LEARNING AND MOTIVATION 26, 203–219 (1995)

Perceptual Learning in Flavor Aversion Conditioning: Roles of Stimulus Comparison and Latent Inhibition of Common Stimulus Elements

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In three experiments, rats received training in which an aversion was established to one flavor and the extent to which this aversion generalized to a second flavor was tested. Experiment 1 showed that nonreinforced preexposure to both flavors resulted in reduced generalization between them. Experiments 2 and 3 demonstrated that this reduction in generalization required the two flavors to be presented on alternate trials during preexposure. Subjects given preexposure consisting of a block of trials with one flavor followed by a block of trials with the other showed the same degree of generalization as subjects given no preexposure. The two schedules of stimulus presentation were equated in the total amount of exposure given to each stimulus, making it unlikely that differences in latent inhibition could be responsible for the difference seen on the test. It is suggested that the opportunity for stimulus comparison offered by the alternating schedule might be important in a process of perceptual learning that is responsible for the reduced generalization. © 1995 Academic Press, Inc.

Honey and Hall (1989) and Mackintosh, Kaye, and Bennett (1991) have demonstrated, using the flavor aversion procedure, that preexposure to a pair of flavors substantially reduces the generalization between them when a conditioned response (CR) is established to one and the other is presented in a non-reinforced generalization test. This result has been taken to reflect an increase in the discriminability of the target stimuli as a consequence of preexposure (e.g., Honey & Hall, 1989). Although procedurally very different, this finding constitutes a clear parallel to the paradigm case of *perceptual learning* introduced by Gibson and Walk (1956), in which it was shown that prolonged exposure to a pair of objects

This work was supported by grants from the United Kingdom Science and Engineering Research Council. We thank L. Aguado, C. Bonardi, and R. Honey for helpful discussion.
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0023-9690/95 $6.00

can enhance the ability of rats to learn a visual discrimination between them (see Hall, 1980).

It is usual to assume (e.g., Mackintosh, 1974; Rescorla, 1976) that the degree of generalization between two stimuli, A and B, will depend on the extent to which these stimuli hold elements or features in common. Each stimulus can be conceptualized as consisting of a compound of elements, *ac* and *bc*, where *c* represents elements common to both, and *a* and *b* those elements that are unique to A and B respectively. Following conditioning to A (i.e., to *ac*), presentation of the test stimulus B (i.e., *bc*) will evoke the CR to the extent that the *c* elements have become associated with the reinforcer. Generalization will thus depend on the extent to which A and B have features in common (the number of *c* elements), and the extent to which these features acquired strength during conditioning. This analysis suggests two main classes of mechanism by which preexposure might bring about a reduction in generalization. One possibility is that preexposure might in some way reduce the proportion of elements that stimulus A shares with B; the other is that preexposure might be particularly effective in restricting the ability of common, *c*, elements to acquire associative strength.

The *differentiation* account of perceptual learning proposed by Gibson (1969) is the best known example of a theory belonging to the first of these classes. It is proposed that exposure to a set of stimuli allows a subject to come to respond to aspects of these stimuli that were not initially responded to. This differentiation consists of an increase in the ability of the subject to detect distinctive features of the stimuli (the *a* and *b* elements of the example given above), a process of abstraction that is aided by experience of contrasted instances (Gibson, 1969, p. 108). In addition to abstraction, Gibson (1969, p. 111) postulates a second perceptual learning process whereby a subject comes to ignore irrelevant aspects of the stimuli, that is, aspects that fail to distinguish one stimulus from another (the *c* elements of the preceding example).

One of the proposed mechanisms for perceptual learning in the theory developed by McLaren, Kaye, and Mackintosh (1989) provides an instance of the second class of account. McLaren et al. (1989) note that preexposure to a stimulus will result in latent inhibition, that is, a decline in the ease with which the stimulus can acquire strength as a conditioned stimulus (CS) in a Pavlovian conditioning paradigm. Preexposure to stimuli A (*ac*) and B (*bc*) will, therefore, produce latent inhibition to *a*, to *b*, and to *c*; but it should be particularly effective in establishing latent inhibition to the *c* elements as these will be present on all preexposure trials. Hence, during conditioning to A (*ac*), the unique *a* elements will be much more likely than the *c* elements to acquire associative strength, and the capacity for stimulus B (*bc*) to evoke the CR, via the strength of *c*, will be correspondingly reduced.

The experiments reported here are intended to allow an assessment of these interpretations by investigating the role of stimulus comparison in generating perceptual learning effects. The differentiation theory supposes that the opportunity for the subject to make comparisons between stimuli plays a critical role in producing the perceptual changes underlying improved discrimination; considerations of latent inhibition lead to no such conclusion. This issue is taken up directly in Experiments 2 and 3. As a first step, however, we thought it necessary to establish the reliability of the basic effect of interest and to demonstrate that with our procedures and parameters, prior exposure to two flavors will reduce generalization between them.

