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Blocked and test-stimulus exposure effects in perceptual learning re-examined

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Abstract

Three experiments re-examined the effects of blocked or alternated exposure to the conditioning and test stimuli and the effect of simple exposure to the test stimulus, on stimulus generalization. In all experiments rats received conditioning where a compound flavor, AX, was paired with LiCl-induced illness. All rats were tested for generalization with another flavor, BX. In Experiment 1, rats that received alternating exposure to the two flavor compounds, AX and BX, prior to conditioning showed less generalization to BX than rats that received no exposure. Exposure to BX or AX alone was also somewhat effective in reducing generalization. In Experiment 2 blocked exposure to AX and BX prior to conditioning was effective in reducing generalization, as was alternated exposure, and extended exposure to BX was more effective than the other procedures. In Experiment 3, exposure to X alone prior to conditioning produced generalization equal to that produced by alternated or blocked exposure and replicated the effect of extended exposure to BX found in the previous experiment. The relevance of the results to the theories proposed by McLaren and Macintosh [Anim. Learn. Behav. 28 (2000) 211] and Hall [Q. J. Exp. Psychol. B 56 (2003) 43] is discussed.

Keywords: Perceptual learning; Latent inhibition; Generalization; Rats; Blocked exposure; Intermixed exposure

Stimulus generalization is a well accepted phenomena of conditioning. When a response to one stimulus is acquired, similar stimuli will also tend to produce the response. For example, Honey and Hall (1989) conditioned an aversion in rats to one flavor, A. Later, when tested with B, the aversion generalized. The animals were less likely to consume B as the result of the aversion conditioned to A. To explain generalization of this sort, it is widely assumed that stimuli are multi-faceted and made up of many elements which may, or may not, be sampled or activated during any particular exposure to a stimulus (e.g. Estes, 1950; cf. Wagner, 1981). Generalization is assumed to result from the stimuli having some portion of these elements in common. In the Honey and Hall (1989) example above, the flavors A and B can be thought of as stimulus complexes made up of some elements unique to A and B, and some that are common to both (e.g. X). Thus, the stimuli might be represented as AX and BX. When an aversion is conditioned to AX, the responding that appears to be elicited by BX is thought to result from the conditioning of the X elements that are common to AX and BX.

Another source of generalization can result from what is referred to as within-compound associations (e.g. Rescorla and Cunningham, 1978). Briefly, during conditioning of AX, it is possible that the animals associate each of the sets of elements, A and X, with

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the US. It is also possible that associations are formed within the stimulus compound such that A and X are associated with each other. The result of this association is that presentations of X may retrieve some associatively activated representation of the A elements. Thus, on test with BX, generalization can now result from two sources. First, as discussed above, some aversion will result because of the direct conditioning of X. Now, X might also activate a chain of associations (see Ward-Robinson and Hall, 1996) leading to the US resulting in a further expression of the aversion. By way of the within-compound association X could retrieve a representation of A which is itself associated with the US, increasing the aversion observed to BX. This latter source of generalization is referred to as "mediated" generalization. It is generalization that is theoretically mediated by within-compound associations (see Hall, 1996, for further discussion).

Interestingly, generalization is not static. Exposure to the stimuli prior to conditioning has the effect of reducing generalization between them. Consider another condition in the Honey and Hall (1989) experiment mentioned above. In this condition, rats were exposed to the flavors A and B prior to conditioning with A. When tested with B, there was less generalization than in animals that had not received pre-exposure. The rats that had been exposed to the flavors prior to conditioning showed less of an aversion to B. Generalization was reduced as a function of prior exposure to the stimuli. It is this reduction in generalization that results from previous experience with the stimuli that we refer to as perceptual learning (for a thorough review see Hall, 1991).

One powerful explanation for the generalization-reducing effects of the pre-exposure, that maintains consistency with the common-elements explanation for generalization itself, involves latent inhibition. Exposure to a stimulus prior to conditioning is widely known to result in a decreased ability of the stimulus to serve as conditioned stimulus (CS). That is, when a pre-exposed CS is paired with an unconditioned stimulus (US), conditioned responding is slow to emerge. This "latent inhibition" of conditioned responding is commonly thought to be the result of a decrease in the associability of the CS (e.g. Lubow, 1989). If generalization results from the conditioning of common elements, X, then any manipulation that would reduce conditioning of X should reduce generalization. Pre-exposure to A or B (i.e. AX and BX) would result in some latent inhibition to A, B, and X. However, when exposed to AX and BX, X is exposed twice as much as either A or B. Thus, relative to A and B, X should acquire more latent inhibition and condition very little, effectively reducing the generalization between AX and BX.

