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Analysis of the Role of Stimulus Comparison in Discrimination Learning in Pigeons

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Short title: Comparison in discrimination learning

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Abstract

In Experiment 1, pigeons were trained on a conditional discrimination in which presentations of a color and of a shape signaled that one response would be reinforced, and presentations of a different color and a different shape signaled that another response would be reinforced. For Group C (comparison), both colors were presented in some sessions and both shapes in others; for Group NC (no comparison), some sessions involved presentations of one color and one shape, other sessions of the other color and shape. The discrimination was acquired more readily by Group NC than by Group C and this difference between the groups was maintained in a further task (Experiment 2) involving a successive go/no-go discrimination in which pecking at one of the colors and one of the shapes was reinforced, response to the other color and shape being nonreinforced. Analysis of the details of the birds' performance supported an explanation in terms of responses governed by the absolute properties of the stimuli. In contrast to what has been found for human subjects, there was no support for the notion that the opportunity to compare similar stimuli (available to Group C in Experiment 1) engages a perceptual learning process that enhances their discriminability.

Keywords: discrimination, comparison, relational learning, perceptual learning, pigeons

Analysis of the Role of Stimulus Comparison in Discrimination Learning in Pigeons

According to some accounts of perceptual learning (e.g., Gibson, 1969), exposure to similar stimuli, when it is arranged in such a way as to permit comparison between them, will enhance the discriminability of the stimuli, increasing the perceptual effectiveness of features that distinguish between them and reducing the effectiveness of features that they hold in common. Demonstrations of the importance of comparison are provided by studies of perceptual learning in humans. For example, Mundy, Honey, and Dwyer (2007; see also Mundy, Honey, & Dwyer, 2009) tested their participants on a categorization task involving two very similar visual stimuli. Performance was enhanced by giving prior exposure in which the stimuli were presented simultaneously (side by side), allowing the opportunity for comparison. Successive presentations, with the stimuli presented in an intermixed fashion during preexposure, were less beneficial. Some degree of comparison (between the stimulus being presented and the trace of the preceding stimulus) could still occur when the events are presented successively; it is significant, therefore, that inserting a distractor between presentations of the test stimuli has been found to attenuate the positive effect of this form of exposure (Dwyer, Mundy, & Honey, 2011).

These results contrast with those obtained from studies with nonhuman animals. Although there are many experiments (usually using rats as subjects and flavors as the stimuli, e.g., Bennett & Mackintosh, 1999; Blair & Hall, 2003; Mondragón & Hall, 2002; Symonds & Hall, 1995; but also with auditory stimuli and appetitive procedures, e.g., Mondragón & Murphy, 2010) showing that preexposure in which the stimuli are presented in alternation is particularly helpful in facilitating subsequent discrimination, we may doubt that this arises because such exposure promotes comparison of the stimuli. In these experiments the interval between preexposure trials was long and reducing it, a procedure that might be

expected to facilitate comparison, has uniformly been found to convey no special advantage (and sometimes to be disadvantageous) (e.g., Alonso & Hall, 1999; Bennett & Mackintosh, 1999; Rodriguez, Blair, & Hall, 2008). In a recent review, Mitchell and Hall (2014) concluded that a difference in the ability to benefit from the opportunity to compare the stimuli might constitute an important distinction between the perceptual learning effects seen in animals and those seen in humans.

This conclusion may seem to face a challenge from the results of studies conducted in the 1950s, and designed to test Spence's (1936) account of discrimination learning. These (e.g., Bitterman, Calvin, & Elam, 1953; Bitterman, Tyler, & Elam, 1955; MacCaslin, 1954; North & Jeeves, 1965) generally found that rats learn a simultaneous discrimination task more readily than a successive discrimination involving the same stimuli. These results do not, however, require the conclusion that the simultaneous task is easier because it allows the possibility of comparing the stimuli, as the two types of discrimination that were used differed in other ways. In the simultaneous task the rat could learn simply to approach black (say) and to avoid white; in the successive version it had to learn to go to the left (say) when faced with two black cues, and to the right when faced with two white cues. The latter task could be more difficult because it requires the use of a configural or conditional cue involving two stimulus dimensions (brightness and position). There is, however, one early study (by Saldanha & Bitterman, 1951) that avoids this issue by using a different design, and that produces evidence suggestive of a role for stimulus comparison.

In the procedure used by Saldanha and Bitterman (1951), the rats were trained on two simultaneous discriminations concurrently. In their Experiment 2, one group (to be referred to as Group C for comparison) received some trials on which choice lay between two gray cards differing in brightness, and other trials on which the choice was between black and

white stripes that differed in width. A second group (Group NC, for noncomparison) received trials in which the positive gray was presented along with the nonrewarded stripe-width, intermixed with trials in which the positive stripe-width was presented along with the nonrewarded gray. Group C thus got the chance to compare each pair of similar stimuli, whereas Group NC did not. Saldanha and Bitterman found that Group C learned the discriminations much more readily than Group NC and concluded that the opportunity for comparison promoted discrimination learning. This result is consistent with the proposal that a perceptual learning process can go on alongside the associative changes that are necessary for accurate performance on a discrimination task -- that the opportunity for comparison available to animals in Group C makes them better able to perceive the distinctive features of the wide and narrow stripes (say) and thus allows them to form the associations between these features and reward (or nonreward) that permit correct choice.

