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Perceptual Learning in a Human Conditioned Suppression Task

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The present experiment demonstrated a "perceptual learning" effect found in the animal literature with human participants. The common finding in animal work is that intermixed exposures to two stimuli prior to conditioning facilitates their subsequent discrimination on a generalization test more than the same amount of exposure to the stimuli in a blocked arrangement. The method was a suppression task implemented in a video game. Participants learned to suppress a baseline response (mouse clicking) when a colored sensor (i.e., CS) predicted an attack (i.e., US). First, prior to conditioning, they received either intermixed pre-exposures to two sensor CSs, blocked pre-exposures, no pre-exposures, or pre-exposure to the individual visual elements of the CSs. Second, in conditioning, one of the sensor CSs was paired with an attack US. Finally, generalization of suppression to the other sensor CS was assessed. Pre-exposures to the sensor CSs reduced generalization relative to no-exposure at all, with intermixed pre-exposures producing the greatest reduction in generalization. The importance of the present work is that it reduces the possible idiosyncrasy of existing results with humans that used evaluative-conditioning methods by demonstrating the effect with a method that has been used to reproduce a variety of associative-learning phenomena and is easily amenable to associative-learning explanations.

Perceptual learning implies, as Fahle (2002) discusses, an improvement in discrimination between stimuli that could not be discriminated by the organism before the learning experience. As recently outlined by both Hall (2009) and Mackintosh (2009), it is an area of research with two traditions within it; one with humans and the other with animals. These two traditions use very different methods to approach what is assumed to be a common phenomenon. Research in perceptual learning with humans predominately uses simple verbal reports to measure the ability of participants to discriminate. Examples include "same/different" tasks where people are simply asked to respond whether pairs or sequences of stimuli are the same or different (e.g., Mitchell, Kadib, Nash, Lavis, & Hall, 2008; Mundy, Honey, & Dwyer, 2009), vernier discriminations where participants report whether one line is to the left or right of another (e.g., Crist, Kapadia,Westheimer, & Gilbert, 1997), and motion detection tasks such as where participants report whether or not there exists coherent motion among moving dots (e.g., Watanabe, Náñez, & Sasaki, 2001). The idea is very simple: If participants' self-report is accurate, then it is inferred at face value that their perception has been altered as the result of some experience.

With the absence of self-reports, animal research must use variables that rely on overt behavior. Taste-aversion procedures are the most common example. A rat may receive a particularly flavored solution (e.g., a mixture of quinine and lemon, generically referred to as AX) which is paired with lithium chloride-

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induced illness during a conditioning phase, producing an aversion to the flavor. When tested with an arguably similar flavor (e.g., salt and lemon, generically referred to as BX, with X representing the elements of the stimuli that are common), the animals reject the new solution as if it were the same as that paired with the illness. Behaviorally, they do not discriminate between the flavors.

If the stimuli are simply pre-exposed by being presented without consequence before conditioning occurs, the generalization observed between those stimuli on test presentations following conditioning is reduced (e.g., Symonds & Hall, 1995). Rats are more likely to consume the test flavor which was not paired with poison when the flavors have been pre-exposed than when they have not. Such a reduction in generalization in the taste-aversion procedure has been termed "perceptual learning" (see Hall, 1991, for review). Although these types of reduction in generalization are termed perceptual learning, research with animals tends to be uncommitted as to whether the changes in behavior are the actual result of changes in perception (Mackintosh, 2009).

Perhaps due to the wide variety of tasks used, research with humans has been criticized as leading to the development of "specialized mini-theories, devised solely to explain the effects seen in a particular experimental paradigm" (Hall, 2009). Research in perceptual learning with animals, on the other hand, is largely opposite of that with humans. Research in perceptual learning with animals has led to theories of expansive scope and applicability that have been derived in large part from the taste-aversion procedure with rats. The two predominant theories are those of McLaren and Mackintosh (2000) and Hall (2003).

The development of these theories has been greatly influenced by the usual finding in an animal experiment (e.g., Symonds & Hall, 1995; but see Sanjuan, Alonso, & Nelson, 2004) that intermixed pre-exposure to stimuli across multiple trials (e.g., AX,BX,AX,BX) reduces generalization more so than the same amount of exposure to the stimuli presented in blocks across trials (e.g., AX, AX…| BX, BX…). An aversion conditioned to AX after an intermixed schedule of pre-exposure generalizes less to BX on test than if AX and BX were pre-exposed in blocks of trials.

