Blocking Effects on Dimensions:
How attentional focus on values can spill over to the dimension level

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Abstract

Blocking effects were examined in an associative learning task in which to-be-learned cues varied along two dimensions. Experiment 1 replicated the standard blocking effect when to-be-learned cues had two predictive dimensions. In Experiment 2, cues varied on one predictive dimension and a second non-predictive dimension. Results were that blocking a particular cue (e.g. purple circle) led to blocking its entire dimension value (purple shapes). These findings suggest that attentional biases can be created by blocking effects that spill across dimensions, including dimensions that have traditionally been accepted as separable.

Keywords: Cognitive Science; Psychology; Associative Learning; Blocking, Attention.

Introduction

Attention is a primary component of associative learning (Kruschke, 2003). In the course of learning paired associations, the learner needs to discriminate between values and dimensions present in the stimulus. In doing so, attention is generally shifted to the predictive and away from the non-predictive. For example, when learning categories of furniture, shape tends to be predictive, while color is not. In particular three attentional learning phenomena have been documented: latent inhibition, attentional persistence, and conditional blocking. Latent inhibition refers to the phenomenon in which people and animals have difficulty learning the predictiveness of cues that were initially observed to be non-predictive (e.g. Lubow, 1989). Secondly, attentional persistence is a mechanism by which attention is shifted to predictive dimensions and away from non-predictive dimensions (see Kersten, Goldstone, & Schaffert, 1998 for discussion). As a result, people have difficulty with inter-dimensional shifts where an initially irrelevant, non-predictive dimension later becomes predictive while the initially predictive dimension becomes non-predictive. Finally, conditional blocking (discussed in more detail below) is a phenomenon in which new predictive cues are difficult to learn when associated with previously learned cues (Kamin, 1969; Kruschke, 2003, Kruschke & Blair, 2000; Mackintosh & Turner, 1971). Latent inhibition and attentional persistence are mechanisms which seem to operate on the level of dimensions. For example, if objects vary in shape and color such that specific shapes predict some outcome and color is irrelevant, then attention is focused on the dimension of shape and not on the dimension of color. Blocking, however, is typically observed with particular values on a dimension or perhaps correlated values of more than one dimension. For example, learning may involve associating particular colors with specific outcomes. Perhaps *red* is learned and *blue* is blocked. Here, specific colors such as red and blue are values on the dimension color.

Taken together, people tend to learn predictability and in doing so attention is shifted to relevant, predictive dimensions and away from irrelevant, non-predictive dimensions. Furthermore, within the relevant dimension, attention can be focused on some predictive values and away from other predictive values, namely those that are observed later. What remains unclear is how attention to values within a dimension may interact with attention to predictive and non-predictive dimensions. In particular, can blocking of a value within a predictive dimension affect the allocation of attention to another non-predictive dimension?

Conditional blocking

Blocking occurs when a predictive cue is presented later in the course of learning. More specifically, learners acquire the knowledge that cue A predicts outcome O_1 (denoted $A \rightarrow O_1$). Later they observe that cues *A* and *B* predict outcome O_1 ($AB \rightarrow O_1$). They are also learning another association ($CD \rightarrow O_2$), with an equal number of AB and CD trials being presented. After learning, participants are tested on the predictability of B and D (B→?, D→?). If learning is dependent only on the number of associations observed, then scores on B and D questions should be equivalent. However, responses of $B \rightarrow O_1$ are significantly lower than responses of $D \rightarrow O_2$ (Kruschke, 2003, Kruschke & Blaire, 2000). Furthermore, when cues B and D are presented together (BD→?), outcome O_2 is preferred. While this behavior in its simplest form may be explained by simple associative, error-reduction models such as the Rescorla-Wagner Model (Rescorla & Wagner, 1972), traditional blocking as well as additional effects such as backward blocking and attenuated learned of the blocked cue can be explained by the attentional learning. (e.g., see Kruschke, 2003; Kruschke & Blaire, 2000). By initially learning $A \rightarrow O_{1,}$ attention is shifted to cue A. Little attention is given to cue B; and as a result the learning of B is blocked.