Latent inhibition alone cannot be the only mechanism that contributes to the generalization-reducing effects of pre-exposure. It would not affect the contribution of mediated generalization. To help explain how pre-exposure to the stimuli might reduce the contribution of mediated generalization McLaren et al. (1989) and more recently McLaren and Mackintosh (2000) have proposed that while pre-exposure to AX and BX results in latent inhibition to X, it also produces inhibition between A and B. Animals may form associations between A and X, and B and X such that when X is present, representations of A and B may also be active (i.e. the source of mediated generalization). However, A and B never occur together in pre-exposure thus they also serve as negative features for each other (X $\rightarrow$ *A*, BX $\rightarrow$ *no*, A|X $\rightarrow$ B, AX $\rightarrow$ *no* B) and become mutually inhibitory. In the generalization test with BX, B theoretically suppresses the representation of A, ordinarily retrieved by X, eliminating the source of mediated generalization (for further discussion see McLaren and Mackintosh, 2000).

Evidence most relevant to the current studies that a mechanism such as mutual inhibition between A and B can contribute to the generalization-reducing effects of pre-exposure has typically come from studies where the type of exposure is manipulated. One way that the stimuli can be pre-exposed is in an alternating fashion. During one session animals are exposed to AX, and the next BX, and so forth. This type of exposure would be ideal for producing mutually inhibitory associations between A and B. The effects of this type of alternated exposure are typically contrasted with the effects of blocked exposure where the animals receive all of their exposures to either AX or BX, and then all of their exposures to the other stimulus complex. The lack of alternation in the blocked exposure schedule should reduce the ability of inhibition to be formed between A and B, and result in more generalization between the stimuli than that produced by alternated exposure (Bennett and Mackintosh, 1999). Additional, more direct, evidence for this type

of inhibitory mechanism can be found in Dwyer et al. (2001) and Dwyer and Mackintosh (2002).

The issue that prompted the current re-examination of the effects of blocked and alternated exposure concerns the effects of blocked exposure. Blocked exposure should result in more generalization than alternated exposure, but it should still produce less generalization than no exposure at all. During the blocked exposure the common elements X should still theoretically acquire latent inhibition, reducing one major source of generalization. With this interpretation, a study that demonstrates the effectiveness of blocked exposure would not be a surprise. However, the efficacy of blocked exposure in reducing generalization is more of an assumption than a widely established fact. In studies that included a no-exposure control to assess the actual baseline of generalization, the results of blocked exposure in reducing generalization have been mixed. Symonds and Hall (1995) found that while alternated exposure reduced generalization more than blocked exposure, blocked exposure produced no observable reduction in generalization whatsoever. Other authors (Alonso and Hall, 1999) more recently have found that blocked exposure does reduce generalization as would be predicted by explanations for perceptual learning that incorporate latent inhibition.

The current experiments simply re-examine conditions where generalization between stimuli is reduced and relate the findings to existing theories of perceptual learning. In Experiment 1, we replicate, and extend, Symonds and Hall's (1995) common finding that alternated exposure to two flavors (AX and BX) reduces generalization between them. Our study shows, unlike Symonds and Hall (1995), that generalization is also reduced where it would be expected based on a latent-inhibition account. In Experiment 2 we assessed the effects of blocked exposure to the stimuli against a water control as well as groups that received alternated exposure or exposure to the test stimulus. In Experiment 3 the effects of exposure to the test stimulus and exposure to only the common elements (X) were compared.

1. Experiment 1

The goal of Experiment 1 was to replicate the first experiment of Symonds and Hall (1995) using a more thorough test. In that study, alternated exposure to two compound flavors reduced generalization of a conditioned aversion. No reduction was observed after exposure to only one of the flavors (AX or BX). In the current experiment generalization was tested more extensively in a series of five extinction tests. Thus, the first trial of the test provides the opportunity to replicate the basic findings of Symonds and Hall (1995). The repeated testing in extinction will extend their findings as it allows for responding to come out of a floor to reveal any differences that might not have otherwise been observed in their study. Beyond the extensive testing, the design and parameters used were the same as in the original study.

1.1. Method

1.1.1. Subjects and apparatus

Subjects were 32 experimentally naïve male Wistar male rats with a mean weight of 479 g. Rats were housed in individual cages with access to food ad lib. The cages were housed in a room with a constant temperature (23 °C), humidity (50%) and a 12 h-light:12 h-dark cycle with the light portion beginning at 8:00 am.

Solutions were delivered trough 50-ml graduated cylinders. Solutions consisted of mixtures of either 1% salt or 10% sugar (A and B, counterbalanced) with tap water. X was 1% hydrochloric acid (1 M). All percentages were calculated as weight of solution/volume of water.