The difference in generalization that is produced by these two schedules of stimulus pre-exposure has been of importance in the development of the two theories mentioned above. Each follows the common assumption (e.g., Estes, 1955) that all stimuli are essentially compound stimuli, stimuli that are composed of many simpler elements. Thus, it is possible for any two stimuli (e.g., AX and BX) to be composed of elements that are unique to each (i.e., A and B) and elements that are common to both (i.e., X). When AX is conditioned, both A and X elements come to control the response. Apparent generalization will be observed on a test with BX by way of the conditioning that accrued to the X elements.

One common outcome of simple stimulus pre-exposure is that it reduces the ability of the stimulus to enter into future associations with other stimuli, the well-known latent-inhibition effect (Lubow, 1973), which is one of two important factors in the theory of McLaren and Mackintosh (2000). Exposure to AX and BX should cause latent inhibition to accrue to A, X, and B. Notice that X is experienced twice as often as it is present each time either A or B is present, and should accrue more latent inhibition. Thus, when the aversion is conditioned to AX, it is predominately controlled by A. Excessive latent inhibition prevents X from being conditioned, resulting in less generalization to BX.

Not only should presentations of AX and BX allow latent inhibition to be acquired, according to McLaren and Mackintosh (2000) those presentations should allow A, X, and B, to enter into associations with each other. A and X should become associated so that each could evoke a representation of the other (e.g., Holland, 1981), as should B and X. As these associations develop, X should be able to evoke associative representations of both A and B, yet B is physically absent on trials with A, and A is physically absent on trials with B. Procedurally, some aspects of these presentations mirror Pavlov's (1927) conditioned-inhibition design where X can be thought of as a signal for A (X→A) but not with B (XB → NO A) and vice versa. Accordingly, McLaren and Mackintosh (2000), suggested that those conditions should allow for the development of inhibition between A and B such that potentially evoked representations of A are suppressed when B is present, and vice versa. On a test with BX following conditioning of AX, X might otherwise retrieve a representation of the well-conditioned A, promoting generalization, but that capacity is inhibited by the presence of B.

It is this inhibition mechanism that is assumed to allow for intermixed pre-exposures to produce less generalization than blocked pre-exposures. The intermixed pre-exposures of AX and BX supposedly allow the associations between A and X and B and X to be maintained better than in a blocked sequence. When the stimuli are pre-exposed in blocks, a long run of AX, for example, will allow the extinction of the association between B and X, reducing the ability of inhibition between A and B to form. With these associations maintained through the intermixed arrangement, inhibition is more likely to develop (see Mclaren & Mackintosh, 2000, for a full exposition).

The theory of Hall (2003) is similar in that it makes assumptions (though different ones) about the *associative learning* that takes place among the elements which constitute stimuli. The details need not be considered here as the present work does not contrast these theories. Rather, the important point in this discussion is that like that of McLaren and Mackintosh (2000), the effects of pre-exposure on generalization are thought to rely on associations established between stimulus elements that may, or may not, alter perception. However, these associations do alter the way in which stimuli enter into associations with other stimuli (such as unconditioned stimuli, or USs) and control overt behavior on a generalization test. These theories are not particular to perceptual learning effects. They are general theories of associative learning and any supposed principle discovered through research on perceptual learning type phenomena should be generally applicable to other phenomena as well.

With the void between research with animals and humans on the issue of perceptual learning, there has been interest in demonstrating the intermixed/blocked pre-exposure effect found in animal learning with humans, and further assessing the adequacy of associative learning accounts within human perceptual learning. Recent work has demonstrated that effect. In those reports, participants received either intermixed or blocked pre-exposures to AX and BX where AX and BX were complex checkered patterns on a computer screen that consisted of largely identical elements (i.e., X) with some small portion that were distinct (i.e., A and B). Participants were then presented with these stimuli sequentially and asked to respond on a keyboard whether the one they were viewing was the same or different as one just presented, or they might be required to press a key indicating whether what they just encountered was an AX stimulus or a BX stimulus. Some of these studies were without feedback (Mitchell, Kadib, Nash, Lavis & Hall, 2008; Mitchell, Nash, & Hall, 2008). Some were explicit discriminations (Lavis & Mitchell, 2006; Mundy et al., 2009) where the participants received feedback as to the correctness their response. These studies have successfully demonstrated that intermixed pre-exposures do appear to enhance people's ability to discriminate between stimuli more than blocked pre-exposures.

