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BRIEF REPORT

The Role of Instructions in Perceptual Learning Using Complex Visual Stimuli

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Although modeled on procedures used with nonhuman animals, some recent studies of perceptual learning in humans, using complex visual stimuli, differ in that they usually instruct participants to look for differences between the to-be-discriminated stimuli. This could encourage the use of mechanisms not available to animal subjects. To investigate the role of instructions, in 2 experiments, participants were given preexposure to checkerboards that were similar except for the presence of a small distinctive feature on each. For participants instructed to look for differences, performance on a same-different test was enhanced by preexposure in which the critical stimuli were presented on alternate trials—the usual perceptual learning effect. No such effect was found in 2 other preexposure conditions: when participants were told only to look at the stimuli and not explicitly told to look for differences; and when participants were instructed on an alternative task requiring attention to the stimuli. These results indicate a role for a learning process reinforced by success in finding stimulus differences; they challenge previous interpretations of results from studies using complex visual stimuli in the study of perceptual learning.

Keywords: perceptual learning, instructions, discrimination, stimulus preexposure

Perceptual learning can be defined as a set of changes in the perceptual system of an organism that improves its ability to respond to the environment (Goldstone, 1998). In essence, this means that an organism can learn to accurately discriminate between similar stimuli, and even to detect previously undetectable differences (Mitchell & Hall, 2014). An early demonstration of this phenomenon in nonhuman animals was provided by Gibson and Walk (1956), using geometrical figures. Rats that were exposed to the figures learned a later discrimination faster than other rats for which the stimuli were unfamiliar. More recently, Mackintosh, Kaye, and Bennett (1991) introduced a procedure for the study of perceptual learning in rats that involved exposure to compound flavors, referred to as AX and BX, where A and B represent unique features (e.g., salt and sugar) and X a common element (e.g., acid). After an aversive conditioning to AX, rats that had been previously exposed to the flavors showed less generalized aversion to BX. Many subsequent studies have used versions of this procedure (for a review, see Mitchell & Hall, 2014) and in most of these a comparison has been made between a preexposure schedule in which AX and BX are presented in alternation (i.e., are intermixed) and a schedule in which presentations of the two stimuli are given in separate blocks (see Symonds & Hall, 1995). It has been reliably found that discrimination between AX and BX is better after intermixed than after blocked preexposure. Explanations offered for this perceptual learning effect have stressed the role of associations among the elements of these compound stimuli and the implications for changes in the effective salience of these elements (Hall, 2003; McLaren & Mackintosh, 2000).

The comparison of intermixed and blocked schedules has also been made in studies of visual perceptual learning in human subjects, studies intended to parallel those done with rats. For example, Lavis and Mitchell (2006) made use of complex colored checkerboards as the stimuli; these had a common pattern of many squares as the background (X) with just a few being different and forming the unique features, A and B. Subjects given intermixed preexposure were superior on a subsequent test requiring same/different judgments and also on a categorization task requiring them to learn to make one response to AX and a different response

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to BX. This procedure is formally directly comparable with that used for animals, the outcome is the same, and the same theoretical interpretation can be applied to both. Mitchell and Hall (2014) have argued, however, that the procedure used for humans introduces features not present in the animal experiments and that these may allow the use of mechanisms other than (or in addition to) those responsible for the effects seen in experiments with animals (see, e.g., Dwyer, Mundy, & Honey, 2011; Mundy, Honey, & Dwyer, 2007).

Mitchell and Hall (2014) commented on two aspects of the procedure adopted for human subjects. First, the stimuli are more complex and more difficult to discriminate than those used with rats. Second the timing of presentations during preexposure (rapid alternation of stimuli presented for 1 s or so) is quite different from that of the animal experiments (where stimuli are presented for minutes, and spaced hours apart). They suggested that, for the stimuli used with people, a critical first requirement is to discriminate the distinctive feature of a stimulus from the background, and that habituation of the background cues with repeated closely spaced presentations of the stimuli would promote such discrimination during intermixed preexposure. Once the unique features have been detected, other processes can operate.