The aim of the work reported here was to attempt to replicate the essence of the effect reported by Saldanha and Bitterman (1951) (using pigeons as the experimental subjects), and to analyze its source. We modified the original experimental design to take account of certain complications noted by Wills and Mackintosh (1999). In an experiment with pigeons, modeled on that of Saldanha and Bitterman, Wills and Mackintosh found that the comparison condition was helpful only for some stimuli (specifically for rectangles that differed in luminance and not for stars differing in the number of vertices). Furthermore, the difference in performance between these two discriminations (luminances and stars) was not sustained when the pigeons were given a test in which the stimuli were presented individually rather than simultaneously. Wills and Mackintosh concluded that their results were best explained in terms of the operation of a low-level sensory process that, at least for some stimulus dimensions (and luminance is an obvious candidate), allows the contrast between similar

stimuli to enhance the perceived difference between them. Such an enhancement would not involve a learning process and thus would not operate in a subsequent test in which the stimuli were presented individually. Standard interpretations of perceptual learning, on the other hand, envisage a process that has long-lasting, even permanent, effects and thus predicts positive transfer to other discriminations involving the same stimuli.

The first experiment to be described here used a modified version of the Saldanha and Bitterman (1951) design that was intended to rule out an explanation in terms of sensory contrast effects. The subjects were pigeons required to learn discriminations involving a pair of colors (R and G; red and green) and a pair of shapes (+ and x; a white plus or cross on a black background). For all subjects the stimuli were presented one at a time, thus precluding the operation of simultaneous contrast effects. All subjects experienced just two of the stimuli in any given training session, but the two groups differed in the pairings that were arranged. For Group C some sessions contained presentations of R and G and other sessions presentations of + and x; that is, both members of each pair of similar stimuli occurred in the same session. For Group NC the members of each pair occurred in different sessions; that is, they received, for example, presentations of R and + on some sessions and presentations of G and x on the other sessions. The arrangement adopted for Group C may be less effective in promoting the operation of a comparison process than one in which the two similar stimuli are presented simultaneously, but, as we have noted for the human case, intermixed presentations, although not as effective as simultaneous presentation, still produce positive transfer to a subsequent discrimination. It may reasonably be assumed that any comparison process will be more likely to operate in Group C, when the difficult-to-discriminate stimuli are presented a few seconds apart, than in the arrangement used for Group NC in which these stimuli are separated by the intersession interval of about 24 hr. If the opportunity for

comparison bestows an advantage in addition to any that might accrue from simultaneous contrast effects, we might expect to find that the superiority of Group C over Groups NC that was observed in the Saldanha and Bitterman procedure would be evident in this case too.

Experiment 2 was intended to provide a direct test of the proposal that the training given to Groups C and NC in Experiment 1 might engender long-lasting differences between them in the ease with which the stimuli could be discriminated. Experiment 1 employed a conditional discrimination in which the nature of the critical stimulus (displayed on the center key of a three-key pigeon box) signaled which of the two side keys (both illuminated with white light) should be pecked to obtain food. During this training, a peck was required to each of the target stimuli (R, G, +, and x) to initiate the trial, and food was available with equal frequency on each of these trials. In Experiment 2, the birds were transferred to a successive go/no-go discrimination in which all four stimuli were presented in the session, one of the colors and one of the shapes being followed by food, the other color and shape being nonreinforced. It was anticipated that, initially, the birds would peck at all the stimuli, but that the formation of a new discrimination could be assessed by measuring the rate at which responding to the nonreinforced cues declined. The question of interest was whether the two groups would differ in the rate at which they acquired this new discrimination.

Experiment 1

All birds in this experiment were trained on the successive, conditional, go-left/go-right task, in a three-key pigeon box. The critical stimuli were two colors and two shapes presented on the central key. One group (Group NC) received presentations of a color and of a shape in each session; one pair of stimuli was consistently presented on odd-numbered sessions and the other pair on even-numbered sessions. On one type of session, presentation of the color indicated that a response to the left side-key would be rewarded and presentation

of the shape indicated that a response to the right side-key would be rewarded. On the other session type, the arrangement was reversed, with the color signaling reward for a right-key response and the shape reward for a left-key response. Pigeons in Group C were treated identically except that sessions alternated between a type in which both colors were presented and a type in which both shapes were presented.

The question of central interest was whether the two groups would differ in their acquisition of this discrimination (performance being pooled over both session types). For Group C, it is possible to assess separately performance on the two sub-problems (colors and shapes) and these data will also be presented. In addition, after the birds had made progress in learning their discriminations, probe test sessions were inserted in which subjects in each group were confronted with the task employed for the other group. Performance on these tests can give information about the mechanisms used in solving the original task.

