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Differential Effect of the Intermixed and Blocked Preexposure Schedules on the Strength of Within-Compound Associations

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In Experiment 1, we demonstrated an intermixed-blocked effect where intermixed preexposure to a flavor compound and to an element of that compound (AX, X, AX, X . . .) reduced generalization between them more than equivalent blocked preexposure (AX, AX . . . X, X . . . , or X, X, AX, AX). Then we used sensory preconditioning (Experiment 2) and conditioned flavor preference (Experiment 3) procedures to assess the strength of the X-A within-compound association resulting from those preexposure schedules. In both experiments, we observed that the within-compound association was stronger after blocked than intermixed preexposure. We suggest that these differences in strength produce more mediated generalization in the blocked than intermixed preexposure.

Keywords: intermixed-blocked, perceptual learning, preexposure, rats, within-compound association

Experience with stimuli can change the way in which they are perceived. One example of this perceptual learning phenomenon is the observation that prior experience with two similar stimuli can improve the ability to discriminate between them (e.g., see Mitchell & Hall, 2014, for a recent review). To get a better understanding of the mechanisms involved in this sort of perceptual learning, researchers have attempted to determine which conditions of stimulus exposure are most optimal in enhancing stimulus discriminability (i.e., in reducing stimulus generalization). In this regard, the research related to the so-called *intermixed-blocked effect* has played an important role in the development and testing of different theoretical proposals. This effect is shown by the demonstration that intermixed preexposure to a pair of similar stimuli (e.g., A, B, A, B . . .) is more effective in reducing the generalization between them than an equivalent preexposure to the stimuli in separate blocks of trials (e.g., A, A . . . B, B . . .). The first demonstration of the intermixed-blocked effect was reported by Honey, Bateson, and Horn (1994) using visual stimuli and chicks as experimental subjects. However, almost all the subsequent research that has explored the nature of the effect in nonhuman animals has made use of the flavor-aversion learning paradigm with rats. The first demonstration of the effect using this procedure was reported by Symonds and Hall (1995, Experiment 2). In this experiment, rats were given preexposure to two compound flavors, AX and BX (where A and B represent unique features of the stimuli, sucrose and salt, and X represents an explicitly added common feature, a small amount of dilute acid) in intermixed trials (AX, BX, AX, BX . . .). Control subjects received an equivalent amount of preexposure to the stimuli, but in separate blocks (e.g., AX, AX . . . , BX, BX . . .). For all subjects, an aversion was then established to AX and generalization to BX was tested. Rats given intermixed preexposure showed less generalization between AX and BX than did those that received blocked preexposure. This intermixed-blocked effect has been replicated in numerous other studies using a variety of conditions (e.g., Artigas, Sansa, & Prados, 2006; Bennett & Mackintosh, 1999; Blair & Hall, 2003; Rodríguez & Alonso, 2004). And more recently, equivalent effects have also been demonstrated in a variety of human studies involving flavor (e.g., Dwyer, Hodder, & Honey, 2004), visual (e.g., Lavis & Mitchell, 2006; Mundy, Honey, & Dwyer, 2007; Nelson & del Carmen Sanjuan, 2009), and tactile (Rodríguez & Angulo, 2014) stimuli.

The nature of the learning mechanism (or mechanisms) responsible for the superiority of the intermixed over the blocked preexposure in enhancing stimulus discriminability is currently a matter of theoretical debate (for a recent review, see Mitchell & Hall, 2014). Some authors (e.g., Rodríguez & Alonso, 2004; Symonds & Hall, 1995) suggested that a *stimulus differentiation* process such as that proposed by Gibson (1969) might be a candidate. According to her nonassociative account, perceptual learning occurs because preexposure brings into play a differentiation process which enhances the attention paid to the distinguishing features of the stimuli. Gibson (e.g., 1969, p. 145) emphasized that this differentiation process would be particularly likely to happen under conditions promoting stimulus comparison. It seems reasonable to assume that stimulus comparison (and therefore stimulus differentiation) might be better promoted by presenting the stimuli in an intermixed rather than a blocked schedule. This account, however, has been directly challenged by the fact that some preexposure schedules in which the flavors to discriminate are presented concurrently (and which therefore should promote stimulus comparison even more) have been found to enhance, rather than decrease,

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stimulus generalization in rats (e.g., Bennett & Mackintosh, 1999; Rodríguez & Alonso, 2008; Rodríguez, Blair & Hall, 2008; but see the opposite result in studies with humans and visual, e.g., Mundy et al., 2007, 2009, and tactile stimuli, Rodríguez & Angulo, 2014). Other associative theoretical proposals have emphasized the role of superior salience of the stimulus unique features in the intermixed preexposure, but without appealing to stimulus comparison (e.g., Hall, 2003; McLaren, Kaye, & Mackintosh, 1989; McLaren & Mackintosh, 2000). Although these theories differ in many specific details, they all rely on the notion that intermixed preexposure can, by some means, enhance the relative salience of the unique stimulus features (and hence their discriminability) more effectively than blocked preexposure.