Mitchell and Hall (2014) identified two processes likely to be of importance. One was that the unique features could become readily encoded in memory—that a "well-formed representation" of the feature would be established, allowing it to be easily recognized when presented later (de Zilva & Mitchell, 2012), perhaps because one aspect of the feature would cue retrieval of another (Lavis, Kadib, Mitchell, & Hall, 2011). The second was based on a suggestion of Mackintosh (2009). This was that the detection of unique features will be rewarding for the human participant, so that an attentional response could be acquired, by reinforcement during preexposure. Thus, if the unique features A and B attract attention over the course of the preexposure trials, because they are presented on the habituated X background, participants may begin to orient to A and B habitually, and would carry this reinforced response-tendency over to the test phase.

This latter proposal prompts consideration of a further difference between the human and animal experimental procedures that was not discussed by Mitchell and Hall (2014). It is that the human participants are routinely instructed to look for differences between the stimuli during preexposure. For example, in the experiment by Lavis and Mitchell (2006), the subjects received the following instructions: "In [. . .] this experiment you will see some colored grids [. . .] Please examine them carefully. The grids are very similar but some of them have small differences. Please try to find these differences" (Lavis & Mitchell, 2006, p. 2087). Such instructions can be expected to enhance the rewarding properties of detecting a unique feature and might thus promote the development of an appropriate attentional response and of a perceptual learning effect. In the absence of instructions, the effect might be reduced or even absent. The present experiments were designed to test this idea.

Experiment 1

In this experiment, human subjects were trained on a version of the task of Lavis and Mitchell (2006), comparing the effects of intermixed and blocked preexposure schedules with checkerboard stimuli. A within-subjects design was used, with all subjects receiving intermixed presentations of one pair of stimuli (AX/BX) and blocked presentations of another pair (CX_DX). This preexposure was followed by a same/different test. One group of participants (instructions group, INST) received the usual explicit set of instructions, and, for these, better test performance with AX and BX than with CX and DX can be expected. For a second group (no instructions, NOINST), there were no instructions about the need to look for differences. It is possible that participants in this latter group might fail to attend to, or even look at, the stimuli, so that a reduction in the perceptual learning effect might occur simply because these subjects were not exposed to the stimuli. Accordingly, we included a third group (FAKE), which was given "fake" instructions that required the participants to look at and respond quickly to the stimuli, but with no requirement to look for differences among them. A reaction time (RT) task was chosen as having had a very low demand on cognitive resources, so direct interference with the perceptual learning process would not be expected.

Method

Subjects. The subjects were 214 students of psychology from the University of Granada (26 male) who agreed to participate in exchange for course credit. Their mean age was 19 years (range = 19 to 36). There were 67 assigned to the INST group, 71 to the NOINST group and 76 to the FAKE group. All of the participants had normal or corrected-to-normal vision. Anyone reporting anomalous color vision was excluded from the study.

Apparatus and stimuli. The stimuli consisted of eight different 20 × 20 square checkerboards, with a size of 321 × 321 pixels. Each checkerboard shared the same common structure (X), which was created by coloring 298 of the 400 squares with eight easily distinguishable colors. The remaining squares were gray. Each color had between 35 and 39 squares, and clusters of the same color did not exceed more than four squares. Each checkerboard included a unique element consisting of a cluster of seven squares of the same color. The unique element was different in shape, color, and position in each of the checkerboards. For each participant, four stimuli (AX, BX, CX and DX) were randomly selected from the eight different checkerboards. Additionally, for the practice block, eight checkerboards with similar features but completely different common and unique elements were created, and four were randomly chosen for each participant. The stimuli were presented centered on the 17-in. screen of a PC, against a black background. The participants interacted with the program using a Spanish QWERTY keyboard.

Design and procedure. All the procedures used here were approved by the Ethics Committee of the University of Granada. The participants were required to sign a consent form before carrying out the task, and were then assigned to one of the three experimental conditions. They were seated in front of the computer in an adjustable chair, at approximately 1 m from the screen, in a small isolated room. They were asked to read the instructions carefully and to resolve any doubts with the experimenter before the start of the experiment. For the INST group, the instructions, translated from the Spanish, were as follows:

> [. . .] Your task is to focus on the checkerboards and try to discover any difference that you can find between them. It is very important

> that you try to find and remember these differences, because they will be useful in a later task. [. . .].

