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Flexibility of a Conditioned Response: Exploring the Limits of Attentional Capture By Fear

Greta Nicole Minor
University of Wisconsin-Milwaukee

FLEXIBILITY OF A CONDITIONED RESPONSE: EXPLORING THE LIMITS OF

ATTENTIONAL CAPTURE BY FEAR

by

Greta N. Minor

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ABSTRACT

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Greta N. Minor

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Recent work from the attention capture literature suggests that attention may be captured by stimuli with learned aversive value, even when these fear conditioned stimuli (CS) are task-irrelevant and not physically salient. Moreover, relatively little work in the human fear conditioning literature has investigated whether conditioned fear responses can flexibly transfer to a neutral associate of a CS. We examined, for the first time, whether fear-conditioned capture effects were able to transfer to the associate of a CS. Twenty-seven participants encoded novel scene-object pairs. Following encoding, scenes were presented alone during a conditioning phase. Scenes co-terminated with shock 100% (CS100), 50% (CS50), or 0% (CS0) of the time, depending on the object that they had been paired with during encoding, while participants made shock expectancy ratings. Subsequent to conditioning, participants performed a visual search task; the search display occasionally contained one of the encoded objects as a distractor. Eye movements were recorded. Results indicated that, during search, significantly more overt eye movements were made, in error, to the object associate of a CS relative to baseline distractors, and target-directed saccades on trials containing a CS associate were slower relative to target-directed saccades on baseline trials. However, there were no differences in capture effects across the three CS conditions (which varied in threat learning history), suggesting that fear-conditioned capture effects to a CS may not transfer to novel associates encountered for the first time in the episodic context of an experiment.

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Introduction

We encounter a multitude of visual stimuli in our daily environment, and the cognitive process of attention permits us to selectively attend to a small subset of relevant information in order to serve our goals. According to standard models of attentional control (see Egeth & Yantis, 1997 for review), attention can either be deployed in a manner consistent with our internal goals (i.e., top-down attentional control) or can be involuntarily captured by a task-irrelevant, salient stimulus in our environment (i.e., bottom-up attentional control). For example, you may be actively searching for a familiar face in a crowd (using top-down control mechanisms) when a stranger with bright pink hair suddenly captures your attention. The stranger in this example, with hair that stands out by virtue of its physical (or perceptual) salience, slows down the search for your friend and disrupts goal-directed behavior.

Currently, the specific circumstances under which attention may be captured are subject to debate (e.g., Awh, Belopolsky, & Theeuwes, 2012; Belopolsky, 2015; Gaspelin & Luck, 2018; Theeuwes, 2018). While there are several demonstrations of capture by objects that are physically salient (e.g., based on color, luminance, or sudden appearance; Theeuwes, 1992, 1994; Yantis & Jonides, 1984, 1990), recent work suggests that capture is not limited to items with distinctive perceptual characteristics. For example, recent studies suggest that attention may be deployed automatically or involuntarily toward stimuli with learned appetitive or aversive value (e.g., Anderson, Laurent, & Yantis, 2011; Hopkins, Helmstetter, & Hannula, 2016; Nissens, Failing, & Theeuwes, 2017; see Anderson, 2016 for review). These capture effects are surprising because the stimulus materials are task-irrelevant based on instructional manipulations and need not be physically salient.

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From an evolutionary perspective, it makes intuitive sense that threatening information in our environment would be preferentially attended (LeDoux, 1998). Being able to rapidly orient attention toward a predatory animal, for example, is beneficial to survival. However, if this attentional bias becomes excessive or generalizes to other, non-threatening situations, as is characteristic in anxiety disorders (American Psychiatric Association, 2013; see Lissek, 2012 for review), an attentional system that prioritizes perceived threat may actually prove maladaptive. For example, it has been reported that anxious individuals show higher rates of attentional capture by threatening stimuli, quicker eye fixations to threatening stimuli, and sustained attention toward threatening stimuli as compared to non-anxious individuals across dot probe, visual search, and spatial cueing tasks (see Armstrong & Olatunji, 2012 for review). These results point to the attentional prioritization of threat in anxious individuals beyond the adaptive level seen in normative populations (see Cisler & Koster, 2010 for review). This heightened prioritization of threat may, in turn, result in an exaggerated fear response, ultimately leading to additional maladaptive behaviors like recurrent avoidance of a feared situation or similar situations (Craske et al., 2009; for review see Dymond, Dunsmoor, Vervliet, Roche, & Hermans, 2015; Lissek et al., 2005). In other words, fear and avoidance of one situation that is perceived as threatening may spread to other, related situations, a phenomenon referred to as generalization (Dymond et al., 2015). Basic scientific studies that further examine whether and when aversive value might transfer across materials are warranted, and such studies may allow more complex questions (e.g., questions about the role that attention to threat plays in anxiety) to be addressed in future work.

Much of the early work investigating the interaction of attention and threat has focused on stimuli with intrinsic threat value, such as snakes or angry faces (e.g., Öhman, Flykt, &

Esteves, 2001; Schmidt, Belopolsky, & Theeuwes, 2012). In a typical study (Öhman et al., 2001), participants are instructed to indicate whether a unique target is present among distractors. On each trial, targets are categorized as either "fear-relevant" (e.g., a snake) or "fear-irrelevant" (e.g., a flower), while distractors belong to the opposite category. When a fear-relevant target is presented among fear-irrelevant distractors (e.g., a snake among flowers), response times are faster than when the target is fear-irrelevant and the distractors are fear-relevant (e.g., a flower among snakes). These results suggest that innately threatening stimuli obligatorily attract attention, facilitating search when the fear-relevant stimulus is a target and interfering with search otherwise.

While many studies have replicated this finding (e.g., Devue, Belopolsky, & Theeuwes, 2011; Fox, Russo, Bowles, & Dutton, 2001; Öhman, Lundqvist, & Esteves, 2001; Schmidt et al., 2012), others report negligible effects of threat on the deployment of attention (e.g., Hunt, Cooper, Hungr, & Kingstone, 2007; Lipp, 2006). Because findings have been inconsistent, critics have suggested that this observed "attentional priority" may be due to low-level featural or categorical differences between innately threatening and "neutral" stimuli (e.g., the presence of distinct visual features, such as a flange on a syringe, that distinguish threatening from neutral stimuli; see Quinlan, 2013 for review). One potential solution to this problem is to use fear conditioning procedures that repeatedly pair a neutral stimulus (CS) with an aversive outcome (US; e.g., a shock) until presentation of the CS alone elicits a fear response (CR; see Maren, 2001 for review). By associating simple objects (e.g., a colored circle) with a US, investigators are better able to control for perceptual differences between threat-associated and neutral stimuli.

As summarized in more detail below, there is now considerable evidence in favor of the view that fear-conditioned materials can capture attention involuntarily (Koster, Crombez, Van

Damme, De Houwer, & Theeuwes, 2004; Mulckhuyse, Crombez, & Van der Stigchel, 2013; Mulckhuyse & Dalmaijer, 2016; Nissens et al., 2017; Notebaert, Crombez, Van Damme, De Houwer, & Theeuwes et al., 2011; Preciado, Munneke, & Theeuwes, 2017; Schmidt, Belopolsky, & Theeuwes, 2015a, 2015b, 2017), even without explicit awareness of the learned contingencies (Hopkins et al., 2016). In the study described here, the goal was to further examine the limits of capture by a CS. To that end, we examined whether threat-related capture effects were able to flexibly transfer to neutral associates of a conditioned stimulus. To provide context for this project, findings from the basic attention literature, which support standard dichotomous models of attention that distinguish goal-directed from stimulus-driven attention, are reviewed briefly below. This is followed by a more focused discussion on how this traditional perspective fails to accommodate recent findings of value-driven capture (for review see Anderson, 2016; Awh et al., 2012; Mulckhuyse, 2018; Theeuwes, 2018) and how the flexibility of these value-driven capture effects has yet to be addressed. Subsequent to this literature review, the current experiment is outlined in more detail.

Evidence for Dichotomous Models of Attentional Control

Selective attention permits us to prioritize a small subset of available information for detailed processing and evaluation in service of meeting current goals or objectives. As indicated briefly above, attentional control mechanisms have traditionally been categorized as top-down or bottom-up (see Egeth & Yantis, 1997 for review). Top-down (i.e., goal-directed, endogenous, voluntary) deployment of attention is characterized by a selection process that is tuned to the intentions or goals (i.e., attentional set) of the observer. At its most fundamental level, top-down attention is viewed as entirely volitional, subject to the current goals of the observer. Conversely, bottom-up (i.e., stimulus-driven, exogenous, involuntary) capture of attention is characterized by

the involuntary selection of perceptually salient stimuli that 'pop out' from their surroundings (e.g., Treisman & Gelade, 1980; for review see Wolfe & Horowitz, 2004, 2017). In other words, bottom-up selection is determined by the physical properties of a stimulus.

Perhaps the most well-known experimental paradigm that illustrates the role of top-down control in the deployment of attention is Posner's endogenous cueing task (Posner, 1980). In this classic paradigm, trials begin with the presentation of a central arrow cue that indicates where a target (a simple visual stimulus left or right of fixation) is likely to appear. Participants are instructed to make a button press as quickly as possible when the target is presented. Since the cue accurately predicts the location of the upcoming target on most trials, it is assumed that participants will come to rely on the cue and will voluntarily shift attention to the cued location prior to the appearance of the target. In line with these assumptions, response times are fastest when arrows are valid predictors of target location and slowest when they are invalid predictors of target location. More recent studies have replicated the response time facilitation effect and have also shown that observers make fewer errors when cues validly predict the location of the target (e.g., Theeuwes, 1989; Theeuwes & Van der Burg, 2007). Together, these findings are consistent with the view that voluntary deployment of attention improves information processing, making it more efficient, and has beneficial effects on goal-directed behavior.