In the present series of experiments we attempted to test an alternative (or complementary) explanation to the salience modulation account. It has been widely assumed that preexposure to AX and BX allows the establishment of the X-A and X-B within-compound associations, and that these associations will constitute a source of mediated generalization between the preexposed stimuli (e.g., Bennett & Mackintosh, 1999; McLaren et al., 1989; McLaren & Mackintosh, 2000; Mitchell & Hall, 2014; Symonds & Hall, 1995). The X-A association will allow activation of A on the BX trials, and this might contribute to treating BX as being more similar to AX. Similarly, the X-B association will allow associative activation of B on the AX trials, which might contribute to AX being treated as more similar to BX. The intermixed-blocked effect could emerge because the contribution of mediated generalization on test performance may be less after intermixed than blocked preexposure. An account in these terms has already been suggested. It is the analysis of the effect that relies on the inhibitory mechanism proposed by McLaren et al. (1989). According to this analysis, the establishment of mutual inhibition between A and B during intermixed preexposure would attenuate mediated generalization (e.g., Dwyer, Bennett, & Mackintosh, 2001; Dwyer & Mackintosh, 2002). However, there could be an even simpler reason by which mediated generalization is less after intermixed than blocked schedule. It is possible that the within-compound associations are simply better established in the blocked than in the intermixed preexposure. The aim of the present experiments was to test this hypothesis because, to our knowledge, no study has yet examined this possibility.

To this end, we exploited an experimental procedure developed in our laboratory that has been shown to generate an intermixed-blocked effect (e.g., Rodríguez & Alonso, 2004, 2008; Rodríguez, Lombas, & Alonso, 2009; see also Hall et al., 2006). In this procedure, rats receive either intermixed or blocked preexposure to AX and X (rather than to AX and BX as was the case in the experiment by Symonds & Hall, 1995). Then, for all the rats, an aversion is established to X, and generalization to AX is tested. Rats given intermixed preexposure show more consumption of AX (i.e., less generalization between X and AX) than do those that receive blocked exposure. This demonstration of the effect is an ideal starting point for our present purposes. Obviously, the establishment of inhibition between B and A is not possible during the intermixed preexposure to AX and X (simply because B is not present). Having discarded any possible contribution of this sort of inhibition, we will be in a better position to examine whether the intermixed and blocked schedules generate within-compound associations of varying strength under the same conditions that produce the intermixed-blocked perceptual learning effect. There are theoretical grounds for expecting stronger within-compound associations after blocked than intermixed preexposure, derived from the Pearce and Hall (1980) model. Consider a series of simulations conducted using the amended version of this theory proposed by Pearce, Kaye, and Hall (1981). Although developed for classical conditioning, the algorithms of this model can be readily applied to the case of within-stimulus learning. A preexposure trial in which the AX compound is presented can be simulated as an effective conditioned stimulus (CS)–unconditioned stimulus (US) pairing (i.e., an X-A pairing), and a preexposure trial in which X is presented in isolation can be simulated as a CS-alone presentation.

We simulated the effects of the three reinforcement schedules. All of them included eight trials: four trials in which the CS (X) and the US (A) are paired (corresponding to those four trials in which X and A are presented in compound), and four trials in which the CS (X) is presented in the absence of the US (corresponding to the four preexposure trials in which X is presented alone). The distribution of these trials in the three schedules was as follows. In schedule INT (intermixed), we simulated that each conditioning trial was followed by an extinction trial. In schedule BLK AX-X (blocked AX-X), we simulated that a block of four conditioning trials was followed by a block of four extinction trials. In schedule BLK X-AX (blocked X-AX), we simulated that a block of four nonreinforced (latent inhibition) trials was followed by a block of four conditioning trials. According to the Pearce-Hall model, the salience of the CS and the US are represented by two constant parameters, S and λ, respectively. We simulated that the salience for both X and A was the same (as in most of the experiments these stimuli have been counterbalanced), being S of X and λ of A equal to 0.4. The initial value for the associability of the CS (X) was set at 0.5.