1.1.2. Procedure

1.1.2.1. Water deprivation. The water deprivation regime began with the removal of the water bottles in the morning. Animals received 30-min access to fluids at 11:00 and 16:00 h throughout the experiment except where noted in the following. On the first 3 days water was delivered in both sessions. During experimental sessions described in the following the flavored solutions were delivered in the morning session and water in the afternoon session.

1.1.2.2. Pre-exposure. Groups were formed by matching subjects on water consumption based on the third day of the deprivation schedule. The

pre-exposure phase lasted 8 days. During this phase, animals had 30-min access to 10 ml of the solutions or water. Animals in Group I (intermixed) first received presentations of AX followed by BX on the alternate days for a total of four exposures to AX and four to BX. Animals in Group AX or BX received either AX or BX, respectively, on the same days as AX and BX were presented in Group I, and water on the alternate days for a total of four exposures to the corresponding stimuli. To assess the base level of generalization, Group W received water and no exposure to either AX or BX.

1.1.2.3. Conditioning. After pre-exposure animals received three conditioning trials, one every-other day, in the morning sessions of the next 6 days. On these conditioning days water was not available in the afternoon session. The trials consisted of the presentation of 10 ml of AX followed immediately by one intraperitoneal injection of lithium chloride (LiCl) 0.3 M at 10 ml/kg of body weight. Each conditioning trial was followed by a recovery day where animals had free access to water for 30 min in both the morning and afternoon sessions.

1.1.2.4. Generalization testing. Following the final recovery day, the animals received five test trials with BX over five consecutive days where the rats had unlimited access to BX in each 30-min session. Symonds and Hall (1995) only used one test trial thus the current study slightly extends their findings.

1.1.3. Data analysis

Data consisted of the milliliters of AX consumed during conditioning and milliliters of BX consumed during testing by the subjects. All data were analyzed with analysis of variance (ANOVA). All subsequent ANOVAs and pairwise *t*-tests were conducted using error terms and degrees of freedom derived by the pooling of the relevant terms from the overall ANOVA following the procedures outlined by Howell (1987, pp. 431–435). Any result with a probability of $P < 0.05$ was considered reliable, although, exact probabilities for the results of simple-effect tests where the null hypothesis was rejected are reported to allow the reader to monitor the probability of a Type I error.

1.2. Results

1.2.1. Conditioning

Acquisition of the aversion to AX is shown at left in Fig. 1. An aversion was acquired in all groups, but the rate at which that aversion was acquired differed between the groups with the aversion being acquired more slowly in groups that received pre-exposure to AX. A Group × Trial ANOVA confirmed this description revealing an effect of Group, $F(3, 28) = 6.77$; Trial, $F(2, 56) = 270.29$; and a Group × Trial interaction, $F(6, 56) = 4.78$.

1.2.2. Generalization test

The five generalization test trials with BX, shown at right in Fig. 1, were analyzed with a Group × Trial ANOVA. This analysis showed an effect of Group, $F(3, 28) = 11.03$; Trial, $F(4, 112) = 18.30$; and a Group × Trial interaction, $F(12, 112) = 5.83$. The pairwise comparisons show that the procedures each produced an orderly reduction in generalization (increase in consumption). No exposure (Group W) produced the most generalization and groups AX, BX, and I each produced progressively less.

Pairwise comparisons of each experimental group to Group W at each trial showed that Group I consumed more than Group W, on the first four trials, ts$(57) = 6.03$, 6.45, 4.23, and 3.67, Ps < 0.001 for trials 1 through 4, respectively. Groups I and W did not differ on Trial 5, $t(57) = 1.87$. Group AX differed from Group W on Trial 3, $t(57) = 2.89$, $P = 0.006$, but not on any other trial, largest $t(57) = 1.94$, Ps ≥ 0.06. Group BX differed from Group W on the first four trials, ts$(57) = 2.91$ ($P = 0.005$), 5.60, 3.85 (Ps < 0.001), and 2.70 ($P = 0.009$), for trials 1 through 4, respectively. There was no difference on Trial 5, $t(57) = 1.66$.

The next set of comparisons compared the groups on each trial. On Trial 1, Group I consumed more than groups AX and BX, ts$(57) = 5.28$ ($P < 0.001$), and 3.12 ($P = 0.003$), respectively. Group BX consumed slightly more than Group AX, $t(57) = 2.17$ ($P = 0.03$). On Trial 2, Group I consumed more than Group AX, $t(57) = 4.52$ ($P < 0.001$), but not Group BX, $t(57) < 1$. Group BX consumed more than Group AX, $t(57) = 3.66$ ($P < 0.001$). On trials 3, 4, and 5, groups I, AX, and BX, did not differ, ts$(57) \leq 1.91$, Ps > 0.06.