Visual search tasks also require top-down attentional control. As described briefly above, in visual search tasks, participants are instructed to quickly and accurately locate a target that is defined by specific features or combinations of features and embedded in an array of distractors. Results from basic visual search experiments indicate that search is more efficient (i.e., response times do not vary as a function of set size) when targets are physically salient and sufficiently different from distractors, as well as when the distractors themselves are relatively homogenous

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(for review see Wolfe & Horowitz, 2004, 2017). A small subset of characteristics have been defined by Wolfe and Horowitz as "guiding features," features that unambiguously draw attention – these include color, motion, orientation, and size. In standard search tasks, when the defining attribute of a target (e.g., its color) is known and part of the active attentional set, response times are facilitated (e.g., Bacon & Egeth, 1994; Wolfe, Butcher, Lee, & Hyle, 2003). As targets and distractors become more perceptually similar or when the heterogeneity of distractors increases, search becomes more difficult and time to detect the target increases as a consequence (Wolfe, 2010). In our study described below, we took care to ensure that targets were distinguishable from distractors based on a single feature (i.e., shape), and that distractors were homogenous, conditions which should have permitted relatively efficient search. Sometimes though, one of the distractors was physically salient – distinguishable by color from the otherwise homogenous search set. Under these circumstances, it was expected that attention would occasionally be directed in error to this colored distractor (i.e., colored singleton). The critical question was whether, and under what circumstances, these attention capture effects would vary as a function of learned aversive value.

That a physically salient singleton distractor may capture attention in a bottom-up manner is consistent with previous reports (e.g., Franconeri & Simons, 2003; Jonides, 1980; Theeuwes, 1992, 1994; Yantis & Jonides, 1984, 1990). These studies indicate that despite the intentions of the observer, attention is sometimes involuntarily deployed to task-irrelevant information, a phenomenon commonly referred to as attentional capture. Evidence for capture comes from studies in which participants were instructed to search for a target among distractors. When one of the distractors is physically salient, search efficiency is compromised, and participants are more likely to involuntarily direct their attention to the salient distractor instead of the target. For

example, in a classic demonstration of capture by a physically salient stimulus, Yantis and Jonides (1984) presented participants with a display containing three figure-8 pre-masks, which gradually faded to reveal three letters. On some trials, coincident with the offset of the masks, another letter (i.e., an onset) appeared suddenly at a location that had been empty. Participants were instructed to determine whether a specific target letter was present in the search array. It was predicted that attention would be directed involuntarily to the abrupt onset whether it was the target or not. Consistent with this hypothesis, reaction times were faster when the onset was the target stimulus and slower when the onset was a distractor relative to no-onset control trials (e.g., Jonides, 1980; Yantis & Jonides, 1984, 1990). This suggests that attention was directed first to the onset, despite the fact that it was not always the target stimulus. An important shortcoming of this approach is that the onset could be the search target; this means that it was not task-irrelevant and attending to it was not *always* detrimental to task performance. As such, it is possible that participants learn to voluntarily prioritize the onset (see Theeuwes, 2018 for review). In our study, salient distractors were never search targets, which should have discouraged voluntary prioritization of these stimuli.

The task used in our study was an adaption of the additional singleton paradigm, which was designed to address concerns about the conflation of voluntary and involuntary prioritization of salient stimuli (Theeuwes, 1992, 1994). A variation on a standard visual search task, the additional singleton paradigm is optimized to address questions about capture because singleton distractors are never task-relevant. In this task, participants direct attention to a shape target (e.g., a gray diamond among gray circles) and report the orientation of an embedded line segment. On a subset of trials, a task-irrelevant singleton distractor is present in the display (e.g., a red circle). Results indicate that search for the target is slower in the presence of the irrelevant singleton.

This suggests that the observer inadvertently attends to this distractor, even though doing so is inconsistent with task demands (e.g., Hickey, McDonald, & Theeuwes, 2006; Theeuwes, 1991, 1992). In addition to increasing response latencies, the presence of irrelevant singletons in the search display also decreases response accuracy (e.g., Hickey et al., 2006; Theeuwes, 1991, 1992; see Theeuwes & Godijn, 2001 for review).

Although it is commonly used in the attention literature, reaction time is an indirect measure of attention. In the studies discussed above, capture by an irrelevant singleton can only be inferred, as no direct evidence that the stimulus was attended is available. Button press responses do not, for example, permit investigators to determine how often attention is captured by an irrelevant singleton, how long attention remains on the singleton, or how quickly attention is directed successfully to the target location. Eye tracking is a more sensitive approach, as research has shown that saccadic movements of the eyes are tightly coupled with deployment of the metaphorical spotlight of attention. It has been demonstrated in several studies, for example, that covert attention precedes overt movement of the eyes to a target location (e.g., Belopolsky & Theeuwes, 2009; Deubel & Schneider, 1996; see van Zoest, Van der Stigchel, & Donk, 2017 for review). In contrast to discrete button press responses, eye movements permit investigators to examine moment-to-moment changes in the focus of attention, providing a continuous record of priority, that indicates more definitively whether and when attention is directed to singleton distractors or to targets.

Capture by physically salient singleton distractors has been documented in several eye tracking investigations (e.g., Godijn & Theeuwes, 2002; Irwin, Colcombe, Kramer, & Hahn, 2000; Mulckhuyse, Van der Stigchel, & Theeuwes, 2009; Theeuwes, De Vries, & Godijn, 2003; Theeuwes, Kramer, Hahn, & Irwin, 1998; Theeuwes, Kramer, Hahn, Irwin, & Zelinsky, 1999).

Measures commonly used to index capture include overt movement of the eyes to the location of the singleton distractor (overt, or oculomotor, capture) and differences in saccade latency to targets when a distractor is either present or not in the search display. In studies of bottom-up capture, there is evidence for disproportionate oculomotor capture by salient singleton distractors (e.g., green circles) as compared to inconspicuous distractors (e.g., gray circles; Irwin et al., 2000; Ludwig & Gilchrist, 2003; Theeuwes et al., 1998). In addition, a delay in the initiation of target-directed saccades has been reported when a physically salient distractor is present in the search display even when eye movements are not made to the distractor location, which suggests that attention may have been captured covertly (Irwin et al., 2000; Theeuwes et al., 1999).

The interpretation offered in studies like these is that salient distractors can capture attention, with or without eliciting overt eye movements. A recent explanation for the absence of overt attentional capture reported in some studies (e.g., Theeuwes et al., 2003) comes from the signal suppression hypothesis (Sawaki & Luck, 2010), which proposes that top-down inhibitory mechanisms can keep capture in check and that these mechanisms explain why humans are not constantly distracted by task-irrelevant information (Gaspelin, Leonard, & Luck, 2017; see Gaspelin & Luck, 2018 for review). When we lose focus, or are otherwise distracted, inhibition fails, and physically salient items capture attention. In summary, findings from the eye-tracking literature provide compelling evidence for the bottom-up control of attention, demonstrating that saccade endpoints and latencies are directly influenced by the presence of a salient, task-irrelevant distractor. In the study detailed here, eye movement behavior was recorded, as this approach affords more opportunity for the documentation of capture than button-press responses alone.

Shortcomings of Standard Models of Attentional Control

While there is no doubt that the contents of attention can be dictated by top-down or bottom-up mechanisms, recent findings indicate that attention may be directed toward stimuli that are neither goal-relevant nor physically salient, a pattern of results that does not easily fit within the top-down/bottom-up dichotomy. Briefly, stimuli that have been repeatedly encountered and selected on previous trials (i.e., primed; e.g., Maljkovic & Nakayama, 1994; Pinto, Olivers, & Theeuwes, 2005), distractors that appear consistently at specific, high-probability locations across trials (e.g., Ferrante et al., 2018; Wang & Theeuwes, 2018; Zhao, Al-Aidroos, & Turk-Browne, 2013), materials that have been encoded into long-term memory (e.g., Fan & Turk-Browne, 2016; Nickel, Hopkins, Minor, & Hannula, under review), and stimuli previously paired with rewarding (e.g., Anderson et al., 2011; Failing & Theeuwes, 2014, 2015, 2017; Le Pelley, Pearson, Griffiths, & Beesley, 2015) or aversive outcomes (e.g., Hopkins et al., 2016; Koster et al., 2004; Mulckhuyse et al., 2013; Mulckhuyse & Dalmaijer, 2016; Nissens et al., 2017; Notebaert et al., 2011; Preciado et al., 2017; Schmidt et al., 2015a, 2015b, 2017) have been shown to influence the deployment of attention in ways that do not neatly conform to top-down or bottom-up categories of attentional control. Because our study concerns capture by materials with acquired aversive value, the discussion that follows focuses on evidence for attentional capture by a CS.

Capture by a Conditioned Stimulus

Evidence summarized above suggests that intrinsically aversive objects (e.g., snakes) are detected rapidly when they are search targets and disrupt search when they are distractors (e.g., Devue et al., 2011; Fox et al., 2001; Öhman, Flykt, et al., 2001; Öhman, Lundqvist, et al., 2001; Schmidt et al., 2012). However, these effects may be driven to some extent by basic perceptual properties that distinguish fearful from neutral materials (see Quinlan, 2013 for review).

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Importantly, any confounding effects to do with perceptual properties of the stimulus materials used to examine questions about capture by fear can be circumvented by using a fear conditioning approach. Materials in fear conditioning experiments that have examined capture are typically simple shapes (e.g., circles, rectangles) paired with shock (Hopkins et al., 2016; Koster et al., 2004; Mulckhuyse et al., 2013; Mulckhuyse & Dalmaijer, 2016; Nissens et al., 2017; Notebaert et al., 2011; Preciado et al., 2017; Schmidt et al., 2015a, 2015b, 2017). This approach allows for better control of the perceptual characteristics of both search targets and distractors. In differential fear conditioning paradigms, one neutral stimulus is repeatedly paired with an US while another neutral stimulus is not. Subsequent to acquisition, in the absence of the US, presentation of the previously neutral stimulus that is now associated with the aversive outcome (i.e., the CS+) elicits a CR while presentation of the neutral stimulus never paired with the US (i.e., the CS-) does not (Maren, 2001). Repeated exposure to the CS, without reinforcement, eventually leads to extinction of the conditioned fear response (for review see Bouton, 2004; Myers & Davis, 2002).