Studies of blocking have involved cues that are defined over one dimension or perhaps defined over more than one dimension, but with dimensional values being correlated resulting in multiple predictive dimensions. For example, participants might learn associations between specific symptoms and fictitious diseases (e.g. Kruschke & Blaire, 2000). In this case, specific cues are values over one dimension. Blocking has also been demonstrated in perceptual learning tasks involving one dimension, such as specific color being predictive of outcome (e.g. Denton & Kruschke, 2006). Finally, even when cues might naturally be defined using more than one dimension, they can be reduced to one dimension. For example, if presence of light is a to-be-learned cue; and presence of sound is another cue, the situation could be defined with two dimensions (visual, auditory). Cues would then be given arguments indicating presence or absence, i.e. light = (1, 0) and sound = (0, 1). Learning would involve correlated dimensions as the presence of light correlates with the absence of sound. This could be more simply reduced to one dimension of perceptual information with to-be-learned values of light and sound. In sum, previous studies have involved predictive information that is 100% predictive and non-predictive information that does not vary across types of trials, but is present throughout the different learning trials.

Present Study

The goal of the present research was to consider the effect of blocking when learning involved one predictive dimension and one non-predictive dimension. In other words, suppose that Dimension 1 (e.g. shape) is predictive, but initial learning involved a fixed value of Dimension 2 (e.g. color). Suppose also that cue A (e.g. orange triangle) is presented early in learning ($A \rightarrow O_{1,}$); and cue B is a novel cue that differs from A in both dimensions (e.g. purple circle) and is presented later ($AB \rightarrow O_1$). Would the blocking effect of cue A inhibit the learning of cue B as well as the learning of other cues of the blocked value of Dimension 2 (e.g. other purple shapes)?

In the present study, the predictive dimension was shape and the non-predictive dimension was color. These dimensions were chosen because they are simple perceptual dimensions that are considered to be separable, as opposed to integral (Garner, 1976). Separable dimensions are those that can be attended to independently. Integral dimensions are those that cannot be processed independently (see Rogosky & Goldstone, 2005 for a brief discussion). A classic example of integral dimensions is brightness and saturation (Garner, 1976). If blocking involved integral dimensions, one would predict that blocking effects might spill over to the non-predictive dimension. However, if blocking involves cues of separable dimensions, the uninformative dimensions may not be affected. The present study investigated whether blocking would affect separable dimensions.

One possibility is that blocking effects would remain at the value level and not the dimension level. This argument is supported by both latent inhibition and attentional persistence that demonstrate attentional shifts at the level of dimensions. If early in the course of learning, Dimension 1 is predictive and Dimension 2 is not, then attention is pulled toward Dimension 1 and away from Dimension 2. If attention to Dimension 2 is significantly attenuated, then there is little reason to expect an unequal allocation of attention across Dimension 2 that would in turn affect learning involving other values on Dimension 2.

On the other hand, while two dimensions may be considered separable, it is possible that as attentional weights are being shifted on a predictive dimension, they are also being increased on the observed value(s) of the non-predictive dimension(s). An increase in attentional weights for specific value of Dimension 2 might lead to a bias in future learning. Extraneous, non-predictive information can be encoded in the course of learning and influence performance on later tasks (Sloutsky & Fisher, in press). Additionally, an earlier study considered blocking in the context of differentially salient cues where the blocking cue was either more or less salient than the blocked cue (Heckler, Kaminski, & Sloutsky, 2006). Results found that when the blocking cue was more salient than the blocked cue, novel salient cues were preferred significantly over novel less salient cues. When the blocking cue was less salient than the blocked cue, the preference for novel salient cues over novel less salient cues disappeared with a moderate preference for the less salient cue. These findings suggest that blocking of a relevant dimension influences allocation of attention on an irrelevant dimension (that of salience).

The present research tested the hypothesis that blocking a value on a predictive dimension can affect attentional focus on another non-predictive dimension. In a conditional blocking paradigm, participants first learned associations involving different shapes of one color. Here shape was predictive and color was not. In the second phase, participants learned associations of different shapes of two colors, the original color and a potentially blocked color.

Experiment 1

Method

Participants Forty-four undergraduate students from Ohio State University participated in the experiment and received partial credit for an introductory psychology course. Students were randomly assigned to one of two conditions that varied the particular colored shape cues to be learned.