Figure 1 illustrates the predictions of the theory for these three schedules. The black boxes of three upper panels show the increments in the excitatory strength of the CS (X) on the conditioning trials (i.e., those trials in which X and A are presented in compound). As can be observed, the size of these increments is predicted to decrease progressively in both the INT and BLK AX-X schedules. Critically, it can be seen that, from the second to the fourth conditioning trial, the size of these excitatory increments are bigger for schedule BLK AX-X than for schedule INT. This difference arises because on these trials the associability of the CS (X) will be less in schedule INT than in schedule BLK AX-X. Consider, for example, the fourth conditioning trial. Before this trial, the CS (X) will have been presented three times in schedule BLK AX-X (during the three previous conditioning trials), but six times in schedule INT (during the previous three conditioning trials and during the previous three CS-alone trials). The Pearce-Hall model (along with many other theories) is able to accommodate the well-known finding that a stimulus loses its effectiveness in entering into associations to the extent that it is repeatedly presented alone (e.g., Lubow & Moore, 1959). The model thus predicts that longer preexposure to the CS in schedule INT will render the conditioning trials less effective (specifically, from the second to the fourth conditioning trial) compared with schedule BLK AX-X. The predictions of the theory regarding the increments in excitatory strength in the schedule BLK X-AX are also consistent with this characteristic of the latent inhibition phenom-

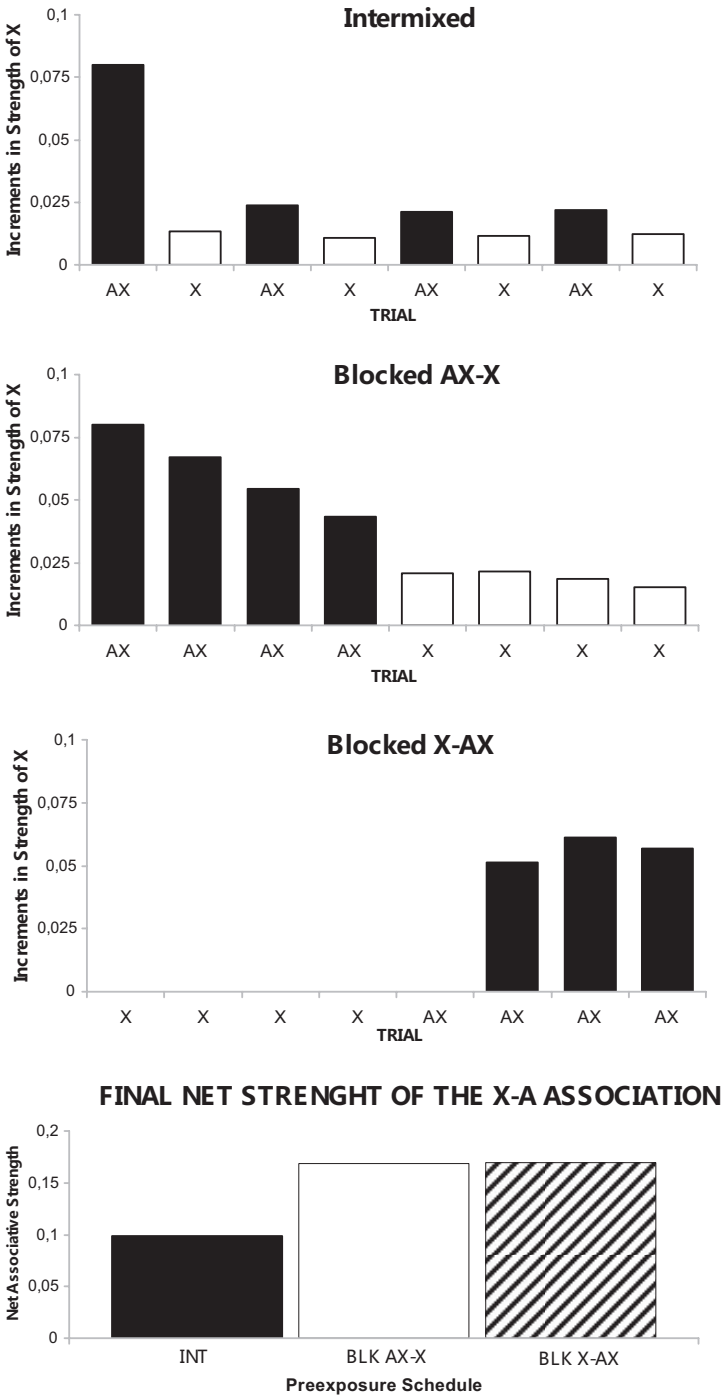

Figure 1. Values of associative strength from simulations using the Pearce, Kaye, and Hall (1981) model. Stimulus X (the CS) had a salience (S) with a value of 0.4, and an initial associability (α) with a value of 0.5; Stimulus A (the US) contributed with a value of λ of 0.4. A value of 0.8 was adopted for the learning-rate parameter γ. The three upper panels show the increments in the strength of the X-A association in the three different distribution of trials resulting from the three preexposure schedules (INT, BLK AX-X, BLK X-AX). The black boxes in these panels represent excitatory learning (increments in the strength of the X-A *association*) on the four X-A pairings. The white boxes represent inhibitory learning (increments in the strength of the *X-no A association*) on the four presentations of X alone. The lower panel shows the net associative strength of X (strength of the X-A *association* – strength of the X-*no A association*).