Much of the work that has examined capture by a CS has used the additional singleton paradigm. Additionally, some of these studies have used eye tracking to investigate whether and when attention is captured by a CS (Hopkins et al., 2016; Mulckhuyse & Dalmaijer, 2016; Nissens et al., 2017). In one representative study (Hopkins et al., 2016), participants were instructed to make a single saccade to the location of a simple target stimulus – i.e., a red rectangle among red circles – during a *training phase*. They were told that they could avoid shock if they were sufficiently quick to look at the target, but, in reality, US delivery was probabilistically tied to the orientation of the rectangle (e.g., vertically-oriented rectangles co-terminated with shock 80% of the time). Subsequent to training, the search task was modified.

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Now participants were instructed to make a single saccade to a *new* target – i.e., a gray circle; sometimes, a rectangle was present in the search display, but participants were instructed to ignore it as well as all other distractors in the display. When rectangles were present, participants were (marginally) slower to initiate saccades to the target in the presence of a CS+ as compared to a CS-, suggesting that attention was potentially captured covertly by the CS+. Moreover, the CS+ elicited more instances of oculomotor capture relative to the CS-, providing evidence for the claim that eye movements are disproportionately captured by a CS+. These effects were evident even among the subset of participants who remained unaware of the imposed CS-US contingencies. Additionally, Hopkins et al. (2016) noted that these capture effects were strongest early during testing, in line with evidence from fear conditioning studies that report a rapid extinction of the CR in the absence of the US (e.g., Raio, Carmel, Carrasco, & Phelps, 2012). One limitation of this work, however, is that, although participants were never explicitly informed of the CS-US association, the CS was still task-relevant during the training phase. Thus, it is possible that the reported results can be partially accounted for by carryover effects of voluntary prioritization.

Similar effects have been reported in a handful of other eye tracking studies (Mulckhuyse et al., 2013; Mulckhuyse & Dalmaijer, 2016; Nissens et al., 2017; Schmidt et al., 2015b, 2017). In most of these studies, participants were explicitly told, in advance of the search task, that a stimulus of a particular color (e.g., yellow circle) may be paired with shock and when that was likely to happen (i.e., an instructed fear manipulation; Nissens et al., 2017; Schmidt et al., 2015b, 2017). Others have used a standard fear conditioning protocol (e.g., in which a red circle is paired with shock and a green circle is not) prior to search (e.g., Mulckhuyse et al., 2013; Mulckhuyse & Dalmaijer, 2016) or have combined contingency learning with the primary search

task (Schmidt et al., 2015b, 2017). In these studies (Schmidt et al., 2015b, 2017), a cue was a reliable predictor of target location and, occasionally, the cue was the CS+. In each case, and across a number of measures (e.g., misallocation of viewing to task-irrelevant singletons, saccade latency, response times), evidence for involuntary covert and overt capture by a CS has been documented. In instructed fear tasks, capture effects are reported even when the CS is not physically salient because it is a colored circle among differently colored circles in the search display (Nissens et al., 2017).

Flexibility of a Conditioned Response

One question that has yet to be addressed in the capture literature has to do with the flexibility of fear responses. Generalization, the process by which a CR flexibly transfers to a stimulus never paired with an US, has been documented extensively in the animal literature (see Jasnow, Lynch III, Gilman, & Riccio, 2016 for review). In a classic example (Rudy & Pugh, 1996), rats were conditioned to associate an auditory cue (e.g., 2976-Hz tone) with a shock in a first-order conditioning procedure (i.e., a CS was paired with an intrinsically aversive stimulus). The animals showed evidence of generalized freezing behavior when they were later exposed to a different, non-conditioned auditory cue (e.g., 741-Hz tone). These findings suggest that aversive value can be transferred to a non-conditioned stimulus in the same sensory modality as the CS, resulting in a generalized CR.

Similar perceptual fear generalization work has been conducted with human participants. The first human study that showed generalization of a CR within a sensory modality used a paradigm very much like the one described above (Hovland, 1937). In a conditioning phase, participants learned to associate an auditory tone (CS) with a shock (US). Later, during a generalization test, the CS, as well as three different tones that had never been paired with shock,

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were presented. Skin conductance responses (SCRs) were measured, and results showed that even the three tones that were never paired with shock elicited elevated SCRs during test. Additionally, it was observed that the closer in similarity the tone was to the CS, the larger the generalized CR (i.e., the larger the SCR). Subsequent work has demonstrated that a generalized CR is elicited by visual stimuli that are perceptually similar to a CS (e.g., Dunsmoor & LaBar, 2013; Lissek et al., 2008). Lissek and colleagues (2008) had participants complete a fear conditioning task in which a large ring was paired with shock (CS+) and a small ring was not (CS-). Then, participants were presented with rings of varying sizes, and the rings that more closely approximated the size of the CS+ elicited a larger generalized fear response (in the form of an eye-blink startle reflex), suggesting that fear responses are able to generalize to stimuli in the same sensory modality, especially when they are perceptually similar to the CS+.

In addition to perceptual forms of generalization, *non-perceptual* forms of generalization have also been documented, both in humans and non-human animals (for review see Dunsmoor & Murphy, 2015; Gewirtz & Davis, 2000). Much of this work has been conducted using higher-order conditioning procedures, in which one stimulus is paired with another that has *acquired* rather than *intrinsic* aversive value. In the human literature, some of the earliest studies in this domain investigated generalization of fear responses to the semantic associate (e.g., "plant") of a fear-conditioned word (e.g., "tree"; Maltzman, Langdon, Pendery, & Wolff, 1977). This work provided some of the first evidence for a generalized fear response (i.e., enhanced SCRs) to semantic associates of conditioned stimuli that were never directly paired with the US (i.e., a shock) themselves. In one recent study, Boyle and colleagues (2015) used semantically equivalent words (i.e., synonyms) to examine similar questions about semantic generalization. During a conditioning phase, one word (e.g., "broth") was associated with a shock (CS+) and

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another (e.g., "assist") was not (CS-). In a subsequent test phase, synonyms of the CS+ and CS- (e.g., "soup" and "help," respectively) were presented in the absence of shock while SCR data were collected. Larger SCRs accompanied synonyms of the CS+ relative to the CS-, suggesting that threat can transfer to semantically related associates of conditioned words (Boyle, Roche, Dymond, & Hermans, 2015).

A related form of non-perceptual generalization is category-based fear generalization, in which within-category transfer of fear across category exemplars of a CS has been demonstrated (e.g., Dunsmoor, Kragel, Martin, & LaBar, 2013; Dunsmoor, Martin, & LaBar, 2012). In these studies, 50% of the exemplars from one category (e.g., tools) co-terminated with shock, while exemplars from another category (e.g., animals) never co-terminated with shock. Participants showed enhancements in SCRs and higher ratings of shock expectancy when presented with novel category members from the US-associated category, as well as category-specific activity changes in fear-learning networks (Dunsmoor et al., 2013; Dunsmoor et al., 2012). Such results suggest that aversive value can flexibly transfer across categories of objects.

The studies described above indicate that a CR can generalize to a different stimulus in the same sensory modality (e.g., a new tone when the CS itself was a different tone; Hovland, 1937) and to materials that are semantically related to a CS (e.g., a CR to "plant" after "tree" was paired with a US; Maltzman et al., 1977). Fewer studies have examined whether a conditioned fear response might also be elicited when the associates of a CS are arbitrary, experienced for the first time in the context of the experiment itself (e.g., in a pre-conditioning memory encoding phase). The first evidence to suggest that a conditioned response might transfer to an arbitrarily-paired associate of a conditioned stimulus came from the non-human animal literature (e.g., Pfautz, Donegan, & Wagner, 1978; Rizley & Rescorla, 1972). Rizley and Rescorla (1972)

exposed rats to paired stimulus associations (i.e., a light with a tone), prior to conditioning. In a subsequent conditioning procedure, rats were conditioned to associate one of the stimuli (i.e., the light) with an aversive stimulus (i.e., a shock), which resulted in a suppression of reward-related bar-pressing behavior (i.e., a standard conditioned response). When the animals were later presented with the associated stimulus (i.e., the tone), the experimenters observed a similar suppression of bar-pressing behavior, despite the fact that the tone itself was never paired with the US. This type of experimental paradigm, in which stimulus associations are learned prior to a conditioning phase, has been referred to as a sensory preconditioning manipulation (Brogden, 1939; Gewirtz & Davis, 2000). Here, we use the term *associative preconditioning* because our focus is on higher-order learning relationships (between items and their context) rather than a simple association between sensory stimuli.

Significantly fewer investigations in the human literature have used a similar paradigm, in which materials without a pre-existing (e.g., semantic) relationship are encoded prior to a conditioning phase. One published study, however, does suggest that transfer of a conditioned response can occur to an arbitrarily-paired associate. In this experiment, participants were instructed to encode two pairs of faces (Vansteenwegen, Crombez, Baeyens, Hermans, & Eelen, 2000). The faces were pre-experimentally unfamiliar (i.e., not famous faces) and were affectively neutral. Each pair was presented ten times. After encoding, participants were presented with pictures of two faces, presented individually rather than in pairs. These faces were either single exemplars from the previously studied pairs (experimental group) or novel faces that had not been seen during encoding (control group). Next, one exemplar from each pair (the exemplar that had not been seen in the preceding phase by participants in the experimental group) was presented in a fear conditioning task. One of the faces was paired with the US (i.e., a shock;

CS+) while the other was not (CS-). Finally, in a test phase, the associates, paired with the conditioned stimuli prior to conditioning, were presented and SCR data were recorded. Results from the control group indicated that SCR was higher for the associate of the CS+, which itself was never paired with shock, relative to the associate of the CS-. These results suggest that transfer of a CR to a learned associate is possible, but only when the associate has not been presented in isolation after the pair was learned in the initial encoding phase.