For the NOINST group the instructions were as follows:

> [. . .] Your task is to look carefully at the checkerboards until you receive new instructions. [. . .].

Subjects in the FAKE group were told,

> [. . .] The goal of this experiment is to check how the complexity of visual stimuli affects the speed of the response. [. . .] Your task consists of pressing the spacebar as fast as you can every time a checkerboard appears. [. . .].

The participants in the other two groups were also required to press the spacebar when a checkerboard appeared on the screen, to maintain attention to the stimuli.

The experiment consisted of three phases: practice, preexposure, and test. In the practice phase, four checkerboards were used, each presented twice. Each trial began with a fixation point on the center of the screen for 300 ms, followed by a checkerboard. The checkerboard remained on the screen for 480 ms, and this duration was independent of the response of the participants. After this interval, the participants received a feedback screen, with a duration of 1,000 ms, recording that the spacebar response had been made. For the FAKE group, the feedback screen also presented the RT (if the response was made in less than the 480-ms duration of the display). The RT was included to give plausibility to the task given to these subjects. Before the next trial, there was a variable interval of between 500 and 1,500 ms, during which the screen remained blank. This same trial structure was used in the preexposure phase.

The participants received a reminder of the instructions on screen before the preexposure phase began. There were 80 preexposure trials in total; 40 consisted of the intermixed exposure of AX and BX (AX/BX/AX/BX . . .), and 40 of the blocked preexposure of CX and DX (CX/CX . . . DX/DX . . .). The order of the type of exposure was randomized between participants.

At the end of the exposure phase, participants received new instructions about the test. They were told that two checkerboards would be presented consecutively, and that they must press the "k" key if they thought the stimuli were the same, and the "a" key if they thought them to be different. There were four types of trials in this phase: with different stimuli that had been presented intermixed (INT-DIF: AX-BX or BX-AX), same intermixed stimuli (INT-SAME: AX-AX or BX-BX), blocked different stimuli (BLK-DIF: CX-DX or DX-CX), and blocked same stimuli (BLK-SAME: CX-CX or DX-DX). There were 10 of each type, presented in random order, with the constraint that there could not be two identical consecutive trials. Trials began with a fixation point in the center of the screen, which remained for 1,000 ms; then a checkerboard appeared for 800 ms, followed by a blank screen for 3,000 ms, and then another checkerboard for 800 ms. Finally, there was a screen with a reminder of the instructions that remained on until the participant had made a response. No feedback about the response was provided.

Statistical analysis. The analyses were conducted on the proportion of correct responses for each type of test trial. In this sort of task, same trials usually have a higher proportion of correct responses. Because the stimuli are hard to discriminate, a complete failure to do so would give results approaching 100% correct responses for the same trials. A proportion of correct responses close to 0.5 on same trials would mean responding by chance and thus not following instructions. Bearing this in mind, we used as an a priori exclusion criterion a mean proportion of correct responses on same trials lower than 0.6. Following this, 25 participants were excluded from further analysis (six from Group INST, nine from Group NOINST, and ten from Group FAKE). In addition, sensitivity (d') analyses were also conducted. Because of the presence of extreme values, d' was calculated using a *loglinear* correction, as indicated in Stanislaw and Todorov (1999). This approximation consisted on adding 0.5 to the number of hits and false alarms and adding 1 to the total number of trials, before calculating the hit and false alarms rate.

General linear model analyses were conducted, adopting a critical p value of 0.05. Greenhouse–Geisser correction was used for the within-subjects analysis. In addition, following Jones and Dwyer (2013), we conducted Bayesian t tests for the simple INT versus BLK comparisons on different trials. We chose the Jeffreys-Zellner-Siow (JZS) prior and a specified effect size of 1, as recommended by Rouder, Speckman, Sun, Morey, and Iverson (2009). According to Rouder et al. (2009), a Bayes factor (B_{01}) higher than 3 can be interpreted as a support for the null hypothesis, with higher values indicating stronger support. Values lower than one third can be interpreted as a support for the alternative hypothesis, with lower values indicating stronger support. For the Bayesian contrasts, we used JASP software (Love et al., 2015).

