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Stimulus comparison and stimulus association processes in the perceptual learning effect

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Abstract

In four experiments rats were given preexposure to two flavoured fluids, presented simultaneously in separate bottles. A conditioned aversion was then established to one flavour and the generalization of this aversion to the other was tested. Experiments 1a and 1b demonstrated that, in contrast to the effect obtained when the two flavours are presented at separate times during preexposure, such preexposure enhances generalization. Experiments 2a and 2b examined the hypothesis that this enhanced generalization was a consequence of the formation of an excitatory association between the two flavours during preexposure. In these experiments, the preexposure phase was followed by a phase of training (in which each flavour was presented alone on separate occasions) designed to extinguish the postulated association. It was found, however, that the enhancement of generalization survived the introduction of this procedure. Implications for the perceptual learning effect (the observation that certain forms of preexposure can restrict generalization between preexposed stimuli) are discussed.

Keywords: Perceptual learning; Associative processes; Generalization; Flavour aversion

1. Introduction

Symonds and Hall (1995) demonstrated that, under certain conditions, preexposure to a pair of stimuli can reduce the extent to which generalization occurs between them. Rats in the experimental condition were given preexposure to two flavours (A and B) presented in strict alternation over the course of four days, with A being presented each morning and B each afternoon (6 h later). Control subjects received blocks of trials with these flavours, experiencing only A on the first 2 days and B on the second 2 days (or vice versa). All subjects then received aversion conditioning in which A was established as a conditioned stimulus (CS) for the illness induced by an injection of lithium chloride (LiCl). A final test revealed that this aversion generalized readily to flavour B in the control subjects but not in the experimental subjects. It was concluded that intermixed preexposure to A and B enhanced the ability of the animal to discriminate between them, that is, produced a perceptual learning effect.

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Symonds and Hall (1995) suggested that their result might be the product of a process of stimulus differentiation; that exposure to the stimuli might bring into play a perceptual learning process that allowed the animals to detect more easily the distinctive features of the stimuli, thus enhancing their discriminability and reducing generalization between them (see Gibson, 1969). This process, it was argued, would be likely to occur more readily in preexposure conditions that allow stimulus comparison to occur and thus the perceptual learning effect should be more evident in animals given A and B on alternate trials during preexposure than in animals given a block of A trials and a separate block of B trials (see also Honey et al., 1994; Honey and Bateson, 1996). It was acknowledged, however, that this version of the perceptual learning effect could also be explained in terms of the associative processes described by McLaren et al., (1989).

McLaren et al. (1989) pointed out that each stimulus, A and B, can be regarded as being composed both of certain distinctive features or elements (designated *a* and *b*, respectively) and also of other features (*c* elements) that are held in common by the two stimuli. Preexposure to the stimuli can be expected to allow excitatory associations to be formed among these features — an *a*–*c* link on A trials and a *b*–*c* link on B trials. These associations could then play a role in determining the performance seen on a generalization test. In particular, the conditioned response (CR) elicited by B would be determined not only by the associative strength acquired by the *c* elements on the reinforced A trials but also by the ability of B to activate the representation of the *a* elements by way of the associative chain *b*–*c*–*a*. This source of generalization could contribute substantially to the test performance of animals in the control condition (those given separate blocks of exposure to A and to B). But for animals given alternating trials in preexposure it might be restricted by the occurrence of inhibitory learning.

In the alternating preexposure condition, the early trials of preexposure will allow the formation of the excitatory, within-stimulus associations just described. But once these have been established, further trials will result in inhibitory learning. The associative chain *a*–*c*–*b* will enable presentation of A to activate the representation of stimulus features (the *b* elements) that are not in fact presented on that trial; similarly presentation of B will activate (by way of *b*–*c*–*a*) the representation of the absent *a* elements. According to standard associative theory (e.g. Wagner and Rescorla, 1972), an inhibitory link will form between a stimulus that is present and one that is activated only associatively. The result will be that mutually inhibitory links will be formed between the unique elements of each stimulus, that is, between *a* and *b*. Once these links have formed, stimulus B would no longer be able to activate the *a* representation on the test and this source of generalization would be lost.

There are thus two possible explanations for the results obtained by Symonds and Hall (1995). The perceptual learning effect observed after alternating exposure to stimuli might be due either to the operation of some stimulus comparison process that aids perceptual differentiation, as Gibson (1969) has suggested, or to the formation of mutual inhibitory links between distinctive features of the stimuli, as McLaren et al. (1989) have proposed. The aim of present experiments was to test between these possibilities. In order to do this we have investigated the effects of a *concurrent* preexposure regime in which, for subjects in the experimental condition, both flavours are made available simultaneously. Inhibitory links will not be formed between events that are presented together. Indeed, with this procedure, in which the rat will have the opportunity to sample the two flavours in quick succession, the formation of excitatory links seems a possibility. According to the associative account, therefore, concurrent preexposure will not generate the perceptual learning effect and, if excitatory links are formed, might in fact enhance the degree to which generalization occurs between the stimuli. On the other hand, if a stimulus comparison process plays an important role in producing the perceptual learning effect, concurrent exposure to two stimuli, a procedure that might be expected to provide the optimum conditions for comparison to occur, should produce a particularly strong effect.

