Journal of Experimental Psychology:
Animal Behavior Processes
2012, Vol. 38, No. 4, 407–418

0097-7403/12/$12.00 DOI: 10.1037/a0029733

Location and Salience of Unique Features in Human Perceptual Learning

Tony Wang
University of New South Wales

Yvonna Lavis
University of York

Geoffrey Hall
University of York and University of New South Wales

Chris J. Mitchell
Plymouth University and University of New South Wales

Preexposure to intermixed presentations of a pair of similar stimuli (AX and BX, where A and B represent distinctive features, and X the features the stimuli hold in common) facilitates subsequent discrimination between them. This perceptual learning effect has been interpreted as indicating that the loss of effective salience resulting from repeated presentation of a stimulus is attenuated or reversed by a salience-modulation process that operates on the unique stimulus features A and B during intermixed preexposure. In 3 experiments, we examined discrimination after intermixed preexposure to AX and BX, making comparison with a condition in which novel unique features were added to the preexposed background (CX and DX). In all experiments, we also monitored eye gaze during both preexposure and the test. Experiments 1 and 2 found discrimination of the preexposed stimuli to be superior. This result cannot be explained by salience-modulation theories that suppose that intermixed preexposure merely attenuates loss of salience to the unique features A and B; it suggests, rather, that intermixed preexposure to AX and BX enhances the salience of, or attention paid to, the distinctive features. Experiment 3 demonstrated that exposure increases sensitivity to the spatial location of the features, a conclusion confirmed by analysis of eye gaze.

Keywords: attention, discrimination, eye gaze, perceptual learning

Supplemental materials: http://dx.doi.org/10.1037/a0029733.supp

Appropriately scheduled exposure to a pair of similar stimuli can enhance the ease with which they are subsequently discriminated. This perceptual learning effect has been extensively studied in experiments with nonhuman animals. For example, Symonds and Hall (1995) gave rats a series of preexposure trials in which two compound flavors (AX and BX) were presented alternately (here A and B refer to the distinctive tastes of salt and sugar and X to the sour taste of acid added to both of these). Control subjects received equivalent preexposure, except that the scheduling of trials was different: They received all AX trials in a single block and all BX trials in another block. Discrimination was tested by conditioning an aversion to AX and testing for generalization of the conditioned response to BX. Generalization was found to be less after intermixed than after blocked preexposure, indicating that discrimination between AX and BX was superior in the former case. This result has been taken as support for the supposition that exposure to stimuli arranged in a way that allows the opportunity for comparison between them will enhance their discriminability.

This difference between intermixed and blocked preexposure has been replicated many times in experiments with rats as subjects (e.g., Blair & Hall, 2003; Mondragón & Hall, 2002). An equivalent result has been obtained in recent experiments with human participants. Lavis and Mitchell (2006) exposed participants to four complex, multicolored, visual checkerboard patterns (similar to those shown in Figure 1; for a full-color version of this figure, please see the online supplemental materials). These checkerboards were visually similar because the majority of the constituents of each checkerboard were held in common (thus equating to the X element of the animal experiments). A small cluster of colored squares differed from one stimulus to the next. These unique features (A–D) were superimposed on the common background, creating four different checkerboards, AX, BX, CX, and DX. During preexposure, two of these checkerboards (AX and BX) were presented on an intermixed schedule, and the two remaining checkerboards (CX and DX) were presented on a blocked schedule. Lavis and Mitchell demonstrated that discrimination between AX and BX (the intermixed stimuli) was superior to that between CX and DX (the blocked stimuli). This was true both when the test involved a categorization task (which, like the

This article was published Online First September 17, 2012.

Tony Wang, School of Psychology, University of New South Wales, Sydney, Australia; Yvonna Lavis, Department of Psychology, University of York, York, United Kingdom; Geoffrey Hall, Department of Psychology, University of York, and School of Psychology, University of New South Wales; Chris J. Mitchell, School of Psychology, Plymouth University, Plymouth, United Kingdom, and School of Psychology, University of New South Wales.

Tony Wang is now at the Melbourne School of Psychological Sciences, University of Melbourne, Melbourne, Australia.

Correspondence concerning this article should be addressed to Tony Wang, Melbourne School of Psychological Sciences, University of Melbourne, Parkville VIC 3010, Australia. E-mail: tony.wang@unimelb.edu.au

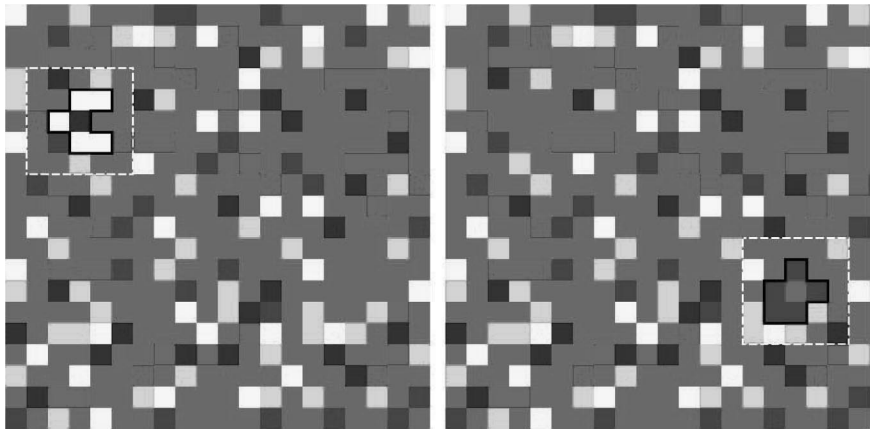

Figure 1.

procedure used with animal subjects, associates each of the cues with a different outcome) and also when a same–different task was employed, in which the participants simply had to judge whether two patterns, presented in succession, were the same or different.

One interpretation of Gibson's (1969) stimulus differentiation account of perceptual learning is that the effect reflects changes in attention to the unique features. Thus, the intermixed–blocked effect would be found if unique features attracted greater attention following intermixed than following blocked exposure. According to Gibson, stimulus differentiation will occur most readily when participants are able to compare the stimuli, as comparison of AX and BX will highlight the differences between them and this will allow an increase in attention to these differences. Intermixed exposure to AX and BX provides the opportunity for comparison; therefore, attention to the unique elements should be greater following intermixed than blocked exposure.

This general account has received support from experiments with animal subjects designed to assess changes in the effective salience (i.e., the attention-getting properties) of the distinctive features of preexposed stimuli. For example, Blair and Hall (2003) gave rats two compound flavors (AX and BX) on an intermixed schedule, with a third compound (CX) presented on a separate block of trials (AX/BX_CX). Following preexposure, an aversion was established to the X element, presented alone. If intermixed preexposure enhances the effective salience of the distinctive features of the stimuli, then, following preexposure, the elements A and B should be more salient than the blocked element C. A final test showed that the rats were more willing to consume BX than CX, a result consistent with the suggestion that the salient B element was better able to interfere with the aversion controlled by X than was the less salient C element.

Subsequently, Blair, Wilkinson, and Hall (2004) showed that the unique features of compound flavors presented on an intermixed schedule produced a stronger unconditioned response than those presented on a blocked schedule. Rats find quinine aversive and sucrose appetitive, and this effect is related (within limits) to the strength of the solution. Following AX/BX_CX preexposure, rats consumed less quinine on test if quinine had served as the B element in preexposure (intermixed) than if it had served as the C element (blocked). Conversely, rats consumed more sucrose on test if sucrose had served as B than if it had served as C. This suggests that flavors presented as unique elements on an intermixed preexposure schedule (element B) are functionally more concentrated than those preexposed on a blocked schedule (element C).