While such tasks might be assumed get at the issue of perception more directly, we wonder how well they can, at present, be used to expand or assess associative learning theories developed from animal learning that are based largely on generalization tests. In a generalization test with animals, a response is conditioned to one stimulus, and generalization is inferred from similar responding to other stimuli. While a same/different task may be affected by generalization, the task itself does not mirror the type of generalization tasks in the majority of the animal research. Responding "same" and "different" does not necessarily require that the stimuli be associated with any particular response-inducing outcome, thus their sufficiency as tools for using human participants in the assessment of the afore-mentioned theories is unclear. As Mundy, Honey, and Dwyer (2007) point out, stimuli may be perceived as different, yet associations can still exist between them. Such associations can influence apparent generalization. Comparatively, same-different tasks do not parallel the types of generalization tasks used in animal studies. Indeed, precious little is known, or explicitly assumed, about how classic associative mechanisms (e.g., latent inhibition, conditioned inhibition, excitation) might translate into introspective judgments. Thus, for using humans to investigate factors derived from theories of animal learning it should be efficacious to use behavioral methods that are modeled in some way after tasks developed in animals.

Two studies used a generalization task with humans that had parallels with those used in the majority of the animal studies. These two used the same method, thus there is presently little variety in methodology. Drawing on the taste-aversion procedure extensively used with rats, Dwyer, Hodder, and Honey (2004) as well as Mundy, Dwyer, and Honey (2006) have demonstrated the effect in humans using flavors. During the pre-exposure phase in these studies, participants would receive either intermixed or blocked pre-exposures to 5-ml mixtures of saline (e.g., A) and lemon (X) or sucrose (e.g., B) and lemon (saline and sucrose were counterbalanced as A or B). These pre-exposures were followed by conditioning where participants received pairings of AX with a bitter substance designed to alter how "pleasant" they perceived AX to be. On a generalization test with BX, they found that pleasantness ratings for BX, obtained on a Likert scale, were higher (less generalization) in a group that received intermixed pre-exposures than in a group that received blocked pre-exposures.

These results are promising, but it is important to consider that the method employed in the two studies just discussed was an "evaluative conditioning" method (e.g., Bayens, Crombez, Van den Bergh, & Eelen, 1988) where the extent to which people presumably like a stimulus is changed by pairing that stimulus with an otherwise pleasant or unpleasant event. That method alone is not without controversy regarding the mechanisms of action. Questions have been raised as to whether such conditioning occurs, or if conditioning-like effects could be an artifact in the absence of between-subject controls (no controls for conditioning were included in Dwyer et al., 2004 and Mundy et al., 2006). The procedure has also been questioned as to whether such changes in likeability represent a form of associative learning, and whether such changes can undergo extinction. In short, with "evaluative conditioning" the boundary conditions under which it is observed and general applicability to other presumed forms of associative learning are relatively vague (for a review of these issues, see Baeyens et al., 1988; Baeyens & De Houwer, 1995; Davey, 1994; De Houwer, Baeyens, & Field, 2005).

A further evaluation of the intermixed/blocked effect in other human generalization tasks that bear parallels with animal procedures is not unwarranted. As with any evaluation of an effect using different techniques, such an evaluation helps to further establish the effect's generality. Given that theories of perceptual learning derived from animal research are increasingly being extended to research with humans, another important role of this evaluation is that it will establish additional techniques with which the effect might be investigated. Using techniques that parallel those used in animal learning from which associative learning explanations have been derived should facilitate the extension of associative learning interpretations to the human condition.

In the present experiment we sought the effect using a method where conditioning in humans has been robustly and reliably observed (e.g., Nelson & Sanjuan, 2006; 2008; for a conceptually identical task see Arcediano, Ortega, & Matute, 1996). The method was a conditioned-suppression task implemented in a video game designed to explicitly parallel conditioned-suppression (e.g., Estes & Skinner, 1941) tasks with rats (see Arcediano, Ortega, & Matute, 1996, for additional discussion). In rats, a baseline of lever pressing was established by reinforcing the lever presses on a variable schedule of reinforcement. On this baseline, CSs and USs were presented, with the US typically being a mild electric shock. As the association between the CS and US was acquired, the rats begin to suppress their responding in preparation for the upcoming shock (e.g., freezing, Bolles, 1970).