2. Experiments 1a and 1b

Each of these experiments employed three training conditions. The critical experimental group (Group Concurrent) received preexposure in which two bottles were presented simultaneously, one containing flavour A, the other flavour B. There were two control conditions. Group Blocked received equivalent exposure to the flavours but they were presented on separate blocks of sessions; that is, for half the preexposure sessions, both bottles contained flavour A and for the remaining sessions, both contained flavour B. Group Control received no preexposure to the flavours; on sessions in the first phase of training, both bottles contained unflavoured water. All subjects then received aversion conditioning with flavour A as the CS followed by a generalization test with flavour B. The question of interest was whether concurrent preexposure would generate a perceptual learning effect (reduced generalization between A and B) of the sort obtained by Symonds and Hall (1995) with their alternating preexposure schedule.

Experiments 1a and 1b differed only in the duration of preexposure. In Experiment 1a the bottles containing the flavoured solutions (or water for Group Control) were available for 24 h a day throughout the 8 days of preexposure. In Experiment 1b we reverted to the procedure used by Symonds and Hall (1995) of giving exposure on 30-min trials at a given time each day.

2.1. Method

2.1.1. Subjects and apparatus

The subjects for Experiment 1a were 30 male albino Wistar rats with a mean ad lib. weight of 585 g (range: 495–648 g). They had previously served as subjects in an appetitive conditioning experiment, but were naive to the present stimuli and procedures. The subjects for Experiment 1b were 30 naive male albino Wistar rats with a mean ad lib. weight of 462 g (range: 398–508 g). Rats were individually housed in makrolon cages ($15 \times 27.5 \times 27.5$ cm) located in an air-conditioned temperature-controlled room on a 12-h light/dark cycle (lights on at 21:00 h). The experimental procedures were conducted in the home cages during the dark portion of the cycle. Dry food was available throughout the experiment, but access to water was limited as indicated below. For each experiment the rats were randomly assigned to one of three equal-sized groups.

The flavours used in these experiments were a saline (0.5% NaCl) solution and a 1% sucrose solution. For half the subjects in each group stimulus A was saline and stimulus B was sucrose; for the remainder the arrangement was reversed. The unconditioned stimulus (US) was an intraperitoneal injection at 10 ml/kg of 0.3 M LiCl.

2.1.2. Procedure

During the preexposure phase of Experiment 1a the rats were given unrestricted and continuous (24-h) access to fluid in two bottles (separated from one another by 15 cm) for 8 days. For Group Concurrent, one bottle contained solution A and the other solution B. The left/right position of the bottles was counterbalanced. For Group Blocked, the two bottles contained the same solution; for half of subjects in this group solution A was presented during the first 4 days and solution B during the last 4; for the remaining subjects the order of presentation was reversed. Subjects in Group Control received two bottles containing water during this phase. At the end of the preexposure phase, a deprivation regime was initiated. Over the next 3 days all animals received access to water for 30 min, twice a day with drinking sessions beginning at 11:00 and 18:00 h.

Prior to the preexposure phase, animals in Experiment 1b were introduced to a schedule of water deprivation equal to that described above for Experiment 1a (sessions starting at 11:00 and 17:00 h). The preexposure procedure in this experiment differed from that of Experiment 1a in the following respects. The phase lasted only 4 days and a restricted amount of fluid was available on each of the two daily 30-min sessions. Two tubes were presented on each session, each containing 7.5 ml of the appropriate fluid (flavour A, B, or water). Subjects in Group Concurrent received A and B on all trials. Subjects in Group Blocked received flavour A (or B) for the first 2 days and B (or A) for the last 2 days. Group Control received only water.

On each conditioning trial, all subjects were given access to 15 ml of solution A for 30 min followed by an injection of LiCl. The conditioning trials took place in the morning, subjects having free access to water for 30 min in the afternoon. Each conditioning day was followed by a recovery day in which subjects received two sessions of free access to water. There were two conditioning trials in Experiment 1a and three in Experiment 1b.

After a further recovery day, consumption of B was tested. For Experiment 1a this test consisted of a single trial in which all subjects received unrestricted access to the B solution for 30 min. Subjects in Experiment 1b received four such test trials spaced 24 h apart.

2.2. Results

2.2.1. Experiment 1a

Consumption during preexposure was not measured although informal observations suggested that animals tended to sample both bottles. Fig. 1 shows group mean amounts of solution A consumed during the two conditioning trials. (There was no obvious effect of whether A was saline or sucrose and the results are pooled over this counterbalanced factor). The groups did not differ on the first trial suggesting that flavour A evoked no marked degree of neophobia in Group Control, for whom this flavour was novel at the start of conditioning. All groups acquired the aversion showing a marked decline in consumption on the second trial. Perhaps surprisingly, there was no evidence of latent inhibition in that the groups given preexposure learned no less readily than the non-preexposed control group. An analysis of variance (ANOVA) with group and trial as the variables was conducted in the data summarized in the figure. It revealed a significant main effect of trial, $F(1,27) = 463.44$. Neither the effect of group, $F(2,27) < 1$, nor the group by trial interaction, $F(2,27) = 1.06$, were statistically significant. (For this and all subsequent analyses a rejection criterion of $p < 0.05$ was adopted).