Further support for this line of reasoning comes from a study of human perceptual learning by Wang and Mitchell (2011), who attempted to measure stimulus salience by monitoring their participants' eye movements. Using an intermixed–blocked procedure similar to the one described by Lavis and Mitchell (2006), they found that participants spent more time looking at the intermixed than at the blocked unique elements during both the preexposure phase and the same–different task used in the test phase. Together, these studies support the notion that intermixed exposure renders the unique elements more salient than does blocked exposure. It remains to explain the mechanism by which this occurs.

Hall (2003) proposed an account based on the well-established phenomenon of habituation. Exposure to stimuli, he suggested, allows habituation to occur, resulting in a reduction in the effective salience of (all elements of) the stimuli. This process proceeds unopposed during blocked preexposure. The particular conditions of intermixed preexposure, on the other hand, limit the extent to which unique features lose salience via the normal process of habituation. According to Hall, direct activation of a stimulus representation (via exposure) decreases salience, but indirect activation (i.e., activation of a stimulus representation via an association) reverses this effect. Hall pointed out that intermixed preexposure to AX and BX should establish and maintain within-compound associations (X–A and X–B links). This will allow A to be associatively activated on BX trials and B to be associatively activated on AX trials. Exposures to AX and BX will reduce the salience of X (via habituation), but associative activations of A (on BX trials) and B (on AX trials) will attenuate the loss of salience undergone by these features (a reverse habituation process). Hall argued that reverse habituation is more likely to occur on an intermixed than on a blocked exposure schedule. Thus, the total amount of habituation undergone by the unique elements will be greater in the blocked case than in the intermixed case. The blocked unique elements will, therefore, be less salient than their intermixed counterparts.

Hall (2003) provided no specification of the mechanism by which associative activation might act to reverse habituation, but one follows readily from the model of learning proposed by McLaren and Mackintosh (2000). According to their account, salience declines during exposure to a stimulus as a consequence of *unitization*—the formation of associations among its various components (see also Goldstone, 1994). Exposure to AX will allow the formation of associations between A and X, and also among the various aspects that define the unique feature A (e.g., its shape and its color, call them A1 and A2). But the connection between A1 and A2 will be disrupted by intermixed presentations of BX. On a BX trial, the presentation of X will produce associative activation of both A1 and A2 in the absence of these cues. According to the learning principles adopted by McLaren and Mackintosh, this circumstance brings about extinction of the excitatory link between them, and as a consequence, the salience of the unique feature will be restored. With blocked preexposure to AX, no such extinction will occur, the A1–A2 connection will be strong and salience will be lost. (This will be true even if a block of BX trials follows the AX block. Extinction of the X–A association on such trials will reduce the ability of X to activate A1 and A2 associatively, and thus remove the conditions needed for extinction of the A1–A2 association.)

An important implication of the unitization mechanism proposed by McLaren and Mackintosh (2000) is that stimulus salience is greatest when the stimulus is novel. Salience is likely to be lost with any form of preexposure, and intermixed exposure to AX and BX can serve only to attenuate the loss of salience by A and B. The model thus makes the prediction that discrimination should be better between two stimuli having novel distinctive features than between two equivalent stimuli given intermixed preexposure (all being presented on a common background). Gibson's (1969) differentiation theory, by contrast, seems to generate the opposite prediction. Novel stimuli are, by definition, not differentiated and their unique features do not command special attention. Only after appropriate preexposure will the unique features, on the basis of which discrimination will be made, come to stand out. Hall's (2003) theory is ambiguous on this point because it does not specify a mechanism for salience modulation it leaves open the possibility that the salience of a preexposed feature may increase beyond the salience of a novel feature.

The present experiments were designed to evaluate these theoretical accounts by comparing the discriminability of preexposed and novel stimuli. The stimuli were checkerboards with a common background on which distinctive features were superimposed, like those used in the experiment by Lavis and Mitchell (2006). On test, comparison was made between stimuli that had been preexposed according to an intermixed schedule (e.g., AX and BX) and stimuli that featured the same X background but had novel unique features. We sought to address two empirical questions. Experiments 1 and 2 examined whether intermixed unique features, following exposure, become more salient than novel features. To anticipate, Experiments 1 and 2 confirmed this prediction. Experiment 3 investigated a possible source of this finding.

Experiment 1

Experiment 1 examined whether discrimination between intermixed patterns is better than that between novel patterns when all stimuli share the same common background. It should be noted that comparisons between preexposed and novel stimuli have previously been reported in studies of animal discrimination learning. For example, Mackintosh, Kaye, and Bennett (1991) exposed a group of rats to two compound flavors (AX and BX) prior to aversion conditioning with AX and a generalization test with BX. They found that these animals showed reduced generalization of the aversion from AX to BX, compared with subjects for whom AX and BX were novel at the time of the test. This observation does not, however, constitute convincing evidence that preexposure enhances the discriminability of the stimuli. The extent of generalization will be influenced by a range of factors, and, in particular, by the strength of the aversion acquired by AX during conditioning. Preexposure to a stimulus will reduce the readiness with which it acquires an aversion (the well-known latent inhibition effect; e.g., Lubow, 1989). The reduced generalization observed by Mackintosh et al. could thus be a consequence of the fact that conditioning to AX was rather poor in the first place. Our use of the same–different test, in which latent inhibition will not play a role, allowed us to avoid this complication in the present experiment.

An experiment very similar to the current one was conducted recently with human participants by Wang and Mitchell (2011; see also Mundy, Honey, & Dwyer, 2007). They preexposed two similar checkerboards, AX and BX, and compared discrimination of those checkerboards with that of CY and DY, where only the Y background had been preexposed. On test, AX and BX were better discriminated on a same–different task than were CY and DY. If this difference is due to a difference in the salience of the unique features, the result cannot be accommodated by McLaren and Mackintosh's (2000) unitization mechanism. However, in Wang and Mitchell's study, the salience of the common elements (X and Y) was not necessarily matched in the two discriminations. It is possible that intermixed exposure to the AX and BX compounds was especially effective in reducing the salience of the common feature X (see Mondragón & Hall, 2002, for evidence of such an effect). If the common element X was less salient than Y on test, then better discrimination of AX and BX than of CY and DY would be expected. The current experiment adopted Blair and Hall's (2003) procedure of using the same background for the novel and preexposed stimuli to control for background salience.

Following Wang and Mitchell (2011), participants' eye movements were recorded in these experiments to provide an index of attention. Eye gaze is thought to correlate well with attentional focus (Rehder & Hoffman, 2005), and has been used recently to examine learned changes in attention (Hogarth, Dickinson, Austin, Brown, & Duka, 2008; Kruschke, Kappenman, & Hetrick, 2005).

Method

Participants. Twenty-five first-year psychology students from the University of New South Wales participated in this experiment in exchange for course credit.

Apparatus and stimuli. The experimental stimuli were 20 × 20-square checkerboard patterns. The common background, X, was created by coloring 156 of the 400 squares green, red, yellow, purple, or blue, with the remaining squares being gray.

Each of the four unique features was an arrangement of six adjacent colored squares, and each was preassigned to a different quadrant of the X background. For example, the *yellow* unique feature, outlined in Supplemental Figure 1, always appeared in the top-left quadrant. Each stimulus (AX, BX, CX, and DX) was created by randomly selecting a unique feature and placing it on the X background (see Supplemental Figure 1). Each unique feature replaced an area that was previously filled with gray squares. The location of a given unique feature was constant across exposures. Thus, features A–D differed both in color and in location on the checkerboard. A custom-written program was used to control stimulus presentation on an IBM-compatible PC.

