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## Augmentation: Synergistic Conditioning in Taste-Aversion Learning

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### Abstract

Recent work in taste-aversion learning has revealed a new phenomenon in classical conditioning. When a pre-conditioned gustatory cue (taste or odor) is conditioned in compound with a second gustatory

cue, conditioning to the second cue is augmented. This enhanced conditioning of the second cue is noteworthy because studies with other forms of classical conditioning have shown blocked conditioning to the second cue. This new phe-

nomenon has been termed *augmentation*, and it has implications for the study of taste and odor interactions, formal models of learning, and clinical interventions with cancer patients.

### Keywords

taste-aversion learning; augmentation; blocking; cancer treatment; classical conditioning

It is very adaptive for a foraging animal to determine whether edible substances are safe or dangerous. One process that facilitates

avoidance of toxic foods is taste-aversion learning: When an organism consumes a novel food and then experiences illness, the animal will be reluctant to consume that food on subsequent occasions. In fact, taste-aversion learning has been demonstrated in numerous species ranging from mollusks to humans. Taste-aversion learning is a type of classical conditioning wherein the taste is the conditioned stimulus (CS), the illness-producing agent is the unconditioned stimulus (US), illness is the unconditioned response, and avoidance or decreased consumption is the conditioned response. Throughout the history of the study of taste-aversion learning, researchers have debated whether taste-aversion phenomena require explanations that are different from those used to explain more traditional types of classical conditioning, such as fear conditioning or eyeblink conditioning. In a seminal review, Logue (1979) concluded that taste-aversion learning does not differ from other forms of classical conditioning, and among the evidence used to support this claim was the fact that all forms of classical conditioning, including taste-aversion learning, demonstrated what is called blocking (e.g., Gillan & Domjan, 1977).

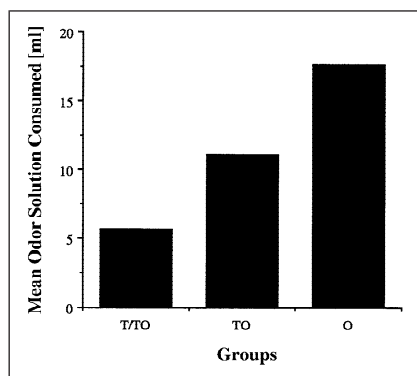
Kamin (1969) introduced the concept of blocking following his examinations of fear conditioning in a two-phase conditioning design known as the A+/AX+ design. In Phase 1 (the A+ phase), he gave rats numerous presentations of CS A (e.g., a light) with a shock US. In Phase 2 (the AX+ phase), the rats received the preconditioned CS A along with a novel CS X (e.g., a tone), followed by the shock US. Subsequent testing with X revealed significantly weaker responding relative to the response of control subjects that had received only AX+ conditioning during Phase 2 (control subjects did not receive

Phase 1 training). Kamin concluded that preconditioning of A with the US blocked learning to the novel X stimulus. One important outcome of this research is that it demonstrated when more than one CS is presented, these multiple stimuli compete with each other for association with the US. Moreover, the concepts of competitive conditioning and blocking have been central in the development of various models of associative learning (e.g., Pearce & Hall, 1980; Rescorla & Wagner, 1972).

In a real-world setting, blocking of taste-aversion learning could be beneficial. Assume an animal learns an aversion to toxic cheese (A). During a second feeding, it consumes a small amount of the toxic cheese (A) and safe cereal (X), and becomes ill. The animal's previous learning that cheese makes it sick should block learning that cereal makes it sick. As a result, safe cereal remains a viable choice in the animal's diet. Blocking, however, would not be adaptive in other foraging situations. Reconsider the scenario in which an animal has already learned a taste aversion to cheese. On a second occasion, the animal reencounters the cheese (A), but now, a distinctive odor (X) emanates from it. Unfortunately, the taste cue that signals illness cannot be detected until the animal consumes the cheese. Thus, the animal falls ill from consuming the tasty-and-smelly cheese. What does the animal learn about the odor during this episode? The substantial research on blocking suggests that the preexisting cheese aversion should block learning of the odor aversion, and the animal should learn nothing about the odor. In contrast, if the animal could associate the odor of the substance with illness, it could identify the substance by this odor on subsequent occasions, and avoid the cheese and its toxic consequences.