In the game, a baseline of responding was established by having participants fire torpedoes at an onscreen spaceship by clicking the standard left button on a computer mouse, earning points on a variable-ratio schedule. On this baseline CSs, in the form of colored sensors, and USs, in the form of an inescapable attack from the onscreen spaceship, could be presented. The attack left the participant's own "spaceship" drained of power and the participant unable to continue the game for a period of time until the power was replenished. Though we did not systematically record their verbal self reports, post-experiment conversations with participants in previous studies supported the assertion that the attacks were frustrating, and at the very least annoying. Behaviorally, participants learned to suppress their own torpedo firing during the presentation of the CSs to conserve power immediately before an attack to be better prepared for the attack (see method for details). In both the rat and human case, a baseline of responding was suppressed in the presence of stimuli that predicted an event with some presumed degree of emotional consequence.

There has been no controversy with this method as to whether it involves associative learning mechanisms. The method has been used to demonstrate associative learning phenomena such as latent-inhibition (Nelson & Sanjuan, 2006). Nearly identical methods have been used to demonstrate "blocking" (Arcediano, Matute, & Miller, 1997), recovery of extinguished responding following a context switch (e.g., Neumann, 2006), and occasion setting (e.g., Baeyens et al. 2004; 2005). Thus, the method is not one that is largely isolated to demonstrating perceptual learning as the tasks developed by Lavis and Mitchell 2006; Mitchell, Kadib et al., 2008; and Mitchell et al., 2008) could be considered.

We conducted two experiments, each with three groups. The procedures for two of the groups across experiment were identical. The procedures in the third groups did vary (discussed in the next paragraph), but the third groups never differed in their behavior. Thus, for conciseness, we present the two experiments here as one experiment with a replication (the second experiment being a replication of the first). In both, CSs were presented in the form of compound stimuli by illuminating a sensor at the bottom of the screen with two colors consisting of yellow and green, or blue and green, which were counterbalanced as AX and BX. The US was the attack from the onscreen spaceship.

The design of the experiment is shown in Table 1. Training was divided into three stages: pre-exposure, conditioning, and a generalization test. During pre-exposure, Group Intermixed and Group None received different treatments, but the same treatment in each group across the first experiment and the replication. In both the experiment and the replication, Group Intermixed received four intermixed pre-exposures to each AX and BX alone where these stimuli simply appeared without consequence. Each presentation represented a trial, and trials were separated by a short inter-trial interval (i.e., AX, BX, AX, BX, AX, BX, AX, BX). In both the experiment and the replication, Group None played the game for the same total amount of time during this period without any stimulus presentations. In the experiment a third group received exposure to the stimulus elements that made up the compounds separately (A, X, B, X, A, X, B, X, A, X, B, X, A, X, B, X) with the number of exposures to A, B, and X equated with Group Intermixed. In the replication participants received pre-exposure to the compounds in a blocked schedule (AX, AX, AX, AX, BX, BX, BX, BX), which also equates the number of exposures to A, B, and X with Group Intermixed. In neither of these latter groups should inhibition between A and B develop, and both groups received the same amount of exposure to X, thus they should accrue the same latent inhibition and, in theory, be functionally equivalent. These latter two conditions never differed behaviorally and were referred to collectively as “Group Other.”

In all groups, the pre-exposure phase was followed by the conditioning phase. In the conditioning phase, the sensor CS representing AX (either blue and green or yellow and green, counterbalanced) was paired with an attack US across a series of trials. The CS would appear for five seconds and its termination was concurrent with the attack.

Table 1
Design of experiment.

Group		Pre-Exposure	Conditioning	Test
Intermixed		AX,BX,AX,BX,AX,BX,AX,BX		
None		---------------		
Other	Elements	A,X,B,X,A,X,B,X,A,X,B,X,A,X,B,X	AX+	BX-
	Blocked	AX,AX,AX,AX,BX,BX,BX,BX		

Note: AX and BX were multi-colored sensors in a video game. The position of AX and BX in the pre-exposure sequence was counterbalanced. ‘+’ and ‘–‘ represent an attack from an onscreen spaceship in the game, or not, respectively.

After the conditioning phase, all groups received a generalization test. On the generalization test the sensor CS representing BX was presented four times in extinction. That is, the sensor CS was illuminated for five seconds on each trial, but no attack occurred. Both the theory of Hall (2003) and McLaren and Mackintosh (2000) predict here that pre-exposure would reduce generalization, with the intermixed pre-exposure producing the greatest reduction. In McLaren and Mackintosh’s terms, generalization should be reduced because of latent inhibition accrued to the X portion of the stimuli, with intermixed pre-exposures producing the largest reduction in generalization due to both latent inhibition to X and mutual inhibition between A and B.