Materials and Design Participants were told of a fictitious manufacturing company that used specific computer chips in particular appliances. Computer chips had different components which appeared as different colored shapes. As such, participants were learning associations of colored shapes (represented by letters in Table 1) to four different appliances. Shape and color were correlated, so that both dimensions were predictive of outcome. Two different between-subjects conditions were constructed that differed only in the particular colored shape that was associated with each appliance. For example, in one condition, cue A was a blue circle and was associated with a blender. In another condition cue A was a purple trapezoid.

The experiment consisted of two training phases followed by a testing phase (see Table 1). Phase 1 involved single cue learning of two different associations. Twenty trials of each association were randomly presented. In Phase 2, trials involved two cues. Twenty trials presented one of the previously learned associations with an additional cue ($AB \rightarrow O_1$). In addition two novel two-cue associations were learned ($CD \rightarrow O_2$ and $EF \rightarrow O_3$), with twenty trials of each being presented. Trials were presented in twenty blocks including one of each type of association (AB, CD, and EF) in a random order. After training, eight multiple-choice questions were asked (see Table 1).

Table 1. Design of Experiment 1

Training Phase 1	$A \rightarrow O_1$ $G \rightarrow O_4$	20 trials 20
Training Phase 2	$AB \rightarrow O_1$ $CD \rightarrow O_2$ $EF \rightarrow O_3$	20 20 20
Test	$A \rightarrow ?$ $B \rightarrow ?$ $D \rightarrow ?$ $F \rightarrow ?$	2 questions 2 2 2

Note: Letters denote colored shape cues (computer chip components) and $O_1 – O_4$ denote outcomes (appliances).

Procedure Training and testing were presented to individual participants on a computer screen in a quiet room. They proceeded through training and testing at their own pace; and their responses were recorded.

On each trial, participants were presented with a 'computer chip' with one or two colored shape cues and asked: "In which appliance is this computer chip used?" Participants selected from six answer choices. Four were previously seen appliances; and one was a novel appliance. The sixth choice was "I don't know". All training trials were followed by corrective feedback.

Table 2. Mean learning scores - Experiment 1 (% correct)

	Means	Standard Deviations
A	88.4	5.55
X	91.15	4.55
AB	90.25	8.35
CD	89.05	8.8
EF	88.9	5.9

Results and Discussion

Six participants were eliminated from the analysis because one or more of their learning scores (on training questions) were more than 2.5 standard deviations below the mean. Participants successfully learned during training (see Table 2). Learning scores were above chance on all training questions, independent t-test, $t(37)$s < .001.

The test results replicate the standard blocking effect (see Figure 1). While participants had observed the same number of $AB \rightarrow O_1$ trials as each of $CD \rightarrow O_2$ trials and $EF \rightarrow O_3$ trials, responses of $B \rightarrow O_1$ to B questions were significantly fewer than responses of both $D \rightarrow O_2$ to D questions and responses of $F \rightarrow O_3$ to F questions, pair-wise t-tests $t(37)$s > 2.57, *p*s < .02.

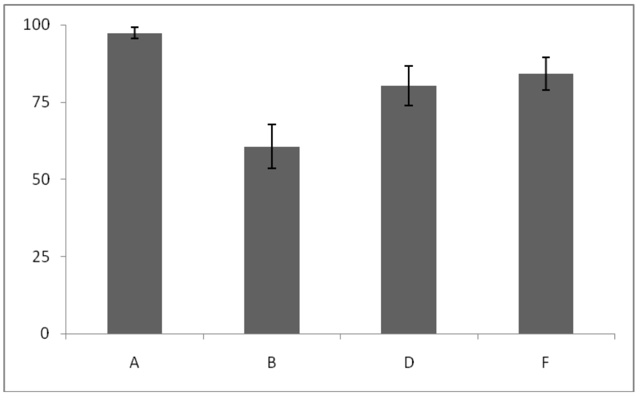

Figure 1: Mean Test Scores – Experiment 1 (% correct).
Note: Error bars represent standard error of mean.