EXPERIMENT 1

The aim of this experiment was to confirm the finding of Honey and Hall (1989) and of Mackintosh et al. (1991) that preexposure to a pair of flavors will reduce the generalization of associative strength between them. The experimental procedures were in general the same as those used by Honey and Hall (1989). The choice of the particular flavors to be used was determined by the demonstration by Mackintosh *et al.* (1991, Experiment 1) that a perceptual learning effect is more likely to be obtained when the flavors to be discriminated (saline and sucrose in their experiment) are made more similar by the addition of a common feature (in their case, lemon) to each. Accordingly we made use of similar compound flavors in the present experiment. They are symbolized below as AX and BX, where X represents the explicitly added common feature (dilute HCl in our experiment).

All subjects received a phase of conditioning in which consumption of the AX stimulus was paired with a lithium chloride (LiCl) injection, followed by a test trial on which consumption of the BX flavor was measured. The four groups differed in their previous experience of the flavors. Group AX/BX received nonreinforced preexposure to both AX and BX; we expected this group to show less evidence of an aversion to BX than that shown by subjects (Group W) that were allowed access to water only during the preexposure phase. In order to determine whether preexposure to both stimuli is necessary for an effect to be obtained, two further preexposure conditions were included (see Honey & Hall, 1989). Group BX was given preexposure to just the test stimulus (BX); Group AX was given preexposure just to that used as the CS.

Method

Subjects and apparatus. The subjects were 32 male hooded (Lister) rats with a mean free-feeding weight of 413 g (range: 380–480 g). They had previously served as subjects in an experiment using an appetitive conditioning paradigm, but were naive to all aspects of the current stimuli and procedures.

Inverted 50-ml centrifuge tubes equipped with stainless steel, ball-bearing-tipped spouts were used to present measured amounts of unflavored tap water, a compound solution of .01 *M* hydrochloric acid (HCl) and .16 *M* saline (stimulus AX), or a compound solution of .01 *M* HCl and .33 *M* sucrose (stimulus BX). The molarities given are those that apply to the compounds. Fluid consumption was measured, by weighing, to the nearest .5 ml. The unconditioned stimulus for the conditioning trials was an intraperitoneal injection of .3 *M* LiCl at 10 ml/kg of body weight.

Procedure. The initial stages of water deprivation were conducted with subjects housed in pairs in their home cages. The standard water bottles were first removed overnight. On each of the following 2 days, access to water was restricted to two daily sessions of 30 min initiated at 1200 h and 1700 h. Presentations of fluid continued to be given at these times throughout the experiment. The subjects were then individually housed and on the next morning given 30 ml of unflavored tap water in the centrifuge tubes, consumption being measured in order to establish individual baseline levels of fluid intake. Free access to water was then given in the standard water bottles for 30 min at 1700 h.

The rats were then randomly assigned to one of four groups for the 8 days of the preexposure phase. Subjects in Group AX/BX were given access to 10 ml of one of the compound flavors on the morning session of each of these days. The flavors were presented in alternation, beginning with AX on the first preexposure day. Group AX received four presentations of flavor AX, with 10 ml of water being presented on those days on which Group AX/BX was given flavor BX. Group BX received just the BX presentations, with water being presented on alternate days. Group W received 10 ml of water on the morning session of each preexposure day. All received free access to water for 30 min in the afternoon session.

There followed three conditioning trials. On each trial, all subjects received a 30-min presentation of 10 ml of flavor AX followed by an injection of .3 *M* LiCl. Each trial was followed by a recovery day on which the animals were permitted free access to water for 30 min in the morning and 30 min in the afternoon. A test trial followed the last of these recovery days. On this trial, all subjects were given unrestricted access to flavor BX for 30 min.

Results

During the preexposure phase, the animals almost invariably drank all 10 ml of the fluid presented in the morning drinking sessions.

The group mean quantities of fluid consumed on each of the three conditioning trials are presented in Fig. 1. It is apparent that the acqui-