enon. As can be seen, the theory predicts that, in this schedule, preexposure to the CS (X) during the first block of trials will retard, compared with the other two groups, the acquisition of excitatory strength. In summary, the model predicts that the efficacy of the CS-US pairings (i.e., the X-A pairings resulting of the AX trials) in generating associative strength will be greater in the blocked preexposure than in the intermixed preexposure.

The white boxes of the three upper panels of Figure 1 show the predictions regarding the increments in inhibitory strength of the CS (X) during its presentations in isolation. On the one hand, it is predicted that these presentations will have no effect in schedule BLK X-AX, because for this condition the CS (X) will not yet have excitatory strength when it is presented alone. On the other hand, the theory predicts bigger increments in inhibitory strength (more extinction) in Group BLK AX-X than in Group INT.

Finally, the lower panel of Figure 1 shows the predictions regarding the net strength (excitatory strength–inhibitory strength) of the CS (X) at the end of the three schedules of training. As can be observed, the theory predicts more net strength (i.e., stronger within-compound associations) as a result of the two blocked schedules. In summary, these simulations show that if one takes into account the possible contribution of latent inhibition and extinction on the establishment and maintenance of within-compound associations, there are theoretical grounds to expect stronger within-compound associations in the blocked than in the intermixed preexposure.

Experiment 1

Experiment 1 (see Table 1) was designed to confirm that the between-subjects procedure employed by Rodríguez and Alonso (2004, 2008) would generate an intermixed-blocked effect using a new set of stimuli, sucrose and almond, rather than the sucrose and salt used in the previous studies. Three groups of rats received preexposure to AX and X. Group INT received intermixed presentations of AX and X. Group BLK AX-X first received a block of presentations of AX and then a block of presentations of X. Group BLK X-AX received these two blocks of preexposure in the reverse order. Subsequently, the three groups received flavor aversion conditioning with X as the conditioned stimulus (CS). The generalization of the aversion to AX was then tested. The intermixed-blocked effect would appear as there being less of a generalized aversion (more consumption) in Group INT than in Groups BLK-AX-X and BLK-X-AX.

Table 1
Experimental Designs

Group	Preexposure	Conditioning	Test
Experiment 1			
INT	4 (AX, X)		
BLK AX-X	4 AX, 4 X	2 X → LiCl	1 AX
BLK X-AX	4 X, 4 AX		
Experiment 2			
INT	4 (AX, X)		
BLK AX-X	4 AX, 4 X	3 A → LiCl	6 X
BLK X-AX	4 X, 4 AX		
Experiment 3			
INT	4 (AX, X)		
BLK AX-X	4 AX, 4 X		
BLK X-AX	4 X, 4 AX		
X	8 X		1 X

Note. In Experiments 1 and 2, A and X were 2% sucrose and 2% almond, counterbalanced; In Experiment 3, A was 20% sucrose reinforcer and X was 2% almond. See text for further details.

Method

Subjects and apparatus. All procedures relating to the maintenance and use of animals were in accordance with the European Law of Animal Welfare, and were approved by the Animal Welfare Committee of the University of the Basque Country (UPV/EHU). The subjects were 24 experimentally naïve Wistar male rats with a mean weight of 307 g at the start of the experiment. Animals were singly housed with continuous access to food in a colony room with a constant temperature (23°C), humidity (50%), and a 12:12-h light: dark cycle, with light switched on at 08:00. Access to water was restricted as detailed below.

The solutions used as experimental stimuli were administered in the home cages, at room temperature in 50-ml plastic centrifuge tubes, each equipped with a rubber stopper to which was fitted a stainless steel, ball-bearing tipped spout. The following flavored solutions were used: a solution of 2% almond flavoring (Super-Cook, Leeds, U.K.), a solution of 2% (wt/vol) sucrose, and a compound consisting of 2% (vol/vol) almond and 2% (wt/vol) sucrose. Consumption was measured by weighing the tubes before and after trials, to the nearest 0.1 g. The unconditioned stimulus for the conditioning trials was an intraperitoneal injection of 0.3M lithium chloride (LiCl) at 10 ml/kg of body weight.

Procedure. A water deprivation regime was initiated by removing the standard water bottles in the morning. On the next 4 days access to water was restricted to two daily sessions of 30 min, beginning at 13:00 (afternoon session) and 18:00 (evening session). This schedule was in place throughout the experiment. The rats were then randomly assigned to one of the three equal-sized experimental groups matched for their consumption of water.