Method

Subjects. The subjects were 16 experimentally naive adult pigeons supplied by Abbott Brothers (Norwich). They were housed in pairs in standard cages with free access to water and grit in a colony room that was lit from 8:00 hr to 20:00 hr. Training sessions occurred during the light phase of this cycle. The birds were reduced to 80% of their free-feeding weights by restricted feeding and were maintained at this level throughout the experiment. It proved impossible to establish a reliable keypecking response in four. Data were available, therefore, for 12 subjects; six were assigned to Group C and six to Group NC.

Apparatus. The apparatus was a standard pigeon test chamber, 35 x 35 x 35 cm, supplied by Campden Instruments Ltd. On one wall were three translucent, circular, response keys, each 2.4 cm in diameter and positioned 24 cm above the grid floor of the chamber. The keys were 8 cm apart, edge to edge. An aperture 9 cm below the central key gave access to a

grain feeder that was operated for 3 s to supply reinforcement. Behind each key was an in-line projector allowing the presentation of plain red, green, and white fields, and of a white line, 2 mm wide, on a black background. Lines running horizontally and vertically were presented together to produce a plus (+) symbol; two obliques presented together generated a cross (x). Illumination was supplied by a houselight in the center of the ceiling. An extractor fan attached to the chamber provided some background noise.

Procedure. After initial magazine training, in which the birds learned to eat from the illuminated food tray, the subjects received autoshaping training designed to establish a tendency to peck at all three keys. In the first three sessions of this phase, trials consisted of the illumination of one of the keys with white light for 10 s followed by a 3-s presentation of the food tray. The interval between offset of the keylight and the onset of the next trial was 15 s and there were 40 trials per session. The left key was presented on the first of these sessions, the right key on the second, and the center key on the third. The birds then received two sessions of 3-key training. In these, trials began with illumination of the central key with white light. A peck at this key turned off the light and turned on both white side keys. A peck at either side key extinguished both and resulted in reinforcement.

Phase 1 of discrimination training consisted of 15 pairs of sessions, with an interval of at least 24 hr between successive sessions. Each session consisted of 20 trials, organized as follows. A trial began with the presentation of one of the target stimuli on the center key. A peck at this key turned it off and turned on the two white side-keys. A peck at the side-key designated as correct gave access to food for 3 s and initiated the 15-s intertrial interval; a peck at the wrong side-key resulted in the chamber being darkened for 25 s before the start of the next trial.

For birds in Group C, one session of each pair used red and green as the target

stimuli; alternate sessions used + and x. For three subjects, red signaled that a response to the left side-key would be rewarded and green that a response to the right side-key would be rewarded. For these subjects, + signaled that a left response would be rewarded and x that a right response would be rewarded. For the other three subjects in this group, the assignments were reversed; that is, red and x signaled that a response to the right would be rewarded, green and x that a response to the left would be rewarded. Birds in Group NC received presentations of a color and a shape in each session. Three birds were rewarded for choosing left after red and right after x and, on alternate sessions, right after green and left after +. The remaining three birds were required to choose left after green and right after + in one session-type, and right after red and left after x in the other session-type. Within each session, trials were scheduled so that no more than two of a given type could occur in succession. A summary of the contingencies employed is presented in Table 1.

After 30 sessions of Phase-1 training (15 sessions of each type), all birds received a test (Test 1) in which each member of a given group (C or NC) was exposed to the contingencies that had applied to the other group. The correct response associated with each of the target stimuli was unchanged. The resulting contingencies experienced by each of the counterbalanced subgroups are detailed in Table 1. There were two test sessions, one of each type. The birds then received a second phase of training on their original discrimination tasks. There were 12 Phase-2 sessions, six of each type. This phase was followed by a second test (Test 2), identical to the first. Finally, in Phase 3, the birds received a further four sessions of training (two of each type) on the original discrimination in order to reestablish performance prior to a the training to be given in Experiment 2.

Results and Discussion

Figure 1 summarizes group mean percent correct choices for all phases of the

experiment. Each data point is based on the total number of correct choices summed over adjacent pairs of sessions (one of each type), giving a possible maximum of 40 correct responses per 2-session block.

It is evident that the initial discrimination task was learned only with difficulty in both groups and that, even after 15 session-blocks of Phase 1, performance did not reliably exceed 70% correct. Both groups, however, were performing significantly above chance. Comparing performance on the last block of this phase with chance level (50%) gave $t(10) = 3.87$, $p = .008$ for Group C, and $t(10) = 6.54$, $p < .001$ for Group NC. (Here and elsewhere a significance level of $p < .05$ was adopted.) Contrary to our expectations, the performance of Group NC was superior to that of Group C. An analysis of variance (ANOVA) conducted on the Phase-1 data revealed no significant main effect of group, $F(1, 10) = 2.68$, but there was a significant effect of block, $F(1, 14) = 12.17$, $p < .001$, partial eta squared (η_p^2) = .55, and a significant interaction between these variables, $F(14, 140) = 1.96$, $p = .025$, $\eta_p^2 = .16$. An analysis of simple main effects showed that the superiority of Group NC was statistically reliable on block 5, $F(1, 103) = 4.04$, $p = .047$, block 9, $F(1, 103) = 5.21$, $p = .025$, and block 12, $F(1, 103) = 6.54$, $p = .012$. In Phase 2 of discrimination training, the performance of both groups continued to improve, but the effect was more marked in Group NC than in Group C, resulting in a substantial and sustained difference between the groups. An ANOVA conducted on the Phase-2 data showed there to be a significant effect of group, $F(1, 10) = 11.94$, $p = .006$, $\eta_p^2 = .54$, and of session, $F(5, 50) = 3.96$, $p = .004$, $\eta_p^2 = .28$, but no significant interaction between these variables ($F < 1$). The difference between the groups was maintained in the phase of training that followed the second test. Analysis of the Phase-3 results revealed a significant difference between the groups, $F(1, 10) = 6.99$, $p = .019$, $\eta_p^2 = .41$; the effect of session ($F < 1$), and the interaction, $F(1, 10) = 2.35$, were not