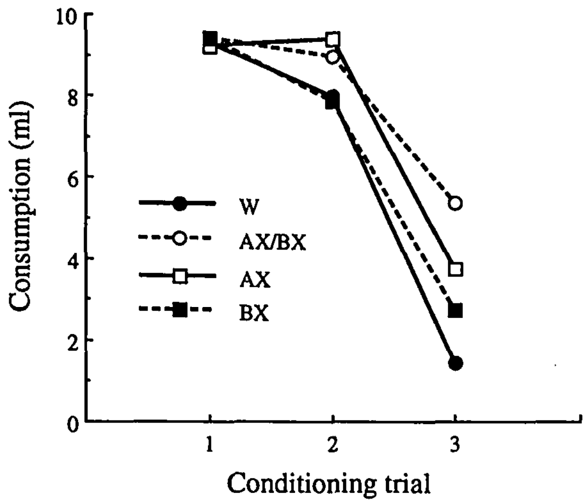

FIG. 1. Experiment 1: Group mean scores for three conditioning trials on each of which presentation of AX was followed by an injection of LiCl. Group AX had received preexposure to AX, Group BX had received preexposure to the flavor BX, Group AX/BX had received preexposure to both flavors, Group W had received only water in preexposure.

sition of suppression of consumption of the AX flavor was somewhat retarded in Groups AX and AX/BX relative to Group W. Group BX's performance differed little from that of Group W. This pattern of results presumably reflects a latent inhibition effect in subjects given preexposure to the CS, flavor AX. An ANOVA (analysis of variance) was conducted on the conditioning data with group and trial as factors. The rejection level adopted for this and all subsequent analyses was $p < .05$. This analysis showed there to be a significant effect of group, $F(3, 28) = 7.43$, of trial, $F(2, 28) = 189.16$, and a significant interaction between these two factors, $F(6, 56) = 3.69$. This interaction was explored using an analysis of simple main effects. This showed there to be significant difference among the groups on the second, $F(3, 28) = 5.53$, and third, $F(3, 28) = 5.36$, conditioning trials. A further analysis using Duncan's multiple range test revealed that on the second trial both Groups AX and AX/BX differed significantly from each of Groups W and BX. On the third trial Groups AX and AX/BX differed from Group W. The other pairwise comparisons yielded no significant differences.

Consumption of the test flavor BX on the test trial is presented in Fig. 2. It shows that Group AX/BX drank substantially more than any of the other three groups. These latter differed little from one another, with Group W showing only marginally less consumption than Group AX or Group BX. Analysis of the data shown in Fig. 2 revealed a significant effect of group, $F(3, 28) = 6.11$. Pairwise comparisons using a Duncan's

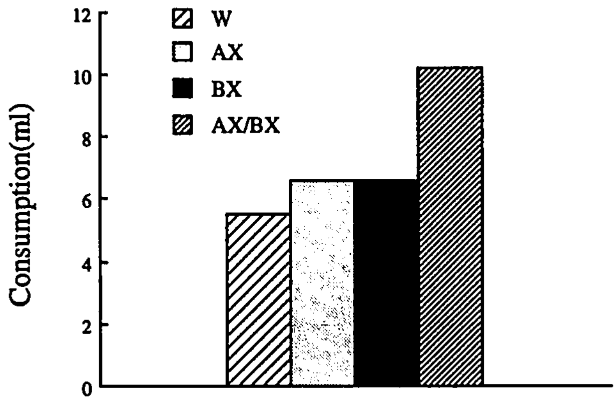

FIG. 2. Experiment 1: Group mean scores on the test session with flavor BX. Group AX had received preexposure to AX, Group BX had received preexposure to the flavor BX, Group AX/BX had received preexposure to both flavors, Group W had received only water in preexposure.

test showed that Group AX/BX differed significantly from each of the other three groups AX, BX, and W, and that these latter groups did not differ among themselves.

Discussion

Rats given prior exposure to two flavors (in this case the compound flavors AX and BX) showed evidence of poor generalization to BX of an aversion established to AX, compared with subjects that received no preexposure to the flavors. This result accords with previous findings (Honey & Hall, 1989; Mackintosh *et al.,* 1991). Also in accord with previous work is the finding that preexposure to the CS alone (Group AX) does not appear to limit the extent of generalization (Hall & Honey, 1989). Less expected is the finding that subjects given prior exposure to just the test flavor (Group BX) showed the same low level of consumption on test as Groups W and AX; previous experiments (Best & Batson, 1977; Honey & Hall, 1989) have found this preexposure treatment to be effective in attenuating generalization.

It is not clear what feature of the experimental procedure used here is responsible for the unexpected effect observed in Group BX. The outcome does, however, allow us to exclude the possibility that the results obtained in the other groups might be a direct consequence of the novelty of flavor B. It might be argued that the low levels of test consumption shown by Groups AX and W reflect a neophobic reaction to stimulus element B, encountered for the first time on the test. This cannot be the whole explanation, however, as Group BX, for whom flavor B was familiar, showed the same low level of consumption. Again, it has been argued

(Best & Batson, 1977; but see also Bennett, Wills, Wells, & Mackintosh, 1994) that an aversion established to one novel flavor will generalize especially readily to a novel test flavor. This suggestion might be used to explain the difference in test performance between Group AX/BX and Group W, but it wrongly predicts that consumption should be high in Group BX.