Over the next 4 days (the preexposure phase), all the rats received four presentations of each of the flavors (AX and X). A and X were either almond or sucrose, counterbalanced. Animals in Group INT were given access to the flavors in alternation, with the order counterbalanced. Animals in Groups BLK-AX-X and BLK-X-AX received the solutions in two blocks of trials. For animals in Group BLK-AX-X, AX was presented on the first 2 days in both daily sessions and X on the last 2 days. The animals in Group BLK-X-AX received the opposite sequence.

After preexposure, all the animals received two conditioning trials. The first was given in the afternoon session of the next day. The rats received 10 ml of flavor X for 30 min, followed immediately by an injection of LiCl. The next day was a recovery day on which animals had unrestricted access to water for 30 min during both afternoon and evening sessions. The second conditioning trial was given in the afternoon session of the next day. It was identical to the first except that the animals were given free access to X for 30 min before the injection. Water was made available to the rats in the evening session after this conditioning trial. A recovery day followed, and on the next afternoon session, all the animals received a single test trial in which they were given unrestricted access to AX for 30 min.

Data analysis. Data were analyzed with analysis of variance (ANOVA) using type III sums of squares. A criterion of statistical

significance of $p < .05$ was adopted. Simple effect tests were conducted using Duncan's multiple-range tests. Effect sizes for ANOVA are reported as partial eta squared and those for pairwise comparisons are reported using Cohen's *d*. The 95% confidence intervals around the effect sizes will be reported in parentheses following the effect size.

Results and Discussion

The rats almost invariably consumed all 10 ml of the fluid offered during each preexposure trial. The conditioning trials successfully established an aversion to X. On the first conditioning trial, all rats drank almost all the 10 ml available (the mean amounts consumed were 9.6, 9.6, and 9.5 ml, for Groups INT, BLK-AX-X, and BLK-X-AX, respectively). Consumption was suppressed on the second trial (the means were 4.1, 3.7, and 3.1 ml for Groups INT, BLK-AX-X, and BLK-X-AX, respectively). A Group × Solution × Trial ANOVA showed a significant effect of trial, $F(1, 18) = 404.17$, $\eta_p^2 = 0.96$ (0.90–0.97). Neither the main effect of group ($F < 1$) nor that of conditioned solution (sucrose or almond as stimulus X), $F(1, 18) < 1.16$, was significant. None of the interactions were significant; largest, $F(1, 18) = 1.46$, for the interaction between conditioned solution and trial.

Group mean amounts of AX consumed during the generalization test trial are depicted in Figure 2. A Group × Solution ANOVA conducted on these data revealed a main effect of group, $F(2, 18) = 5.53$, $\eta_p^2 = 0.38$ (0.02–0.58). Subsequent pairwise comparisons using Duncan's multiple-range test confirmed that Group INT drank significantly more on this test than did Groups BLK-AX-X, $d = 1.48$ (0.34–2.58), and BLK-X-AX, $d = 1.4$ (0.28–2.49). The other pairwise comparisons yielded no significant differences. Neither the effect of conditioned solution ($F < 1$) nor the interaction between group and conditioned solution, $F(2, 18) = 1.37$, were significant. These results confirm that the intermixed-blocked effect can be obtained with the set of stimuli and parameters used here.

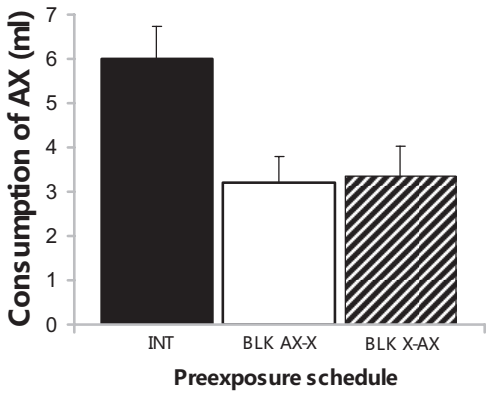

Figure 2. Group mean consumption of the compound AX after aversion conditioning with X. Group INT had received preexposure to AX and X in alternating trials. Group BLK AX-X had received preexposure consisting of a block of trials with AX followed by a block of trials with X. Group BLK X-AX had received preexposure consisting of the block of X-trials followed by the block of AX-trials. Vertical bars represent the standard errors of the means.