significant.

On the test sessions, in which the subjects of each groups experienced the scheduling of stimuli previously used for the other group, the performance of Group C rose marginally, and that of Group NC fell substantially. For statistical analysis the two test scores of each individual were pooled, as were the scores on the last block of Phase-1 or Phase-2 training that immediately preceded the test. An ANOVA with group (C and NC) and session (end of training vs test) as the variables revealed no significant main effect of group, $F(1, 10) = 2.98$, a marginally significant effect of session, $F(1, 10) = 4.62$, $p = .057$, and a significant interaction between the variables, $F(1, 10) = 5.85$, $p = .036$, $\eta_p^2 = .37$. Analysis of simple main effects showed that the groups differed in their end-of-training scores, $F(1, 20) = 4.65$, $p = .018$, and that the decline from end of training to test was significant for Group NC, $F(1, 10) = 10.43$, $p = .009$ (other Fs < 1).

These results provide no support for the proposal that the opportunity to compare similar stimuli within the same session (as was made available to Group C) will help discrimination learning -- on the contrary, Group C learned the discrimination significantly less readily than Group NC. We conclude that the effect reported by Saldanha and Bitterman (1951) is not to be observed with the version of their procedure used here; it remains to explain the outcome that was obtained.

The poor overall performance of Group C is attributable largely to its failure to solve the shape discrimination. On the final shapes session of Phase 1, the mean percent correct score was 55%, which was not significantly different from chance, $t(10) = 1.00$, $p = .34$; the score for the final colors session was 73%, $t(10) = 3.14$, $p = .007$. The equivalent scores for the end of Phase 2 were 56% for shapes, $t(10) = 1.08$, $p = .300$, and 69% for colors, $t(10) = 4.05$, $p = .002$. The results from the test sessions that immediately followed Phases 1 and 2

indicate that the scheduling of stimuli of the same type in each session played little part in generating these outcomes. Performance on the test sessions, in which these birds experienced the no-comparison procedure, differed little from that shown at the end of the training phase that preceded them.

Group NC also performed well with the colors and poorly with the shapes, as is shown by the scores for the test sessions in which they experienced the comparison procedure. The group mean score over the two test sessions when the shapes were the critical cues (53%) was not significantly above chance level, $t(10) = 0.96$, $p = .360$; the group mean score for the test sessions with colors was 77%, which was significantly above chance, $t(10) = 6.45$, $p < .001$. For these subjects, however, performance was influenced by the way in which the stimuli were scheduled. On these test sessions, subjects trained in the NC condition showed much the same levels of performance as were attained by Group C during training on this task; that is, the superior performance of Group NC was evident only under the conditions that prevailed under training. If we assume that their performance on the colors was no better than that seen during the test sessions, this must mean that their performance on the shapes made some contribution to the overall score during the training sessions. Perhaps the most plausible hypothesis is that although these birds were unable to distinguish the two shapes (as suggested by their test performance), they could learn to respond according to the context in which each was presented during training. That is, during NC training, they might have learned to respond right to red (say) and left to whatever other stimulus was presented in the same session and to respond left to green and right to the other stimulus presented in the session. Performance would thus be good during training and also on the test session in which both cues were colors, but would fall to chance on the test session in which both cues were shapes and were thus presented without the context supplied

during training by the trials in which one of the colors was presented.

In summary, the results obtained can be explained if it is assumed that birds in both groups learned to make the correct response to each of the colors with a fair degree of accuracy, but failed to acquire the correct response to either of the individual shapes. (The overall superiority of Group NC during training implies above-chance performance on trials with shapes as the cues, but, as we have seen, this does not require the conclusion that they learned to discriminate the plus from the cross.) Critically, for our present concern, there was no sign that the opportunity for within-session comparison of similar stimuli, that was available to Group C in the training phase, had any effect on the outcome.

Experiment 2

The aim of Experiment 2 was to determine if the different training regimes experienced by the two groups of Experiment 1 would generate differences when the birds were required to learn a new discrimination involving the same stimuli, but having quite different response requirements. Accordingly, all the birds from that experiment were transferred to a successive go/no-go discrimination in which all four of the critical cues were presented in the same session. Reinforcement was available after a peck to one of the colors and one of the shapes, but not after a response to the other color or the other shape.