Therefore, the given paradigm does result in the traditional blocking effect when the design included cues that varied in two correlated dimensions (color and shape). Thus, both dimensions were predictive. The purpose of Experiment 2 was to examine the effect on a non-predictive dimension of blocking along another predictive dimension.

Experiment 2

Method

Participants Forty-eight undergraduate students from Ohio State University participated in the experiment and received partial credit for an introductory psychology course. Students were randomly assigned to one of four conditions that varied the particular shape cues to be learned.

Materials and Design The materials and design were very similar to that of Experiment 1 (see Table 3). The significant difference was that shape and color were not correlated. Shape was predictive and color was not. Two colors were used. All cues seen in Phase 1 of training were of Color 1 (denoted by * in Table 3). The second phase of training presented all two-cue associations. On each trial, one cue was of the 'blocking' color (Color 1); and the other cue was a novel color (Color 2 denoted in Table 3 by $^+$). As in Experiment 1, another predictive cue was associated with outcome O_1. This cue was a novel shape of a novel color (Color 2) Two novel associations were also presented involving four novel shapes ($C^* D^+ \rightarrow O_2$ and $E^* F^+ \rightarrow O_3$). Each of these cue pairings had one shape of Color 1 and one shape of Color 2.

After both training phases, sixteen multiple-choice test questions were posed. Single-cue questions (B, D, F) were asked. In addition, competing cue questions ($C^* F^+ \rightarrow ?$ and $D^* E^+ \rightarrow ?$) were asked. As in previous research (e.g. Kruschke, 200, 2003), responses to such questions are a more sensitive indication of blocking effects than the single cue questions.

Table 3. Design of Experiment 2

Training Phase 1	$A^* \rightarrow O_1$	20 trials
	$G^* \rightarrow O_4$	20
Training Phase 2	$A^* B^+ \rightarrow O_1$	20
	$C^* D^+ \rightarrow O_2$	20
	$E^* F^+ \rightarrow O_3$	20
Test	$A^* \rightarrow ?$	2 questions
	$C^* \rightarrow ?$	2
	$E^* \rightarrow ?$	2
	$B^+ \rightarrow ?$	2
	$D^+ \rightarrow ?$	2
	$F^+ \rightarrow ?$	2
	$C^* F^+ \rightarrow ?$	2
	$E^* D^+ \rightarrow ?$	2

Note: Letters denote shape cues (computer chip components) and O_1 – O_4 denote outcomes (appliances). * denotes Color 1; $^+$ and denotes Color 2.

Table 4. Mean learning scores - Experiment 2 (% correct)

	Means	Standard Deviations
A	85.94	8.56
X	85.4	9.3
AB	87.43	9.25
CD	91.48	7.8
EF	86.89	9.74

Procedure Training and testing were presented in the same format as Experiment 1 to individual participants on a computer screen in a quiet room. Participants proceeded through training and testing at their own pace; and their responses were recorded.

Results and Discussion

Eleven participants were eliminated from the analysis because one or more of their learning scores (on training questions) were more than 2 standard deviations below the mean. Participants successfully learned during training (see Table 4). Learning scores were above chance on all training questions, independent t-test, $t(36)$s > 41.7, ps< .001.

Test results are presented in Figure 2. Mean scores on B^+ questions were lower than scores on the questions with novel cues of Color 1 (C* and E*), paired-sample t-tests $t(36) > 2.11$, ps < .05. More interestingly, across the three cue pairings (A^*B^+, C^*D^+, and E^*F^+), there was a trend of lower test scores on questions with "Color 2 cues" than on questions with "Color 1 cues". Scores on F^+ questions were lower than on scores on E* questions, paired sample t-test $t(36) > 2.35$, $p < .03$. While scores on C* and D^+ were no different, $t(36) > .669$, $p = .508$, the overall pattern of responses suggests blocking of the Color 2 cues. In addition, responses on the competing cue questions ($C^* F^+ \rightarrow ?$ and $D^* E^+ \rightarrow ?$) support the argument that attention has been shifted to the blocking color. The outcome associated with Color 1 was chosen more than twice as often as the outcome associated with Color 2 (24% versus 49%). This difference was statistically different, χ^2 (df = 2, N=37) = 17.12, $p < .001$. Specifically, the same pattern was found on both $C^* F^+$ and $D^* E^+$ questions (21% versus 45%, χ^2 (df = 2, N=37) = 7.49, $p < .024$; and 26% versus 49%, χ^2 (df = 2, N=37) = 11.13, $p < .004$ respectively). The preference for the outcome associated with the original blocking cue color suggests that blocking occurred on both the originally predictive dimension (shape) as well as the non-predictive dimension (color).