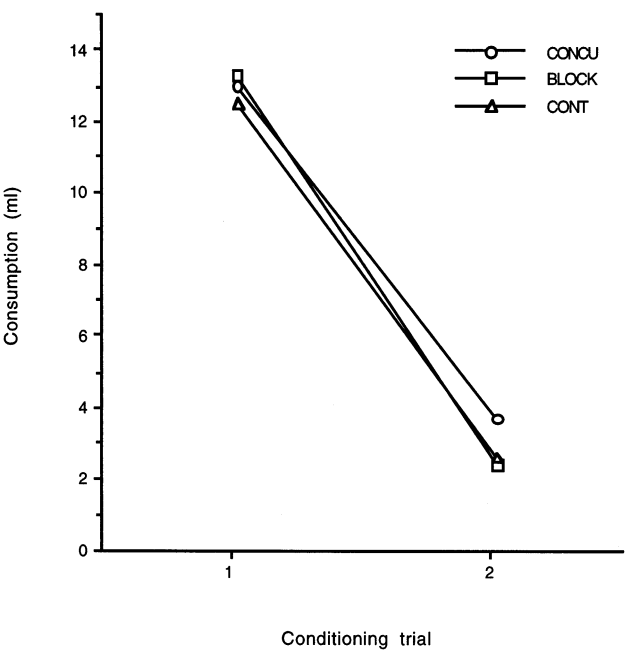

Fig. 1. Mean consumption of flavour A on the conditioning trials of Experiment 1a. Group CONCU had received concurrent preexposure to flavours A and B; Group BLOCK had received blocked preexposure; Group CONT received no preexposure to the flavours.

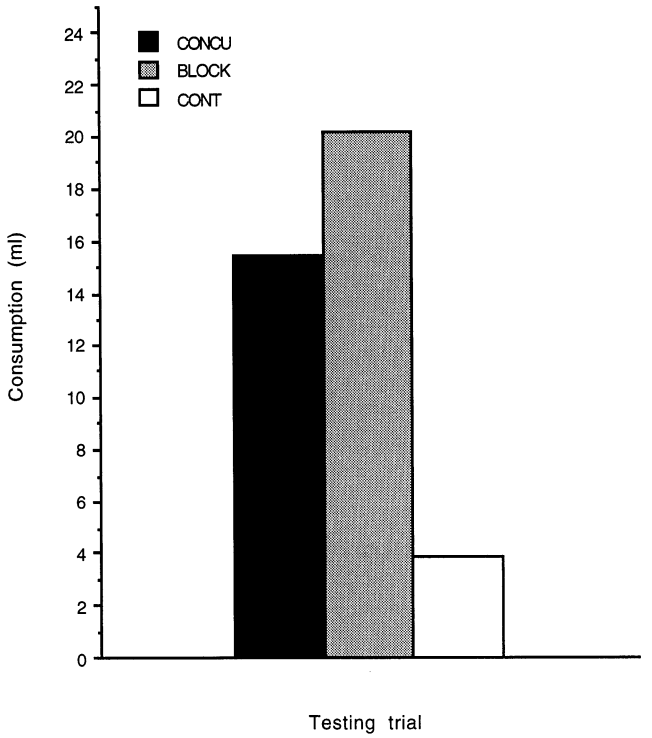

Fig. 2. Experiment 1a. Group mean consumption of B on the test trial. Group CONCU had received concurrent preexposure to flavours A and B; Group BLOCK had received blocked preexposure; Group CONT received no preexposure to the flavours. All subjects had received two reinforced trials with A.

The results of primary interest, group means for consumption of solution B on the test trial are shown in Fig. 2. It is evident that the groups given preexposure (Groups Concurrent and Blocked) consumed more of solution B than Group Control. More importantly, the two preexposed groups differed from one another, with Group Concurrent drinking less that Group Blocked. It appears, therefore, that generalization occurred more readily in subjects given the concurrent preexposure treatment. A one-way ANOVA conducted on the data summarized in Fig. 2 confirmed that there was a significant difference among the groups, $F(2,27) = 36.98$. Pairwise comparisons using Newman–Keuls tests revealed that Group Blocked consumed significantly more than Group Concurrent, and that each consumed significantly more than Group Control.

2.2.2. Experiment 1b

Fig. 3 shows, for each group, the mean amount of solution A consumed on each of the three conditioning trials. As in Experiment 1a, there was no evidence of neophobia in Group Control—all groups consumed the solution readily on the first conditioning trial. Latent inhibition was evident, however, in that Group Control displayed a substantial aversion after just one trial, whereas the two groups given preexposure required two trials to do so. By the third trial, consumption was suppressed to a similar extent in all groups. An ANOVA with group and trial as the variables revealed significant main effects of group, $F(2,27) = 11.28$, trial, $F(2,54) = 144.19$, and a significant interaction $F(4,54) = 8.79$. An analysis of simple effects revealed that the groups differed significantly only on the second condi-

tioning trial, $F(2,76) = 27.23$. Pairwise comparisons using Newman-Keuls tests indicated that the consumption of Groups Concurrent and Blocked was significantly greater than that of Group Control on this trial.