Eye gaze analysis. Participants sat in a position such that viewing distance was 60 cm from the participant to the screen. The use of a chin rest ensured that this distance was fixed throughout the experimental session. At this distance, each checkerboard subtended a visual angle of 12.23° × 12.23°, and each unique element subtended a visual angle of 1.86° × 1.86°. An area of interest (AOI) with visual angle of 3.98° × 3.98° was defined around each unique element. The liberal definition prevented eye gaze points near and around the unique element from being missed.

Eye gaze was measured using a Tobii T60 eye-tracking system. A 17-in. monitor with resolution of 1280 × 1024 showed the experiment stimuli. The Tobii eye-tracking system sampled the spatial location of an eye gaze every 1/60th s (approximately 17 ms). A custom-written program calculated the number of these samples that fell within each AOI, and from this the total gaze length in each AOI for all stimulus presentations within a test block. The eye gaze analysis included only gaze length to the AOI corresponding to the relevant unique features on each trial (e.g., A for AX). The eye tracker was not correctly calibrated for some participants; consequently, the eye tracker failed to record any eye gaze data on a number of preexposure and test trials. Following Wang and Mitchell (2011), we excluded participants' data from all analyses (i.e., discrimination performance and eye gaze) if more than 50% of their eye gaze data were missing. Specifically, data for two participants were excluded because the total number of recorded gaze points to the checkerboard pattern for each participant was fewer than 50% of total possible number of gaze points. This exclusion criterion was also applied in the subsequent experiments.

Procedure. The experiment started with a preexposure phase in which all participants received 60 presentations of AX in alternation with 60 presentations of BX. At the start of this phase, participants were instructed to pay attention to the presented stimuli and told that any differences detected would be useful later in the experiment. Each stimulus was presented for 480 ms, followed by a 2,000-ms intertrial interval during which the stimulus disappeared and only the black background was present.

On completion of the preexposure phase, participants received another set of instructions detailing the requirements of the same–different task. Participants were told that two checkerboard patterns would be presented in succession and that they must decide whether the two patterns were the same or different. Each stimulus was presented for 900 ms and a gray square held the place of the stimulus during an 880-ms interstimulus interval. Participants pressed the *A* key or the *5* (number pad) key on the keyboard to indicate whether the two stimuli were the same or different. Participants made their response following the presentation of the second stimulus. The next test trial was initiated 1,400 ms after this key response. Participants were not given feedback following their response. There were four types of test trial: (1) preexposed different, in which AX and BX were presented; (2) preexposed same, in which AX and AX (or BX and BX) were presented; (3) control different, in which CX and DX were presented; and (4) control same, in which CX and CX (or DX and DX) were presented. There were four blocks of 24 test trials, for a total of 96 trials. Within each 24-trial block on test, there were six trials of each type, and all 24 trials were presented in a random order.

Statistical analysis. Planned contrasts using a multivariate, repeated measures model (O'Brien & Kaiser, 1985) were used to analyze the data from this and the subsequent experiments. A significance level of $p < .05$ was set for all of the statistical analyses.

Results and Discussion

Same–different performance. Panel A of Figure 2 shows the mean proportion of correct responses for the four types of test trial across the four blocks of test trials in the same–different task. The figure shows that performance accuracy was better for the same trials than for the different trials. A bias in favor of making the "same" response is to be expected given that the stimuli were chosen as being difficult to discriminate. More important, there was also an effect of preexposure, as overall performance accuracy was better for the preexposed condition than for the novel condition. The statistical analyses confirmed these observations: Significant main effects were observed for trial type (same vs. different), $F(1, 22) = 21.55$, $MSE = 0.29$, and preexposure, $F(1, 22) = 7.42$, $MSE = 0.12$. The interaction effect of trial type (same vs. different) and preexposure (preexposed vs. novel) was significant, $F(1, 22) = 8.63$, $MSE = 0.12$. This interaction confirms the observation that the effect of preexposure was observed on the different but not on the same test trials. There was no general improvement in performance across the test blocks, $F(1, 22) = 2.59$, $MSE = 0.06$. The effect of test block did not interact with either the main factors of preexposure condition (preexposed vs. novel), $F < 1$, or trial type (same vs. different), $F(1, 22) = 1.56$, $MSE = 0.04$. The three-way interaction between these three main factors was also not significant, $F(1, 22) = 3.33$, $MSE = 0.06$.

The two-way interaction between preexposure condition and trial type prompted a simple effects analysis of only the different trials. This analysis showed that discrimination performance on the different trials was better for AX and BX than for CX and DX, $F(1, 22) = 8.38$, $MSE = 0.23$. Across both test conditions, performance accuracy did not improve over test blocks, $F(1, 22) = 2.66$, $MSE = 0.07$. The interaction between different trials and test blocks was also not significant, $F(1, 22) = 2.05$, $MSE = 0.18$.

A signal detection analysis was also conducted to measure participants' sensitivity to detecting differences between AX and BX and between CY and DY. This analysis gives a clearer indication of the participants' ability detect the unique elements. Sensitivity scores, d', were calculated for each partici-

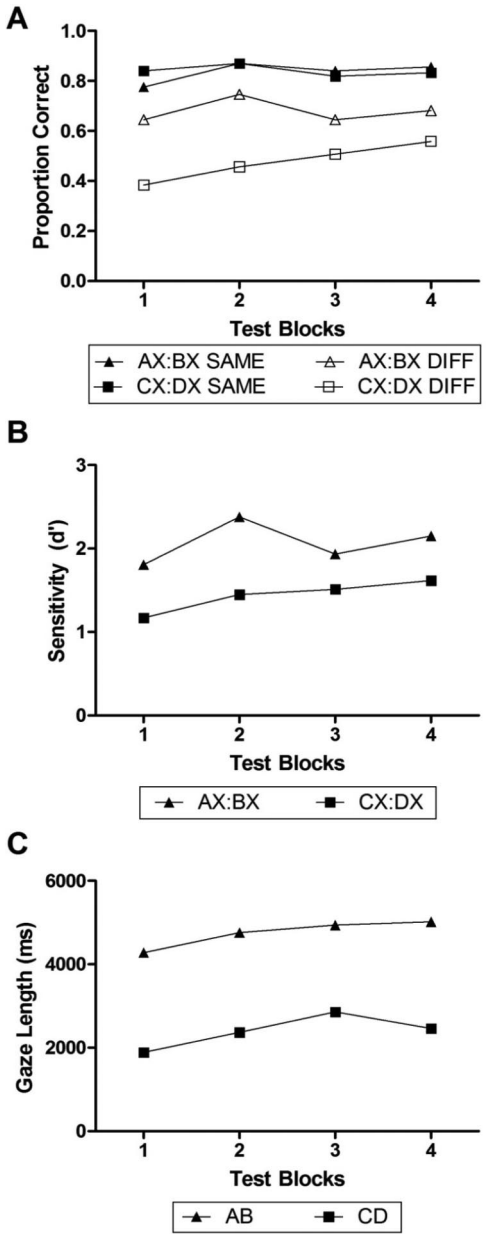

Figure 2. Panel A shows mean proportion of correct responses on each test block on the four types of test trial in Experiment 1. Panel B shows mean sensitivity scores (d') for each preexposure condition across test blocks. Panel C shows the total gaze length to the two unique elements within each preexposure condition (A and B; C and D) across test blocks.

pant. Hits were defined as proportion of different trials on which a correct response ("different") was given. False alarms were defined as the proportion of same trials on which an incorrect response was given (also "different"). Panel B of Figure 2 shows the mean sensitivity scores for the two preexposure conditions across the test blocks. Sensitivity scores were greater for AX and BX than for CX and DX, $F(1, 22) = 7.36$, $MSE = 2.49$. Participants were better at detecting the differences between AX and BX than between CX and DX. Sensitivity scores for both conditions did not increase across test blocks, $F(1, 22) = 2.50$, $MSE = 0.92$. The interaction between the factors of preexposure condition and test block was also not significant ($F < 1$).