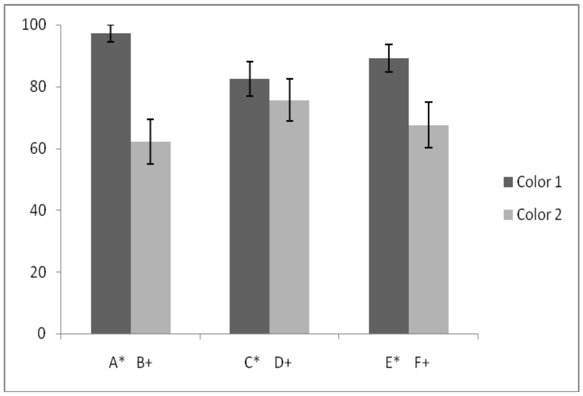

Figure 2: Mean Test Scores – Experiment 2 (% correct).
Note: Error bars represent standard error of mean.

General Discussion

The results of Experiment 1 replicate the effect of conditional blocking during associative learning. Initial learning of an association between cue A and outcome O_1 ($A \rightarrow O_1$) blocked later learning of another cue B also associated with outcome O_1 ($AB \rightarrow O_1$). In this experiment, learned cues varied across two dimensions (color and shape), each of which was predictive.

Experiment 2 involved a similar associative learning task, however only one dimension was predictive. Initial learning fixed the value of Dimension 2 (color), while Dimension 1 (shape) was predictive. The second phase of learning introduced novel cues of two different values on Dimension 2, a potential blocking color (Color 1 of cue A) and a potentially blocked color (Color 2 of cue B). Test scores on questions involving cues of Color 2 were lower than scores of questions involving cues of Color 1. Furthermore when participants were asked to predict the outcome for cues of Color 1 paired with cues of Color 2, a clear preference was found for Color 1.

One could argue that the observed pattern of responses is simply an effect of familiarity. Participants were more familiar with Color 1 than Color 2 because they had seen it first. However, familiarity does not explain the underlying mechanism, but rather can be explained by the underlying mechanism of attentional shifting. Furthermore the present findings would not be predicted by latent inhibition which would suggest that attention is diverted from the dimension of color because color is non-predictive.

Taken together, these results suggest that in the course of conditional blocking, an attentional bias can be formed on two levels. First, on the predictive dimension, attention is drawn to the predictive value of the blocking cue over the blocked cue. Second, on the non-predictive dimension, attention is also drawn to the value of the blocking cue over that of the blocked cue. These results are a first step in suggesting a possible mechanism explaining origins of attentional bias in which blocking of a value on a relevant dimension leads to an attentional shift that spills over to an irrelevant dimension. Further research would consider whether this blocking effect is present in the context of learning more than two non-predictive dimensional values (e.g. phase 2 of learning presents cues of the blocking color, the blocked color, and novel colors) as well as present when learning other types of dimensions (e.g. semantic dimensions). In short, attention may be diverted from an abstract dimension level (e.g. color) and at the same time be shifted to a value level (e.g. orange).

These findings may add to our understanding of attentional biases that possibly underlie some types of scientific misconceptions. For example, people have experiences with moving objects and tend to focus attention on the direction of the object's motion. Acquired information about object movement may block later learning of other information such as force. When asked about forces that are acting on objects, a common belief is that the only forces on an object are those in the direction of its motion (Pfundt & Duit, 1991). While motion is salient, there are other forces that may be acting on the object, such as gravitational forces downward, normal forces perpendicular to contact surfaces, and frictional forces in the opposite direction of the motion. In such situations, the learner is attending to a possible force in the direction of the motion and is ignoring the other forces. By better understanding mechanisms that underlie attentional biases that might be associated with such misconceptions, more effective teaching methods can be designed to promote accurate knowledge acquisition.

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