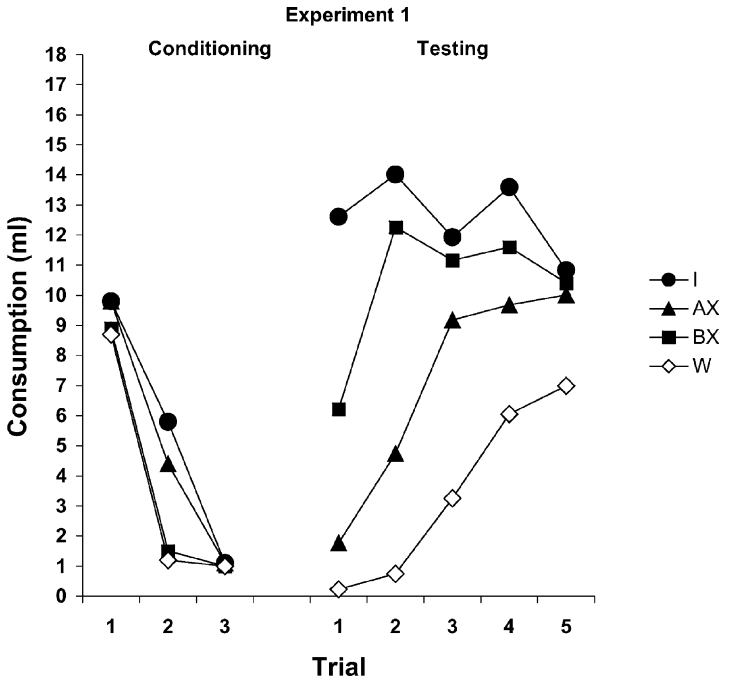

Fig. 1. Group names refer to the method and compound of pre-exposure (I: intermixed AX/BX exposure, AX: exposure to AX, BX: exposure to BX, W: water). Data from conditioning are shown at left where all groups received pairings of AX with LiCl. Generalization testing, shown at right, was conducted in extinction with BX.

1.3. Discussion

This experiment replicated and extended the findings of Symonds and Hall (1995). On the first test trial, results showed that alternated exposure to two flavor compounds, AX and BX, reduced generalization between them more so than exposure to only AX or BX. Unlike the findings of Symonds and Hall (1995) we found that exposure to BX produced a reduction in generalization. Also, exposure to AX was somewhat more effective in reducing generalization than was observed by Symonds and Hall (1995). Interestingly, exposure to BX was more effective in reducing generalization than exposure to AX. These results will be considered in more detail in Section 4.

2. Experiment 2

The results of Experiment 1 are consistent with the common assumption that latent inhibition is contributing to the enhanced discriminability observed after exposure to AX and BX. The findings also suggest that exposure to the test stimulus itself during AX/BX exposure may contribute to the increased consumption on the test. Experiment 2 examined the effects of blocked exposure (AX and then BX, or vice versa) which equates exposure to X to that obtained with intermixed exposure. In some experiments, this procedure has resulted in a reduction in generalization (Alonso and Hall, 1999), but not in others (Symonds and Hall, 1995). The experiment also examined the effect of exposure to BX more extensively and included a group that received eight exposures to BX that matched exposure to X with that of the other conditions.

2.1. Method

2.1.1. Subjects and apparatus

Subjects were 32 experimentally naïve male Wistar rats, with a mean weight of 479 g at the start of the experiment. Housing conditions, apparatus, and solutions were the same as the Experiment 1.

2.1.2. Procedure

As in Experiment 1, the animals passed through three phases: pre-exposure, conditioning, and test. With the following exceptions, the parameters were the same as in Experiment 1. Pre-exposure lasted for 4 days and subjects received the solutions in both the morning and afternoon sessions, at 10:30 and 16:30 h, respectively, following the procedure of Symonds and Hall (1995). Groups I (intermixed) and B (blocked) received presentation of the two compounds AX and BX but on different schedules of exposure. Group I received intermixed, alternated, exposure to AX and BX with AX being exposed in the morning and BX in the afternoon for a total of four presentations of each stimulus. Subjects in Group B received presentations of AX or BX (counterbalanced) in both sessions for the first 2 days, and the other compound on the last 2 days totaling four exposures to each stimulus. Group BX received exposure to BX in all sessions for a total of eight exposures. Group BX received the same exposure to X as in the other groups (eight) and four additional exposures to B. A control group, Group W, received water. Following pre-exposure all subjects received three conditioning trials with AX as in Experiment 1 followed by four extinction test trials conducted identically to the ones described in Experiment 1. Water was available in the afternoon sessions during generalization testing.