Eye gaze. Panel C of Figure 2 shows mean gaze length to the unique elements in the same–different task. The results for features A and B were pooled, as were those for C and D. Gaze length for each condition is the time spent in each block looking at the AOI corresponding to the unique elements that were present (e.g., the time spent looking at A on AX trials and B on BX trials). Gaze length to the unique elements increased overall across test blocks, $F(1, 22) = 6.65$, $MSE = 4.26 \times 10^6$. Participants spent more time looking at the unique elements in the preexposure condition (i.e., to A and B) than in the novel condition (to C and D), $F(1, 22) = 7.11$, $MSE = 3.59 \times 10^7$. The test block by preexposure condition interaction was not significant ($F < 1$).

These results demonstrate that discrimination is better for stimuli given intermixed preexposure than for novel stimuli. Furthermore, participants spent more time looking at the preexposed elements (A and B) than at the novel elements (C and D). The implication that intermixed preexposure increases the salience of the unique features so that they become more salient than the novel features is problematic for a salience-modulation mechanism, such as that proposed by McLaren and Mackintosh (2000), which allows only that such preexposure might attenuate loss of salience. But before turning to a discussion of processes that might act to enhance the salience of distinctive features above their starting levels, it is necessary to explore an alternative interpretation of the present results.

Experiment 2

In addition to the salience-modulation process, the model proposed by McLaren and Mackintosh (2000) incorporates further mechanisms that can contribute to the perceptual learning effect and that may be active in the procedure used in Experiment 1. As described above, preexposure to AX and BX, it is supposed, will allow the formation of within-compound associations between the common and unique elements (X–A and X–B associations). As a result, on test, the presence of X will activate a representation of B on AX trials and will activate a representation of A on BX trials. In this way, within-compound associations formed during preexposure will increase the effective similarity of AX and BX and impair discrimination performance. A second proposed associative mechanism will, however, reduce this effect. Specifically, intermixed exposure to AX and BX will result in the formation of inhibitory associations between the unique elements, A and B. Thus, although X will activate B on AX test trials (and A on BX trials), the presence of A will offset this effect by inhibiting the activation of B (and vice versa); therefore, discrimination performance will remain high.

How will the associative mechanisms described above affect the CX and DX test trials? Just as on AX and BX test trials, X will activate the representations of A and B. However, the absence of A and B on the CX and DX trials means that these activated representations (of A and B) will not be suppressed through inhibition. Thus, associative activation of A and B by X may reduce the discriminability of CX and DX by increasing the number of elements they have in common (in addition to X, they

will share the associatively activated representations of A and B). On the basis of these associative mechanisms, therefore, McLaren and Mackintosh's (2000) model can account for the better test performance to AX and BX than to CX and DX seen in Experiment 1. Perhaps, then, the salience-modulation mechanism envisaged by McLaren and Mackintosh was in operation in Experiment 1, but its effects were outweighed by within-compound and inhibitory associations. In the current experiment, therefore, we conducted a further comparison of preexposed and novel stimuli, but with a changed procedure designed to control for any possible effects of these associative links.

As in Experiment 1, participants received preexposure to AX and BX. In the same–different task, however, novel elements C and D were added to the AX and BX patterns. Similarly, A and B were added to the CX and DX patterns. Thus, in one condition, participants were required to discriminate ACDX and BCDX. In the other condition, the discrimination was between CABX and DABX. The additional common elements (AB and CD) should reduce discrimination performance in both test conditions. However, the impact of this attenuation will depend on the relative salience of the preexposed and novel elements. According to the salience-modulation mechanism of McLaren and Mackintosh (2000), discrimination of CABX and DABX should be better than that of ACDX and BCDX because C and D are more salient than A and B; the salient discriminating features C and D will stand out on the less salient ABX background. But our interpretation of Gibson's (1969) differentiation theory predicts the reverse: Because A and B are more salient (perceptually effective) than C and D, ACDX and BCDX will produce the best performance.

Most important, this design controls for the influence of McLaren and Mackintosh's (2000) associative mechanisms. The presence of AB on the CABX and DABX trials will prevent any associative activation of A and B by X from having a negative impact on discrimination performance. Indeed, according to some accounts (e.g., Wagner, 1981), associative activation of A and B might be expected to reduce the impact of the presence of these stimuli on CABX and DABX trials and so increase the discriminability of these test stimuli. On the ACDX and BCDX trials, the surprising presence of the novel and salient C and D should, according to McLaren and Mackintosh, lead to very poor discrimination performance.

Method

The method differed from that of Experiment 1 in the following respects. Thirty first-year students from the University of New South Wales participated in this experiment in exchange for course credit. In the preexposure phase, all participants received alternating presentations of AX and BX for 60 trials of each. In the subsequent test phase, two novel elements, C and D, were added to the AX and BX patterns to create the discrimination pair ACDX and BCDX. Similarly, A and B were added to the novel patterns, CX and DX, to create the discrimination pair CABX and DABX. The test involved four trial types: (1) preexposed different (e.g., ACDX and BCDX), (2) preexposed same (e.g., ACDX and ACDX), (3) novel different (e.g., CABX and DABX), and (4) novel same (e.g., CABX and CABX). Procedural details not specified here were the same as those described for Experiment 1.

Results and Discussion

Five participants were excluded from this analysis according to the criterion described in Experiment 1.

Same–different performance. Panel A of Figure 3 shows the mean proportion of correct responses for the four types test of test trial across the four blocks of trials. As in the previous experiment, performance was more accurate on the same trials than on the different trials, $F(1, 24) = 22.26$, $MSE = 0.14$. Most important, performance accuracy was greater for the ACDX and BCDX trials than for the CABX and DABX trials, $F(1, 24) = 6.64$, $MSE = 0.17$. Participants did not show an overall improvement in performance accuracy across the test phase (main effect of test blocks), $F(1, 24) = 2.81$, $MSE = 0.07$. A marginally significant interaction effect was observed between the factors of preexposure condition (preexposed vs. novel) and trial type (same vs. different), $F(1, 24) = 3.72$, $p = .07$, $MSE = 0.18$. Although the interaction is not significant, the pattern of data is consistent with the previous experiment. The effect of preexposure was stronger on the different than on the same trials. A significant interaction was observed between the factors of test block and trial type, $F(1, 24) = 13.95$, $MSE = 0.02$. This confirms the trend in the figure that the difference in performance accuracy between same and different trials was reduced across test blocks. The interaction between the factors of test block and preexposure condition was not significant, $F(1, 24) = 1.36$, $MSE = 0.03$. The three-way interaction between test block, trial type, and preexposure was also not significant ($F < 1$).

Although the interaction of trial type and test block was not significant, a simple effects analysis of the different trials was conducted for consistency with previous experiments. The analysis showed that participants were better at discriminating ACDX from BCDX than at discriminating CABX from DABX, $F(1, 24) = 5.38$, $MSE = 0.32$. Participants showed a general improvement on the different trials as accuracy in both test conditions improved across test blocks, $F(1, 24) = 8.84$, $MSE = 0.05$. The interaction between test block and preexposure condition was not significant, $F(1, 24) = 1.02$, $MSE = 0.06$.

An analysis of sensitivity was also conducted for the results in the same–different task. Panel B of Figure 3 shows sensitivity scores (d') for each test condition across the four blocks of test trial. Sensitivity scores were greater for the ACDX and BCDX trials than for the CABX and DABX trials, $F(1, 24) = 7.65$, $MSE = 3.49$. Across both test conditions, sensitivity scores did not improve over test blocks, $F(1, 24) = 1.58$, $MSE = 1.64$. The interaction of preexposure (preexposed vs. novel) and test block was also not significant ($F < 1$).