Method

Participants

Undergraduate university students (62) predominately between the ages of 18 – 22 (65% female) participated for course credit across the experiment and the replication, with different participants in each. Credit could be obtained through non-research activities, thus their participation was voluntary.

Apparatus

We used the same video-game apparatus as previously published in Nelson and Sanjuan (2006; 2008), and provide the description they used here (with permission) with minor modifications. Instructions were used that informed participants that they were playing a game where clicking a mouse earned points by shooting torpedoes at a spaceship. They were informed that they would be attacked and that attacks would drain their power, leaving them unable to continue until recharged. Participants were informed that attacks could not be avoided, but that they could prepare for attacks by suppressing their rate of torpedo firing (conserving power, resulting in less of a drain) when they were about to be attacked, which would prevent them from being offline for long periods of time. They were told that sensors would appear that might help them in the game, but were told neither what the sensors would indicate nor how they could be helpful. The exact instructions were those reported in detail in Nelson and Sanjuan (2006).

The video game was viewed on a standard computer monitor where an image was presented as if the participant was sitting inside of a spaceship looking out of a viewscreen (images available in Nelson and Sanjuan, 2006; 2008). A box appeared at the top of the screen where the word “Points” appeared in yellow. At the bottom of the screen five black ovals were continually present that were each 3.28 cm in diameter. The third was centered from left to right and the other four ovals were spaced at intervals of approximately 2 cm to the left and right of the center oval. A colored background (Hubble Space telescope photo of the Eagle 1 nebulae) could be seen through the viewscreen on which a 3-dimensional representation of a spaceship was flying in a randomly determined path.

All conditioned stimuli (those pre-exposed, conditioned, and/or tested) were the 5-s illumination of the middle oval. During these illuminations, the oval appeared predominately one color, with the left edge appearing as a different color. Stimuli were composed of the elements X, A, and B. X was the illumination of 97% of the oval from the right to the left with the color green. Elements A and B were created by illuminating the remaining 3% of the oval (left most side) with either blue or yellow (A or B, counterbalanced). AX and BX were presented by illuminating the portions corresponding to A or B, and X. When A, B, or X were presented alone, the other portion of the oval remained black. When not lit, the oval remained black.

The “unconditioned stimulus” was an inescapable attack from the enemy spacecraft. On the offset of a sensor stimulus, the attack consisted of the emergence of a small, round, green torpedo from the rear of the spaceship that moved to the center of the screen where it grew larger until it exploded. The length of the sequence varied depending on the position of the spaceship on the screen, with the sequence being longer as the distance of the spaceship from the center increased. Nevertheless, the entire sequence was between 1 and 1.5 seconds regardless of the spaceship’s position.

Concurrent with the explosion, the message, “Power at___ percent. Controls Frozen for ____ seconds.” appeared in the center of the viewscreen and remained until “Power” incremented to 100 and “Controls Frozen for ____” decremented to zero (changes occurring roughly every second). During this time, the computer mouse was inoperable and actions of the participant were not reflected on the screen. The numbers in the blanks above were determined by a modified suppression ratio [CS responses / (Average pre-CS responses + CS responses)]. CS responses were simply the number of times the participant clicked the mouse during the CS, while the average pre-CS responses was the number of times the participant clicked the mouse in the five seconds immediately preceding the CS, averaged across all previous trials (including the current trial). The resulting ratio was then multiplied by 120. For example, if a participant clicked the mouse, on average, 10 times prior to the sensor CS and did not suppress their rate of mouse clicking the ratio would calculate to 0.5 and their controls would be frozen for 60 seconds by an attack. If they did suppress, then the ratio would calculate closer to zero and their controls would be frozen for less time, allowing them to resume the game more quickly. Participants were not informed of that relationship.

Procedure

The experiment was conducted with a replication, with minor changes to one group between the two runs. Except where specified in the treatment of Group Other in the pre-exposure phase, the two procedures were identical.

***Group assignment and startup*.** In each experiment, conditions were assigned to participants randomly. Each condition had an equal probability of being assigned to the participant with no attempt at equating group sizes. Participant by participant, a condition was selected from a canister, and replaced into the canister. Such a procedure prevents the potential non-random assignment of participants to conditions during events that might encourage participant participation (e.g., a class collectively doing poorly on a test and seeking extra credit). The results of the assignment are reported in the *Results*.

