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Increasing trial number produces augmentation, not blocking, in flavor-aversion conditioning

Ian Good, Dana Allswede, Katherine Curley, W. Robert Batsell Jr.*

Kalamazoo College Department of Psychology, Kalamazoo College, 1200 Academy St., Kalamazoo, MI 49006, United States

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ABSTRACT

Typically, A+ → AX+ conditioning yields significantly weaker responding to CS X, a phenomenon known as blocking. Yet, in flavor-aversion conditioning, A+ → AX+ conditioning yields a significantly stronger response to X, termed augmentation. Two flavor-aversion experiments with rat subjects and rotationally induced illness were conducted to determine if trial number was a factor that affected the expression of augmentation. An increase in the number of A+ preconditioning trials resulted in a stronger augmented aversion (Experiment 1). Similarly, an increase in the number of AX+ compound conditioning trials also produced a significantly stronger augmentation effect (Experiment 2). Therefore, these data show that variations in trial number are not the determining factor in the expression of augmentation or blocking, and they confirm that the strength of augmented aversions are directly related to the strength of the aversion of the preconditioned cue. Finally, these results are the first to show odor-aversion conditioning and augmented taste aversions produced via rotational stimulation.

In classical conditioning, when a conditioned stimulus (CS) such as a light, is paired with an unconditioned stimuli (US), such as a shock, an association forms between the two and the organism learns that the light predicts the shock. Yet, if the light is conditioned in compound with another CS (tone) that is already a reliable predictor of the shock US, learning to the light is blocked. Kamin (1969) introduced the term "blocking," which has been used to describe both the A+ → AX+ conditioning design and the experimental outcome of the weakened conditioned response (CR) to the redundant CS X. The phenomenon of blocking is of theoretical importance because it is one of the cue competition designs whose outcomes suggest that when two or more CSs are conditioned in compound, these cues compete for associative strength with the US. Furthermore, the general concept of cue competition has been incorporated into all current models of associative learning (e.g., Pearce & Hall, 1980; Rescorla & Wagner, 1972), and they successfully predict blocking. In some flavor-aversion experiments, however, the use of the A+ → AX+ design does not result in a weakened CR to X, but instead, it results in a significantly stronger or "augmented" CR to X (Batsell & Batson, 1999; Batsell, Paschall, Gleason & Batson, 2001; Batson & Batsell, 2000). These augmentation results present a challenge to the aforementioned formal models of associative learning that would predict blocking. Because the same design yields different results, identification of the variable(s) that produces blocking or augmentation may further understanding of these phenomena.

Based on previous work with the A+ → AX+ design (see Experiment 1, Batsell & Batson, 1999; Experiment 1, Batsell et al., 2001), one variable that influences the expression of blocking or augmentation is mode of stimulus presentation

* Corresponding author.
E-mail address: rbatsell@kzoo.edu (W.R. Batsell Jr.).

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(simultaneous vs. sequential) during AX+ conditioning. For example, following odor preconditioning, if the taste + odor compound was presented simultaneously in solution during AX+ conditioning, the subsequent taste aversion was significantly stronger than controls (i.e., augmentation). In contrast, following odor preconditioning, if the taste and odor were presented sequentially (i.e., one solution after the other in separate tubes), the resulting taste aversion was significantly weaker than controls (i.e., blocking). It is not surprising that augmentation is only observed with a simultaneous compound presentation; Rescorla (1981) argued that because an A–X within-compound association forms during simultaneous compound conditioning, and responding to X may occur via its association with A, this within-compound association could counteract the cue competition that produces blocking (see also Rescorla & Durlach, 1981; Speers, Gillan, & Rescorla, 1980). Indeed, Allswede, Curley, Cullen, and Batsell (2014) have recently demonstrated that both odor-mediated taste augmentation and taste-mediated odor augmentation are produced via a within-compound association between the flavors. So, it appears that with flavor cues, the A–X within-compound association exerts enough behavioral control to produce a significantly stronger aversion to X. Yet, a simultaneous compound presentation alone cannot be the sole factor responsible for producing augmentation rather than blocking because the vast majority of successful blocking experiments have used simultaneous compounds (e.g., Kamin, 1969; Kohler & Ayres, 1982).