Results and Discussion

Figure 1 (upper panel) shows the proportion of correct responses for all three groups and for each type of trial. As expected, participants were much more accurate on same than on different trials. Also, it is evident that only the participants in the INST group benefited from the intermixed exposure. A mixed 2 × 2 × 3 analysis of variance (ANOVA), with preexposure (BLK vs. INT) and test trial (DIF vs. SAME) as within-subjects variables, and instructions (INST, NOINST, and FAKE) as a between-groups variable was conducted. There were significant main effects of test trial, $F(1, 186) = 367.09$, $\eta_p^2 = 0.66$, and of instructions, $F(2, 186) = 5.50$, $\eta_p^2 = 0.06$. There were significant interactions between test trial and instructions, $F(2, 186) = 5.31$, $\eta_p^2 = 0.05$, and between preexposure and instructions, $F(2, 186) = 3.66$, $\eta_p^2 = 0.04$. The triple interaction was also significant, $F(2, 186) = 6.53$, $\eta_p^2 = 0.07$. To explore this interaction further, we conducted individual 2 × 2 ANOVAs for each instruction group. For Groups NOINST and FAKE only the main effect of test trial was significant, $F(1, 61) = 166.02$, $\eta_p^2 = 0.73$, and $F(1, 65) = 120.97$, $\eta_p^2 = 0.65$, respectively. For Group INST, the main effects of both test trial, $F(1, 60) = 90.64$, $\eta_p^2 = 0.60$, and of preexposure, $F(1, 60) = 9.94$, $\eta_p^2 = 0.14$, were significant, as was the interaction between these variables, $F(1, 60) = 10.95$, $\eta_p^2 = 0.15$. Planned comparisons between INT and BLK different trials revealed a significant difference in Group INST, $F(1, 60) = 12.50$, $\eta_p^2 = 0.17$, $B_{01} = 0.04$, but not in Groups NOINST and FAKE, both $F\text{s} < 1$, $B_{01} = 7.9$ and $B_{01} = 7.0$, respectively.

Figure 2 (upper panel) shows the same results expressed as sensitivity scores (d'). It is evident that only Group INST showed an improvement in discrimination as a result of the intermixed