Similar associative preconditioning paradigms have been utilized in the human reward literature. In a representative experiment (Wimmer & Shohamy, 2012), participants encoded six unique pairs of images in an incidental encoding phase. One image in each pair was a face, body part, or scene, and the other image was a patterned circle. As above, these pairs of images were pre-experimentally unfamiliar and were not semantically or conceptually related prior to encoding. Each pair was presented 10 times. During the reward phase that followed, half of the patterned circles were associated with a monetary reward (CS+), while the other half were not (CS-). In a final decision phase, participants had to choose between two stimuli and were told that their decision could result in a possible monetary reward (although no reward was given during this phase of the experiment). Stimuli presented together in the decision phase were either two patterned circles (one CS+ and one CS-) or their corresponding associates. Results showed that participants more often chose the associate of a previously rewarded stimulus (i.e., the associate of the CS+) and that these decision biases were predicted by hippocampal activity and reactivation of category-specific visual regions during reward learning. Therefore, it was concluded that reward value is able to transfer to the associate of a rewarded stimulus.

As summarized above, published studies suggest that pre-experimentally unfamiliar associates of a CS+ or a rewarded stimulus, which have not been paired with an aversive or

reward stimulus themselves, can elicit a conditioned response (e.g., Vansteweegen et al., 2000; Wimmer & Shohamy, 2012). Furthermore, recent work from the attention capture literature has indicated that a CS+ is distracting and can capture attention, despite instructions to ignore it (e.g., Hopkins et al., 2016; Nissens et al., 2017). In the study outlined here, we examined, for the first time, whether the learned associate of a CS+ might also capture attention. This work goes further than published studies, which have predominantly focused on CRs in the form of skin conductance responses. The lack of research examining associative preconditioning in humans is surprising, since models of anxiety highlight the potential role of higher-order conditioning processes in the development and maintenance of overgeneralized fear responses seen in clinically anxious individuals (Dymond et al., 2015; Foa, Steketee, & Rothbaum, 1989).

Participants in the current study first encoded novel scene-object pairs. Following encoding, scenes were presented alone during a conditioning phase. Scenes co-terminated with shock 100% (CS100), 50% (CS50), or 0% (CS0) of the time, depending on the object that they had been paired with during encoding. During conditioning, we expected that the presentation of the scenes would elicit the spontaneous retrieval of their encoded object associates (e.g., Horner, Bisby, Bush, Lin, & Burgess, 2015), enabling the associations between the US and the object associates to be learned despite the absence of a direct link between US administration and the associates themselves. If participants were able to learn the associations between the US and the object associates, we anticipated that contingency learning would be evident in the shock expectancy ratings made by participants during conditioning. Subsequent to conditioning, participants performed a visual search task. The search display occasionally contained one of the encoded objects as a distractor. During the visual search task, we predicted that participants would direct attention to the task-irrelevant associates (i.e., because they were physically salient,

colored circles), despite instructions to ignore them. Furthermore, if contingency learning is indeed flexible and can transfer to the associate of a CS, as demonstrated in previous work (Vansteenwegen et al., 2000; Wimmer & Shohamy, 2012), then viewing effects should be different, depending on whether displays contained the CS100 associate, the CS50 associate, or the CS0 associate.

Method

Participants

Thirty-one students were recruited from the University of Wisconsin-Milwaukee (UWM) community to participate in this experiment. Written, informed consent was obtained from participants in accordance with the UWM Institutional Review Board, and students received course credit or compensation in the form of a gift card for their participation. Data obtained from three participants were excluded because too few trials remained after exclusion criteria were applied to eye tracking data, and data from one participant were excluded due to poor compliance with task instructions. Thus, reported analyses contain data from 27 participants. A power analysis was calculated in R using a two-tailed sample size estimation approach. To detect a difference between conditions with an effect size equal to .6 (medium effect size), and with the *p*-value and power set to .05 and 80%, respectively, the minimum required sample size was 23. We increased this number to 27 for counterbalancing purposes and replaced discarded data until we reached a full sample of 27 participants.

Materials and Apparatus

Three luminance-matched colored circles – blue, green, and orange (CIE L*a*b*: 66, 9, -73; 66, -79, 81, and 66, 45, 75, respectively) – and three gray shapes (circle, hexagon, and diamond; CIE L*a*b*: 66, 0, 0) were used as visual stimuli. In addition, 30 outdoor scenes were

selected from an existing database (see Hannula, Ryan, Tranel, & Cohen, 2007). These materials were displayed on a 22-inch View Sonic monitor with 1,680 x 1,050 pixel resolution and a refresh rate of 60 Hz.

Eye movements were recorded with an EyeLink 1000 eye tracking system (SR Research LTD: Ontario, Canada). This system has a temporal resolution of 1000 Hz and head-supported spatial resolution of .01º. Eye movements were identified as saccades using an automated algorithm that requires a minimum velocity of 30º/s and a minimum acceleration of 8000º/s^2. The Experiment Builder and Data Viewer software packages (SR Research LTD: Ontario, Canada) were used to deliver stimuli and to analyze eye movement data, respectively.

The US was a 500 ms electrical stimulus delivered using a 60 Hz AC source (Contact Precision Instruments: Boston, MA) via two 8 mm silver/silver chloride surface cup electrodes (Biopac: Goleta, CA). Each electrode was filled with electrolytic gel and placed on the tibial nerve above the medial malleolus of the right leg.

Design and Procedure

After participants consented to participate, the experiment began with a work-up procedure that was used to determine US (i.e., shock) intensity for each participant. The work-up procedure consisted of five presentations of the electrical stimulus, and at each presentation, participants rated the perceived intensity on a scale from 0 (*no sensation*) to 10 (*painful but tolerable*). Following each presentation of the electrical stimulus, intensity was increased incrementally until a rating of 10 was made, at which point the work-up procedure was terminated. US intensity remained at the individually-chosen level for the duration of the experiment. Upon completion of the work-up procedure, participants were seated 70 cm from the computer monitor and a chinrest was adjusted to a comfortable position. An automated 9-point

calibration process was then performed to align eye movements with screen coordinates before the experiment began; this process was repeated as necessary until calibration was successful and a drift correction procedure ensured accurate tracking throughout the experiment. Prior to completing the experiment, participants practiced the basic visual search task (described below). Baseline search displays were used for practice (i.e., a colored circle was never present). Participants completed 30 practice trials to acquire familiarity with the task.

This study was subdivided into four parts: encoding, conditioning, visual search, and recognition (see Figure 1). First, participants learned scene-object pairs. Then, a subset of the encoded scenes was paired with shock. Following conditioning, participants completed a visual search task that occasionally included the neutral associates of scenes that were safe (CS0) or paired with shock (CS50, CS100). The experiment ended with an explicit recognition test and a post-experimental questionnaire (PEQ).

Encoding. Following practice, participants completed the encoding phase (see Figure 1A). Participants were instructed to commit 30 scene-object pairs to memory for a later recognition test (30 total encoding trials). Objects were colored circles (i.e., blue, green, and orange) and each circle was paired with 10 different scenes. Every trial began with a central fixation cross (1s), followed by a scene (1s; 8 x 6° of visual angle). A colored circle (diameter = 2.45° of visual angle) positioned in the center of a black box (3° in each direction) was superimposed on top of the scene, in its center, and the pair remained in view for 2s. Counterbalancing was performed to ensure that colored circles and scenes rotated across conditions of interest (i.e., CS100, CS50, CS0) and were paired equally often across participants. Trial order was pseudorandomized so that no more than three trials of the same type (e.g., three CS0 trials) were presented consecutively.
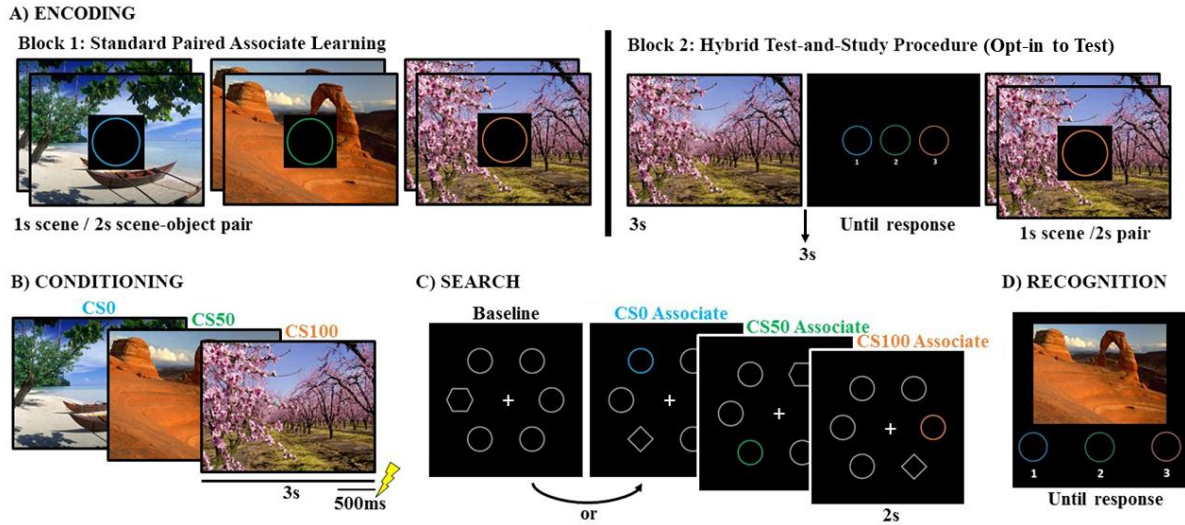
Figure 1. *Trial structure and event timing.* A) During encoding, a central fixation (1s) was followed by a scene (1s) and then the scene-object pair (2s). In the subsequent test-and-study procedure, scenes were presented (3s), followed by a blank screen (3s). During this period of 6s, participants indicated via button press whether they recalled the associate or not. If participants indicated that they remembered the associate (i.e., opted-in to test), the scene was followed by the three colored circle options (until a button press response was made). Regardless of response accuracy, the scene-object pair (1s scene/2s pair) was re-presented following a response. If participants indicated that they could *not* remember the associate (i.e., opted-out of test), the scene-object was re-presented right away. B) During conditioning, after a fixation (1s), encoded scenes were presented (3s) in the center of the screen, and shock was administered in the last 500ms according to contingencies. C) Visual search trials began with a fixation (1s), followed by a blank screen (100-200ms), and then a search display (2s). Occasionally, an associate of a CS was present in the display. A blank screen (300-400ms) was presented until approximately 3.5s had elapsed from the start of the trial and the next trial began. D) During recognition, after a fixation (1s), scenes were presented in the middle of the display above the three colored circles until a button press response.