Fig. 4 shows group mean amounts of solution B consumed on the four test trials. In all groups consumption increased (presumably as a result of extinction of the aversion) over the course of testing, but throughout the test, the same pattern of differences among the groups was maintained. As in Experiment 1a, Group Blocked drank somewhat more than Group Concurrent and both drank more than Group Control. An ANOVA with group and trial as the variables found significant main effects of group, $F(2,27) = 7.86$, and of test trial, $F(3,81) = 30.5$. The Group × Trial interaction was not significant, $F(6,81) = 1.24$. Subsequent pairwise comparisons, using Newman-Keuls tests, were conducted on the overall group means. They revealed that Group Control differed from both Group Concurrent and Group Blocked; the difference between these latter two groups was not significant.

2.3. Discussion

Experiment 1a demonstrated that generalization of a conditioned aversion between two flavours, A and B, was reduced in animals given preexposure to these flavours. The magnitude of this reduction depended on the schedule of stimulus presentation in preexposure—generalization was greater in animals given concurrent exposure to A and B than in animals given A and B in separate blocks of training. To the extent that the concurrent procedure used here is taken to be equivalent to the alternating preexposure used by Symonds and Hall (1995) these results contrast with those previously reported in that Symonds and Hall found that generalization was greater in the blocked condition than in the alternating condition. This apparent discrepancy is not to be explained in terms of the fact that Symonds and

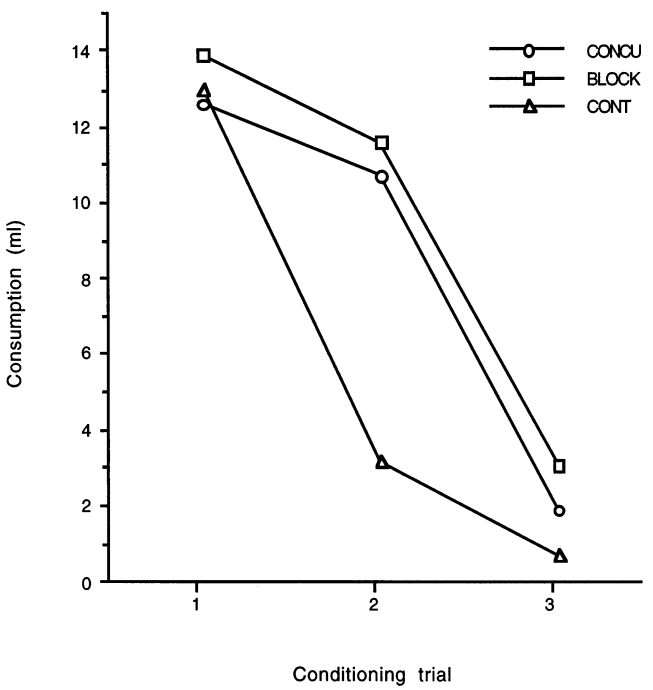

Fig. 3. Mean consumption of flavour A on the conditioning trials of Experiment 1b. Group CONCU had received concurrent preexposure to flavours A and B; Group BLOCK had received blocked preexposure; Group CONT received no preexposure to the flavours.

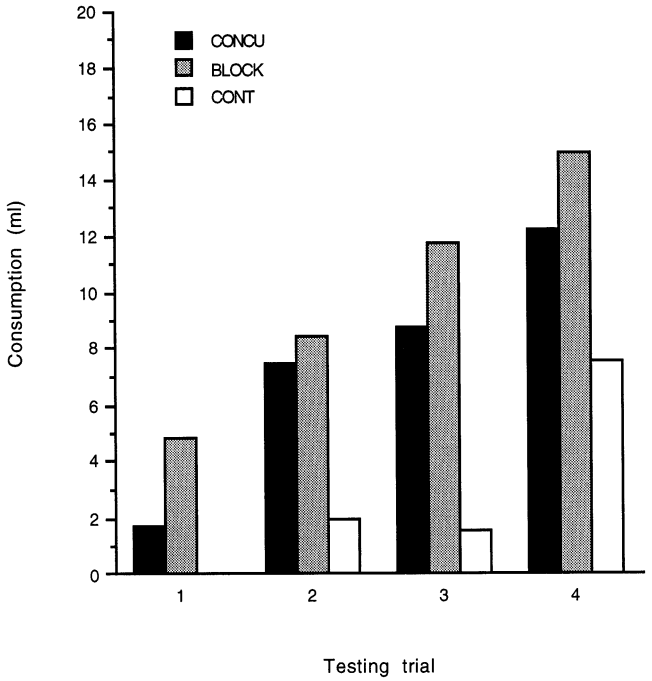

Fig. 4. Experiment 1b. Group mean consumption of B on the test trials. Group CONCU had received concurrent preexposure to flavours A and B; Group BLOCK had received blocked preexposure; Group CONT received no preexposure to the flavours. All subjects had received three reinforced trials with A.

Hall gave discrete and relatively short exposure trials (8 sessions of 30-min trials) whereas in Experiment 1a we gave continuous and prolonged preexposure (8 days at 24-h per day). In Experiment 1b we made use of the trial structure employed by Symonds and Hall and (although the difference between the concurrent and blocked conditions was not, in this case, statistically significant) reproduced the same pattern of results as had been produced by Experiment 1a.