2.2. Results

2.2.1. Conditioning

The mean consumption of the AX compound in the different groups along the conditioning phase is shown at left in Fig. 2. The initial consumption of this compound in groups BX and W was somewhat lower than in groups I and B. A Group × Trial ANOVA showed effects of Group, $F(3, 28) = 4.99$; Trial, $F(2, 56) = 248.37$; and an interaction, $F(6, 56) = 2.90$. Simple-effects analyses showed that there were differences between the groups on the first two trials, Fs$(3, 78) > 3.3$, but not on the third, $F(3, 78) < 1$.

2.2.2. Generalization test

Data from the test trials are shown at right in Fig. 2. The test trials were analyzed with a Group × Trial ANOVA. The analysis revealed an effect of Group, $F(3, 28) = 11.75$; Trial, $F(3, 84) = 10.13$; and a Group × Trial interaction, $F(3, 84) = 5.43$. Group I differed from Group W on the first three trials, ts$(30) = 3.56, 3.94, 3.88$, Ps ≤ 0.003, but not on Trial 4, $t(30) = 1.17$. Group B differed from Group W on all four trials, ts$(30) = 3.39, 3.76, 3.17, 2.87$, Ps ≤ 0.007. Group BX differed from Group W on all four trials, ts$(30) = 2.71 (P < 0.02)$, 5.65, 6.29, and 5.15 (Ps ≤ 0.001). Groups I and B never differed from each other, ts$(30) \leq 1.67$, Ps ≥ 0.10. Group BX differed from groups B and I on trials 3 and 4, ts$(30) = 3.11$, 2.51 (Trial 3), and 3.99, 2.29, Ps ≤ 0.03 (Trial 4) but not on the first two trials, ts$(30) \geq 1.89$, Ps ≥ 0.07.

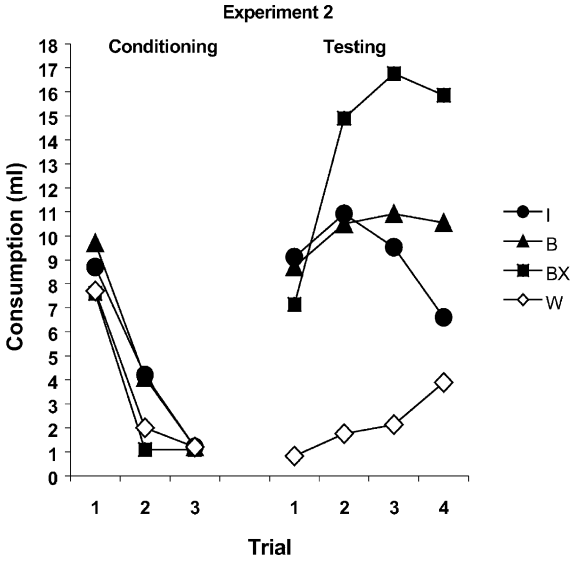

Fig. 2. Group names refer to the method and compound of pre-exposure (I: intermixed AX/BX exposure, B: blocked exposure, BX: exposure to BX, W: water). Data from conditioning are shown at left where all groups received pairings of AX with LiCl. Generalization testing, shown at right, was conducted in extinction with BX.

2.3. Discussion

When exposure to the common elements was matched, both blocked and alternated exposure to the stimuli produced a substantial reduction in generalization. The effect of blocked exposure in this experiment was so robust that no difference between the intermixed and blocked exposure procedures could be detected.

Interestingly, eight exposures to BX alone was minimally as effective as intermixed or blocked exposure to both compounds. Moreover, there was evidence on the last two trials that exposure to BX was more effective in reducing generalization than exposure to both the test and conditioning compounds.

3. Experiment 3

Experiment 2 provided needed evidence that blocked exposure to the stimuli affects perceptual learning, an effect not always been observed. Since these results help to clarify what are otherwise mixed findings, Experiment 3 was conducted to replicate the findings of Experiment 2, and directly assess the extent to which exposure to X, the common element, contributes to the magnitude of the observed discriminations. This experiment included three conditions, groups I, B, and BX, as in the previous experiment. The superiority in discrimination by these groups to a water control was established in the previous study, thus it was not included here. A fourth group, X, was included to assess whether the other conditions reduced generalization over and above simple exposure to the common element X.

3.1. Method

3.1.1. Subjects and apparatus

Subjects were 32 experimentally naive Wistar male rats with a mean weight of 355 g at the start of the experiment. All other conditions were the same as in the previous experiments. In the case of the X solution, the molarity of X was the same as in the compounds (0.01 M in the total solution).