The experiment was conducted with participants in assemblies of 5 or fewer participants at a time. Those participants were distributed as widely as possible across a $16m^2$ room and instructed not to talk among themselves (no talking was evident during the experiment). Participants were seated at the computers, read and signed a consent form, and were given the instructions. They read the instructions to themselves, and then had the instructions read to them by the researcher. Participants were instructed to place their left hand on the "s" key and their right hand on the mouse. The lights in the room were dimmed, and they were instructed to press the "s" key, starting the game.

Pre-Exposure. During this phase, a trial was the 5-s presentation of one of the sensor stimuli (AX, BX, or A, X, or B separately) defined above, depending upon the group assignment. The inter-trial interval (stimulus offset to stimulus onset) was determined randomly and averaged 11.28 seconds.

All participants began by playing the game for 60 seconds with no stimulus presentations (neither CS nor US) occurring. During these 60 seconds, and throughout the game, they clicked the mouse on a schedule where a random one in three clicks launched a torpedo at the spaceship flying on the screen. A random half of those torpedoes exploded on the enemy spacecraft, adding a point to the point counter. The spacecraft was never destroyed to maintain continuity across the game.

Following the initial 60 seconds, pre-exposure began. Treatment of participants in Groups Intermixed and Group None was identical across the initial experiment and the replication. In Group Intermixed participants received eight trials that consisted of four alternating exposures to the AX and BX stimuli with the position of AX and BX in the sequence counterbalanced (AX,BX… or BX,AX…) between participants. Thus, Group Intermixed received a 5-s presentation of AX (or BX, depending on the counterbalance condition) while firing torpedoes at the spaceship, followed a short time later by a 5-s presentation of BX, and that sequence repeated four times. Participants in Group None simply played the game, firing torpedos at the spaceship, for the same total amount of time with no other events occurring.

In the first study participants in Group Other received 16 trials consisting of four alternations of the sequence A, X, B, X with the position of A and B in the sequence counterbalanced. Thus, they might receive, for example, a 5-s presentation of the yellow portion of the stimulus only (as defined in the apparatus section earlier) followed by a presentation of the green portion, followed by the blue portion, followed by the green portion and that sequence was repeated four times.

In the replication participants in Group Other received eight trials consisting of four trials with either AX or BX (counterbalanced) followed by four trials with the other stimulus. Thus, rather than receive a presentation of AX followed by a presentation of BX as in Group Intermixed, they received four pre-exposure trials all with one stimulus followed by four pre-exposure trials with the other.

Conditioning of AX. Conditioning consisted of 10 presentations of the AX stimulus with each followed by an attack US. The ITI (US offset to CS onset) averaged 11.2 seconds. The first conditioning trial began 11 seconds after the last pre-exposure trial.

Testing of BX. The BX stimulus was presented four times in extinction (no attack US was presented) with the first trial occurring 12 seconds after the last AX conditioning trial. The ITI on these trials averaged 11 seconds.

Data analysis

Data. The number of times the participant clicked the mouse during the 5-s CS and the 5-s preceding the CS was recorded on each trial. Standard suppression ratios [CS / (CS + pre-CS)] were calculated.

Exclusion criteria. Zero responses in the pre-CS, makes interpretation of the resulting suppression ratio difficult. We adopted Nelson and Sanjuan's (2006) procedure of excluding participants with an average response rate less than one click per second. Because detection of generalization depended on observing conditioning, we excluded participants for whom suppression ratios on either trial nine or 10 of conditioning were 0.4 or higher. A ratio of 0.5 indicates no change in behavior, thus the choice of a ratio of 0.4 allowed room in the response scale to see a change in behavior and was consistent with criteria we have used previously (Nelson & Sanjuan, 2008). Chi-square tests of independence were used to assess whether the exclusions were independent of the grouping variable.

Hypothesis tests. Suppression-ratio and pre-CS data were analyzed with mixed-factorial analysis of variance (ANOVA) using the typical Type III (unique and unweighted) sums of squares. Simple-effect tests were conducted with ANOVA using error terms and degrees of freedom derived from the overall analysis (Howell, 1987). Degrees of freedom were reduced using the Welch (1938) – Satterthwaite (1946) procedure to compensate for the pooling of potentially heterogeneous variances. Any effects associated with running portions the study at two different times in an academic year, including the procedural difference in Group Other, were assessed directly with multiple independent-samples *t*-tests. Throughout, a rejection criterion of $p < 0.05$ was adopted and exact probabilities are reported for the reader.