That the animals given preexposure (however scheduled) showed little evidence of aversion to B on the test can be readily explained in terms of latent inhibition. For Group Control, flavour A was novel at the time of conditioning and thus the associative strength acquired in this group over a given number of reinforced trials can be expected to be greater than in either of the other two groups for whom A will have suffered latent inhibition during preexposure. If A has little strength in the first place there will be little scope for generalization to occur to B. It should be acknowledged that the conditioning data (Figs. 1 and 3) provided evidence of latent inhibition only in Experiment 1b and that, even in that experiment, no differences among the groups were present by the last trial of conditioning. It is quite possible, however, that latent inhibition effects were present but were impossible to detect on this trial simply because all groups were consuming so very little of the solution.

Theoretically more significant is the difference obtained between the two preexposed groups in their test performance. These groups presumably suffered latent inhibition to much the same extent in preexposure (but see Symonds and Hall, 1997); certainly there was no sign (even in Experiment 1b) of any difference between them in acquisition of the aversion to A. None the less, Group Concurrent consumed less of flavour B on test than did Group Blocked. This is not the result predicted by the suggestion that the opportunity for stimulus comparison offered by concurrent preexposure will promote the occurrence of a percep-

tual learning effect. It accords perfectly well, however, with an associative analysis that supposes that concurrent preexposure will allow the formation of excitatory associations between A and B. In this case the aversion conditioned to A would be evoked at some extent when stimulus B was presented in the test resulting in a reduced consumption of B—the result obtained.

3. Experiments 2a and 2b

Although the results of Experiments 1a and 1b seem to reflect the consequences of the formation of a direct excitatory associations between A and B in the concurrent condition, they cannot be taken to be a convincing disproof of the notion of stimulus differentiation. Both processes could be operating; that is, concurrent preexposure might allow both the formation of an association between A and B and as well as promoting differentiation between them. The first of these processes would enhance generalization between A and B and the second would tend to attenuate it. The overall outcome would depend on the balance of the two processes.

What follows from this analysis is that the use of some procedure that would eliminate the excitatory A–B association might allow the perceptual learning effect to be obtained in the concurrent condition. In Experiments 2a and 2b, animals were given concurrent preexposure as before, but this was followed by a phase of training in which A and B were presented separately. There is no reason to suppose that this second phase would influence any stimulus differentiation that might have occurred in the first phase. It should, however, bring about extinction of excitatory A–B associations formed during the first phase (see, e.g. Rescorla and Freberg, 1978). According to the associative account, therefore, this extinction treatment, if it is fully effective, should abolish the enhancement of generalization produced by concurrent preexposure. To find an effect of extinction would confirm the role of associative processes in this procedure. It would not, however, rule out the additional influence of a differentiation process. If the stimulus differentiation process is also at work, the extinction treatment, by eliminating the obscuring effect of the associative process, might allow it to be observed as reduced generalization in the concurrent condition.

The experimental design involved four groups. The preexposure treatment was divided into two phases. Group Concurrent-ext received an initial phase of concurrent preexposure identical to that described for the previous experiments. This was followed by an extinction phase of the same duration in which A was presented alone on half the sessions and B was presented alone on the other sessions. Group Concurrent-control also received concurrent preexposure during the first phase, but received only unflavoured water in the second phase. Group Blocked-ext received the same total amount of preexposure to A and B as Group Concurrent-ext but arranged in separate blocks. Thus, just one flavour was presented during the first preexposure phase, and the other flavour was presented in the second phase. (The label 'ext' applied to this group does not indicate that the subjects underwent an extinction treatment; rather it indicates that this group is comparable to Group Concurrent-ext in the amount of exposure to the flavours that was given.). Group Blocked-control received separate blocks of A and B trials during the first phase of preexposure and exposure to water only in the second phase. All animals then received reinforced trials with A followed by a generalization test with B. We expected that the two control groups would allow a replication of the effect obtained in Experiment 1 (i.e. more generalization in the concurrent condition). The question of interest was whether this effect would be abolished or reversed for the comparison between Groups Concurrent-ext and Blocked-ext.

Experiments 2a and 2b employed the same design. They differed only in that preexposure was continuous and prolonged in Experiment 2a but was given as discrete short trials in Experiment 2b.

3.1. Method

The subjects for Experiment 2a were 40 experimentally naive, male Wistar rats with a mean weight of 437 g (range: 398–475 g). A further 32 rats from the same stock (mean weight of 583 g; range: 518–668 g) were used in Experiment 2b.

Except where specified otherwise, the procedure employed in Experiment 2a followed that described for Experiment 1a. Half the subjects were given concurrent preexposure to A and B, presented in two separate bottles, over the course of 8 days, as in Experiment 1a. For the second phase of preexposure, these subjects were assigned at random to two equal-sized groups. Those in Group Concurrent-ext received the extinction treatment consisting of exposure for 4 days to two bottles containing the same flavour (A for half the animals and B for the remainder), followed by 4 days in which both bottles contained the other flavour. Animals in the Concurrent-control group received access to two bottles containing unflavoured water during this phase. Two further equal-sized groups received blocked preexposure. Group Blocked-Control received 4 days of exposure to one flavour and 4 days of exposure to the other followed by an 8-day phase in which just unflavoured water was available. Group Blocked-ext received 8 days of exposure to one flavour followed by 8 days of exposure to the other. There were three conditioning trials with A; the test consisted of a single 30-min session of free access to B.