After each of the scene-object pairs had been presented once, encoding continued with a hybrid test-and-study procedure (e.g., Raine et al., 2013). The purpose of this procedure was twofold – first, it is known that this kind of approach improves encoding and subsequent retention of learned items relative to repeated study exposures alone (Karpicke & Blunt, 2011); second, using the scene as a cue (during test) should have encouraged participants to retrieve associates during the conditioning phase of the experiment, which is a necessary step for transfer of a fear response to an associate (Shohamy & Wagner, 2008). Each trial in the hybrid test-and-study phase began with the presentation of a fixation cross (1s) and was followed by a previously

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studied scene (3s) and then a blank screen (3s). Participants were told to use the scene as a memory cue and to attempt to retrieve the associate. They were instructed to indicate via a button press whether they were able to recall the associate or not, either while the scene remained in view or within the 3s period after the scene disappeared. If they remembered the associate of the scene, participants were told to press a button on the keyboard labelled "1"; if they were unable to remember the associate, participants were instructed to not press any buttons.

If participants indicated that they remembered the associate of the scene (i.e., if they *opted-in* to test), all three colored circles were presented and participants were told to select the associate. Three keyboard buttons were labelled as "1," "2," and "3" and corresponded to the numbers presented below the three colored circles. The display remained on screen until a button press response was made. Whether participants responded correctly or not, the scene reappeared, and its associate was superimposed on top of the scene with timing matched to the original encoding run. If an incorrect response was made, then memory for the pair was tested and studied again later in the run.

If participants indicated that they did *not* remember the associate of the scene while the scene was in view or during the 3s following the disappearance of the scene (i.e., if they *opted-out* of test), the scene-object pair was re-presented right away with original timing (1s scene/2s pair). Participants were told that they would have one chance (per scene-object pair) to opt-out of test. We imposed a cap on the number of opportunities participants were allowed to "opt-out" of test in order to limit the length of the experiment. On average, participants opted-out of test on 7.67% of the test-and-study trials. When participants were re-tested on these scene-object pairs later in the run, they were instructed to take their best guess on which circle was previously paired with the scene, if they were still unable to recall the associate. The three-circle display

remained on screen until a button press response was made, and regardless of accuracy, the scene-object pair was re-presented with original timing. Again, if an incorrect response was made, memory for the scene-object pair was tested again later. The hybrid test-and-study procedure continued until correct responses had been made for all 30 pairs. On average, 49.92 exposures (including the 30 required study exposures) were necessary to reach criterion level of performance.

Conditioning. Following encoding, participants completed a conditioning phase (see Figure 1B). Participants were told that the scenes from the encoding phase would be presented and that a shock would be delivered occasionally. They were instructed to make predictions about whether shock would occur via a button press response. When they believed that a shock was "not likely to occur," participants were told to press the keyboard button labelled "1." In contrast, when they believed that a shock was "very likely to occur," they were instructed to press button "3." If they were unsure whether shock was likely or unlikely, participants were told to press button "2." Use of button presses during conditioning provided an online measure of contingency awareness (see Schultz & Helmstetter, 2010 for a similar approach) and permitted us to examine whether and when participants became aware of the imposed contingencies, which, as described below, were based on the color of the circle that was paired with a given scene during encoding.

The conditioning phase consisted of 30 trials. Following a central fixation cross (1s), each encoded scene was presented in the center of the screen for 3s and sometimes the scenes co-terminated with the US (i.e., a shock was delivered in the last 500ms of scene presentation). Shock delivery was contingent upon the color of the circle that was paired with the scene during encoding. For example, scenes paired with one of the colored circles (e.g., blue) never co-

terminated with shock (CS0), 50% of the scenes paired with another colored circle (e.g., green) co-terminated with shock (CS50), and 100% of the scenes paired with the final colored circle (e.g., orange) co-terminated with shock (CS100). Critically, scenes were presented alone during the conditioning phase, and the assignment of color (i.e., blue, green, orange) to experimental conditions (i.e., CS0, CS50, CS100) was counterbalanced. Additionally, trial order pseudorandomized so that no more than two shocks were administered consecutively, and no more than two or three trials of the same type were presented consecutively (e.g., two CS100 trials, three CS0 trials). While the scene was in view, participants made shock expectancy ratings via a button press.

Visual Search. Immediately after conditioning, participants completed a visual search task (see Figure 1C). The visual search task consisted of six blocks of 48 trials, resulting in 288 total trials. Every trial began with the presentation of a central fixation cross. Once the participant had remained fixated on the central fixation cross for 1s, the fixation cross was removed from view. The screen remained blank for a short period of time (variable duration = 100-200ms in 20ms intervals randomized across trials; e.g., 100ms, 120ms, 140ms, etc.) before the search display was presented. When the search display appeared (together with the reappearance of the central fixation cross), it remained in view for 2s, after which a blank screen was presented for 300-400ms; the duration of the blank screen varied systematically such that total time from the start of the trial amounted to approximately 3.5s.

During the search task, participants were told to make a single saccade to the target and to ignore all other objects (including colored circles) in the search display. Search displays consisted of six objects – five circles and either a hexagon or a diamond – each occupying a region 2.45° of visual angle square. Objects in the search displays were situated at the joints of

an imaginary hexagon and were equidistant from the center of the screen (7.36° from center) and each other (3.07° from adjacent objects). The search target was a gray object, distinctive by shape (i.e., a diamond among circles), and targets were hexagons or diamonds equally often across all trial types. In every block, one-quarter of the trials ($n = 12$) were baseline trials. On baseline trials, all of the objects in the search display were gray. On the remaining trials ($n = 36$), one of the gray circles was replaced with a colored circle from encoding. In contrast to some investigations of capture by fear (Nissens et al., 2017; Notebaert et al., 2011; Preciado et al., 2017; Schmidt et al., 2017), critical distractors (i.e., the colored circles from encoding) were singletons and, thus, were physically salient. While it was anticipated that each of the color singletons would capture attention based purely on physical salience (e.g., Theeuwes et al., 1998), the frequency of this capture effect was expected to vary as a function of the imposed CS manipulation. Across trials within a block, targets and distractors appeared equally often in each spatial location, and distractors had an equal likelihood of being one, two, or three positions away from the target stimulus. Trial order was pseudorandomized so that no more than three trials with the same target shape were presented consecutively and no more than three trials of the same type (e.g., three CS0 associate trials) were presented consecutively.

Recognition. The experiment ended with a recognition test (see Figure 1D). An explicit test of recognition for learned pairs was administered (30 total recognition trials). Trials began with a central fixation cross (1s). Each scene from the encoding phase was presented above the three colored circles, and participants were instructed to choose the colored circle that had appeared with each scene during encoding using the keyboard buttons labelled "1," "2," and "3." The keyboard button numbers corresponded to the numbers below the three colored circles. The display remained on the screen until a button press response was made. Trial order was

pseudorandomized so that no more than three trials of the same type (e.g., three CS0 trials) were presented consecutively.

After completion of the recognition test, participants completed a PEQ to assess contingency knowledge. The PEQ, adapted from a previous study (Hopkins et al., 2016; see Appendix A), included questions about the purpose of the study as well as specific questions about the association between shock administration and scene-object pairs (see Appendix B). After completing the PEQ, participants were debriefed and had an opportunity to ask any remaining questions.

Eye Movement Analyses

Visual search displays were subdivided into eight regions of interest (ROIs). Six of the ROIs surrounded areas occupied by the six search display objects. Combined, these six ROIs formed a hexagon around the center of the screen (subtending 24° of visual angle), and each of these ROIs were of equal size (extending 30° of arc in both directions from the center of each search display object). Separately, a central ROI surrounded the fixation cross (approximately 5.8° of visual angle), and the remaining ROI encompassed the entire screen.

Trials were removed from analyses if saccades began off center (i.e., outside of the center ROI) or if saccades were initiated before 80ms or after 600ms following display onset (cf. Theeuwes & Belopolsky, 2012). Additionally, trials were eliminated if participants failed to make a saccade out of the center ROI before the display was removed from view. Three participants data were removed because, after these exclusions were applied, the percentage of discarded trials was more than two times greater than the interquartile range of the full sample. For the remaining participants, an average of 2.36% ($SD = 2.33$) of trials were removed from analysis, due to these exclusionary criteria.

Three eye movement measures were used to examine the effects of fear learning on attention allocation during visual search: 1) percentage of trials on which a saccade was made, in error, to a CS associate (i.e., overt, or oculomotor, capture), 2) time course (in ms) of overt capture effects, and 3) time (in ms) required to initiate target-directed saccades (i.e., a potential index of covert capture). A baseline measure of overt capture was obtained by calculating the percentage of baseline trials (i.e., trials that did not contain a CS associate in the display) on which participants made an erroneous eye movement to a distractor.