Eye gaze. Panel C of Figure 3 shows mean gaze length to the unique elements A–D in the same–different task. Only gaze length to the relevant unique element on each test trial was considered in this analysis (e.g., A on ACDX and C on CABX trials). Gaze length to the preexposed unique elements (A and B) was greater than to the novel unique elements (C and D), $F(1, 24) = 11.26$, $MSE = 1.38 \times 10^7$. Gaze length to the unique elements did not change across the test blocks ($F < 1$). The interaction effect of preexposure condition and test block was also not significant, $F(1, 24) = 2.03$, $MSE = 1.09 \times 10^6$.

A further analysis examined how participants attended to A–D when they served as common elements. If A and B are more salient

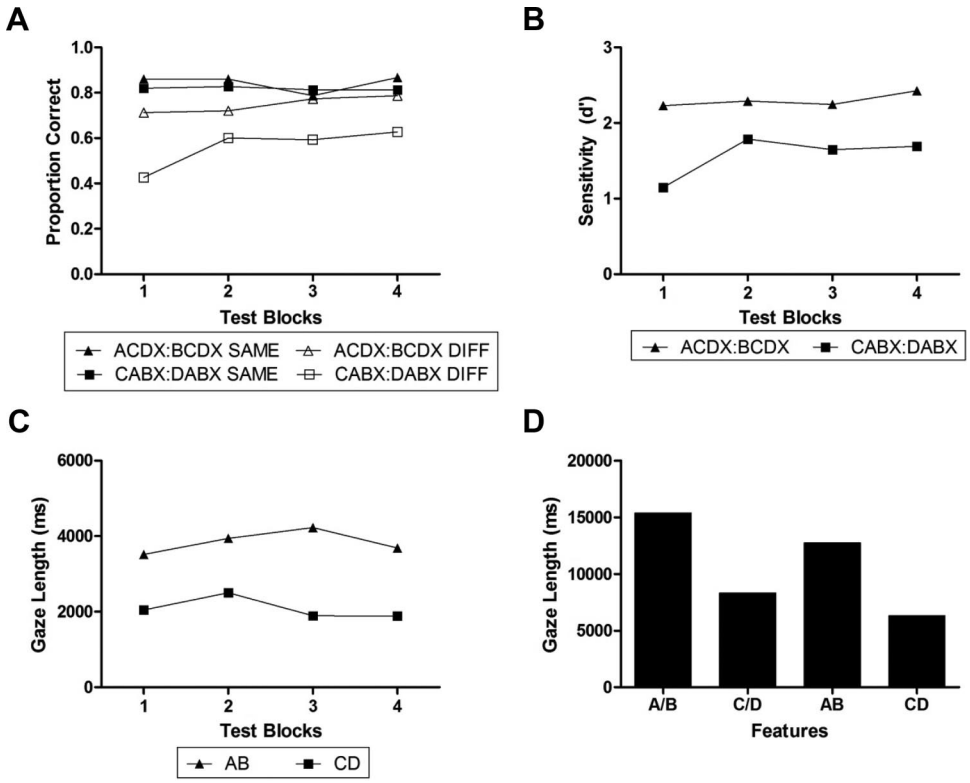

Figure 3. Panel A shows mean proportion of correct responses within each test block on the four types of test trial in Experiment 2. Panel B shows mean sensitivity scores (d') for each preexposure condition across test blocks. Panel C shows the total gaze length to the two unique elements within each preexposure condition (A and B or C and D) across test blocks. Panel D shows mean gaze length to elements A–D across test blocks. The two left bars show gaze length to elements A–D when they were presented as the unique elements. The two right bars show gaze length to A–D when the elements were presented as common elements.

than C and D, then gaze length to the common elements (A and B) on CABX and DABX trials should be greater than to the common elements (C and D) on ACDX and BCDX trials. Gaze lengths for AB and CD, when these served as common elements, are shown by the two columns on the right of Panel D of the figure. These were calculated by averaging gaze length to A and B (and to C and D) on each trial in which these elements were part of the common background (i.e., CD on ACDX:BCDX trials for C and D, and on CABX:DABX trials for A and B). For comparison, gaze length for these features when they served as unique elements is also shown in Panel D, in the columns labeled A/B and C/D (these are the sums of gaze length to the unique elements in each preexposure condition as shown in Panel C of Figure 3). Overall, gaze length was greater for the unique elements (A/B and C/D) than for the common elements (AB and CD), $F(1, 24) = 23.29$, $MSE = 5.83 \times 10^6$. There was a main effect of preexposure as gaze length to A and B was greater than gaze length to C and D, $F(1, 24) = 10.31$, $MSE = 1.10 \times 10^8$. The interaction between element type and preexposure condition was not significant, $F(1, 24) = 1.70$, $MSE = 1.38 \times 10^6$. Thus, gaze length was greater to A and B than to C and D across all test conditions.

Experiment 2 showed that discrimination of ACDX and BCDX was better than of CABX and DABX. Gaze length to A and B was also greater than to C and D regardless of whether A and B were presented as the unique or common elements. Participants spent more time looking at A and B than at C and D across both the ACDX:BCDX and CABX:DABX test trials. These findings rule out the idea that C and D were more salient than A and B, but that the poorer discrimination of CX and DX than of AX and BX seen in Experiment 1 was the result of associative activation of A and B on CX and DX trials (but not the AX and BX trials). That is, they show that the results of Experiment 1 were not due to inhibition between A and B. In Experiment 2, the ease with which the unique features were detected depended on the difference in salience between the preexposed and novel unique elements. The findings support the more straightforward conclusion, that the intermixed unique elements were more salient than novel unique elements in the same–different task.

The major virtue of the design used in the current experiment was that it allowed us to demonstrate an effect similar to that of Experiment 1, using a common X background for all stimuli, while at the same time ruling out a non–salience-based account derived from McLaren and Mackintosh (2000). Thus, the poor performance to CX and DX in Experiment 2 cannot have been the result of activation of representations of A and B by X. Conversely, the superior performance to AX and BX cannot have been due to suppression of associatively activated representations of A and B by inhibition between the two elements. In summary, none of the

mechanisms proposed by McLaren and Mackintosh described here is able to account for the results of Experiment 2.

Experiment 3

The findings reported so far support the notion that, following exposure to AX and BX, their unique features become more salient than novel features. But the features used as A and B were complex and multidimensional, each with its own distinctive color, shape, and location. Certain perceptual dimensions may be more relevant for discrimination than others, and exposure may increase attention only to these dimensions. In particular, in the task used here, discrimination can be based simply on the presence of bright color in a specific location. Each unique element (A–D) appeared in a specific quadrant of the common background (X), and it remained in that position throughout preexposure. Thus, participants do not need to encode the physical properties of the unique elements (their shape and color) for them to discriminate the patterns. Participants can simply encode and attend to the spatial locations of the unique elements for discrimination.

Experiment 3 investigated this possibility by repeating the basic preexposure procedure of the previous experiments, but including a novel test in which the unique preexposed features, as defined in terms of shape and color, were presented in new locations for the test. If discrimination of AX from BX, following preexposure, depends importantly on attention to the spatial locations of A and B, then shifting the unique elements from their locations in preexposure to novel locations in test should then impair their detection. In the current experiment, therefore, participants received intermixed presentations of AX and BX in preexposure, followed, as in Experiment 1, by same–different tests with AX and BX and with the novel patterns CX and DX. In addition, two new test conditions were introduced in which the locations of the preexposed and novel unique elements were swapped. In one condition, A and B were placed in the locations that C and D occupied on the CX and DX trials. These patterns are called A′X and B′X. In the other condition, C and D were presented in the locations that A and B originally occupied during preexposure. These patterns are called C′X and D′X. For reference, the locations that A and B occupied on AX and BX trials are called the *attended* locations because, if location is important, it is these locations that should attract attention. The locations that C and D occupied on the CX and DX trials are called the *unattended* locations.