The schedule of fluid presentation used in Experiment 2b was equivalent to that described for Experiment 2a except that the preexposure phase lasted for a total of 8 days with fluid presentations being restricted to two daily 30-min sessions. The procedure used for conditioning and the test exactly matched that described for Experiment 1b. In other respects not specified here, the procedure for Experiment 2b was the same as described for Experiment 1b.

3.2. Results

3.2.1. Experiment 2a

Fig. 5 shows the mean amounts of fluid consumed by the four groups on the conditioning trials. Because of an error on the part of the experimenter, only 5 ml of fluid was made available on each of these trials instead of the 15 ml used in Experiment 1a. None the less, all groups

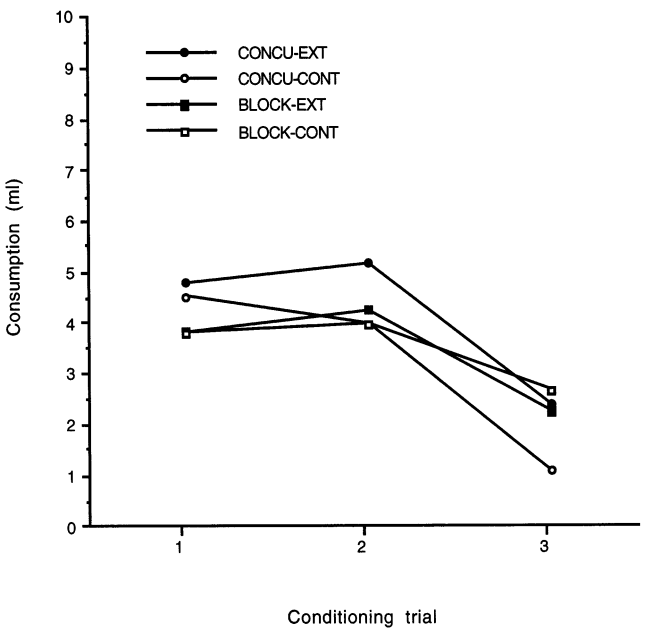

Fig. 5. Mean consumption of flavour A on the conditioning trials of Experiment 2a. Group CONCU-CONT had previously received concurrent preexposure to A and B; Group BLOCK-CONT had received blocked preexposure. Group CONCU-EXT had received concurrent preexposure to A and B followed by experience of A and B presented separately. Group BLOCK-EXT received the same total amount of exposure to A and B, but the two flavours were never presented concurrently.

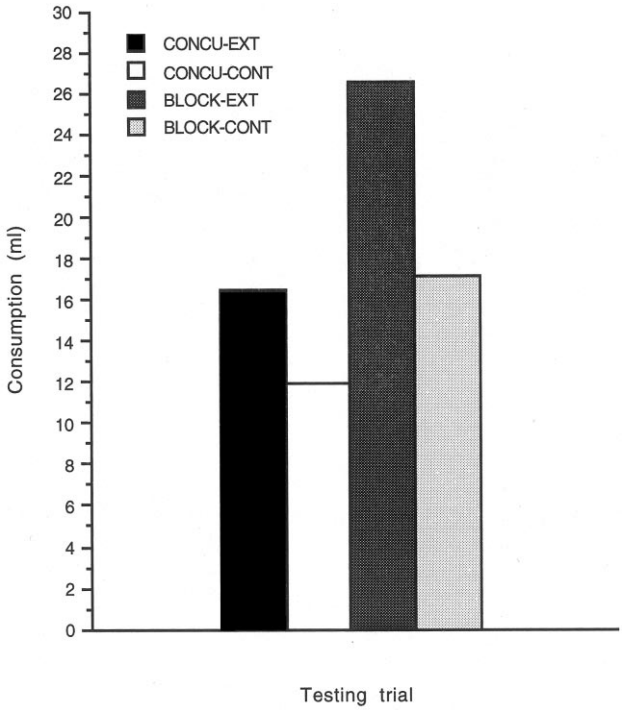

Fig. 6. Experiment 2a. Group mean consumption of B on the test trial. Group CONCU-CONT had previously received concurrent preexposure to A and B; Group BLOCK-CONT had received blocked preexposure. Group CONCU-EXT had received concurrent preexposure to A and B followed by experience of A and B presented separately. Group BLOCK-EXT received the same total amount of exposure to A and B, but the two flavours were never presented concurrently. All subjects had received three reinforced trials with A.

showed a substantial reduction in the amount consumed by the final trial and there were no obvious differences among the groups. An ANOVA was conducted on the data summarized in the figure, the variables being exposure condition (Concurrent or Blocked), extinction treatment (ext vs. control), and trial. This revealed only a significant main effect of trial, $F(2,72) = 9.7$; all other Fs < 2.