The finding that generalization appears to be attenuated only in Group AX/BX encourages the speculation that discrimination will be enhanced by preexposure only when the subjects have had an opportunity to compare the relevant stimuli. An alternative explanation can be devised, however, that makes use only of the well-established principle of latent inhibition. As we have already noted, generalization between AX and BX can be assumed to depend largely on the strength acquired by the explicitly added common element X (although other features that A and B share may also play some role). Now during exposure, latent inhibition is likely to accrue to the X element in all three preexposed groups. But, as McLaren et al. (1989) point out, X will undergo twice as much exposure in Group AX/BX as in either of the other preexposed groups. If four preexposures produce little or no latent inhibition, then Groups AX and BX will condition as well to X as will Group W, and the generalization test performance of these three groups will be similar. But if the eight preexposures given to Group AX/BX is enough to produce substantial latent inhibition, X will acquire little associative strength during conditioning for this group and flavor B will be consumed readily on the test. (It may be noted that an exactly parallel account can be offered based on the assumption that performance on test trials reflects differences in the extent to which neophobia to X has become habituated during preexposure.)

We can examine the course of conditioning to AX (see Fig. 1) for information about the degree to which X suffered latent inhibition in the various groups. Particularly slow learning in Group AX/BX would support the hypothesis that latent inhibition to X was especially profound in this group. The results shown in Fig. 1 give only limited support to this notion—certainly (at least, on the last conditioning trial) Group AX/BX showed numerically less suppression of consumption than any of the other groups; but latent inhibition was also evident in Group AX and the performance of this group did not differ statistically from that shown by Group AX/BX. Such results cannot be theoretically decisive if only because the scores presented in Fig. 1 represent the acquisition of strength by both elements (A and X) of the compound and thus are unlikely to give a true estimate of the associative state of X. Accordingly, we thought it worthwhile to adopt a different approach, seeking evidence of a perceptual learning effect in an experimental design in which the latent inhibition of common elements could not be responsible.

EXPERIMENT 2

According to Gibson (1969) exposure to a pair of events will facilitate subsequent discrimination between them because it allows stimulus differentiation to occur. Although the mechanisms responsible for this process are described in only the most general terms, it seems clear that differentiation is presumed to proceed most readily when the conditions of exposure allow for the subject to make comparisons between the target events (see, e.g., Gibson, 1969, p. 108, p. 145). This suggestion is consistent with the observation from Experiment 1 that it was necessary, in that experiment, for animals to receive exposure both to AX and BX for the perceptual learning effect to be obtained.

An implication of this theoretical analysis is that the likelihood of differentiation (and hence of the perceptual learning effect) occurring will depend on the extent to which the preexposure procedure facilitates comparison of the stimuli. The present experiment was designed to investigate the effects of two preexposure schedules that, it might reasonably be assumed, differed in this regard. In both schedules the subjects received two stimulus presentations on each preexposure day. For group I (intermixed), one presentation each day was of AX and the other of BX, in an alternating sequence. Group B (blocked) did not experience the two stimuli on the same day but was given a block of trials with one of them followed by a block of trials with the other. Although we are not able to specify the mechanisms by which it is carried out, it seems clear that comparison will be more likely in the intermixed case than in the blocked case. If this process is important in producing the perceptual learning effect observed in Group AX/BX of Experiments 1 and 2, then generalization should occur less readily in Group I than in Group B.

An advantage of this experimental design is that, although the scheduling of events differs, both groups experience the same number of presentations of AX and BX in the preexposure phase. Latent inhibition and the habituation of any neophobic response to the various components of the stimuli should therefore occur to an equivalent extent in the two groups, and any difference between them in their test performance will not be attributable to these factors. A third group of subjects, Group W, given only water during preexposure, was included in order to allow us to assess the extent of generalization between AX and BX in the absence of any preexposure; but the effect of central theoretical interest is any difference that might emerge between Group B and Group I.

Method

The subjects were 32 male hooded rats with a mean free-feeding weight of 393 g (range: 330–440 g). They had previously served as subjects in an experiment employing an appetitive conditioning paradigm, but were naive to all aspects of the current stimuli and procedures.

A schedule of water deprivation was established, as in Experiment 1. Over the next four days, all subjects received exposure to the flavor compounds AX and BX. Each subject received twice daily 30-min presentations of 10 ml of fluid. Subjects in Group I ($N = 8$) were given, on each of the four days, flavor AX at 1100 h and flavor BX at 1700 h. Sixteen subjects were assigned to Group B. Half received twice daily presentations of AX on the first two preexposure days and twice daily presentations of BX on the last 2 days; the remainder received BX on the first two days and AX on the last two days. There was no substantial difference in the performance produced by these different schedules and the results of these two subgroups are pooled as Group B. Group W ($N = 8$) received twice daily presentations of 10 ml of water.