We had originally hoped to investigate if an advantage bestowed by training in which both stimuli of the same type occurred in the same session would persist in a procedure in which this arrangement held for all subjects. Given the results of Experiment 1, however, no such effect can be expected, and the issue becomes that of whether the superiority of the NC group shown in Experiment 1 will be maintained under these conditions. If our interpretation of that experiment is correct, no difference should be obtained. We have argued that the two groups differed in Experiment 1 only in that subjects in Group NC were able to make use of a

contextual cue (i.e., the nature of the color that occurred during a given session) to guide choice when one or other of the shapes was presented. This contextual cue would be absent in a procedure in which all stimuli are presented in the same session (and in any case, it is difficult to see how it could affect the learning of a go/no-go discrimination). This experiment thus allows a test of the analysis offered for the results of Experiment 1.

Method

The subjects and apparatus were the same as for Experiment 1. The first of the 10 daily sessions of training began directly after the end of Phase 3 of training in Experiment 1. Each session consisted of 40 trials, 10 presentations of red, 10 of green, 10 of +, and 10 of x. The stimulus was presented on the center key; the side keys were not used in this experiment. Trials occurred in random order with the constraint that no more than two of the same type could occur in succession. The stimulus was displayed on the key for a maximum of 10 s. A peck to the lit key turned it off and initiated a 20-s ITI. For the A subgroups of Experiment 1 (see Table 1), food reinforcement was presented after responses to red and to +. For the B subgroups, food was presented after responses to green and to x.

Results and Discussion

At the start of training, the birds responded readily to all four stimuli. Responding to the positive stimuli was maintained throughout but, as training continued, responding to the negative stimuli began to decline. A discrimination ratio (responses to positive stimuli over the total number of trials with a response) was computed for each animal for each session. Group mean ratios are shown in Figure 2. It is evident that both groups learned the discrimination but that Group NC did so more readily than Group C; that is, the superiority shown by Group NC in Experiment 1 was carried over to this changed procedure. An ANOVA of the data summarized in the figure showed there to be a significant effect of

group, $F(1, 10) = 20.57$, $p = .001$, $\eta_p^2 = .67$, of session, $F(9, 90) = 31.74$, $p < .001$, $\eta_p^2 = .76$, and a significant interaction between these two variables, $F(9, 90) = 3.69$, $p < .001$, $\eta_p^2 = .27$.

Further analysis showed that Group NC outperformed Group C on both of the subproblems of the task (i.e., on both color and shape discriminations). Figure 3 presents, for each group, the mean number of trials per session on which a response was made to the negative color or shape (all birds responded reliably to the positive stimuli). As might be expected, on the basis of the results of Experiment 1, the shape discrimination proved to be more difficult than the color discrimination, but for both the decline in response to the negative stimulus occurred more rapidly in Group NC than in Group C. An ANOVA, with group, session, and stimulus-type as the variables, showed there to be a significant main effects of session, $F(9, 90) = 32.42$, $p < .001$, $\eta_p^2 = .73$, and of stimulus-type, $F(1, 10) = 128.33$, $p < .001$, $\eta_p^2 = .81$; for the main effect of group, $F(1, 10) = 4.73$, $p = .054$, $\eta_p^2 = .32$. The interaction of session and stimulus-type was also significant, $F(9, 90) = 9.90$, $p < .001$, $\eta_p^2 = .49$ (other Fs < 2).

Our interpretation of the differing performance of the two groups on the successive conditional discrimination of Experiment 1 did not lead us to expect differential transfer to the go/no-go task used here. The superior performance of Group NC in that experiment has been attributed to a strategy that could not operate in the present experiment. Evidently something else was learned during in Experiment 1 that transferred to this task and that served to enhance performance in group NC, or to hinder it in Group C, or both.

One possibility is suggested by early work on the relative difficulty of successive and simultaneous discriminations. Bitterman and McConnell (1954) demonstrated that a successive discrimination task, that normally could be solved only with difficulty, was learned much more readily if the rats had received previous training on an easier

simultaneous task. They argued that successful learning of the first task established a “set” that produced positive transfer to the second. A possible parallel effect, with pigeons as the subjects, comes from a study by Seraganian (1979). In this, both discriminations involved successive (go/no-go) procedures. For some birds, the first task was easy; for others it was hard, so that complete success was never attained. Birds given easy initial training learned the second task more readily than those given hard pretraining, a result that Seraganian attributed to the development of a state of “general attentiveness” during solution of the easy task. At a descriptive level, the results we have reported here accord with these findings; that is, the subjects (the NC group) that learned more readily during Experiment 1 showed positive transfer to the new discrimination required in Experiment 2. We accept, however, that a satisfactory explanation would require specification of the nature of the set (or of the process involved in general attentiveness) that is responsible for the transfer.