Experiment 2

This experiment (see Table 1) assessed the strength of the X-A within-compound association resulting from the three preexposure conditions used in the previous experiment. This association was identified by a sensory preconditioning procedure similar to that employed by Rescorla and Cunningham (1978; see also, Rescorla & Freberg, 1978). In this procedure, preexposure to a compound stimulus (AX) allows an aversion subsequently conditioned to one of the elements of the compound (X) to be elicited by the other (A). The most accepted explanation of this result is in terms of the operation of within-compound associations by way of an associative chain on test (X→A→US) or "image" conditioning where X retrieves A at the time the US is presented (see Ward-Robinson & Hall, 1999, for a discussion). In either case, the ability of X to evoke the CR is taken as an index of the strength of the X-A association. According to our predictions in terms of the Pearce et al. (1981) model, we expected the magnitude of the response governed by X on test, which presumably depends on the efficacy of the X-A association, will be greater in Groups BLK-AX-X and BLK-X-AX than in Group INT.

Method

Subjects and apparatus. The subjects were 24 experimentally naïve Wistar male rats with a mean ad lib weight of 299 g at the start of the experiment. They were maintained in the same way and on the same water deprivation schedule as described for Experiment 1.

Procedure. With the following exceptions, the procedure was the same as that used in Experiment 1. Three conditioning trials were given with A as the CS, and following the final recovery day, the animals received 6 test trials with X over 6 consecutive days.

Results and Discussion

As in Experiment 1, the rats drank almost all of the available fluid on each preexposure trial. The conditioning trials successfully established an aversion to A. Mean amounts of solution A consumed during the three conditioning trials were as follows: for Group INT, 9.5, 6.1, and 1.54; for Group BLK AX-X, 9.5, 7.5, and 0.97; for Group BLK X-AX, 9.6, 6.9, and 0.88. A Group × Solution (almond or sucrose) × Trial ANOVA showed a significant effect of trial, $F(2, 36) = 389.89$, $\eta_p^2 = 0.96$, (0.92–0.97). There were no other significant main effects or interactions, the largest being the group and trial interaction, $F(4, 36) = 1.95$.

Figure 3 shows the mean amounts of X consumed during the 6 test trials. Although the level of consumption was low on the initial trials, this level progressively increased at different rates in each group. On early trials, consumption of X was marginally greater in Group INT than in Group BLK-AX-X and Group BLK-X-AX. This difference among the groups increased with continued testing. Statistical analysis confirmed these impressions. An ANOVA conducted on the data summarized in Figure 3 showed there to be a significant effect of trial, $F(5, 90) = 278.17$, $\eta_p^2 = 0.94$ (0.91–0.95). Neither the main effect of conditioned solution nor any interactions involving the conditioned solution variable were significant (Fs < 1.65). There was a significant effect of group, $F(2, 18) = 7.96$, $\eta_p^2 = 0.47$ (0.08–0.65), and a significant interaction

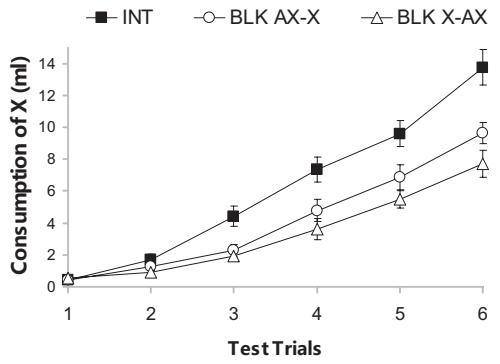

Figure 3. Group mean consumption of X after aversion conditioning with A. Group INT had received preexposure to AX and X in alternating trials. Group BLK AX-X had received preexposure consisting of a block of trials with AX followed by a block of trials with X. Group BLK X-AX had received preexposure consisting of the block of X-trials followed by the block of AX-trials. Vertical bars represent the standard errors of the means.

between trial and group, $F(10, 90) = 8.73$, $\eta_p^2 = 0.49$ (0.28–0.56). An analysis of simple effects revealed that the groups differed significantly on Trials 3, 4, 5, and 6, Fs$(2, 21) \geq 6.97$, $\eta_p^2 > 0.40$ (0.05-0.59). Subsequent pairwise comparisons using the Duncan's multiple-range test revealed that Group INT drank significantly more than did Groups BLK AX-X and BLK X-AX on Trials 3, 4, 5, and 6, ds$\geq$ 1.26 (0.16–2.32).

There were no differences in conditioning of A. Thus, the differences on test indicate that the X-A association responsible for either activating the representation of the US on test or during conditioning of A was less effective after intermixed preexposure than after blocked preexposure.

Experiment 3

Given the theoretical importance of the results obtained in Experiment 2, we thought it important to confirm their reliability and generality by using a different procedure to assess the strength of the X-A association. We adopted a conditioned preference procedure previously used by Balleine, Espinet and Gonzalez (2005; see also Rodriguez & Hall, 2008, Experiment 4). In this procedure, an odor (that serves as the CS) is repeatedly presented in compound with a strong, 20%, sucrose solution that, given its nutrient reinforcing properties, serves as the US. The odor-sucrose association resulting from these compound presentations is then evidenced as a preference for the odor in a subsequent test in which the animals are food deprived.