The critical comparison in this experiment is between the A′X: B′X and C′X:D′X trials. If participants make their discriminations based on the physical identity of the unique elements, then discrimination for A′X and B′X should be better than for C′X and D′X. That is, participants should find A and B easier to detect than C and D regardless of where these elements appear. Conversely, discrimination of C′X and D′X would be expected to be better than of A′X and B′X if participants use the locations of the unique elements for discrimination.

Method

The procedure differed from the previous experiments only in the following details. Twenty-four students (11 female and 13 male; mean age = 18.8 years) from the University of New South Wales participated in this experiment in exchange for course credit. In the preexposure phase, all participants received alternating trials to AX and BX for 60 trials of each. Discrimination of this pair was then measured in the same–different task, along with the novel pair, CX and DX. These trials were intermixed with test trials in which the location of the features were changed. For the A′X and B′X test trials, A appeared in C's usual location and B appeared in D's usual location. For the C′X and D′X trials, C and D appeared in the locations usually occupied by A and B, respectively. Thus, there were eight types of test trial. There were four trial types in which the unique elements appeared in their original locations: (1) preexposed original different (e.g., AX and BX), (2) preexposed original same (e.g., AX and AX), (3) novel original different (e.g., CX and DX), and (4) novel original same (e.g., CX and CX). There were four types of test trial in which the locations of the unique elements were swapped: (5) preexposed swapped different (e.g., A′X and B′X), (6) preexposed swapped same (e.g., A′X and A′X), (7) novel swapped different (e.g., C′X and D′X), and (8) novel swapped same (e.g., C′X and C′X). There were two blocks of 48 test trials, making a total of 96 trials. (Note that in this procedure, the terms *preexposed* and *novel* refer to the physical appearance of A–D, their color and shape.)

Results and Discussion

Three participants were excluded from this analysis according to the criterion as described in Experiment 1.

Same–different performance. Panel A of Figure 4 shows the mean proportion of correct responses, for each of two 6-trial blocks, for the eight different test conditions in the same–different task. Overall accuracy was marginally better when the unique elements (A–D) appeared in their original locations than in their swapped locations, $F(1, 20) = 3.72$, $p = .07$, $MSE = 0.02$. Performance accuracy was again better for same trials than for different trials, $F(1, 20) = 35.14$, $MSE = 0.13$. Performance accuracy did not improve across test blocks, $F(1, 20) = 1.15$, $MSE = 0.04$. There was no effect of preexposure as discrimination performance for patterns in which A and B were unique was not better than for patterns in which C and D were unique, $F(1, 20) = 1.80.$, $MSE = 0.07$. That is, the familiarity or novelty of the unique elements' physical characteristics did not affect discrimination performance. The interaction of preexposure condition (preexposed vs. novel) and trial type (same vs. different) was not significant ($F < 1$). The interaction of preexposure (preexposed vs. novel) and location (original vs. swapped) was significant, $F(1, 20) = 16.40$, $MSE = 0.11$. This interaction confirms the observation that discrimination of AX/BX was greater than that of CX/DX, but swapping the locations of A–D reversed the direction of this effect. A three-way interaction of preexposure, location, and trial type, $F(1, 20) = 14.31$, $MSE = 0.10$, suggested that the interaction of preexposure and location was observed on the different test trials, but not on the same test trials. No other significant interactions were obtained (Fs < 1).

The interaction of preexposure and location prompted a simple effects analysis. In their original locations, discrimination performance for AX and BX was better than for CX and DX, $F(1, 20) = 6.37$, $MSE = 0.04$. Swapping the locations of the unique elements rendered C′X and D′X more discriminable than A′X and B′X, $F(1, 20) = 14.84$, $MSE = 0.05$. These

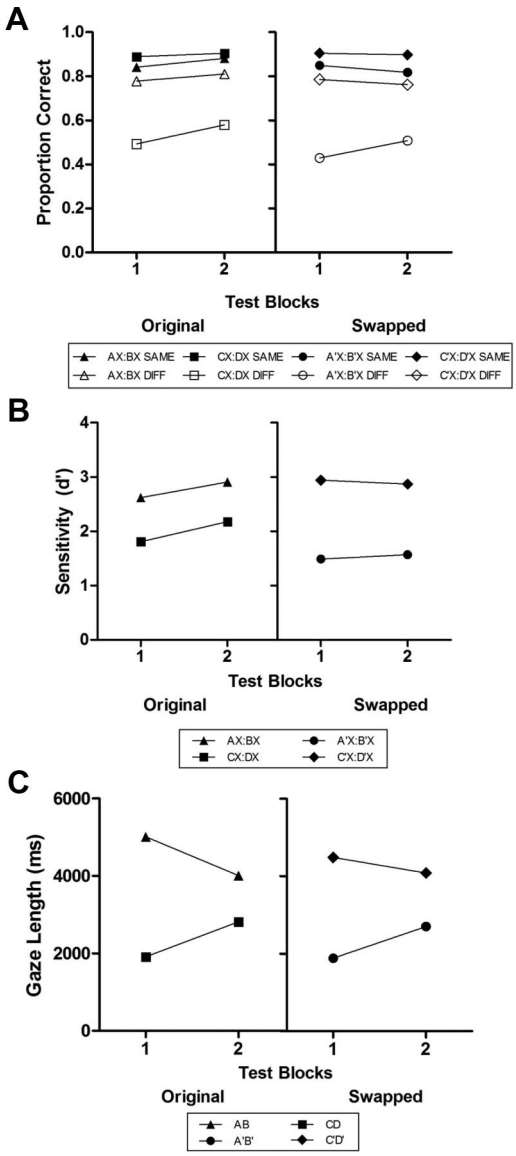

Figure 4. Panel A shows mean proportion of correct responses for the different test conditions in Experiment 3. Original refers to the trials in which the unique elements A–D (defined by their shape and color) appeared in their original locations (i.e., AX–DX trials). Swapped refers to the trials in which the locations for A–D were changed from those used in preexposure (i.e., A′X – D′X trials). Panel B shows mean sensitivity scores (d') for each test type. Panel C shows gaze length to the elements A–D in their original or swapped locations in the same–different task.

comparisons show that spatial location is most important for discrimination.

The previous analysis does not tell us whether or not changes in the salience of the unique elements' physical properties affected discrimination performance. This requires an analysis comparing trials in which the preexposed (A/B) and novel (C/D) unique elements appear in the attended or the unattended location. With attention to spatial location controlled in this way, an effect of preexposure would indicate differences in the effectiveness of other aspects of the cues (their shape and color) in determining discrimination performance. A simple effects analysis revealed that, in the unattended locations, the difference in discrimination performance between the patterns with novel (CX and DX) and preexposed elements (A′X and B′X) was significant, $F(1, 20) = 4.78$, $MSE = 0.02$, with performance to the novel being superior. There was no difference in discrimination performance for the patterns with the novel and preexposed elements when A–D appeared in the attended locations (i.e., AX:BX vs. C′X:D′X), $F < 1$.