An alternative possibility emerges if we focus on the fact that the ease of discrimination will be determined by the extent to which there is generalization between positive and negative stimuli. Primary generalization, which will be strong between the two colors and between the two shapes, could be augmented by learned processes (e.g., Ward-Robinson & Hall, 1999). Repeated presentation of two cues in the same session, separated by a relatively brief ITI as in Experiment 1, would allow the formation of an excitatory connection between them. This process would retard the acquisition of a subsequent discrimination in which one of these stimuli was reinforced and one not (as was the case in the present experiment); on each trial, the presentation of the target cue would activate the representation of another cue that was becoming associated with the "wrong" trial outcome, reducing the likelihood of the appropriate response. As it stands, this mechanism could not explain the difference between Groups C and NC, as, in Experiment 1, both groups received,

in each session, trials with a cue that was subsequently (in Experiment 2) to be reinforced intermixed with trials with a cue that was subsequently to be nonreinforced. But this argument neglects the fact that the scheduling of the events in Experiment 1 was specifically arranged so that Group NC received two very different cues in each session, whereas Group C received two similar cues. Evidence from other experimental procedures (e.g., Testa, 1975; Recorla & Furrow, 1977) suggests that associations may be formed more readily between similar cues than between dissimilar cues. It might be expected then that the association between the two target cues would form more readily in Group C than in Group NC. The interfering effect of this association would be more profound in Group C, and acquisition of the go/no-go discrimination of Experiment 2 would thus proceed less readily in this group.

The results from the test sessions of Experiment 1 are relevant to this analysis. On these, the NC subjects received stimuli of the same type in the same session. Given that their previous training did not involve the presentation of similar stimuli in the same session, their performance on the test should be good, being free from interference produced by associations between the cues. Comparison can be made with the performance shown by Group C on the training block that immediately preceded the test (on this block, Group C received just the same conditions as those holding for Group NC in the test; see Table 1). This comparison supplies only limited support for the account just offered. On both tests, the performance of the NC group was superior that that shown by the C group at the end of training (for Test 1 the scores were 64% and 62%, respectively; for Test 2 they were 67% and 63%); but in neither case was the difference statistically reliable: for the Test 1 comparison, $F(1,10) = 1.39$; for the Test 2 comparison, $F(1,10) = 2.12$.

General Discussion

The aim of these experiments was to determine if a procedure in which subjects were

given the opportunity to compare similar stimuli (arranged in Experiment 1 by presenting the stimuli within the same session) would promote the formation of a discrimination between them. Also, we aimed to see (by means of a transfer test in Experiment 2) if any changes in discriminability were long-lasting and would influence performance when the same cues were encountered in a new situation. The results obtained gave no support to this proposal; subjects in the comparison condition performed less well than those in the no-comparison condition, and the difference was maintained in the transfer test.

These results provide no evidence for the operation of a comparison process; rather, the performance of the pigeons on these tasks seems to be determined by responses acquired to the stimuli defined in absolute terms. In Experiment 1, the birds learned to respond left to red (say) whether the other response required in the session was signaled by green or a geometrical figure. Differential transfer to a different task was obtained in Experiment 2, but the effect seems best explained in terms of associations formed among individual cues, defined in absolute terms. There was no support for the suggestion that the opportunity for comparison enhanced the discriminability of the similar stimuli, performance being worse after comparison training than after no-comparison training.

Given these results, it is necessary to explain why Saldanha and Bitterman's (1951) experiment should have generated the effect it did. One possibility is that their use of a simultaneous discrimination procedure allowed the operation of a sensory contrast mechanism of the sort discussed by Wills and Mackintosh (1999; if this were so, the effect obtained by Saldanha and Bitterman would not constitute evidence for the operation of a longer-term perceptual learning process). As we have noted, Wills and Mackintosh identified a role for sensory contrast for stimuli that differed in luminance, that is, for stimuli similar to the light and dark gray cues used by Saldanha and Bitterman. An alternative possibility is

that the simultaneous training procedure used by Saldanha and Bitterman did in fact engage a perceptual learning process that served to enhance the discriminability of the stimuli. If this process only operates when the stimuli being compared are concurrently available, then the effect would be obtained with simultaneous presentation and not, as for Group C in the present Experiment 1, when a period of several seconds intervenes between successive presentations. Accepting this view means that the strategy adopted in Experiment 1, although effective in eliminating the contribution of contrast effects, will also prevent the operation of the comparison process that we are interested in. A different experimental design will be needed to resolve this issue.

The results reported here accord with the conclusion of Mitchell and Hall (2014) that although the opportunity for comparison facilitates perceptual learning in studies with human participants, it does not do so for animal subjects. As we have noted, animals given exposure in which the stimuli are presented concurrently can sometimes show retarded acquisition of a subsequent discrimination between them (Alonso & Hall, 1999; Rodriguez et al., 2008). This result has been interpreted as being a consequence of the formation, during exposure, of excitatory associations between the stimuli, the mechanism being the same as that advanced here as an explanation of the results of our Experiment 2. If that interpretation is accepted, the results of Experiment 2 allow a further conclusion; that the deleterious effects on discrimination of prior exposure involving closely spaced presentation of the stimuli to be discriminated will (seemingly paradoxically) be more severe when the stimuli are similar. It is no paradox, of course, given the assumption that such exposure will allow the formation of strong excitatory associations between the stimuli; but, it remains to be explained why human subjects should apparently be immune to this associative effect.

