimulus; this may help explain how hunger can modulate behavior (see also [16]). In our view, it is advisable to think of “context” as any of a large number of background stimuli.

It is also appropriate to think more broadly about the inhibitory processes that are engaged by extinction. Is the context important at influencing all forms of inhibitory learning? The answer to this question turns out to be complex. Learning theorists often study inhibition by means of so-called feature-negative discriminations in which one CS (X) is paired with a reinforcer when it is presented alone (X+), but without the reinforcer when it is combined with a second CS (Y) (XY−). In the world of eating and appetite, a child might learn that the sight of a bright blue box of sugary cereal is associated with something wonderful (X+), but not if a disapproving adult is also present (XY−). The box will therefore generate more excitement when the disapproving adult is not around. Learning theories attribute the behavioral pattern to the development of conditioned inhibition to stimulus Y (the adult) (X might also develop a little inhibition of its own after it first acquires an association with food). Interestingly, laboratory experiments on feature-positive discriminations suggest that inhibition to Y is not specific to the original context; inhibition to Y transfers without loss when tested in a new context [70,71]. But surprisingly, in the new context, responding to X becomes
more difficult to inhibit. Thus, the bright blue box may stimulate more excitement and eating at the vacation cottage than at home, even in the presence of the disapproving adult.

A more general implication of this digression is that inhibition per se is not context-specific. It turns out that the second thing learned about a stimulus is often more context-specific than the first thing learned [72]—as if the memory system treats the second thing learned about a stimulus as a conditional, context-specific exception to the rule [23]. Extinction is thus relatively context-specific because it is the second thing the organism learns about the CS or the operant action. In counterconditioning, where a CS is first associated with one reinforcer and then a second reinforcer in a subsequent phase, the principle is the same: the CS’s association with the second reinforcer is more context-specific than the association with the first [73]. It is thus retroactive inhibition (or retroactive interference), not conditioned inhibition, that is specific to its context. What I have been claiming for extinction could apply to any situation in which new learning replaces old learning.

As I stated earlier, the causes of eating and overeating are numerous and enormously complex. Yet, a learning analysis of conditioning and extinction may provide a useful perspective on them. Although conditioning mechanisms have almost certainly evolved to allow organisms to cope effectively with biologically–significant events (e.g., [2,74,75]) the bets are off in the modern world, given the hyperpalatable-ability of modern food, its abundance, and the ease with which it can be eaten and ingested [8]. Given the number of palatable foods out there, and the known behavioral effects of Pavlovian and operant learning processes, it is not surprising that we eat, and are tempted to eat, in the presence of so many CSs and contexts.

The idea developed here is that extinction, whether it is deliberately produced through weight loss regimes or more naturally by naturally-occurring extinction trials, does not permanently undo the effects of conditioning. At the most general level, we should not suppose that it erases, even partially, the learning allowed by our food-saturated world. Instead, in both Pavlovian and instrumental situations, extinction is best thought of as new learning that is at least partly context-dependent. There seems to be a bias or imbalance in basic learning processes such that conditioning tends to generalize across contexts, whereas extinction generalizes less completely. Renewal, spontaneous recovery, resurgence, reinstatement, and rapid reconditioning all suggest that lapse and relapse are understandable (and perhaps inevitable) after extinction. And they may contribute to why behavior, once learned, is so persistent. This point has been made before concerning anxiety disorders and drug dependence. The arguments may apply equally to our understanding of eating, appetite, and their apparent potency today.

Acknowledgments

Supported by Grant R01 MH064847 from the National Institute of Mental Health. I thank Leonard Epstein, Lillya Sitnikov, Travis Todd, Drina Vurbic, and Neil Winterbauer for their discussion and comments, and Stephen C. Woods for his friendship and inspiration.

References


Winterbauer NE, Bouton ME. Mechanisms of resurgence II: response-contingent reinforcers can reinstate a second extinguished behavior. Submitted for publication. Learn Motiv.