Results

Exclusion

Random assignment of volunteers to conditions led to 16 participants in Group None (ns = 9 and 7 in the first study and replication, respectively), 22 in Group Other (ns = 10 and 12 from the first study and replication, respectively), and 24 in Group Intermixed (ns = 10 and 14 from the first study and replication, respectively). Application of the exclusion criteria led to the exclusion of four participants from Group None, and five from each of the other two conditions, for a total of 14. Exclusion was independent of group membership, $\chi^2 < 1$.

Replication

We conducted *t*-tests between the first study and the replication within each of the three groups on each trial of conditioning and the test to directly assess the effect of replication trial by trial. Two of those 42 analyses suggested significance. On trial 2 (AX2 in Figure 1) suppression to AX may have been slightly less in Group Intermixed in the second replication (mean = 0.21) than in the first (mean = 0.06), $t(19) = 2.27$, $p = .04$. On trial 5 (AX5 in Figure1) within Group Other, blocked exposure appeared to have produced less suppression (mean = .35) than did exposure to the elements (mean = 0.09), $t(15) = 2.70$, $p = 0.02$. There were no other effects in the remaining analyses, *t*'s < 1.87. We concluded that these two tests reflected the two spurious effects one would expect to find after 42 comparisons with alpha at $p < 0.05$. The safest conclusion from this set of analyses was that replication (time of the study in an academic semester or both the time of the study and the procedural differences between the two conditions in Group Other) had no effect and it was subsequently ignored. Though they produced statistically identical data, the two conditions constituting Group Other are nevertheless presented separately in Figure 1 for the reader.

Conditioning

Suppression ratios. Data from conditioning are shown in Figure 1, left, above the AX1 to AX10 labels on the abscissa. Errors bars plus/minus one standard error are shown in the figure on the trials of most importance (the steady-state responding at the end of conditioning and where significant differences were found on the test); others were omitted to reduce clutter. An Exposure (Intermixed, Other, None) X Trials analysis of the 10 training trials showed an effect of Trials $F(9, 405) = 43.02$, $p < 0.001$, as suppression increased. There was a visual trend for acquisition to be somewhat slower in the conditions where stimuli were exposed, (compare AX1 – AX5 in Group None to the other conditions). However, that trend was not reliable: There was no effect of Exposure $F(2, 45) = 1.57$ and no interaction, $F(18, 405) = 1.57$, $p = 0.06$.

Pre-CS. The same analysis applied to the pre-CS response rates showed only an effect of Trials $F(9, 405) = 2.81$, $p = 0.003$. Responding increased from 14.68 (SD = 7.39) on the first conditioning trial to 16.54 on the last (SD = 6.78). There were no other effects, Fs < 1.