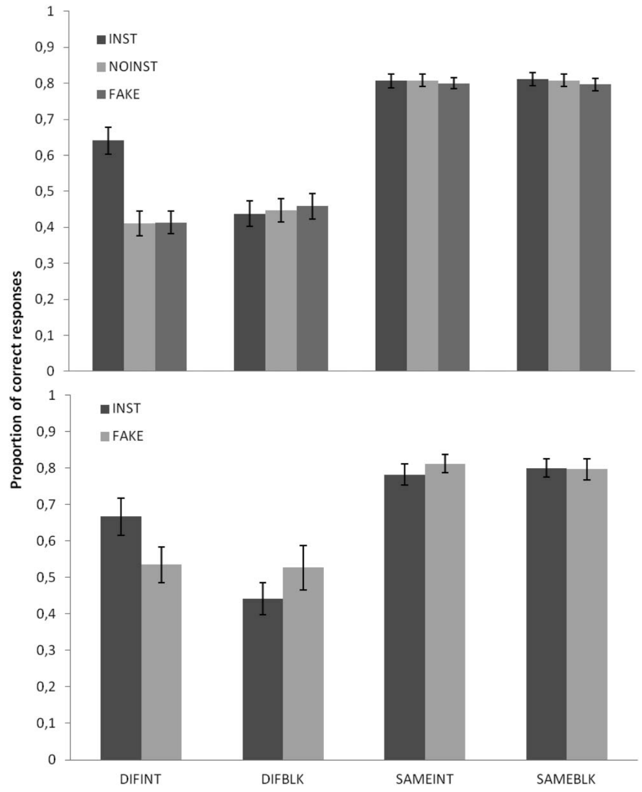

Figure 1. Group mean proportion of correct responses for each test-trial type and instructions group, with brackets indicating *SEM*s. Different groups were instructed to look for differences (instruction [INST]), given no instructions (no instruction [NOINST]), or instructed about a bogus task (FAKE). The upper panel presents the results of Experiment 1, the lower panel the results of Experiment 2. DIFINT = test with different stimuli exposed with an intermixed schedule; DIFBLK = test with different stimuli exposed with a blocked schedule; SAMEINT = test with same stimuli exposed with an intermixed schedule; SAMEBLK = test with same stimuli exposed with a blocked schedule.

exposure. We conducted a 2 × 3 mixed ANOVA, with preexposure as a within-subjects variable, and instructions as a between-groups variable. There was a main effect of instructions, $F(1, 186) = 5.94$, $\eta_p^2 = 0.06$, and a significant interaction, $F(2, 186) = 5.52$, $\eta_p^2 = 0.06$. This interaction was explored by means of planned contrasts for each instruction group. For Group INST, there was a significant effect of preexposure, $F(1, 60) = 11.29$, $\eta_p^2 = 0.16$, $B_{01} = 0.01$. Groups NOINST and FAKE did not show any significant difference, both Fs < 1, $B_{01} = 9.72$ and $B_{01} = 7.65$, respectively.

These results show that the superiority of intermixed over blocked preexposure emerges only when participants have been given instructions to look for differences. This finding appears to challenge any proposal that mere exposure to intermixed presentations of the stimuli should be enough to produce a perceptual learning effect. But before accepting this conclusion, we should acknowledge the possibility that the null result for the subjects without instructions might simply reflect the fact that their preexposure procedure failed to allow adequate exposure to the stimuli. It is true that subjects in the NOINST condition were required to press the spacebar when a checkerboard appeared, and did so reliably; also that the instructions in the FAKE condition kept the participants involved with the task, and forced them to look at the checkerboards. As the interstimulus interval was variable, it was necessary for subjects to detect presentation of the stimuli to press the spacebar appropriately, and accuracy for spacebar pressing was >0.9 for all groups, with no differences among them. This could be taken as an indication that most of the participants were actively attending to the task; but it is none the less possible that subjects in the NOINST and FAKE conditions failed to focus on the stimuli reliably, in which case the importance of the instructions for the INST group might just be that they ensured full exposure to the stimuli. To address this issue requires a further experiment.

Experiment 2

In this experiment we compared two groups, one given the same training as the INST group of Experiment 1, and a second given a new version the FAKE task, with instructions designed to force participants to attend to the stimuli, thus guaranteeing exposure. In this latter task, the subjects were not told to look for differences,