On the next day, all subjects were given a 10 ml presentation of flavor AX at 1100 h followed by an injection of LiCl; at 1700 h they were given free access to water for 30 min in the standard bottles. There then followed a recovery day on which subjects received two 30-min sessions of free water access at 1100 and 1700 h. As in Experiment 1, this cycle was then repeated twice, and was followed by a test trial in which all subjects were given unrestricted access to flavor BX for 30 min at 1100 h. Details not specified here were the same as those described for Experiment 1.

Results and Discussion

The animals drank virtually all the fluid offered on the first conditioning trial; signs of an aversion appeared on the second trial, and suppression of consumption was nearly complete on the final trial. Group mean scores for each of the three trials were: For Group W, 9.4, 5.5, and 0.8 ml; for Group B, 9.3, 8.5, and 1.9 ml; for Group I, 9.0, 6.2, and 0.8 ml. It is apparent that, apart from the relatively high level of consumption shown by Group B on trial two, there is little evidence of latent inhibition in the preexposed subjects. An ANOVA with group and trial as the factors revealed a significant effect of group, $F(2, 29) = 6.68$, a significant effect of trial, $F(2, 58) = 262.55$, and a significant interaction between these factors, $F(4, 58) = 3.88$. A simple main effects analysis confirmed there to be a significant difference among the groups only on trial two, $F(2, 58) = 12.99$, and Duncan's test showed that on this trial, Group B differed significantly from Groups W and I, which did not themselves differ. The failure to find a robust latent inhibition effect in both preexposed groups was unexpected and will be discussed further, after the results generated by similar procedures in Experiment 3 have been described.

Performance on the test trial is shown in Fig. 3. It is evident that of the two preexposure conditions, only that given to Group I produced a perceptual learning effect, as characterized by a high level of consumption relative to that shown by Group W. Statistical analysis confirmed this impression. An ANOVA conducted on the data summarized in Fig. 3

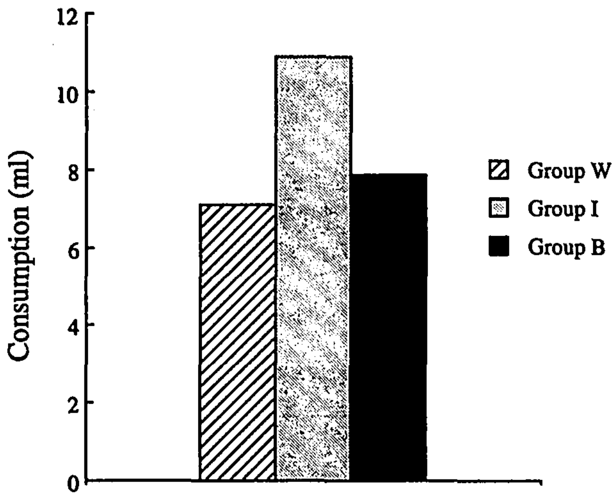

FIG. 3. Experiment 2: Group mean scores on the test session with flavor BX. Group I had received preexposure in which trials with AX and BX were intermixed; Group B had received separate blocks of trials with AX and with BX; Group W had received only water in preexposure.

showed there to be a significant difference among the groups, $F(2, 29) = 8.85$. Pairwise comparisons among the group means using Duncan's test showed that group I differed significantly from Groups B and W, and that these latter groups did not differ significantly from one another.

These results support the conclusion that latent inhibition of common elements plays no more than a minor role in the perceptual learning effect produced by our experimental procedure. Generalization from AX to BX was only slightly less marked in Group B than in Group W, in spite of the fact that Group B was given as much preexposure to the critical stimuli as was given to the AX/BX groups of our previous experiments. As the results for Group I show, the important factor in producing the perceptual learning effect is the way in which the stimulus presentations were scheduled during preexposure. Group I and Group B were equated in their exposure to AX and BX, but only in the first of these groups, in which the stimuli were presented on alternate trials during preexposure, was the effect found. There is no reason to suppose that the intermixed procedure will be more likely to produce latent inhibition than the blocked procedure; and indeed, although the source of the result is obscure, the acquisition data from this experiment produced no evidence of a significant latent inhibition effect in Group I.

Confirmation of the superiority of the intermixed over the blocked procedure in enhancing the ease with which preexposed stimuli can be discriminated comes from a recent study by Honey, Bateson, and Horn

(1994). Their procedures were very different—the subjects were chicks, the stimuli were visually presented geometric figures, and the final test required a simultaneous discrimination between the preexposed figures. Nonetheless, they were able to demonstrate (at least for figures that were fairly similar to one another, as ours presumably were, given the presence of the common X element) that discrimination was superior after preexposure in which the figures were presented intermixed within a given session than after preexposure in which separate sessions were given with each of the figures.