3.1.2. Procedure

The procedure was the same as in the previous experiment. Group X was treated the same as Group BX, except that only the X solution was available during the sessions. Group I received four intermixed

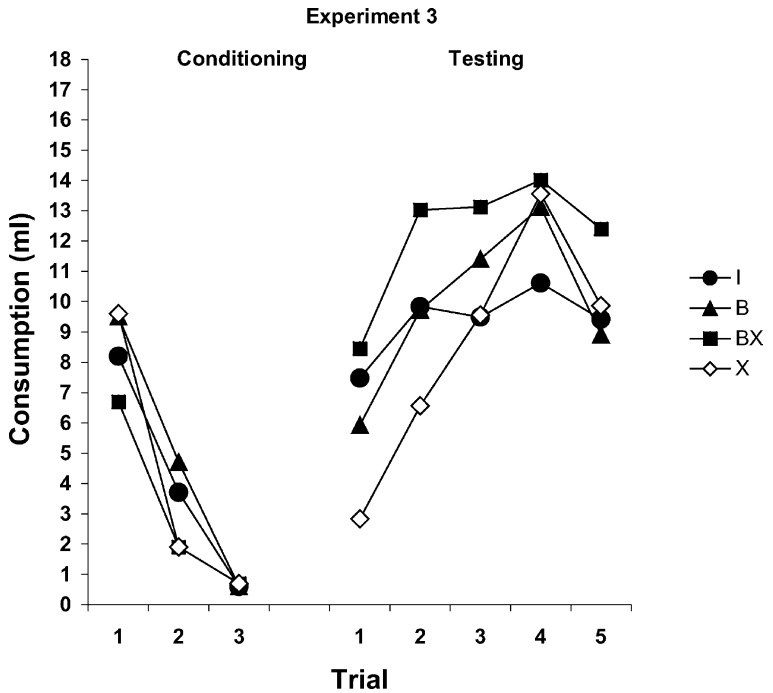

Fig. 3. Group names refer to the method and compound of pre-exposure (I: intermixed AX/BX exposure, B: blocked exposure, BX: exposure to BX, X: exposure to X alone). Data from conditioning are shown at left where all groups received pairings of AX with LiCl. Generalization testing, shown at right, was conducted in extinction with BX.

presentations of AX and BX. Group B received four blocked exposures to one compound (AX or BX, counterbalanced) and then the other. Group BX received eight exposures to BX. Group X received eight exposures to X. Testing was conducted as in the first experiment.

3.2. Results

3.2.1. Conditioning

Fig. 3, left, shows the amount of AX consumed by the subjects during conditioning. Consumption decreased over trials. However, the groups differed in their initial consumption of AX. Groups that received exposure to AX or X tended to consume more solution than did those that received exposure to BX. A Group × Trial ANOVA confirmed this impression. The analysis showed an effect of Group, $F(3, 28) = 2.90$; Trial, $F(2, 56) = 222.34$; and an interaction $F(6, 56) = 3.509$. Simple-effect tests showed that the groups differed on the first two trials, Fs$(3, 75) \geq 4.5$, but not on the third, $F(3, 75) < 1$.

3.2.2. Generalization test

Consumption of BX on the test trials is shown at right in Fig. 3. A Group × Trial ANOVA revealed an effect of Trials, $F(4, 112) = 23.03$, and a Group × Trials interaction, $F(12, 112) = 1.97$, $P = 0.03$. The effect of group was not reliable, $F(3, 28) = 1.16$. Simple-effect tests showed that consumption in Group BX was different than Group X on trials 1 and 2, ts$(30) = 2.30$ and 2.64, Ps $= 0.029$ and 0.01, respectively. There were no other group differences on these, or any other trials, ts$(30) \leq 1.90$, Ps ≥ 0.067.

3.3. Discussion

The results of this experiment demonstrate that the level of generalization between stimuli is similar when the exposure to the common elements is matched. In Experiment 2, both alternated and blocked exposure to the stimuli resulted in a reduction in generalization. Also, those groups did not differ in the extent to which generalization was reduced. Such a result, replicated here, suggests that the main component contributing to a reduction in generalization is exposure to the common element X. In this experiment, a group that received only exposure to X showed equivalent consumption of the test compound as did groups that received either alternated or blocked exposure to both the conditioning and test compounds.