Statistical Contrasts

Mauchly's test of sphericity was calculated for all of the reported ANOVAs with more than one degree of freedom in the numerator. If sphericity was violated, Greenhouse-Geisser adjusted degrees of freedom and p-values are reported along with the corresponding epsilons (G-G ε). Two-tailed post-hoc statistical tests were Bonferroni corrected for multiple comparisons, and p-values were adjusted to reflect this correction. Partial eta-squared (η_p^2) and Cohen's d were calculated as indices of effect size. Effect size for paired t-tests was separately calculated to account for correlations between conditions in a given contrast (Pearson's r) and was calculated using the following equation: $d = (\text{mean}_1 - \text{mean}_2) / \sqrt{((\text{sd}_1^2 + \text{sd}_2^2 - (2*r*\text{sd}_1*\text{sd}_2))}$.

Results

Recognition Performance

Test-and-Study Phase. Results of the test-and-study phase demonstrated that scene-object pairs were successfully encoded. Recognition accuracy was well above chance level, $p <$ .0001. On average, participants identified the correct associate (from three alternatives) on 65% of the trials ($SD = 13.28\%$). Recognition accuracy did not vary across conditions (i.e., CS100,

CS50, and CS0 trials) or across circle colors (i.e., blue, green, and orange), t's ≤ 1.50,

uncorrected p's $\geq .15$.

Final Recognition Test. Results of the recognition test administered at the end of the

experiment confirmed that scene-object pairs had been successfully encoded. Recognition

accuracy was well above chance level, $p < .001$. On average, participants identified the correct

associate (from three alternatives) on 85% of trials ($SD = 10.84\%$). Like above, recognition

accuracy did not vary across conditions or across circle colors, t's ≤ 1.06, uncorrected p's $\geq .22$.

Contingency Awareness

Shock Expectancy. To determine whether participants were aware of shock

contingencies during fear conditioning, we analyzed participant's shock expectancy button press

responses. We split the conditioning block of 30 trials into halves to compare awareness during

the first half versus the second half of the conditioning phase. Button response data were coded

as the following, for ease of comparison: "0" corresponded to a "shock unlikely" response, "1"

corresponded to a "don't know" response, and "2" corresponded to a "shock likely" response. A

repeated-measures ANOVA with factors condition (CS100, CS50, CS0) and half (first half,

second half) revealed no significant differences in shock expectancy ratings across conditions or

halves during the conditioning procedure, F's ≤ 2.078, p's $\geq .14$, suggesting that participants

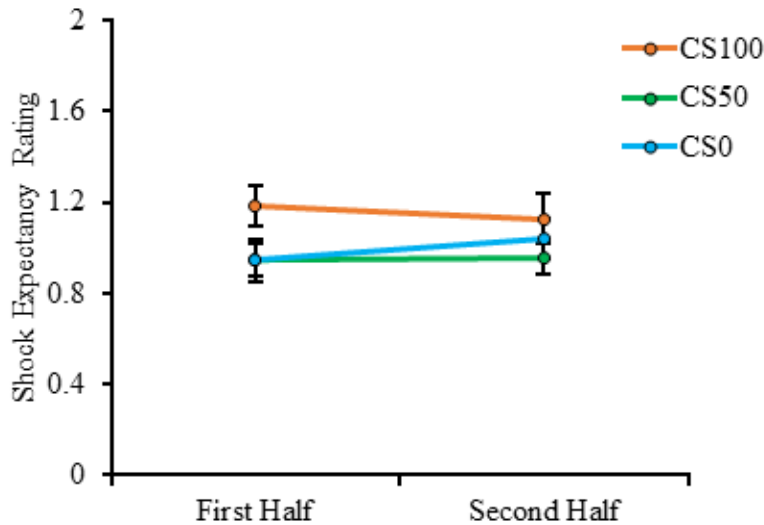were not aware of shock contingencies during conditioning (see Figure 2).

Figure 2. *Shock expectancy ratings.* Average expectancy ratings for CS100, CS50, and CS0 conditions across first and second halves of the conditioning phase. Standard error bars are plotted around the means.

Post-Experimental Questionnaire (PEQ). As an additional measure of awareness, participants completed a PEQ (see Appendix B) at the end of the experiment. The first question on the PEQ asked participants to report the objective of the experiment. To be classified as aware, participants must have indicated that shock was tied to the color of the circle paired with scenes during encoding. No participants met this awareness criterion. Most participants guessed that the experiment had something to do with memory, fear/threat, or some combination of these two (e.g., "to see if participants remembered object pairs better when shocked"). Next, participants were asked to report (yes or no) whether they had noticed an association between stimulus displays and electrical stimulus delivery. Fourteen participants gave a "yes" response and 13 participants gave a "no" response. Participants who indicated "yes" were asked to explain their response. Based on these responses, five participants were categorized as aware (i.e., they indicated there was a scene-color-shock or a color-shock association and correctly identified the color of the circle most frequently paired with shock). The remaining participants who responded

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"yes" on Question 2 did not describe the contingencies correctly. Finally, participants were asked to choose which colored circle they suspected was associated with shock most often. Participants were given five response options: "blue," "green," "orange," "all colors equally often," or "electrical stimulus not related to color." Nine of 27 participants (33% of participants) chose the correct color, which was above chance level (20%), $p < .0001$. Seven participants (26%) indicated that electrical stimulus was not related to color, and three participants (11%) reported that all colors were associated shock equally often.

Viewing Behavior

   Overt Capture by Distractors. A repeated-measures ANOVA was calculated to determine whether there were differences in the percentage of trials on which a saccade was made in error to a distractor between conditions (baseline, CS100, CS50, CS0) or between blocks (six blocks). There was a main effect of condition, $F(1.52, 39.43) = 17.33$, $p < .0001$, G-G $\varepsilon = .51$, $\eta_p^2 = .40$, as well as a main effect of block, $F(3.14, 81.61) = 2.98$, $p = .034$, G-G $\varepsilon = .63$, $\eta_p^2 = .10$. The condition x block interaction was also significant, $F(15, 390) = 1.81$, $p = .032$, $\eta_p^2 = .065$. Post-hoc follow-up comparisons on the condition factor (baseline, CS100, CS50, CS0) showed that all three CS distractors resulted in significantly higher levels of oculomotor capture (CS100: $M = 24.10$, $SD = 15.18$; CS50: $M = 26.63$, $SD = 14.80$; CS0: $M = 27.95$, $SD = 18.44$) as compared to baseline distractors on baseline trials ($M = 10.95$, $SD = 10.24$), $t's(26) \geq 4.31$, corrected $p's < .0006$, $d's \geq .83$. There were no significant differences in overt capture between the three CS conditions (collapsed across blocks) after Bonferroni corrections were performed, $t's \leq 2.22$, corrected $p's \geq .21$. Post-hoc follow-up comparisons on the block factor (six blocks) revealed that percentage of overt capture (collapsed across conditions) did not significantly change across blocks, $t's \leq 2.88$, corrected $p's \geq .12$. The condition x block interaction warranted

a more careful comparison of differences across blocks between conditions, and a linear trend

analysis showed that capture effects in the CS100 and CS0 conditions decreased across blocks,

F's(1, 156) ≥ 4.16, p's ≤ .043, while capture effects did not change across blocks in the baseline

and CS50 conditions, p's ≥ .27 (see Figure 3A).

Because we expected that capture effects would rapidly decrease in the absence of

reinforcement during search (Hopkins et al., 2016), a repeated-measures ANOVA was calculated

to determine whether differences between conditions (baseline, CS100, CS50, CS0) might

appear within the first block alone (first half, second half). There was a main effect of both

condition, $F(2.30, 59.80) = 14.13$, $p < .001$, G-G $\varepsilon = .77$, $\eta_p^2 = .35$, and half, $F(1, 26) = 13.27$, p

$= .001$, $\eta_p^2 = .34$ (see Figure 3B). The condition x half interaction was not significant, $F(2.11,$

$54.84) = 1.04$, $p = .36$. Post-hoc follow-up comparisons on the condition factor (baseline, CS100,

CS50, CS0) again showed that all three CS distractors on CS trials (CS100: $M = 31.46$, $SD =$

22.16; CS50: $M = 29.05$, $SD = 17.80$; CS0: $M = 35.03$, $SD = 27.08$) captured attention

significantly more often than baseline distractors ($M = 9.83$, $SD = 9.91$), t's(26) ≥ 4.89 ,

corrected p's < .0006, d's ≥ .94. There were no significant differences in overt capture across the

three CS conditions after Bonferroni corrections were performed, t's ≤ 1.25, uncorrected p's ≥

.22. Post-hoc follow-up comparison on the half factor (first half, second half) revealed

significantly higher levels of capture (collapsed across conditions) during the first half of Block 1

($M = 30.12$, $SD = 17.04$) than during the second half of Block 1 ($M = 22.53$, $SD = 14.98$) , t(26)

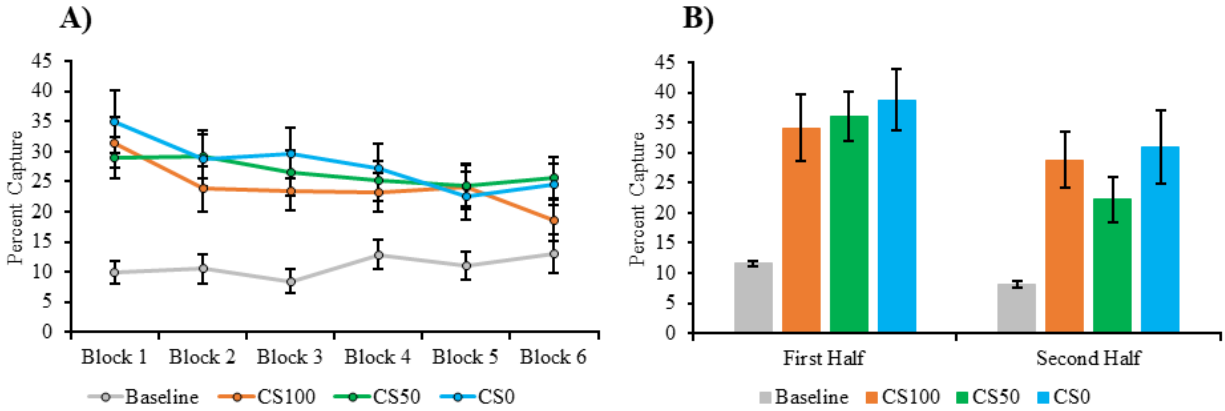$= 3.64$, corrected $p = .001$, $d = .70$.