EXPERIMENT 3

Before taking up the theoretical implications of the effect demonstrated in Experiment 2, we thought it worthwhile to extend the empirical analysis of the phenomenon, particularly in view of further results reported by Honey *et al.* (1994). Their finding, that intermixed preexposure enhances discrimination learning more so than does blocked preexposure, was true only for one of the sets of stimuli they used. This effect was found when the stimuli differed in form alone. But when a color cue was added so that the stimuli differed in both form and color, the reverse effect was found—that is, discriminative performance was now worse after intermixed rather than blocked preexposure. Honey *et al.* (1994) interpreted their results as indicating that the intermixed procedure will be effective in generating a perceptual learning effect only when the stimuli in question are ones between which generalization occurs readily. When the stimuli are easily discriminable (as will be the case when the color difference is present along with the difference in form), there will be no scope for preexposure to enhance discrimination further and the effect of other processes may become evident. In particular, they suggest, the intermixed procedure is likely to foster the growth of direct associations between the preexposed stimuli, associations that, by a process akin to that responsible for sensory preconditioning, will tend to promote generalization between them.

Whatever the merits of this account, it seemed appropriate to attempt to assess the generality of the basic experimental finding by investigating the effects of manipulating stimulus similarity in our own training procedure. This can be readily achieved by eliminating the common X element added to each of the flavors we used in our previous experiments. The simple flavors A and B will still, presumably, hold some features in common, but the elimination of what we suppose to be a salient common element can only act to enhance their discriminability.

Accordingly, in this experiment we employed three groups of subjects (Groups W, I, and B) trained in just the same way as the three groups of Experiment 2, but with the simple flavors A and B as the critical stimuli. Group I received intermixed presentations of A and B; Group

B received the blocked preexposure procedure, and Group W received no preexposure to the flavors. All then received conditioning with A followed by a generalization test with B. The question of interest was whether this change in the nature of the stimuli would bring about a reversal of the effect seen in Experiment 2, with the intermixed procedure now enhancing rather than limiting the degree of generalization seen on the test.

Method

The subjects were 32 male hooded Lister rats with a mean free-feeding weight of 458 g (range: 370–560 g). They had previously served as subjects in an appetitive conditioning experiment. A schedule of water deprivation was established as in Experiment 2, with fluid being presented twice daily, at 1100 and 1700 h. During the 4 days of the preexposure phase Group I (N = 8) received access to A at 1100 h and B at 1700 h. Of the 16 subjects allocated to group B, half received presentations of A on the first 2 days and of flavor B on the final 2 days; for the remaining half, this arrangement was reversed. Group W (N = 8) received only water during this phase. The procedures for conditioning and the test were the same as those employed in Experiment 2 except that the CS was flavor A and the test stimulus was flavor B. Any details not specified here were the same as those described for the preceding experiment.

Results and Discussion

Acquisition of the aversion during conditioning followed much the same course as was seen in Experiment 2. Group mean consumption scores for the three conditioning days were: For Group W, 9.8, 5.8, and 0.8 ml; for Group B, 9.6, 6.3, and 1.0 ml; for Group I, 9.8, 5.9, and .8 ml. An ANOVA conducted on these data revealed a significant effect of trial, $F(2, 28) = 366.99$, but no effect of group and no interaction (Fs < 1). We have thus reproduced the finding of Experiment 2 that no latent inhibition is evident after intermixed preexposure; and in this case, latent inhibition also failed to occur in Group B (in Experiment 2, Group B showed a small but significant latent inhibition effect). These results, taken together with those of Experiment 2, point to the conclusion that some aspect of the present preexposure procedure tends to reduce the chances of obtaining a latent inhibition effect. We can only speculate as to the source of this result. One possibility is that the change of schedule from preexposure to conditioning (from two sessions a day with a flavor to just one such session) constitutes an effective change of context, a change to which latent inhibition is known to be sensitive (e.g., Hall & Channell, 1986); but we can provide no evidence in support of this speculation. What remains the case, however, is that the absence of latent inhibition during conditioning with A renders implausible any attempt to account