4. General discussion

The goal of the current experiments was to re-examine some conditions where perceptual learning effects should occur, but have not. In these experiments, animals that had an aversion conditioned to a flavor compound AX, without any pre-exposure, showed a strong generalization of that aversion to BX (Group W in experiments 1 and 2). Animals that had received either alternated (e.g. Experiment 1) or blocked (Experiment 2) exposure showed much less generalization. Exposure to AX (Experiment 1) or BX (experiments 1–3) alone also reduced generalization, with exposure to BX being more effective. Exposure to X (Experiment 3) produced similar levels of generalization as alternated or blocked exposure. Interestingly, extended exposure to BX (experiments 2 and 3) was very effective in reducing generalization in the current experiments.

According to theories that incorporate latent inhibition to common elements as a mechanism by which generalization can be reduced, any exposure to the common elements should be somewhat effective in reducing generalization (e.g. McLaren and Mackintosh, 2000). In keeping with these theories, the results of the current experiments can be largely, but not entirely, explained with recourse to latent inhibition. In every situation where the common element was presented, generalization was reduced. However, there are interesting new findings that deserve discussion. We observed an effect of blocked exposure that was equal to that of intermixed exposure. While we do not have a definitive explanation for the lack of difference, we develop the idea that it is a function of the salience of the common elements. The current studies also showed that eight exposures to BX was more effective in reducing generalization than was intermixed or blocked exposure to both the conditioning and test compounds. Without going outside current theories, we show how this finding might also be due, in part, to the salience of the common elements.

During the blocked-exposure procedure, both AX and BX were presented, but the animals received all

of their exposures to one of the stimuli, then the other. As with intermixed exposure, X was presented twice as often as A or B, and should accrue the most latent inhibition effectively reducing generalization due to the conditioning of the common element X, but the contribution of mediated conditioning should still be intact. Because of the blocked exposure, the unique elements should not become fully mutually inhibitory. When animals receive presentations of BX, they may associate X with B. When they then receive presentations of AX, they may associate X with A. Early in the AX pairings, before any B–X association is extinguished, there is only a small opportunity for A to become inhibitory for B, and there is no opportunity for B to be inhibitory for A. In this condition, mediated generalization should still contribute to the aversion observed to BX, leaving latent inhibition to X as the main mechanism by which exposure to the stimuli produces an enhanced discrimination.

The ability of blocked exposure to reduce generalization, compared to a water control, has been somewhat controversial in that the results have been mixed. Symonds and Hall (1995) failed to find any reduction in generalization with blocked exposure, leading them to question the role of latent inhibition in perceptual learning. However, the current experiments corroborate the findings of Alonso and Hall (1999) which are consistent with the idea that latent inhibition plays a role. Both sets of studies show that blocked exposure can be effective in reducing generalization.

The blocked-exposure procedure unexpectedly produced as much reduction in generalization as intermixed exposure. Because blocked exposure only eliminates one source of generalization (conditioning of the common elements) and intermixed exposure theoretically eliminates two (conditioning of the common elements and mediated generalization), blocked exposure should not be as effective as intermixed exposure. The lack of difference between these conditions can be explained if we assume that the contribution of mediated generalization was minor relative to that of conditioning of the common elements in producing generalization. With a strong level of initial conditioning and a high level of generalization, perhaps due to salient common elements, conditioning of the common elements would be the major source of generalization and latent inhibition of those elements the major source of reducing that generalization. The results of Experiment 3 support this suggestion in that latent inhibition to X alone produced levels of generalization equivalent to intermixed or blocked exposure.

While only careful speculation, the cause of the differences in effectiveness of blocked exposure, compared to a water control, observed between Symonds and Hall (1995) and the current findings may be related to the observation that blocked exposure was just as effective as intermixed exposure in the current studies. Both observations may be a function of the amount of generalization obtained in the absence of any pre-exposure. In experiments 1 and 2 there was a very high level of generalization from AX to BX in Group W. The final level of consumption of AX measured in Group W was 1 and 1.2 ml for experiments 1 and 2, respectively. On the first session of generalization testing consumption of BX was 0.23 and 0.83 ml, for experiments 1 and 2, respectively, and increased gradually over testing in extinction. In short, the animals rejected BX to the same degree as AX. This high level of generalization contrasts with that observed by Symonds and Hall (1995). In the study of Symonds and Hall (1995) the final level of consumption measured in AX in Group W was roughly 1.7 ml in Experiment 1 and 0.8 ml in Experiment 2. Consumption of BX on the test was roughly 5.5 and 7 ml in experiments 1 and 2, respectively. In the study of Symonds and Hall (1995), animals consumed much more of BX than they were consuming of AX at the end of conditioning. Thus, there appears to be a great deal of generalization in the current studies, and much less in the study of Symonds and Hall (1995).