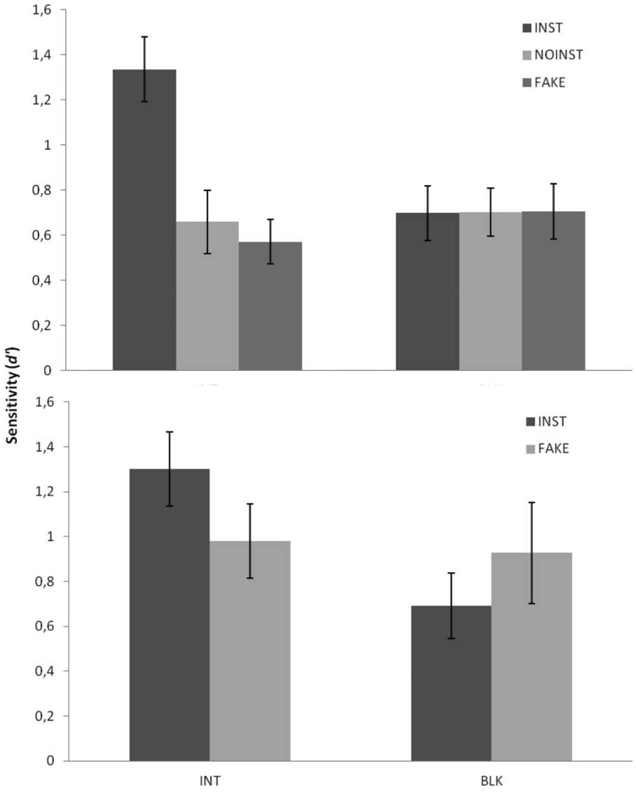

Figure 2. Group mean sensitivity scores (d') for each exposure type and instructions group, with brackets indicating *SEM*s. Different groups were instructed to look for differences (instruction [INST]), given no instructions (no instruction [NOINST]), or instructed about a bogus task (FAKE). The upper panel presents the results of Experiment 1 the lower panel the results of Experiment 2. INT = sensitivity scores for intermixed-exposed test trials; BLK = sensitivity scores for blocked-exposed test trials.

but were instructed to look at and remember all the different colors presented in the checkerboards. These instructions were justified by the inclusion of a brief color recognition test given immediately after preexposure. The critical results came, however, from a final same/different task for which the FAKE instructions were, indeed, irrelevant.

Method

Subjects. The subjects were 75 students of psychology from the University of Granada (nine male) who agreed to participate in exchange for course credit. Their mean age was 19 years (range 18 to 34). Of these, 46 were randomly assigned to the INST group and 29 to the FAKE group. All of the participants had normal or corrected-to-normal vision.

Apparatus and stimuli. In addition to the usual checkerboards, we constructed 16 different single-color squares, with a size of 321 × 321 pixels, to use in the color recognition test. Eight of these were colors that were presented in the checkerboards; the remaining eight were easily distinguishable variations of the same colors, so that each checkerboard color had its nonpresented pair. All the remaining details were the same as described for Experiment 1.

Design and procedure. The procedure was the same as that used for Experiment 1, with the following exceptions. The instructions for the INST group were slightly modified so as to match those given to the FAKE group. Translated from the Spanish, they were as follows:

> [. . .] Your task is to focus on the checkerboards and try to discover and remember all the differences that you can find between them. You will need this information in a later task. [. . .].

For the FAKE group, they were as follows:

> [. . .] Your task is to focus on the checkerboards and try to detect and remember all the different colors you can find in them. You will need this information in a later task. [. . .].

No spacebar pressing was required during preexposure trials.

A color recognition test was conducted immediately after the preexposure phase. After the instructions, participants were presented with a colored square in the center of the screen. They had to press the "z" key if they thought that the color was new or the "m" key if they thought it had been presented previously. A reminder of the significance of the keys was displayed at the bottom of the screen throughout this. Every trial was preceded by a fixation point for 500 ms, and the stimuli remained on the screen until a response was given. The subjects were tested with eight of the 16 colored squares. These were selected randomly with the constraint that there should be four of each type, and were presented in a random order. At the conclusion of this test, all subjects were given the same-different task, as described in Experiment 1.

Results and Discussion

Using the criteria described in Experiment 1, we eliminated 10 participants, seven from the INST group and three from the FAKE group.

The results of the color recognition test provide some indication that participants given the FAKE instructions had been attending to the checkerboards. The mean accuracy score for the INST group was 0.56; that for the FAKE group was higher at 0.61. Although these scores did not differ significantly, $t(26) = -1.02$, $B_{01} = 0.40$, it is worth noting that 46% of the participants in the INST group got a score above the chance level, in contrast with 62% of the participants in the FAKE group. For each group we ran a one-sample Bayesian *t* test against the chance value 0.5. For group the INST the outcome was $t(38) = 2.04$, $B_{01} = 0.89$, whereas Group FAKE showed a significantly higher than chance accuracy, $t(26) = 15.52$, $B_{01} = 0.25$.