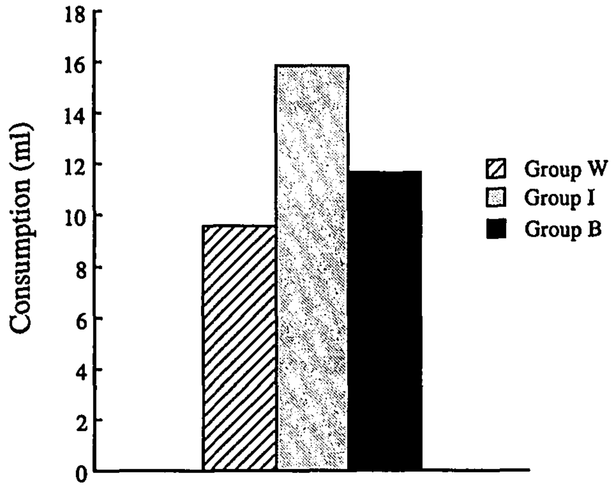

FIG. 4. Experiment 3: Group mean scores on the test session with flavor B. Group I had received preexposure in which trials with A and B were intermixed; Group B had received separate blocks of trials with A and with B; Group W had received only water in preexposure.

for differences seen on the generalization test in terms of differences among the groups in initial acquisition.

The results of the generalization test are shown in Fig. 4. It shows a pattern of results essentially identical to that seen in Experiment 2 (Fig. 3). The overall level of consumption is higher (we have routinely found in other experiments that the addition of HCl to flavors A and B tends to reduce consumption) but again it is Group I that shows a high level of consumption with Groups B and W showing similar low levels. An ANOVA conducted on the test data showed there to be a significant difference among the groups, $F(2, 29) = 6.91$. Pairwise comparisons using Duncan's test showed that Group I differed significantly from Group B and from Group W and these latter two groups did not differ significantly from one another.

In contrast to the results reported by Honey *et al.* (1994), our experiment yields no indication that the effect of the schedule of preexposure can be modified by a manipulation designed to render more similar the stimuli between which generalization is assessed. With our procedures, intermixed preexposure was still effective in producing a perceptual learning effect even when the stimuli lacked the explicit common element that was present in Experiment 2. Although unexpected, this finding does not constitute a major challenge to the interpretation offered by Honey *et al.* (1994). According to their account, the intermixed procedure will fail to produce the perceptual learning effect when the stimuli are so different that little or no generalization occurs between them. It is a simple matter to argue, therefore, that even in the absence of the explicitly added X element, our flavors A and B remain sufficiently similar (share enough intrinsic common elements) for there to be substantial generalization between them. In such circumstances the effect of intermixed preexposure in limiting generalization between A and B may still be evident. It may be added that the other factor supposed by Honey *et al.* (1994) to be operating in their experiment is unlikely to be influential in ours. Intermixed preexposure, they suggest, might act to enhance the degree of generalization between two stimuli to the extent that it allows the formation of direct associations between them. In our intermixed procedure the minimum interval between presentations of the two flavors was 6 hr, clearly not optimum for association formation.

Whatever the explanation of the results reported by Honey *et al.* (1994) it remains the case that in this experiment, as in Experiment 2, we have found that preexposure to a pair of stimuli limits generalization between them only when they are presented in an intermixed fashion during preexposure. Things may be different when very different stimuli are used but, for the flavors used in the present experiments, we can conclude that perceptual learning is more likely to occur when the scheduling of events during exposure is such as to enhance the likelihood of stimulus comparison occurring. A discussion of the mechanisms that might be responsible for this effect is presented next.

GENERAL DISCUSSION

Experiment 1 confirms that preexposure to a pair of stimuli will reduce the extent of generalization between them. This result is analogous to previous demonstrations that prior exposure can enhance the learning of a discrimination between stimuli (e.g., Gibson & Walk, 1956) and may be regarded as an instance of perceptual learning. It is possible, however, to devise an explanation for this effect without introducing any special new mechanism for perceptual learning, making use only of the well established phenomenon of latent inhibition. McLaren *et al.* (1989) point out that nonreinforced exposure to two stimuli will be particularly effective in establishing latent inhibition to the elements that these stimuli hold in common, as these elements will be present on all preexposure trials. These elements will then acquire little associative strength during subsequent reinforced training with one of the stimuli and the generalized responding evoked by the other, which may be presumed to depend on the associative strength of the common elements, will be rather limited. The observation made in Experiment 1, that preexposure to just one or the other of the critical stimuli does not produce the perceptual learning effect, is an accord with this analysis—half the number of exposures, it may be argued, is not enough to produce the degree of latent inhibition to the common elements that is required to produce the effect.

Although the latent inhibition suffered by common elements may well play a role in at least some demonstrations of perceptual learning effects (see, e.g., Bennett *et al.*, 1994), there are reasons to think that it is not fully adequate to deal with all the results reported here. In our Experiment 1 we gave (for experiments using the flavor-aversion paradigm) extensive conditioning to the target CS with a potent US. Latent inhibition will retard conditioning but, given such training parameters, even an extensively preexposed stimulus can be expected to acquire substantial associative strength. Further relevant evidence comes from Experiments 2 and 3. In these it was found that preexposed subjects (in the B groups) showed no perceptual learning effect (their generalization test performance was almost identical to that of nonpreexposed controls) in spite of their having received training capable, in principle, of establishing latent inhibition to the common elements.