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Table 1
Contingencies in Experiment 1

Training	Test
Group C: Subgroup A	
(1) R->L / G->Rt and (2) +->L / x->Rt	(1) R->L / x->Rt and (2) +->L / G->Rt
Group C: Subgroup B	
(1) G->L / R->Rt and (2) x->L / +->Rt	(1) G->L/ +->Rt and (2) x->L / R->Rt
Group NC: Subgroup A	
(1) R->L / x->Rt and (2) +->L / G->Rt	(1) R->L / G->Rt and (2) +->L / x->Rt
Group NC: Subgroup B	
(1) G->L/ +->Rt and (1) x->L / R->Rt	(1) G->L / R->Rt and (2) x->L / +->Rt

Note: In each phase each bird experienced alternating sessions of type (1) and type (2) . Each session contained two trial-types separated by the slash (/). Trials were initiated by the presentation on the center key of red (R), green (G), a white plus (+), or a white cross (x). These indicated that a response to the right (Rt) or left (L) white side-key would be rewarded.

Figure Captions

Figure 1. Experiment 1: Percent correct scores over two-session blocks. Group C: Comparison; Group NC: noncomparison. In Phases 1, 2, and 3, the birds received the discriminations listed as Training in Table 1; the arrangements for the Test session are also shown in Table 1. Vertical lines represent the standard error of the mean (SEM).

Figure 2. Experiment 2: Discrimination ratios (response to positive stimuli over total responses) for Group C (comparison) and NC (noncomparison). The groups were defined in terms of the training they had received in Experiment 1 (see Table 1). Vertical lines represent SEMs.

Figure 3. Experiment 2: Group mean scores for trials with a response to a negative (nonrewarded) stimulus (S-) for Group C (comparison) and NC (noncomparison). The groups were defined in terms of the training they had received in Experiment 1 (see Table 1). There were 10 presentations of the negative shape and 10 presentations of the negative color in each session. Vertical lines represent SEMs.

Figure 1

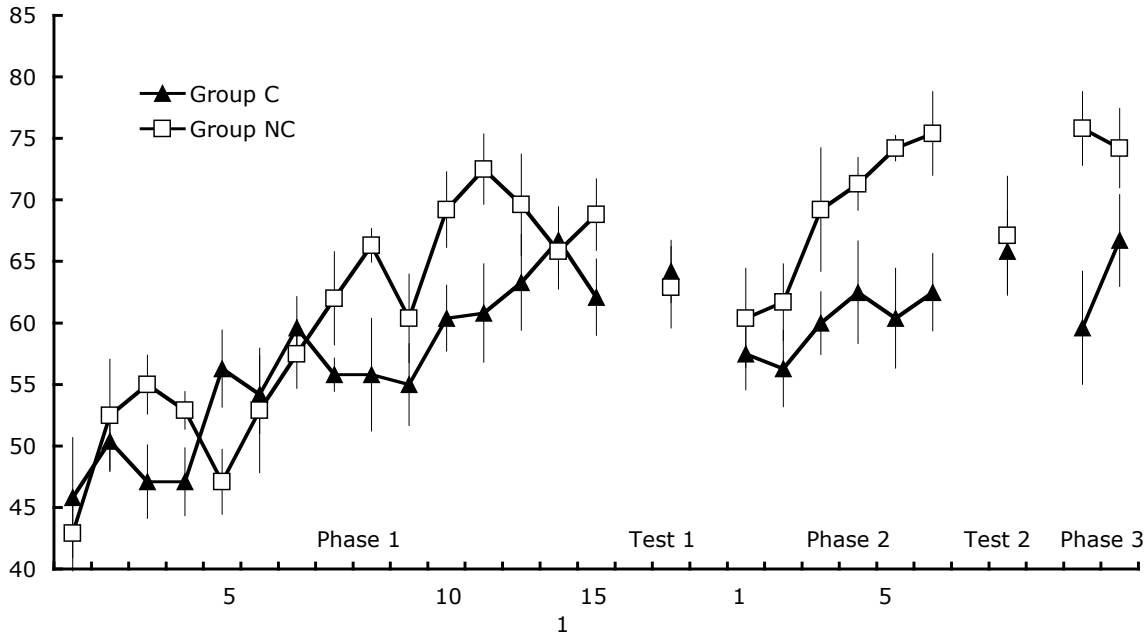

85
80
75
70
65
60
55
50
45
40
Group C
Group NC
Phase 1
Test 1
Phase 2
Test 2
Phase 3
5
10
15
1
5
1