## AUGMENTATION

In recent reports, John Batson and I have shown that under certain conditions, rats conditioned with tastes and odors within the A+/AX+ design do not show blocking to X; instead, we have obtained the opposite result, augmented conditioning to X (Batsell & Batson, 1999; Batsell, Paschall, Gleason, & Batson, in press; Batson & Batsell, in press). In one such experiment, we compared the learning of an odor aversion among three groups of rats (adapted from Batsell et al., in press). Group O was the odor-alone control group, which had odor paired with an emetic US. Group TO received a compound of taste plus odor followed by the US. This group was expected to show an increased or potentiated odor aversion. Potentiation is a form of synergistic conditioning that occurs in the AX+ design when a compound of a strong taste plus a weak odor is followed by illness (for a review of potentiation, see LoLordo & Droungas, 1989). A third group, Group T/TO, received the taste paired with the emetic US in Phase 1, and a presentation of the taste-odor compound followed by the emetic US in Phase 2. Therefore, Group T/TO received a treatment that followed the A+/AX+, or blocking, design, and if blocking of the odor aversion occurred, this group would subsequently show the weakest responding to the odor when presented alone. In other words, this group would consume more of the odorous solution than the other two groups during testing following the conditioning. Figure 1 displays the mean amount of odor solution consumed during testing by the groups. Group O drank the most odor solution, demonstrating a weak odor aversion. Group TO drank significantly less odor solution than Group O, dem-



**Fig. 1.** Mean odor solution consumed in milliliters. Group O received odor plus illness during training. Group TO received taste plus odor, followed by illness. Group T/TO received a taste plus illness pairing, and then a taste-odor compound followed by illness (adapted from Batsell, Paschall, Gleason, & Batson, in press).

onstrating potentiation of the odor aversion. Notably, Group T/TO drank significantly less odor solution than the other groups. This outcome is noteworthy because the so-called blocking design produced the strongest odor aversion.

Other experiments have shown that odor preconditioning can augment taste-aversion conditioning (Batsell & Batson, 1999; Batson & Batsell, in press). Specifically, a group that had odor paired with illness prior to conditioning with an odor-taste compound had a significantly stronger taste aversion than a control group that received only the compound conditioning. Collectively, these experiments show that tastes and odors can combine synergistically when the blocking procedure is used in an aversion conditioning design. We use the label *augmentation* to refer to this facilitated aversion conditioning within the A+/AX+ design.

It is important to note that both augmentation and blocking can occur in the A+/AX+ design in taste-aversion learning. These opposing results were shown in a study examining whether the mode of stimulus presentation (simultaneous vs. sequential) during the

AX+ conditioning phase of A+/AX+ conditioning is responsible for producing synergistic conditioning (see Batsell & Batson, 1999, Experiment 1). The key group, called the simultaneous group, received augmentation training: a pairing of odor and illness in Phase 1 followed by a simultaneous presentation of odor and taste and induction of illness in Phase 2. The sequential group also received an odor-illness pairing in Phase 1, but in contrast to the simultaneous group they received taste followed by odor and illness during Phase 2. Compared with control groups, the simultaneous group showed an augmented taste aversion, whereas the sequential group showed a significantly weaker taste aversion. Therefore, simultaneous conditioning is necessary to produce synergistic conditioning in the A+/AX+ design. Thus, it appears that the major procedural manipulation that produces augmentation or blocking within taste-aversion learning is mode of stimulus presentation. This difference in stimulus presentation is one reason why augmentation was not detected in previous A+/AX+ experiments in taste-aversion learning; they used a sequential presentation of stimuli during the AX+ conditioning phase (cf. Gillan & Domjan, 1977).

#### IMPLICATIONS FOR CLINICAL TREATMENT

Taste-aversion learning is an adaptive process by which organisms learn to avoid toxic substances, but this process can be counterproductive in the modern world. Human cancer patients are prone to learn numerous taste aversions because their treatment (radiation therapy or drug chemotherapy) can produce intense nausea side effects. As a result, patients may experience posttreatment

vomiting and nausea (PVN), an unlearned illness response produced by the treatment, and anticipatory vomiting and nausea (AVN), a learned response when the patient reencounters stimuli that were present during PVN. As a result of PVN and AVN, many cancer patients learn numerous food aversions, along with aversions to the odors of the hospital, the nurses' and doctors' uniforms, and even the hospital itself. In fact, two primary complaints of cancer patients are the illness side effects and the subsequent changes in dietary patterns (e.g., Boakes, Tarrier, Barnes, & Tattersall, 1993).