The special feature of the training given to the B groups was that presentations of the two stimuli during preexposure occurred in separate blocks. In Experiment 1, and in the intermixed procedure used for Group I in Experiments 2 and 3, the two stimuli were presented in alternation during preexposure. The fact that the perceptual learning effect is found only with the latter procedure lends support to the speculation that the process responsible for the effect operates most efficiently when the preexposure procedure is one that allows the possibility of the subject making comparisons between the stimuli. To the extent that comparison is thought to be instrumental in producing stimulus differentiation, Gibson's (1969) account of perceptual learning is strengthened by this result. But before turning to an interpretation of the sort offered by Gibson (1969), we should consider the possibility that the dependence of perceptual learning on the scheduling of exposure might be susceptible to analysis in terms of known processes of associative learning. One possibility has been developed by McLaren *et al.* (1989).

It has already been proposed that stimuli A and B may be construed as consisting of the elements *ac* and *bc,* where *a* and *b* represent unique elements, and *c* the common elements (which will include the flavor X in the present series of experiments). McLaren *et al.* (1989) argued that, for animals that encounter A for the first time during conditioning, associations may be formed not only between the CS and the US, but also among the elements that constitute the CS (i.e., between *a* and *c*). These associations will provide a source of generalized responding on the test—the *c* element present in the *bc* compound will be able to activate a representation of *a* which will in turn be able to activate a representation of the US. That is, generalized responding will be produced not only by the direct *c*-US association but also by way of the chain *c*-*a*-US. McLaren *et al.* (1989) then go on to argue that preexposure to the stimuli will tend to eliminate this second source of generalization. During the initial stages of stimulus exposure the within-stimulus associations (between *a* and *c* and between *b* and *c*) can be expected to form. Once these have been established, presentations of A will evoke a representation of the unique feature of the absent B via the associative chain *a-c-b*. As a consequence, *a* will come to form an inhibitory link with the representation of *b*. Similarly, presentations of B will, via the chain *b-c-a*, result in the formation of an inhibitory *b-a* link. These inhibitory links will counteract the tendency, which will be present in the nonpreexposed subjects, for *c* to activate *a* on the test trials and will thereby reduce generalization to the test stimulus B.

Application of this theory to the results for groups I and B of Experiments 2 and 3 is straightforward. An inhibitory link will form on a *bc* trial, for instance, only when there is already in existence an excitatory *a-c* link of some strength (and vice versa, for the formation of inhibitory links on *ac* trials). The intermixed procedure will be the optimal arrangement for ensuring that the appropriate connection has strength on each trial. With the blocked procedure, on the other hand, there is only a single transition from one trial type to the other, the excitatory connection established during the first block will extinguish during the second block, and the opportunity for inhibitory links to become established will be minimal. It follows that inhibitory links will be weaker with this type of schedule, and if these play an important role in reducing stimulus generalization between the stimuli, then perceptual learning should be attenuated with blocked preexposure.

The proposal that intermixing stimulus presentations is an especially effective form of preexposure because it allows the formation of mutually inhibitory links can be viewed, not as a denial of the importance of a process of stimulus comparison in perceptual learning, but as a specification of a possible mechanism by which this process might work. None the less, it generates an interpretation of the phenomenon that is rather different from that embodied in Gibson's (1969) differentiation theory. According to this latter, exposure to contrasted stimuli will produce a change in the way in which they are perceived, with the organism becoming increasingly sensitive to the unique features that each stimulus possesses and growing correspondingly less responsive to their common elements. The theory developed by McLaren *et al.* (1989) makes no such assumptions—the unique and common elements that constitute a given stimulus are the same at the end of preexposure as they were at the beginning; what changes is the strength of various associations among these elements.

There are at present few compelling arguments that might persuade us to accept one theory rather than the other. An advantage of McLaren *et al.*'s (1989) theory is that it deals only in known associative processes. Further, it has no trouble with the fact that, even in the intermixed condition, the critical stimuli in our experiments are presented several hours apart—it may be thought implausible to suppose that a special process of stimulus comparison would have a powerful effect under these conditions of stimulus exposure. But direct tests that might allow a choice between the alternatives are not currently available. There have been some attempts to pursue the implications of the rather more tightly specified account offered by McLaren *et al.* (1989) but they have so far failed to generate clear support for the notion that mutually inhibitory links form during preexposure (see Honey & Hall, 1991). The possibility remains that we may have to accept the reality of some nonassociative mechanism of stimulus differentiation. A satisfactory experimental test of this alternative may have to await the development of a more precisely specified version of the theory.

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Received August 12, 1994
Revised November 18, 1994