To identify potential candidate variables that may determine the transition from augmentation to blocking, we reviewed blocking with a simultaneous compound in classical conditioning paradigms other than taste aversion. Specifically, considering all demonstrations of augmentation to date have only involved a single, simultaneous AX+ trial, it is most informative to examine blocking experiments that also have only used a single, simultaneous AX+ trial. To our knowledge, only two reports have shown one-trial blocking with the use of a simultaneous compound (Azorlosa & Cicala, 1986, see Experiment 2; Balaz, Kasprow, & Miller, 1982), and both utilized conditioned suppression. Azorlosa and Cicala conducted 20 noise-shock trials in phase 1 and a single light + noise-shock trial in phase 2. Balaz et al. conducted 12 tone-shock trials in phase 1 and a single light + tone-shock trial in phase 2. In each of these studies, the light cue and the auditory cue were spatially separated in the experimental chamber. Notably, Balaz et al. wanted to minimize the formation of a within-compound association so they only provided the light + tone compound for a brief 5-s period; the compound CS duration was 10 s in the Azorlosa and Cicala study. These two reports differ from our augmentation studies in a number of respects, but one can speculate that the differences with the greatest potential to promote stronger within-compound associations include: (1) number of A+ preconditioning trials; (2) method of stimulus compound presentation; (3) duration of the AX compound exposure, and (4) nature of the stimuli (i.e., audiovisual cues vs. flavor cues). In the present research, we chose to explore the effects of variations in trial number on the expression of augmentation and blocking.

With regard to variations in the number of A+ trials, there are a number of possibilities that may alter responding to X. On one hand, some previous work suggests increasing the A+ trials before AX+ conditioning should decrease responding to X. For example, previous studies have shown that experiences with A in the absence of X, either following AX+ conditioning (i.e., post-conditioning extinction) or prior to AX+ conditioning, are sufficient to weaken the A–X within-compound association and subsequent responding to X (e.g., Rescorla & Durlach, 1981). Similarly, in an exploration of unblocking, Rescorla and Colwill (1983) (Experiment 4) showed that increasing the number of A–US presentations from 2 to 8 pairings was sufficient to disrupt the formation of the A–X within-compound association. Another possibility exists if responding to X after A+ → AX+ conditioning reflects a balance of competition between blocking from the A–US association and contributions from the A–X within-compound association. Then, because increasing the number of A+ trials would strengthen the A–US association, it may better counteract the A–X within-compound association, and yield weakened responding to X. On the other hand, it is also possible that increasing the number of A+ trials before AX+ conditioning may result in increased responding to X. In this scenario, because increasing the number of A+ trials will increase the strength of the A–US association, if the A–X within-compound association forms, the subsequent aversion to X may be even more pronounced (i.e., enhanced augmentation).

Furthermore, as we will describe in more detail later, the number of compound conditioning trials was also included as a possible candidate because some theoretical models of associative learning (Mackintosh, 1975; Pearce & Hall, 1980) predict blocking is only possible after two or more compound conditioning trials, whereas the Rescorla–Wagner (1972) model predicts blocking after a single compound trial. Therefore, to determine if trial number was the crucial factor in the transition from augmentation to blocking, the number of A+ preconditioning trials was manipulated in Experiment 1 and the number of AX+ compound conditioning trials was manipulated in Experiment 2.

Experiment 1

Experiment 1 explored whether increasing the number of A+ trials in the A+ → AX+ design with two flavor stimuli would produce blocking or augmentation. One procedural challenge of increasing the number of A+ conditioning trials is that taste-aversion learning is so robust the rat may not sample the flavors on later trials. Initially, we conducted a pilot study using a very weak concentration of lithium chloride (0.03 M), but many rats were already avoiding consumption of the flavor after only 2 conditioning trials. As it was preferable to use an US that produces an even weaker intensity of illness, we chose to use rotational stimulation. The properties of taste aversions produced via rotation have been shown to be similar to flavor aversions produced by lithium (e.g., Batsell & Pritchett, 1995; Braun & McIntosh, 1973; Elkins, Walters, Harrison, & Albrecht, 1990; Green & Rachlin, 1976; Haroutunian & Riccio, 1975; Hutchison, 1973), and both rotation and lithium appear to activate the same brainstem regions that mediate taste-aversion learning (Sakai & Yamamoto, 1997).