Figure 2

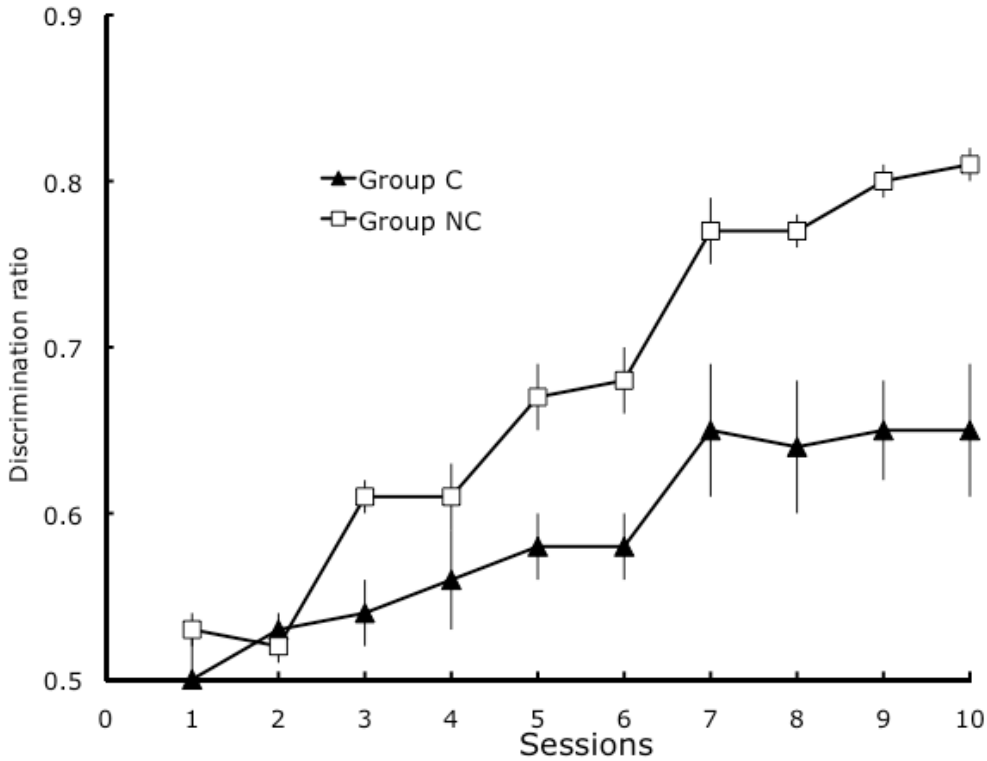
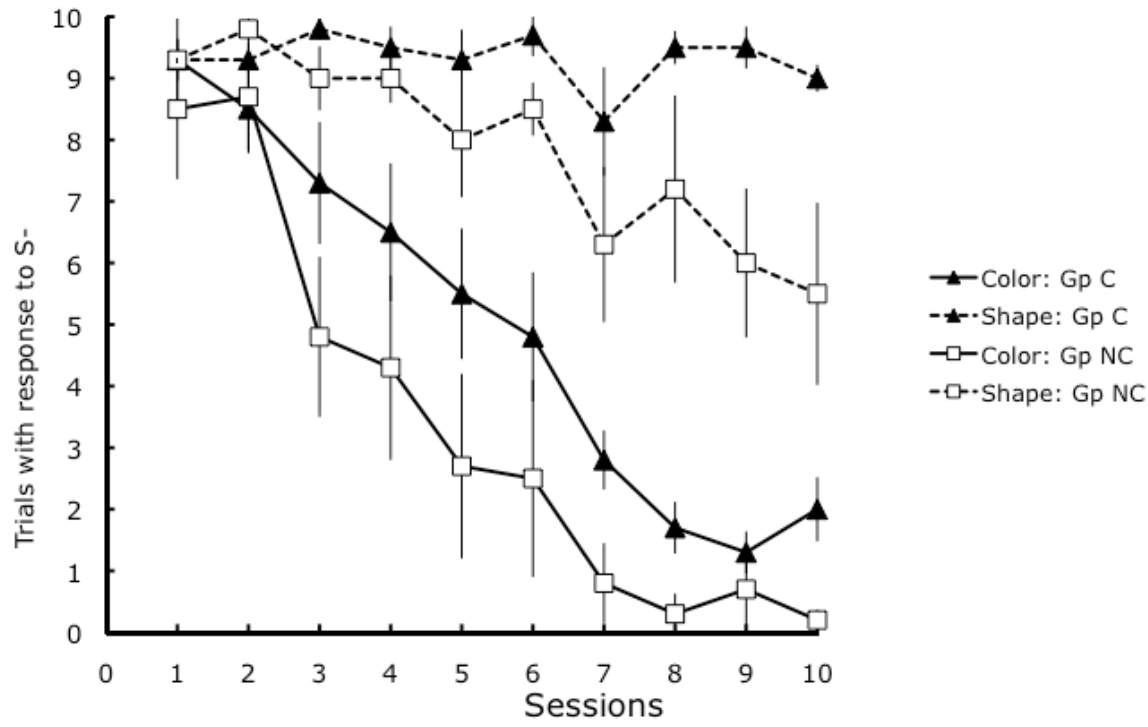

0.9
0.8
0.7
0.6
0.5
Discrimination ratio
Group C
Group NC
0
1
2
3
4
5
6
7
8
9
10
Sessions

Figure 3


Trials with response to S-
Sessions
0
1
2
3
4
5
6
7
8
9
10
Color: Gp C
Shape: Gp C
Color: Gp NC
Shape: Gp NC