One proposed intervention to prevent the development of taste aversions in cancer patients is the use of a *scapegoat flavor*. Support for this intervention comes from the evidence that novel foods are more readily associated with illness than familiar foods. The idea is that a patient would consume an unfamiliar food prior to chemotherapy treatment, so that this unfamiliar food would be the "scapegoat" for aversion learning, and the patient's familiar diet would be protected from becoming a signal of illness (e.g., Broberg & Bernstein, 1987). Yet the presence of augmentation suggests a potentially disastrous shortcoming of the scapegoat method. For example, a patient may undergo the initial treatment in which a novel food is consumed immediately prior to treatment, and subsequently, he or she acquires an aversion to that new food. During a later treatment, the patient eats the novel food again, but this time a salient odor (e.g., coffee) permeates the hospital room. This scenario recreates the A+/AX+ design that produces augmentation of odor-aversion conditioning (Batsell et al., in press). As a result, the scapegoat flavor may produce a robust aversion to the odor of coffee. Although

human studies of augmentation in the context of the scapegoat method have yet to be conducted, it is possible that the scapegoat technique may protect the patient's diet, but facilitate aversion learning to other cues.

## FUTURE DIRECTIONS

Augmentation is important because it shows that both synergistic conditioning and competitive conditioning can occur within the A+/AX+ design in aversion conditioning. In contrast, only competitive conditioning has been observed within traditional forms of classical conditioning. Thus, the presence of augmentation raises two questions that should direct future research. The first is, why did blocking not occur with tastes and odors (Batsell & Batson, 1999; Batsell et al., in press; Batson & Batsell, in press) when it has been observed in other classical conditioning preparations? One approach to this question is to focus on the specific nature of taste and odor cues. Considering that tastes and odors are often experienced together, it is possible that these sense modalities are the only cues that can combine into a compound or configural cue, and this produces synergistic conditioning. One means to determine if augmentation is specific to tastes and odors would be to examine whether other cues (visual cues, auditory cues, contexts) can be augmented or produce augmented conditioning within the aversion-conditioning paradigm. Another approach would focus on the neuronal pathways that underlie the feeding system. The possibility exists that the feeding system processes simultaneous cues differently from pathways that process simultaneous light and tone cues in fear conditioning or eyeblink conditioning.

The second question is, how does synergistic conditioning (potentiation and augmentation) of tastes and odors occur? To date, the majority of studies have examined taste-plus-odor conditioning in the AX+ design; thus, theoretical approaches have addressed potentiation. Two theories have received the most support in explaining potentiation. The within-compound association theory (Durlach & Rescorla, 1980) explains synergistic conditioning in terms of the formation of three associations: taste-illness, odor-illness, and taste-odor. After taste-plus-odor compound conditioning, odor testing elicits a strong response because it activates two pathways, the direct odor-illness pathway and the indirect odor → taste → illness pathway. Control animals that receive only odor-plus-illness conditioning have a weaker odor aversion because of the absence of the indirect odor → taste → illness pathway. Thus, a clear prediction of the within-compound approach is that the strength of the odor aversion at testing is dependent on an intact taste aversion. A second theory is the sensory gate and channeling approach (Garcia, Lasiter, Bermudez-Rattoni, & Deems, 1985), which is based on evidence for an internal gut-defense system and an external defense system. The internal gut-defense system processes cues related to feeding, such as tastes and illness. The external defense system is specialized for defense of the skin and processes cues (e.g., auditory and visual cues) that are related to threats from predators. Odor cues are typically processed by the external defense system, but if they are accompanied by a taste, they can be "gated" into the internal defense system and processed like a taste. In this approach, once the odor has been admitted into the gut-defense system and associated with illness, its

strength is not dependent on an intact taste aversion.

These theories can be differentiated by an experiment that weakens the strength of the taste aversion following compound conditioning. In this type of experiment, two groups are given taste-plus-odor compound conditioning, then one group receives the taste without illness while the other group receives a control flavor. Subsequent odor testing should reveal if the odor aversion is differentially affected by this additional phase of taste exposure. If the odor aversion is weakened by the exposure to the conditioned taste without illness, this would favor the explanation based on within-compound associations, whereas if the odor aversion is not affected, this would support the explanation based on the sensory gate and channeling approach. Unfortunately, this type of experiment has yielded conflicting results. Some researchers have recorded a decreased odor aversion (e.g., Durlach & Rescorla, 1980), whereas others have reported no change in the strength of the odor aversion (Lett, 1984). Therefore, neither of these theories can explain all published reports on potentiation.

Considering the procedural similarities of augmentation and potentiation, augmentation provides a new tool to explore taste and odor interactions in aversive compound conditioning in rats. If a common mechanism of synergistic conditioning effects can be identified, this may dispel the unresolved issues in taste-odor compound conditioning. Furthermore, once the mechanism that produces augmentation has been identified, it will be important to determine if models of learning that predict blocking (e.g., Pearce & Hall, 1980; Rescorla & Wagner, 1972) can be modified to incorporate both phenomena.

### Recommended Reading

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### Note

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