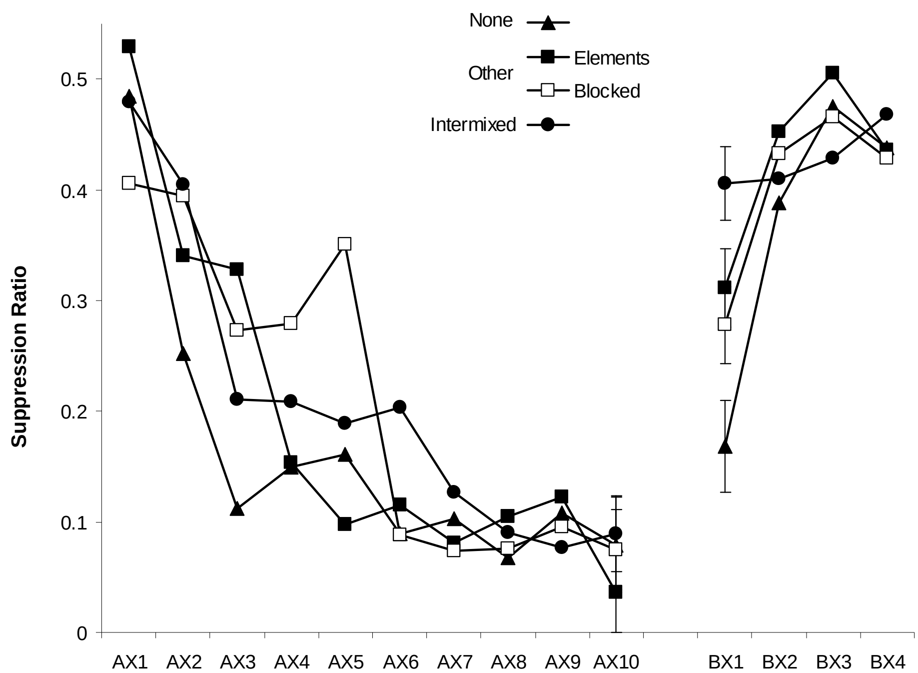

Figure 1. Suppression ratio data on each of the AX conditioning trials and BX test trials for groups that received Intermixed pre-exposures to AX and BX, None or some Other type of pre-exposure consisting of blocked pre-exposures to AX and BX, or pre-exposure to the A, B, and X elements. See text for details.

Generalization test

Suppression ratios. Data from the test are shown at the right in Figure 1 above BX1 – BX5 on the abscissa. An Exposure by Trials analysis of all four test trials showed an Exposure x Trials interaction, $F(6, 135) = 5.26$, $p < 0.001$. Simple-effect tests beginning at BX1 showed that Group Intermixed suppressed less than the other two groups, Fs$(1, 86) \geq 4.31$, ps ≤ 0.04. Group Other suppressed less than Group None, $F(1, 86) = 4.07$, $p = 0.047$. There were no other group differences on the remaining three trials, Fs $(1, 86) < 1.36$, ps ≥ 0.25.

Pre-CS. The same analyses applied to the pre-CS responses (mean = 16.33, SD = 6.38) found no effects, Fs < 1.

Discussion

In the present experiment human participants received conditioning with one stimulus, AX, and a generalization test with a similar stimulus, BX. In the absence of any pre-exposure to these stimuli, substantial generalization was observed. Exposure to the stimulus elements (A, X, B) or blocked exposure to the elements in compounds (AX,AX...| BX,BX….) reduced that generalization. Intermixed pre-exposure to the compounds (AX, BX, AX, BX) produced the largest reduction in generalization.

Reductions in generalization due to pre-exposure are predicted by associative theories of perceptual-learning due to the accumulation of latent-inhibition to the elements which comprise the stimuli, especially those elements in common to the stimuli which are exposed twice as often. Thus, after exposures to AX and BX, little associative strength should accrue to X when AX is conditioned. On a test with BX, there would be few, if any, conditioned elements in the stimulus and little generalization should be observed. Based on the accumulation of latent inhibition, the two conditions that constituted Group Other would be expected to show some reduction in generalization relative to a group which had received no pre-exposures whatsoever. All participants within this group received the same number of pre-exposures to X, and thus would not be expected to differ on the basis of accumulated latent inhibition. In the resulting data, Group Other showed less generalization than Group None, and there were no differences among the participants within Group Other.

Group Intermixed received the same number of pre-exposures to X, yet a greater reduction was expected in this group due to the operation of inhibition that might accrue between the unique A and B elements (see McLaren & Mackintosh, 2000). To the extent that X was associated with A, some associative representation of A might be present on test (e.g., Holland, 1981) and facilitate generalization. Such a representation should be suppressed by the mutual inhibition assumed to form between A and B during the intermixed exposures, further reducing generalization as was observed in the resulting data.

Aside from the efforts of Dwyer et al. (2004) and Mundy et al. (2006), previous demonstrations of this effect with humans have used tasks that do not necessarily parallel behavioral tasks found in animal learning. What we show here is a "perceptual-learning" effect with a method that was designed to parallel conditioned-suppression tasks in animals. The exact method has reliably produced conditioning and latent inhibition (Nelson & Sanjuan, 2006; 2008) and a near identical procedure has been widely used to study a variety of associate learning phenomena (e.g., Arcediano, Ortega, & Matute, 1996; Bayens et al., 2004; 2005; Neumann, 2006). Overall, the methodology is robust and straightforward. The stimuli that were discriminated and learned about by the participants were discreet and isolable (c.f. Mundy, Honey, & Dwyer, 2007). The effect we demonstrated involved generalization of conditioning that is easily amenable to associative learning interpretations. It expands the generality of the intermixed/blocked pre-exposure effect, as assessed with a simple generalization test in humans, beyond evaluative conditioning methods and it conceptually replicates other recent reports (see the introduction) which used tasks where the operation of associative mechanisms is more difficult to identify. The procedure was not designed specifically to assess the effect of perceptual learning manipulations. Conclusions regarding associative learning derived from future investigation of perceptual learning phenomena with this method should generalize to other phenomena.

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