Figure 3. *Oculomotor capture by distractors.* A) Average percentage of trials on which participants made an erroneous, initial saccade to a distractor on baseline, CS100, CS50, and CS0 trials across six blocks. B) Average percentage of trials on which participants made an erroneous, initial saccade to a distractor on baseline, CS100, CS50, and CS0 trials within the first and second halves of Block 1. Standard error bars are plotted around the means.

Time Course of Overt Capture. It has been reported previously (e.g., Nissens et al., 2017) that capture by a CS+ is more likely to occur when saccades are made very quickly following search display onset. While capture effects are consistently greater for a CS+ as compared to a CS-, these differences are less pronounced when saccade latencies are longer. To examine whether oculomotor capture effects across conditions change as a function of saccade latency, data was binned according to a Vincentizing procedure developed by Ratcliff (1979), which has been utilized in past fear-conditioning work (Mulckhuyse et al., 2013; Mulckhuyse & Dalmaijer, 2015; Nissens et al., 2017). For each participant, CS search trials were categorized by condition (i.e., CS100, CS50, CS0). Within a condition, trials were sorted in ascending order based on the latency of the first saccade away from the center of the screen and assigned to eight equally-sized bins (i.e., eight bins of nine trials per condition). Trials in Bin 1 represented the nine quickest eye movements in a specific CS condition, and trials in Bin 8 represented the nine slowest eye movements in a specific CS condition. Then the percentage of trials to a CS in each bin for a given condition (CS0, CS50, CS100) was calculated, with the total number of "good"

trials (within each bin) in that condition as the denominator (e.g., to identify the percentage of CS0 capture trials in Bin 1, Bin 2, etc.), for each participant. Data were then averaged across participants. A repeated-measures ANOVA was calculated to compare capture effects between conditions (CS100, CS50, CS0) and bins (eight bins). There was a main effect of bin, $F(3.45, 89.62) = 30.23$, $p < .001$, G-G $\varepsilon = .49$, $\eta_p^2 = .54$, but no main effect of condition, $F(2, 52) = 2.59$, $p = .085$, or significant interaction, $F(7.31, 190.15) = 1.10$, $p = .36$. A linear trend analysis revealed that capture decreased across bins, which means that capture was less likely to occur when first saccades away from the center of the screen were initiated more slowly, $F(7, 271.25) = 35.91$, $p < .0001$, $\eta_p^2 = .25$ (see Figure 4).
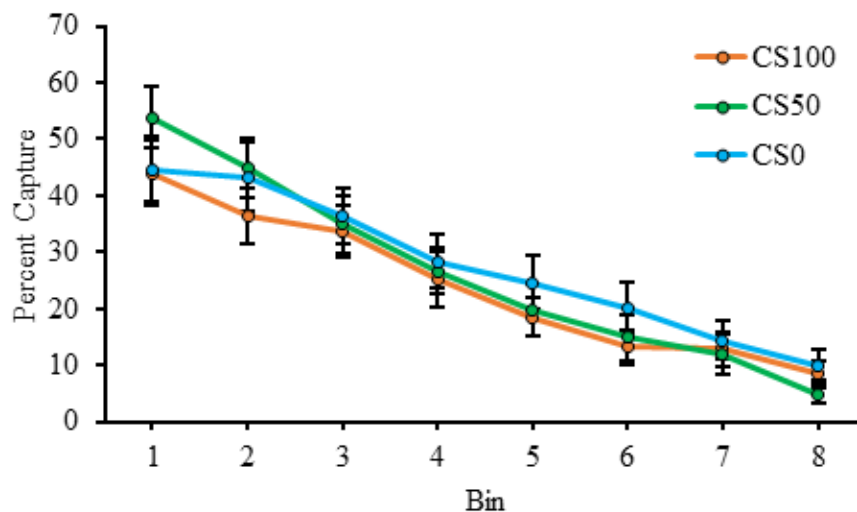
Figure 4. *Time course of overt capture effects.* Average percentage of capture for CS100, CS50, and CS0 conditions as a function of binned saccade latencies of the first saccades away from center (binned in ascending order, with Bin 1 corresponding to quickest eye movements and Bin 8 corresponding to slowest eye movements). Standard error bars are plotted around the means.

Saccade Latency to Target. To investigate whether there were differences in saccade latency when participants made their initial saccade to the target, as instructed, a repeated-measures ANOVA was calculated with factors condition (baseline, CS100, CS50, CS0) and block (six blocks). Five participants were excluded from analysis because they failed to make

eye movements to the target in one of the conditions (baseline, CS100, CS50, or CS0) in one or more blocks of the search task. There were main effects of condition, $F(3, 63) = 17.95$, $p < .001$, $\eta_p^2 = .46$, and block, $F(2.52, 52.85) = 8.24$, $p < .0001$, $G\text{-}G \ \varepsilon = .50$, $\eta_p^2 = .28$. The condition x block interaction was not significant, $F(15, 315) = 1.35$, $p = .17$ (see Figure 5A). Post-hoc follow-up comparisons on the condition factor (baseline, CS100, CS50, CS0) revealed that target-directed saccades made on baseline trials ($M = 278.40$, $SD = 38.19$) were significantly quicker than target-directed saccades made on each of the three CS conditions (CS100: $M = 293.95$, $SD = 45.51$; CS50: $M = 300.77$, $SD = 44.48$; CS0: $M = 292.02$, $SD = 50.46$), t's$(21) \geq 3.60$, corrected p's $\leq .0012$, d's $\geq .78$. Additionally, target-directed saccades in the CS50 condition were made significantly more slowly than target-directed saccades in the CS0 condition, $t(21) = 2.97$, corrected $p = .042$, $d = .67$. There were no other significant differences between CS conditions after Bonferroni corrections were performed, t's ≤ 2.41, corrected p's $\geq$ .15. Post-hoc follow-up comparisons on the block factor (six blocks) showed that participants made significantly slower target-directed saccades during Block 1 ($M = 316.38$, $SD = 66.04$) as compared to Block 3 ($M = 289.95$, $SD = 44.84$), Block 4 ($M = 286.73$, $SD = 47.47$), Block 5 ($M = 281.33$, $SD = 40.38$), and Block 6 ($M = 277.51$, $SD = 39.00$) when data were collapsed across conditions, t's$(21) \geq 3.41$, corrected p's $\leq .045$, d's $\geq .73$; no other differences were significant across blocks after Bonferroni correction, t's ≤ 3.05, corrected p's $\geq .090$.
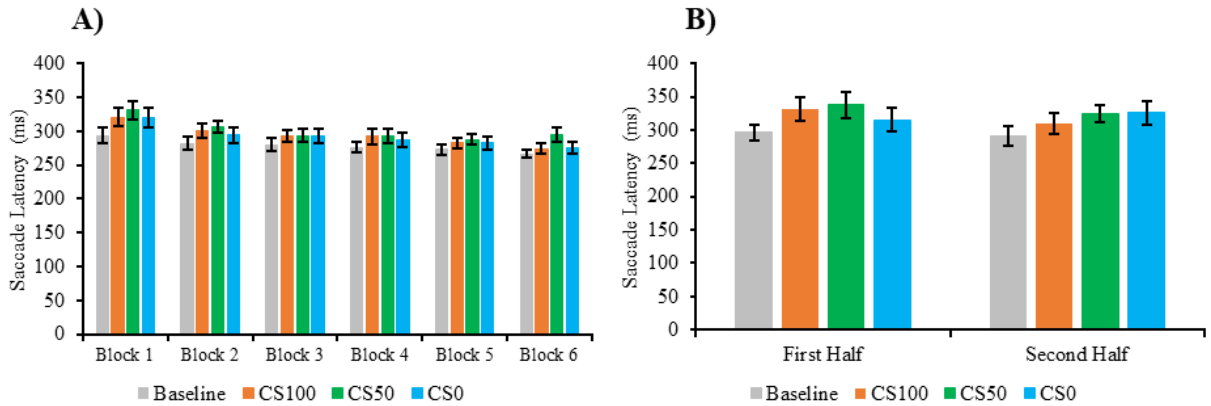
Figure 5. *Saccade latency to targets.* A) Average target-directed saccade latencies when participants made an initial saccade to the target on baseline, CS100, CS50, and CS0 trials across six blocks. B) Average target-directed saccade latencies when participants made an initial saccade to the target on baseline, CS100, CS50, and CS0 trials within the first and second halves of Block 1. Standard error bars are plotted around the means.

A repeated-measures ANOVA was calculated to examine whether target-directed saccade latency differences between conditions (baseline, CS100, CS50, CS0) might exist within the first block alone (first half, second half). There was a main effect of condition, $F(3, 63) = 9.32$, $p <$ .0001, $\eta_p^2 = .31$, but no main effect of half, $F(1, 21) = 1.25$, $p = .28$, or significant condition x half interaction, $F(3, 63) = 1.62$, $p = .19$ (see Figure 5B). Post-hoc follow-up comparisons on the condition factor (baseline, CS100, CS50, CS0) revealed that target-directed saccades were significantly slower in all three CS conditions (CS100: $M = 320.29$, $SD = 72.99$; CS50: $M = 330.96$, $SD = 71.03$; CS0: $M = 320.62$, $SD = 77.39$) relative to target-directed saccades made in the baseline condition ($M = 293.67$, $SD = 58.31$), t's(21) ≥ 3.22, corrected p's $\leq .024$, d's $\geq .69$. There were no significant differences in target-directed saccade latencies across the three CS conditions after Bonferroni corrections were performed, t's ≤ 1.39, uncorrected p's $\geq .18$.