Figure 1 (lower panel) shows the results of principal interest, the proportion of correct responses for Groups INST and FAKE on the same/different test. The results mirrored those of Experiment 1. Both groups were more accurate in the same than in the different trials, but only Group INST showed a difference according to schedule of exposure. We confirmed this by running a mixed 2 × 2 × 2 ANOVA, with preexposure (BLK vs. INT) and test trial (DIF vs. SAME) as within-subjects variables, and instructions (INST and FAKE) as a between-groups variable. We found a significant effect of test trial, $F(1, 63) = 72.09$, $\eta_p^2 = 0.53$, and also an interaction between test trial and preexposure, $F(1, 63) = 3.72$, $\eta_p^2 = 0.06$. More important, the triple interaction was also significant, $F(1, 63) = 4.22$, $\eta_p^2 = 0.06$. We analyzed this interaction with pairwise contrasts between INT and BLK different trials for each group. In the INST group we found a significant difference, $F(1, 38) = 11.07$, $\eta_p^2 = 0.23$, $B_{01} = 0.06$; while in the FAKE group the difference was not significant, $F < 1$, $B_{01} = 4.81$.

Figure 2 (lower panel) shows the sensitivity score results. As in Experiment 1, only in Group INST was there a difference between intermixed and blocked exposure. A 2 × 2 ANOVA with preexposure as a within-subjects variable, and instructions as a between-groups variable showed that the effect of preexposure approached significance, $F(1, 63) = 3.36$, $p = .07$, $\eta_p^2 = 0.05$, but that the interaction was not significant, $F(1, 63) = 2.39$, $p = .12$, $\eta_p^2 = 0.04$. However, based on the sensitivity results of Experiment 1, and the fact that in this experiment we obtained an interaction using raw accuracy data, we thought it appropriate to run planned contrasts between INT and BLK different trials. These analyses showed a significant effect of preexposure for Group INST, $F(1, 38) = 8.13$, $\eta_p^2 = 0.18$, $B_{01} = 0.18$. In contrast, for Group FAKE there was no significant difference, $F < 1$, $B_{01} = 4.76$.

In summary, these results confirm those of Experiment 1, in showing that the intermixed-blocked difference emerges only when participants receive explicit instructions to look for differences during preexposure. There is no effect of the schedule of preexposure in subjects given instructions that ensure that they will inspect the stimuli, but do not specify that differences should be looked for.

General Discussion

The results for the INST group in both of the experiments reported here match those of many previous experiments (e.g., Lavis & Mitchell, 2006; Mitchell, Kadib, Nash, Lavis, & Hall, 2008; Mitchell, Nash, & Hall, 2008; Wang, Lavis, Hall, & Mitchell, 2012) using similar stimuli and training procedures. They show that prior exposure to complex checkerboard stimuli will facilitate subsequent discrimination between these stimuli when the stimuli are exposed according to an intermixed rather than a blocked schedule. In all these studies, the subjects were given instructions that emphasized the need to detect differences between the stimuli. Our new finding is that the superiority of intermixed over blocked preexposure is absent when no such instructions are given. In subjects given no instructions or instructed on a task that did not require the detection of differences, there was no difference between the effects of intermixed and blocked preexposure—performance with the intermixed stimuli was as poor as with the blocked stimuli. Bayesian analyses supplied support for the null hypothesis in this case.

For many proposed explanations of the intermixed/blocked perceptual learning effect, the nature of the instructions should be irrelevant. Provided the subjects are exposed to the stimuli, the processes invoked (such as latent inhibition, habituation, the formation of excitatory or inhibitory links between various elements of the stimuli) should be able to operate, regardless of the nature of the instructions. In Experiment 1, we could not compellingly rule out the possibility that the participants without explicit instructions were not attending to the stimuli, and thus, they might have been receiving less exposure to the checkerboards. It could have been the case that the fake instructions were not engaging enough, or that the RT task could have been solved paying only little attention to the stimuli. However, the fake instructions used in Experiment 2 made full attention to the stimuli more likely, as they involved looking for details inside the checkerboard. That the checkerboards were in fact attended is supported by the fact that participants in this group were better than chance in a color recognition test.

Why then was the intermixed/blocked difference found only when instructions to look for differences were given? The account presented in the introduction suggested that, once the distinctive features of the stimuli have been identified during intermixed exposure, subjects would be reinforced for finding them on subsequent presentations, and would learn to orient toward them. With the stimuli used in these experiments, in which the distinctive features appear in fixed locations, the learning could support the tendency to look at particular parts of the display (see Jones & Dwyer, 2013; Wang et al., 2012). If we assume that the reinforcing power of the successful detection of a feature is enhanced when the subject has been given explicit instructions to find such features, then the learning process involved would operate much more effectively in those given instructions. This assumption is speculative, but seems unlikely to be controversial.