This pattern of results is confirmed by the mean sensitivity scores (d') for the four test conditions shown in Panel B of Figure 4. Overall, there was no difference in sensitivity scores for trials on which the unique elements appeared in their original or swapped locations, $F(1, 20) = 2.09$, $MSE = 0.51$. Sensitivity scores for the preexposed patterns were not better than for the novel patterns, $F(1, 20) = 2.44$, $MSE = 1.56$. However, there was a significant interaction between location and preexposure, $F(1, 20) = 15.15$, $MSE = 3.20$. That is, sensitivity scores for AX and BX were greater than for CX and DX, but the direction of this difference was reversed after the unique elements swapped locations. This interaction prompted a simple effects analysis to compare the sensitivity to detect the preexposed and novel unique elements in either their original or swapped locations. Sensitivity scores for AX and BX trials were better than those for CX and DX trials, $F(1, 20) = 5.52$, $MSE = 2.27$. Similarly, discrimination of C′X and D′X was better than that of A′X and B′X, $F(1, 20) = 15.95$, $MSE = 1.25$. In addition, an analysis was conducted to compare sensitivity when A–D appeared in either the attended or unattended locations. The analysis showed that, when the unique elements appeared in the unattended locations, the difference in sensitivity for CX and DX and for A′X and B′X was significant, $F(1, 20) = 4.63$, $MSE = 0.48$. No such difference was observed when the unique elements appeared in the attended locations ($F < 1$).

Eye gaze. Panel C of Figure 4 shows mean gaze duration to the four unique elements A–D in both the original and swapped locations in the same–different task. Overall gaze length to all unique elements was not affected by the swapping of location ($F < 1$). Gaze length to the preexposed elements A and B was not greater than to C and D across the original and swapped test trials ($F < 1$). It is important to note, however, that the interaction of preexposure condition (preexposed vs. novel) and location type (original vs. swapped) was significant, $F(1, 20) = 11.97$ $MSE = 1.59 \times 10^7$. A simple effects analysis confirmed the observation that gaze length to A and B was greater than to C and D when these unique elements appeared in their original locations, $F(1, 20) = 10.17$, $MSE = 1.90 \times 10^7$. Conversely, gaze length to C′ and D′ was greater to A′ and B′ after their locations were swapped, $F(1, 20) = 11.42$, $MSE = 1.65 \times 10^7$. In other words, gaze lengths toward the attended locations (where A and B appeared in preexposure) were longer than to the unattended locations.

In summary, these results confirm that discrimination performance for the preexposed patterns, AX and BX, is better than for the novel patterns, CX and DX. The new finding is that discrimination accuracy for the C′X:D′X trials was better than for the A′X:B′X trials. That is, when C and D were placed in the locations that had been occupied by A and B during preexposure, they were detected readily, whereas A and B were very difficult to detect when presented in new locations. In the eye gaze measure, participants spent more time looking at A and B than at C and D when

these elements appeared in their original locations. Consistent with the behavioral data, participants spent more time looking at C′ and D′ than at A′ and B′ when the locations of these elements were swapped.

These results indicate that the development of a tendency to look at the locations in which the critical features were presented during preexposure is an important determinant of test performance. Indeed, when we compare test trials on which the features appeared in the attended locations (AX:BX vs. C′X:D′X), both discriminations were performed well. It is interesting, however, that when A–D appeared in the unattended locations, discrimination was better for patterns with novel elements (CX and DX) than for patterns with preexposed elements (A′X and B′X). The implications of this finding are considered in the General Discussion.

General Discussion

The results reported here appear to demonstrate two quite different effects of intermixed preexposure on the discriminability of the two very similar checkerboard stimuli AX and BX. First, the familiar AX and BX are better discriminated on test than are two novel stimuli CX and DX. This suggests, and the eye gaze data confirm, that attention to the familiar A and B features on test is greater than to the novel C and D features. Furthermore, the results of Experiment 3 identified that it is largely the location of features A and B that control attention, and therefore discrimination performance, in the same–different test task. Thus, during intermixed exposure to AX and BX, participants detect the A and B features, and then pay attention to the locations in which those features appeared (the attended locations). Performance on test is then enhanced when stimulus differences (of any kind) appear in the attended locations. The second effect of interest is that, when the unique features (the stimulus differences) are presented outside of the attended locations on test, performance is better when those features are novel. The current results, therefore, highlight two quite different perceptual learning effects: one based on attention to feature locations and one more consistent with attentional capture by stimulus novelty.

Taken together, these two findings suggest that the superior test performance to familiar over novel stimuli seen in all three experiments here (and by Wang & Mitchell, 2011) has little to do with the ability of the unique features to "capture" attention. That is, the effect is not the consequence of a stimulus-driven process. Rather, it appears that attention to A and B on the standard test (with feature locations maintained) reflects an instrumental attentional response to specific locations in the stimuli. This attentional response can be described in two ways. One possibility is that participants are engaged in a top-down, deliberate search. They have learned that the task can be solved by attending to specific locations, and so they engage an endogenous attentional mechanism to monitor those locations in order to solve the task on test. The second way to describe the same process is in terms of reinforcement. Attention to the locations of features A and B has been reinforced during preexposure because it results in the detection of the stimulus differences. Detection of stimulus differences is reinforcing because participants have been given the task of looking for differences (Mackintosh, 2009).

These results have implications for some previous findings of ours. Lavis, Kadib, Mitchell, and Hall (2011; see also de Zilva & Mitchell, 2012) presented participants with checkerboard stimuli on either an intermixed or a blocked schedule. They found that memory for the shape and color of the unique features was better in the intermixed than in the blocked condition. In light of the current results, it seems likely that better memory for intermixed unique features was at least partly the consequence of participants' attention to the locations in which those features appeared in preexposure.

One conclusion that could be drawn from the current results is that stimuli in which the unique features appear in specific locations, such as the checkerboards used here, are inappropriate for the investigation of mechanisms of perceptual learning. That is, unique feature location can be seen as a confound. There are, however, three reasons to question this conclusion. The first is straightforward. Attention to feature location might be argued to fall outside of the kinds of phenomena that animal models of perceptual learning seek to explain (e.g., Hall, 2003; McLaren & Mackintosh, 2000). It is, however, entirely consistent with the theories of perceptual learning proposed by Mundy et al. (2007) and Mitchell, Nash, and Hall (2008), in which, following detection of the unique features (see below), attention is focused on these stimulus features in a top-down way. This is likely to be an important mechanism of human perceptual learning. There can be no doubt that there are many instances of perceptual learning that depend on an ability to attend to specific stimulus locations to detect the subtle differences among the stimuli. That this mechanism might be goal-directed, or deliberate, does not detract from its importance.

The second reason why the specific stimuli used in these experiments should not be seen as especially problematic is that exactly the same top-down processes are just as likely to play an important role in perceptual learning with all other types of stimuli. For example, one type of stimulus that has been used recently, and for which the stimulus differences do not appear in specific locations, is that used by Mundy et al. (2007). Mundy et al. generated stimuli by morphing pictures of human faces. The differences between the resulting similar faces were, therefore, many, and appeared everywhere in the stimulus. As mentioned above, Mundy et al. observed an effect very similar to that found here and by Wang and Mitchell (2011). Thus, familiar face stimuli, which can be described as AX and BX, were better discriminated on test than CY and DY, for which only Y (the morphed average of the two faces) had been exposed. Indeed, the explanation provided by Mundy et al. for their effects was the same as that offered here to explain the attention to feature location. That is, participants detected A and B during preexposure, and then maintained attention to those features (or values on specific dimensions in face space) through a top-down process. Thus, the stimulus features or dimensions that are attended to may differ depending on stimulus type (e.g., checkerboards with unique features in specific locations rather than morphed faces); nevertheless, the psychological processes responsible for the maintenance of attention may be the same.

Lastly, one of the advantages of the checkerboard stimuli used in the current experiments is that they allow us to investigate stimulus salience while controlling for the influence of top-down attentional control. As seen in Experiment 3, when presented in the unattended locations, the novel features C and D produced better stimulus discrimination than did the familiar features A and B. It

is important to note that the results seen in Experiment 3 suggest that when novel stimuli attract attention, they do so independently of controlled attentional processes; when attention is under top-down control, the opposite result (an advantage for familiar stimuli) is observed.