In the present experiment (see Table 1), we extended this procedure by adding presentations of almond alone (X) to the presentations of the almond-sucrose compound (AX), in accord with the intermixed (Group INT) and blocked (BLK AX-X and BLK X-AX) schedules used in the two previous experiments. Additionally, we added a control group (Group X) that simply received almond (X) during preexposure. This control group allowed us to assess the contribution of mere exposure to X to the level of test consumption.

The strength of the almond-sucrose (X-A) association resulting from the different preexposure conditions was assessed by measuring the consumption of the almond solution (X) on a subsequent test, where more consumption is assumed to reflect a stronger association. Based on the predictions of the Pearce et al. (1981) model, and on the results of the previous experiment, we expected consumption to be stronger in the BLK conditions than in the INT condition. It is worth noting that an advantage of the present procedure is that it allows for a more direct and immediate test of the preexposure effects than the sensory preconditioning procedure used in the previous experiment (in which a phase of conditioning to A was inserted between the phases of preexposure and the test).

Method

Subjects and apparatus. The subjects were 32 experimentally naïve Wistar male rats (in each group $n = 8$) with a mean weight of 411 g at the start of the experiment. Two flavored solutions were used; one of these (almond, X) was the same as that used in the previous experiments; the other was a compound consisting of 2% almond and 20% (wt/vol) sucrose (AX). The rats were maintained as described in the previous experiments.

Procedure. After the water deprivation schedule the subjects were divided into four equal-sized groups matched for their consumption of water. The preexposure procedure for Groups INT, BLK AX-X, and BLK X-AX was identical to that described in Experiment 1, except that for all animals the AX compound was the almond-sucrose mixture, and the stimulus X was the almond alone. Group X received treatment identical to that received by these groups except that subjects received eight presentations of almond alone during the preexposure phase.

After the last preexposure trial (on the evening of the fourth day of preexposure) the rats were allowed free access to water but food was removed so that they had been food-deprived for 19 h before the test on the following morning. The rats were deprived of water 3 h before the test. Testing consisted of free access to the almond solution for 30 min. Details not specified here were the same as the previous experiments.

Results and Discussion

The left panel of Figure 4 shows group means for consumption of the almond solution (i.e., solution X) on the test trial. This pattern of results is consistent with our expectations and interpretation of Experiment 2; subjects in Group INT drank less than the two blocked groups. Critically, only the BLK groups drank more than the control Group X, which did not receive almond-sucrose pairings before the test. Only the Groups BLK AX-X and BLK X-AX showed signs of a conditioned preference. A one-way ANOVA confirmed significant differences among the groups, $F(3, 28) = 5.61$, $\eta_p^2 = 0.38$ (0.06–0.54). Subsequent pairwise comparisons using the Duncan's multiple-range test revealed that Group BLK AX-X and Group BLK X-AX drank significantly more than both Groups INT and Group X, ds$\geq$ 1.14 (0.06–2.19). There were no other significant differences.

Because the present conditioning procedure is, perhaps, less well-established than the aversive procedure used in Experiment 2, we thought it worthwhile to confirm the reliability of the result. A further 24 rats (in each group, $n = 8$) were given training identical to that described above for the Groups INT, BLK AX-X, and BLK X-AX. The results of the test trial are shown in the right panel of Figure 4. Absolute levels of consumption were slightly lower in