The current study used the same parameters as did Symonds and Hall (1995), thus, the difference in generalization obtained is unexpected. One contributing factor may be that both studies used tap water to mix solutions, rather than tasteless distilled water. Differences in the mineral and chlorine content of the tap water may have made the taste of the water, a common element, more salient. Strong initial conditioning supported by X would generate a high level of generalization, and leave room to see an effect of latent inhibition. If the common elements are salient then they might overshadow the unique elements and further limit the contribution of mediated generalization, decreasing the added efficacy of intermixed exposure.

Another interesting finding in the current studies is that exposure to the test stimulus, BX, was not only

effective (see also, Bennett et al., 1994) but was actually somewhat more effective than exposure to both stimuli. In Experiment 2 Group BX differed from both groups I and B. This difference could have been due to the differential exposure to the A element of the conditioning compound. Recall that A had been exposed during exposure to AX in groups I and B, but not in Group BX. This exposure might have resulted in latent inhibition accruing to A in these groups leaving it less able to compete with X for associative strength allowing some of the aversion to be controlled by X. In Group BX, the novelty of A would allow it to accrue the majority of the aversion, leaving X more neutral. The results of Experiment 3 make this explanation unlikely. In that experiment, Group BX differed from a group that had only been exposed to X. In these two groups, BX and X, the element A was equally novel. Therefore, these groups should not differ if the only factor contributing to the level of consumption of BX was the differential amount of latent inhibition accrued to A.

Based on the greater consumption of the test solution in Group BX, it seems that there is an additional mechanism contributing to the superior discrimination in Group BX. While Group BX received the same exposure to X as the other conditions, it received four more exposures to the actual test compound BX. It is possible that additional habituation of neophobia to B is what contributed to the level of consumption in that group. The eight exposures to only BX may allow the animals to form better representations of that stimulus itself via a mechanism such as that proposed by Sokolov (1969). This representation may allow the animals to recognize the stimulus on the test, resulting in less neophobia and more consumption of the flavor. It is not unreasonable to assume that such a mechanism could also aid the animals in discriminating AX from BX (fewer matches in the comparison) at the time of conditioning and testing resulting in less generalization.

An alternative explanation for the effect observed with BX is one recently offered by (Hall, 2003; see also Mondragon and Hall, 2002). In explaining perceptual learning (Hall, 2003; see also Mondragon and Hall, 2002) suggested that associatively activating a stimulus' representation may serve to make the actual presentation of the stimulus more effective (or at minimum restore its diminished effectiveness). During pre-exposure to AX and BX, B is absent on AX trials, but its representation is theoretically being retrieved due to the within-compound associations discussed earlier. These retrievals are thought to make the presentation of B more effective than it otherwise might be after exposure (Hall, 2003; see also Mondragon and Hall, 2002). Thus, on a test with BX the B element may be a functionally more salient stimulus than if the stimuli had not been pre-exposed creating more of a generalization decrement from AX to BX.

Applied to the current experiments, such an explanation accounts for the effect of exposure to BX alone relatively easily. The groups receiving only exposures to BX received more exposures to BX than the other groups. The result of such additional exposure (i.e. X → B pairings) might be to strengthen the presumed associations between B and X resulting in a particularly strong representation of B being retrieved during conditioning of AX, enhancing the effectiveness of the B element more than in the other conditions.

Hall's (2003) representation-modification account of perceptual learning effects may also have bearing on the lack of difference we observed between intermixed and blocked exposure. Hall's assumption is that intermixed exposure (AX . . . BX . . . AX . . . BX . . .) preserves the association between X and B on AX trials more so than blocked exposure where it can extinguish in a block of AX trials. Harkening back to the saliency of the common elements, if the common elements were especially salient that salience might result in strong inter-element associations. If so, then the effect of extinction during the block of AX trials might be minimal, allowing for the representation of B to continue to be retrieved, enhancing its ability to produce a generalization decrement on the test equal to that of intermixed exposure.

The current studies do not allow us to differentiate the precise mechanism that may be operating, but the findings are consistent with current theories of perceptual learning. These studies demonstrate that blocked exposure does affect perceptual learning. Although not a surprising result, there has been precious little evidence for the effect. From comparison with other studies that clearly questioned the contribution of latent inhibition in blocked exposure (e.g. Symonds and Hall, 1995; Symonds et al., 2002), the critical factor that determines when blocked exposure will be most effective may be the extent to which

generalization results from the conditioning of the common elements. The current studies also show that exposure to the test stimulus is effective in reducing generalization, perhaps as the result of forming either a distinct representation of the stimulus (e.g. Sokolov, 1969), or a particularly salient representation of the unique element (Hall, 2003).

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