What remains to be explained is why intermixed preexposure should convey no benefit over blocked exposure in subjects not given appropriate instructions. Before the subjects can learn to orient to features they must first detect them, and the processes that we have assumed to be responsible for initial detection during intermixed exposure should operate whatever the instructions given (i.e., as a result of mere exposure). Thus, even in the absence of instructions, the unique features of the intermixed stimuli will be identified, and some degree of advantage in performance with respect to the blocked stimuli in the final discrimination might still be expected. These subjects may not have the benefit of having acquired an orienting response, but this was just one of the processes assumed by Mitchell and Hall (2014). They could still be at an advantage if their experience resulted in, for example, the creation of a well-formed memory representation of the features.

We will offer two possible interpretations of the failure to find any effect in the absence of instructions. The first is simply that, without the instructions that help to reward and maintain the attentional response, the participants failed to receive enough exposure to sustain an intermixed-blocked effect. That is, the participants may have detected some differences between stimuli initially, but without the support supplied by reinforcement of the orienting response, failed to focus on them subsequently, and thus failed to engage fully other mechanisms capable of producing the changes that ensure good discrimination test performance. In these experiments we gave only 20 preexposure trials with each stimulus (in other experiments of this type, 60 or so preexposures have been usual; see Mitchell & Hall, 2014). It is possible that had we given more extended preexposure we would have obtained an intermixed-blocked difference even in the absence of instructions.

The second, more radical, interpretation is that when perceptual learning effects are seen with this procedure, they are solely the result of the acquisition of an attentional response, and that the other mechanisms, such as the memory-based processes envisaged by Mitchell and Hall (2014), play no part in generating the intermixed/blocked difference. This is certainly consistent with our present results, with those of Wang et al. (2012) and Jones and Dwyer (2013), and also with those of Recio, Iliescu, Bergés, Gil, and de Brugada (2016), who showed that additional presentations of the unique features of the displays were effective in enhancing the perceptual learning effect only when they were given in the critical location. It remains to explain the results like those reported by de Zilva and Mitchell (2012) and Lavis et al., (2011, Experiment 1) that seem to indicate an effect of preexposure schedule on the memory representation of the stimuli—in the experiment by Lavis et al., for example, it was shown that intermixed exposure allowed subjects to retrieve the color of a unique feature when given its shape. But this outcome can be interpreted as being a consequence of the effect of preexposure on allocation of attention, and is not necessarily a cause of the perceptual learning effect. If participants detect the unique elements, and keep on looking at them after detection has occurred, then a good memory representation will be formed. It is not necessary to assume, however, that the enhanced memory representation plays a role in discrimination during the test.

Finally, we should acknowledge that the absence of an intermixed-blocked difference for subjects given no (or inappropriate) instructions does not require the conclusion that no perceptual learning was going on during preexposure in these subjects. It is possible that, even without the usual instructions, preexposure (whether intermixed or blocked) could enhance discrimination compared with the performance of subjects given no preexposure (see, e.g., Dwyer et al., 2011; Mundy et al., 2007). Our focus has been, however, not on the general effects produced by preexposure, but on the specific mechanisms responsible for the superiority of the intermixed procedure. It is these mechanisms that have been the central concern of theoretical analyses of perceptual leaning (e.g., Hall, 2003; McLaren & Mackintosh, 2000; Mitchell & Hall, 2014). And although our results cannot resolve the issue of what mechanisms are responsible for intermixed/blocked effect in this particular case, they do show that the effect regularly obtained with this perceptual learning procedure using complex visual stimuli is critically dependent on the subjects receiving instructions to look for differences between the stimuli. This is consistent with

Mackintosh's (2009) suggestion that finding differences can be rewarding and will support the development of an attentional response (which, with the stimuli used here, could be that of orienting toward a particular location). If other processes are involved, the present results give no sign of them.

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