Fig. 6 shows group means for consumption of flavour B on the test trial. It appears that the groups given the extinction treatment showed less of an aversion than the control groups. This outcome is presumably a consequence of the fact that the ext groups received a greater amount of exposure to the flavours than did the control groups. Although it was not evident in the results shown in Fig. 5, this extra exposure might be expected to restrict the development of an aversion to A and thus reduce the scope for generalization to B. As in Experiment 1, subjects given the concurrent treatment drank less than those given blocked preexposure, and this was true not only for the control groups but also for the groups in the ext condition. An ANOVA with exposure condition and extinction condition as the variables revealed a significant main effect of exposure, $F(1,35) = 4.97$; the main effect of the extinction treatment approached significance, $F(1,35) = 3.81$, $P < 0.06$, but the interaction between these variables was not significant, $F < 1$.

3.2.2. Experiment 2b

Group means for the conditioning trials with A are shown in Fig. 7. All groups acquired the aversion and by trial 3 consumed very little of flavor A. Although differences between the groups appeared to be present on the first two trials, statistical analysis showed these to be unreliable. An ANOVA with exposure condition, extinction condition, and trial as the variables found a significant main effect of trial, $F(2,56) = 134.54$, but not of exposure condition ($F < 1$), or of extinction condition, $F(1,28) = 1.29$. None of the interactions were significant: for Exposure × Extinction, $F(1,28) = 1.09$; for Exposure × Trial, $F(2,56) = 2.96$; for Extinction × Trial, $F(2,56) = 2.46$; for the three-way interaction, $F < 1$.

Fig. 8 shows the mean consumption of the four groups on the generalization test trials with flavour B. For the control groups, the effect obtained in the previous experiments is replicated here; that is, the level of consumption was consistently higher in Group Blocked-control than in Group Concurrent-control. For the extinction groups, the pattern is a little less clear. Groups Concurrent-ext and Blocked-ext did not differ on the final two trials of the test. On the first two trials, however, it was again found that Blocked-ext consumed more than Group Concurrent-Ext. Statistical analysis confirmed these impressions. An ANOVA with exposure condition, extinction condition, and trial as the variables revealed significant main effects of trial, $F(3,84) = 11.58$, and

of exposure condition, $F(1,28) = 4.44$. There was a significant interaction between extinction condition and trial, $F(3,84) = 11.58$. All other interactions were nonsignificant; largest $F(3,84) = 2.20$, for the interaction between exposure condition and trial. A simple effects analysis of the Extinction x Trial interaction showed that the effect of trial was significant in the control condition, $F(3,84) = 12.95$, but not in the ext condition, $F(3,84) = 1.70$.

3.3. Discussion

Experiments 2a and 2b were designed to test the hypothesis that the effect obtained in Experiment 1—enhanced generalization between A and B after concurrent as opposed to blocked preexposure—was a consequence of the formation of excitatory associations between A and B during preexposure in the concurrent condition. It was argued that separate presentations of A and B after the concurrent preexposure treatment would allow extinction of any A–B associations thus eliminating the effect seen in the earlier experiments. It was further suggested that once these associations had been extinguished, it might be possible to detect a perceptual learning effect of the sort demonstrated by Symonds and Hall (1995); that is, reduced generalization in subjects given preexposure in conditions that might allow stimulus comparison effects to occur. It turned out, however, that the extinction treatment given in the present experiments proved to be remarkably ineffective in modifying the effects produced by concurrent and blocked preexposure. Certainly there was no reversal of the effect seen in Experiments 1a and 1b and, for the most part, the pattern of generalization shown by the ext groups was the same as that shown by the control groups. Only on the later test trials of Experiment 2b was there a suggestion that extinction might eliminate the difference between the concurrent

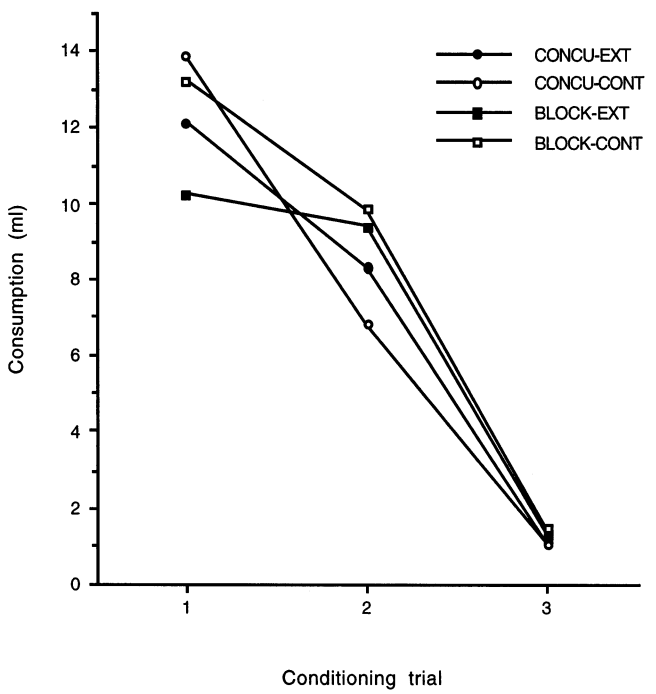

Fig. 7. Mean consumption of flavour A on the conditioning trials of Experiment 2b. Group CONCU-CONT had previously received concurrent preexposure to A and B; Group BLOCK-CONT had received blocked preexposure. Group CONCU-EXT had received concurrent preexposure to A and B followed by experience of A and B presented separately. Group BLOCK-EXT received the same total amount of exposure to A and B, but the two flavours were never presented concurrently.