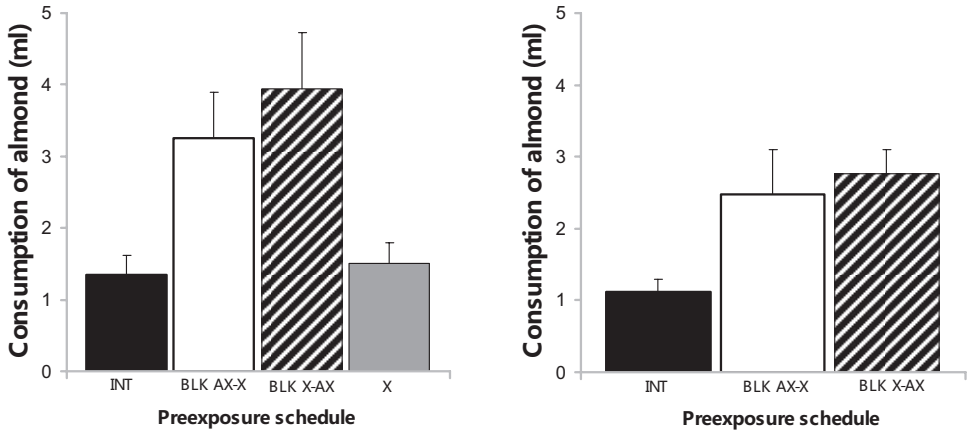

Figure 4. Group mean consumption of almond (X), after conditioning trials on which almond had been presented in compound with sucrose (A). Group INT had received these AX-conditioning trials alternated with additional trials on which X was presented alone. Group BLK AX-X had received first a block with all the AX-conditioning trials and then a block with all the X-alone trials. Group BLK X-AX had received first the block of X-alone trials and then the block of AX-conditioning trials. Control Group X (left panel only) had received only presentations of X alone. Vertical bars represent the standard errors of the mean.

the replication than those of the previous experiment, but the pattern of results was the same. Group INT drank less than the two blocked groups. A one-way ANOVA confirmed significant differences among the groups, $F(2, 21) = 4.3$, $\eta_p^2 = 0.29$ (0.00–0.50). Subsequent pairwise comparisons using the Duncan multiple-range test revealed that Group INT drank significantly less than Group BLK AX-X, $d = 1.12$ (0.05–2.17), and Group BLK X-AX, $d = 1.38$ (0.26–2.47), which did not differ from each other.

The results showed in both panels of Figure 4 parallel those of Experiment 2. Both experiments indicate that the X-A association is better preserved by the blocked than the intermixed preexposure schedule. In Experiment 2, in which we used an aversive sensory preconditioning procedure, this was manifested on test as lower consumption of the X solution in Groups BLK AX-X and BLK X-AX than in Group INT. The appetitive procedure used in this experiment revealed the same effect, but instead it was characterized by the opposite pattern of consumption - a greater level of consumption in the two blocked groups. Observing differences in the correct direction regardless of whether consumption is increasing or decreasing helps us to rule out certain trivial interpretations of the effect. It cannot be said, for example, that there is some feature of the blocked preexposure (e.g., habituation of neophobia) that makes rats drink more (or less) of X when it is presented alone on test. Both outcomes can be observed and, which one is obtained depends on the nature of the conditioning given before the test (aversive in Experiment 2, and appetitive in Experiment 3).

General Discussion

Taken together, the results of Experiments 2 and 3 show that blocked preexposure was more effective than intermixed preexposure in maintaining the strength of the X-A association. They suggest a simple alternative (or complementary) explanation of the intermixed-blocked effect. The starting point in this account is the same as that taken by other previous attempts to explain the effect in associative terms (e.g., McLaren et al., 1989). It is assumed that the within-compound associations established during preexposure can provide an additional source of generalization between the stimuli. For example, exposure to the AX compound in our experiments presumably allowed the establishment of an X-A association. This association would produce associative activation of A on the X-alone trials, activation that may contribute to the perception of the stimulus X as more similar to AX. Or, as it is suggested by the sensory-preconditioning result in Experiment 2, the associative activation of A may itself contribute to responding to X. We observed that both blocked schedules resulted in a stronger X-A association than the intermixed preexposure. This suggests that the source of mediated generalization depending on this association will be greater following blocked than intermixed preexposure, this being sufficient to explain the intermixed-blocked effect.

Our analysis is thus compatible with that appealing to the inhibitory mechanism proposed by McLaren et al. (1989) in so far as we claim that the source of generalization that depends on the within-compound associations is less effective after intermixed than blocked preexposure. However, there is a critical difference between the two analyses. Prior accounts have assumed that mediated generalization was less effective in the intermixed preexposure because it allows the operation of an additional inhibitory mechanism. In contrast, we simply suggest that the within-compound associations responsible for this source of generalization are established and maintained less effectively in the intermixed schedule than in the blocked schedules.

The key distinction between our analysis and other previous analyses of the effect is thus the direction in which the mechanism responsible for the intermixed-blocked effect supposedly affects stimulus generalization. It has been suggested that several generalization-reduction mechanisms might be working in the intermixed schedule (e.g., Gibson, 1969; Hall, 2003; McLaren et al., 1989; McLaren & Mackintosh, 2000). Based on our findings, and according to the new account advanced here, a generalization-enhancing mechanism might be complementarily working in the blocked schedule. This new theoretical analysis is able to accommodate, in purely associative terms,

the instances of the intermixed-blocked effect observed after preexposure either to AX and BX (e.g., Symonds & Hall, 1995) or to AX and X (e.g., Rodríguez & Alonso, 2004, 2008). It would seem worthwhile, therefore, to keep in mind this contrasting new account when conducting future work involving preexposure schedules and the perceptual learning effect.

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