Although it is an important part of the McLaren and Mackintosh (2000) theory of perceptual learning, we are not aware of any previous evidence that the novelty of the unique features might determine stimulus discriminability. By directing top-down attention away from the unique stimulus features, we have, for the first time, provided some support for McLaren and Mackintosh's relative novelty mechanism of perceptual learning. One conclusion that can be drawn from the current experiments, therefore, is that to investigate the automatic processes of association formation and salience change (that models such as that of McLaren and Mackintosh seek to explain), one must first direct top-down attentional processes elsewhere.

The discussion so far has concerned the processes in operation at test. We have not yet discussed, however, how the unique features A and B are detected in the first place during intermixed exposure to AX and BX. Such a process is required for the top-down attentional focus on stimulus locations (or dimensions in the case of morphed faces) to operate. Probably the simplest mechanism is that described by Honey and Bateson (1996), which follows directly from Wagner's (1981) SOP model. Thus, when AX and BX are preexposed, because X is presented on every trial, it is maintained in the periphery of attention, or, to use Wagner's terminology, in the A2 state. As a consequence, A and B, which are presented only on every alternate trial, will receive the majority of attention, or processing resources; they will be activated into Wagner's A1 state. In other words, unique features A and B will be detected because the background, X, always suffers from short-term habituation because of its presentation on the previous trial. Although this is the simplest explanation, it is also possible that, for example, Hall's (2003) dishabituation mechanism plays a role in stimulus detection. This remains to be investigated.

In sum, the current experiments show that intermixed exposure to AX and BX increases attention to the unique features A and B. This increase in attention is, however, quite specific to the spatial location of each feature and not its other perceptual dimensions (shape and color). When attention to feature location is eliminated (Experiment 3), there is also evidence for a novelty-based attentional process (McLaren & Mackintosh, 2000). Thus, novel unique features produce better discrimination than familiar features. Further research in which top-down attention is directed elsewhere at test might reveal further evidence for the models of perceptual learning based on animal research and proposed by McLaren and Mackintosh (2000) and Hall (2003).

References

Blair, C. A. J., & Hall, G. (2003). Perceptual learning in flavor aversion: Evidence for learned changes in stimulus effectiveness. *Journal of Experimental Psychology: Animal Behavior Processes, 29,* 39–48. doi:10.1037/0097-7403.29.1.39

Blair, C. A. J., Wilkinson, A., & Hall, G. (2004). Assessments of changes in the effective salience of stimulus elements as a result of stimulus preexposure. *Journal of Experimental Psychology: Animal Behavior Processes, 30,* 317–324. doi:10.1037/0097-7403.30.4.317

de Zilva, D., & Mitchell, C. J. (2012). Effects of exposure on discrimination of similar stimuli and on memory for their unique and common features. *Quarterly Journal of Experimental Psychology, 65,* 1123–1138. doi:10.1080/17470218.2011.644304

Gibson, E. J. (1969). *Principles of perceptual learning and development*. New York, NY: Appleton-Century-Crofts.

Goldstone, R. (1994). Influences of categorization on perceptual discrimination. *Journal of Experimental Psychology: General, 123,* 178–200. doi:10.1037/0096-3445.123.2.178

Hall, G. (2003). Learned changes in the sensitivity of stimulus representations: Associative and nonassociative mechanisms. *Quarterly Journal of Experimental Psychology: Comparative and Physiological Psychology, 56*(B), 43–55. doi:10.1080/02724990244000151

Hogarth, L., Dickinson, A., Austin, A., Brown, C., & Duka, T. (2008). Attention and expectation in human predictive learning: The role of uncertainty. *Quarterly Journal of Experimental Psychology, 61,* 1658–1668. doi:10.1080/17470210701643439

Honey, R. C., & Bateson, P. (1996). Stimulus comparison and perceptual learning: Further evidence and evaluation from an imprinting procedure. *Quarterly Journal of Experimental Psychology: Comparative and Physiological Psychology, 49*(B), 259–269. doi:10.1080/713932631

Kruschke, J. K., Kappenman, E. S., & Hetrick, W. P. (2005). Eye gaze and individual differences consistent with learned attention in associative blocking and highlighting. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 31,* 830–845. doi:10.1037/0278-7393.31.5.830

Lavis, Y., Kadib, R., Mitchell, C., & Hall, G. (2011). Memory for, and salience of, the unique features of similar stimuli in perceptual learning. *Journal of Experimental Psychology: Animal Behavior Processes, 37,* 211–219. doi:10.1037/a0021888

Lavis, Y., & Mitchell, C. (2006). Effects of preexposure on stimulus discrimination: An investigation of the mechanisms responsible for human perceptual learning. *Quarterly Journal of Experimental Psychology, 59,* 2083–2101. doi:10.1080/17470210600705198

Lubow, R. E. (1989). *Latent inhibition and conditioned attention theory*. New York, NY: Cambridge University Press. doi:doi:10.1017/CBO9780511529849

Mackintosh, N. J. (2009). Varieties of perceptual learning. *Learning & Behavior, 37,* 119–125. doi:10.3758/LB.37.2.119

Mackintosh, N. J., Kaye, H., & Bennett, C. H. (1991). Perceptual learning in flavor aversion conditioning. *Quarterly Journal of Experimental Psychology: Comparative and Physiological Psychology, 43*(B), 297–322. doi:10.1080/14640749108401272

McLaren, I. P. L., & Mackintosh, N. J. (2000). An elemental model of associative learning: I. Latent inhibition and perceptual learning. *Animal Learning & Behavior, 28,* 211–246. doi:10.3758/BF03200258

Mitchell, C., Nash, S., & Hall, G. (2008). The Intermixed-Blocked effect in human perceptual learning is not the consequence of trial spacing. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 34,* 237–242.

Mondragón, E., & Hall, G. (2002). Analysis of the perceptual learning effect in flavor aversion learning: Evidence for stimulus differentiation. *Quarterly Journal of Experimental Psychology: Comparative and Physiological Psychology, 55*(B), 153–169. doi:10.1080/02724990143000225

Mundy, M. E., Honey, R. C., & Dwyer, D. M. (2007). Simultaneous presentation of similar stimuli produces perceptual learning in human picture processing. *Journal of Experimental Psychology: Animal Behavior Processes, 33,* 124–138. doi:10.1037/0097-7403.33.2.124

O'Brien, R. G., & Kaiser, M. K. (1985). MANOVA method for analyzing repeated measures designs: An extensive primer. *Psychological Bulletin, 97,* 316–333. doi:10.1037/0033-2909.97.2.316

Rehder, B., & Hoffman, A. B. (2005). Eyetracking and selective attention in category learning. *Cognitive Psychology, 51,* 1–41. doi:10.1016/j.cogpsych.2004.11.001

Symonds, M., & Hall, G. (1995). Perceptual learning in flavor aversion conditioning: Roles of stimulus comparison and latent inhibition of common stimulus elements. *Learning and Motivation, 26,* 203–219. doi:10.1016/0023-9690(95)90005-5

Wagner, A. R. (1981). SOP: A model of automatic memory processing in animal behavior. In N. E. Spear & R. R. Miller (Eds.), *Information processing in animals: Memory mechanisms* (pp. 5–47). Hillsdale, NJ: Erlbaum.

Wang, T., & Mitchell, C. J. (2011). Attention and relative novelty in human perceptual learning. *Journal of Experimental Psychology: Animal Behavior Processes, 37,* 436–445. doi:10.1037/a0023104

Received August 12, 2011
Revision received July 2, 2012
Accepted July 3, 2012 ■