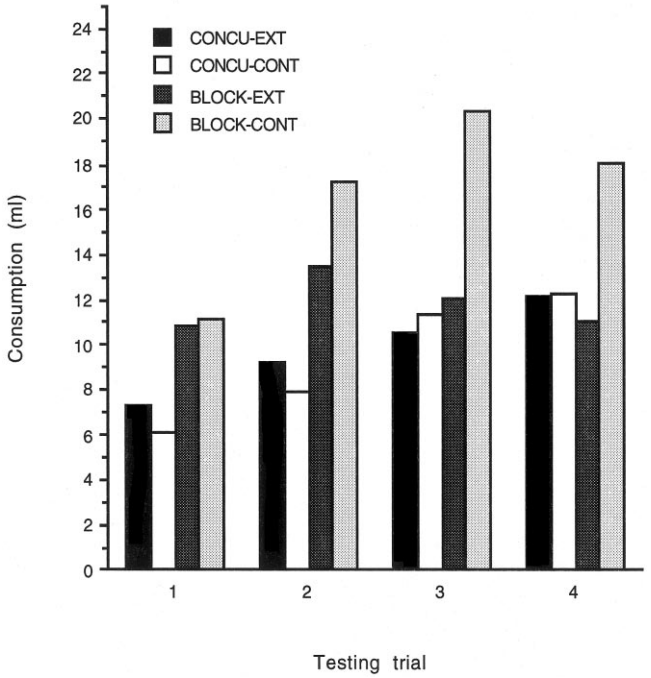

Fig. 8. Experiment 2b. Group mean consumption of B on the test trials. Group CONCU-CONT had previously received concurrent preexposure to A and B; Group BLOCK-CONT had received blocked preexposure. Group CONCU-EXT had received concurrent preexposure to A and B followed by experience of A and B presented separately. Group BLOCK-EXT received the same total amount of exposure to A and B, but the two flavours were never presented concurrently. All subjects had received three reinforced trials with A.

and blocked conditions. The implications of these findings are taken up in the General Discussion.

4. General discussion

Preexposure to a pair of flavours, A and B, will influence the extent to which generalization occurs between them. Specifically, generalization is less after preexposure in which the flavours are presented on alternate trials than when separate blocks of A and B trials are given (Symonds and Hall, 1995). We considered two possible explanations for this effect. One proposal was that alternating preexposure, because it gives the animals a chance to compare the stimuli, brings into play a perceptual learning process that enhances the animal's sensitivity to features that differentiate the stimuli. An alternative suggestion, derived from the account of perceptual learning propose by McLaren et al. (1989), is that alternating preexposure promotes the development of inhibitory associations between the unique features of A and B. Such associations, McLaren et al. argue, will prevent the test stimulus (B) from activating the representation of the conditioned stimulus (A), thus eliminating a source of generalization that will still be operative in the blocked condition.

In order to test between these alternatives we have investigated the effects of a concurrent preexposure procedure in which A and B are presented simultaneously to the animal. We argued that stimulus comparison should occur particularly readily in this condition whereas inhibitory links would be unable to form. The stimulus differentiation notion thus predicts a powerful perceptual learning effect. The associative account predicts no effect, or even a reversal of the effect given that concurrent preexposure might allow the development of excitatory associations between A

and B. The results of Experiments 1a and 1b supported the associative account—generalization between A and B was greater after concurrent preexposure than after blocked preexposure.

According to the associative interpretation of these results, the enhanced generalization seen in the concurrent preexposure condition depends on the integrity of excitatory A–B associations. In Experiments 2a and 2b we attempted to extinguish any such associations by giving animals separate presentations of A and B after they had experienced the concurrent preexposure treatment. The effects of this procedure allow no very firm conclusions. In Experiment 2a the extinction treatment was quite without effect; the difference between the concurrent and blocked groups was as marked in subjects given extinction as in control groups. In Experiment 2b the extinction treatment reduced the persistence of the difference between the concurrent and blocked conditions (the groups did not differ on the later trials of the test) but the difference was still fully present on early test trials. The associative account can thus claim only limited support from these findings.

The relative immunity of the concurrent/blocked difference to the extinction procedure in Experiments 2a and 2b may perhaps be attributed to the ineffectiveness of this procedure in eliminating A–B excitatory associations. It may be simply that not enough training was given in the extinction phase—we have no way of knowing how readily such associations are formed during concurrent preexposure and what will be required to extinguish them. By making the assumption that extinction occurs only slowly with the procedure we have employed, the associative theory can readily accommodate the results of Experiments 2a and 2b. It should be added, however, that this assumption also precludes a categorical rejection of the notion of stimulus differentiation. We have acknowledged the possibility that differentiation may be going on alongside associative learning in our training procedures. The test results obtained, even given the extinction procedures of Experiment 2, may be primarily determined by excitatory associations formed between A and B. But if some more effective extinction procedure could be devised, it remains possible that once these associations have been neutralized, a stimulus differentiation effect could become evident as reduced generalization after concurrent preexposure.

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