Discussion

This study examined whether capture effects may flexibly transfer to an associate of a fear-conditioned stimulus when a CS and its associate were encoded together, prior to US

exposure. Our results show that scene-object pairs were successfully encoded; recognition accuracy on a test following search was well above chance. Although memory representations of the scene-object pairs were strong, shock expectancy ratings made during the conditioning phase, in combination with performances on the PEQ following the experiment, demonstrate that the overwhelming majority of participants were unaware of the relationship between scenes, objects, and shock delivery. During search, participants made significantly more overt eye movements (in error) to colored circle associates relative to baseline distractors and were slower to make target-directed saccades (as instructed) on CS trials than on baseline trials. Additionally, overt capture effects decreased with increasing saccade latency. However, these capture effects did not reliably differ as a function of the associate present in the display (i.e., CS100-, CS50-, or CS0-associated circles), suggesting that fear-conditioned capture effects to a CS may not transfer to novel associates encountered for the first time in the episodic context of an experiment.

Past work has demonstrated that a conditioned fear response can flexibly transfer to a stimulus never paired with an unconditioned stimulus in a process referred to as generalization (Dymond et al., 2015; Jasnow et al., 2016). Contemporary models of anxiety disorders implicate flexibility of fear-conditioned responses in the development and maintenance of clinical anxiety (Mineka & Zinbarg, 2006), and, thus, experimental paradigms which allow for the exploration of flexible conditioned responses hold clear translational value for future examination of these effects in clinical populations. Several studies have provided evidence for the generalization of fear responses to semantically related words (Boyle et al., 2015; Maltzman et al., 1977) and to exemplars within categories (Dunsmoor et al., 2013; Dunsmoor et al., 2012), suggesting that higher-order, associative forms of generalization can be observed in humans. However, flexibility of a conditioned response to the bound associate of an encoded object or context,

absent any pre-existing semantic or conceptual relationship, has rarely been documented in human fear conditioning work (e.g., Vansteenwegen et al., 2000). One published study demonstrated that, following the encoding of novel pairs of faces and the subsequent conditioning of one face from each pair (in a differential fear conditioning paradigm), participants showed an enhanced skin conductance response to a face previously paired with the CS+ relative to a face previously paired with the CS- during a test phase (Vansteenwegen et al., 2000). This work provided preliminary evidence for the claim that, within an associative preconditioning paradigm, a CR can flexibly transfer to an arbitrarily-paired associate of a CS, even when the associate was never directly paired with the US. No published studies have examined whether similar preconditioning effects can be observed in the deployment of attention to learned associates of a CS, although recent work from the attention capture literature has demonstrated a clear influence of fear-conditioned stimuli themselves on the deployment of attention (e.g., Hopkins et al., 2016; Nissens et al., 2017).

The only finding from the current study that is suggestive of a potential effect of associative preconditioning on eye movement behavior is the significant difference in target-directed saccade latencies between search trials containing the CS50 associate and trials containing the CS0 associate. Specifically, our results showed that initial saccades made toward targets were delayed when search displays contained the CS50 associate relative to the CS0 associate. We had expected that capture effects across all eye movement measures would be greatest for the CS100 associate, due to its association with scenes that were always paired with shock. However, this saccade latency effect between the CS50 and CS0 conditions suggests another possibility – that the absence of a uniformly predictable relationship between CS50 scenes and US delivery may have caused a slowdown in target-directed saccades when the

corresponding associate was present during search. Since uncertainty about a threatening

outcome can increase anxiety (e.g., Bennett, Dickmann, & Larson, 2018), uncertainty about the

relationship between the CS50 scenes and shock delivery during conditioning may have resulted

in higher priority for the CS50 associate during search. However, we might expect a similar

pattern to arise in the overt capture effects between conditions if the CS50 associate was indeed

prioritized over both CS100 and CS0 associates, and differences in the percentage of capture

between CS conditions were not significant. Thus, the lack of a clear and consistent pattern of

capture effects across eye movement measures makes interpretation of these target-directed

saccade latency differences difficult.

Despite the absence of unambiguous preconditioning effects in the current experiment,

standard saliency-based capture effects were observed. In our study, object associates of the

conditioned stimuli (i.e., scenes) were three differently colored circles, matched for luminance

(or brightness). During search, one of these colored circles was occasionally embedded in the

search display as a distractor. Because the remaining objects in these search displays, including

targets, were gray objects, it was expected that the colored circles would disproportionately

capture attention, since salient singleton distractors are known to capture attention (e.g.,

Theeuwes, 1992, 1994). Specifically, previous studies have demonstrated that overt eye

movements are made disproportionately toward salient singleton distractors in a search display

(Irwin et al., 2000; Ludwig & Gilchrist, 1002; Theeuwes et al., 1998) and that salient singleton

distractors in a search display delay the initiation of target-directed saccades (Irwin et al., 2000;

Theeuwes et al., 1999), effects which we have replicated here. Furthermore, consistent with

previous reports (e.g., Anderson & Kim, 2019; Nissens et al., 2017; van Zoest, Donk, &

Theeuwes, 2004), results indicated that capture was most likely to occur when saccades were

made quickly. This observation supports the view that fast eye movements made toward task-irrelevant singletons (or stimuli previously associated with threat – Nissens et al., 2017) are less likely to be under volitional control. This is because salient materials are thought to have preferential access in the attentional priority map early in the visual selection process (van Zoest et al., 2004).

Because we conflated perceptual saliency with value in the current study (i.e., CS associates were both salient and indirectly associated with value), one explanation for why we did not observe flexible CRs in the form of eye movement behavior might be that the magnitude of basic stimulus-driven capture effects is simply *larger* than the magnitude of value-based capture effects. For example, it might be the case that saliency-based capture effects in the current study were already near ceiling, such that they may have obscured any subtler capture effects that might have been a result of a transferred fear response to an associate of a CS. Only one study, to our knowledge, has measured both value-based capture effects (by a previously rewarded stimulus) and saliency-based capture effects together in one experiment (Anderson & Kim, 2019). However, in this study, participants always completed the value-driven capture task *before* the saliency-driven capture task, making a direct comparison of the magnitude of these two effects difficult to meaningfully assess (as other factors, such as practice effects or fatigue, may have been at play). Future work should address this question by reversing the sequence of events across participants.

Additionally, virtually no studies have investigated the relative contributions of salience and threat to attention capture effects using a manipulation in which stimuli are both salient and have been previously associated with threat. Indeed, a number of investigations of capture by fear have been designed such that fear-conditioned stimuli are purposely *non-salient*, to

eliminate uncertainty about whether the observed capture effects are saliency-based or threat-related (e.g., Nissens et al., 2017; Notebaert et al., 2011; Preciado et al., 2017; Schmidt et al., 2017). To more comprehensively address questions about the magnitude of different kinds of attention capture, future studies might consider comparing capture effects to three different types of distractors in one experiment: perceptually salient distractors; non-salient, fear-conditioned distractors; and perceptually salient, fear-conditioned distractors.

It is important to consider the possibility that design features distinguishing the current study from previous associative preconditioning studies may have contributed to the results reported here. In past studies that have used a similar paradigm (i.e., in which associations were learned in an encoding phase, prior to conditioning), participants were not required to learn as many stimulus pairs as in the current study. Vansteenwegen and colleagues (2000) only required participants to learn two pairs of stimuli, while participants were exposed to six pairs of stimuli during encoding in a previous reward study (Wimmer & Shohamy, 2012). Additionally, in both studies, stimulus pairs were unique (i.e., the mapping of CS to associate was 1:1), and participants were exposed to the pairs 10 times during the encoding session. In the present study, participants were required to learn 30 scene-object pairs. Here, all 30 scenes were unique but 10 each were paired with one of three associates (i.e., a blue, green, or orange circle). During conditioning, 10 of these scenes were paired with shock 100% of the time, 10 were paired with shock 50% of the time, and 10 were paired with shock 0% of the time. Thus, stimulus pairs were not entirely unique; the mapping of CS to associate was 10:1. Further, participants in this study only saw each pair about 2.6 times on average (i.e., 30 times during encoding and 49.92 times, on average, during the test-and-study procedure).

This difference in mappings and exposures may have impacted the ability of participants to learn shock contingencies during conditioning, a possibility that is consistent with the null findings of our shock expectancy and PEQ data, and the lack of contingency awareness may have, in turn, prevented the transfer of capture effects to the encoded associates during the search task. It is unclear whether awareness of imposed contingencies is a necessary prerequisite for the transfer of a conditioned response, although Wimmer and Shohamy's (2012) work suggests that appetitive value-based effects to arbitrary associates can still occur in the absence of contingency awareness. Of note, capture effects to a CS+ (in a first-order conditioning procedure) have also been documented in the absence of explicit contingency knowledge (Hopkins et al., 2016).

Another difference between the work presented here and prior studies is our inclusion of a CS50 conditioning category. None of the associative preconditioning studies reviewed here (Vansteenwegen et al., 2000; Wimmer & Shohamy, 2012) included an "intermediate" CS condition, in which stimuli were paired with shock only 50% of the time during the conditioning phase. Inclusion of this condition may have made contingency learning more difficult overall, since the relationship between CS50 scenes and the US delivery may have made all shock contingencies more unpredictable. Moreover, to our knowledge, no studies have investigated the impact that including a CS50 conditioning category has on standard capture effects to a CS, making predictions about the influence of this shock contingency on associative preconditioned responses even more challenging. Of note, one previous study (Schmidt et al., 2015b) has observed capture effects toward a neutral stimulus that was sometimes paired with a fear-conditioned stimulus and sometimes paired with another neutral stimulus in a two-object search display. The authors indicated that the neutral stimulus that was sometimes paired with the fear-conditioned stimulus indirectly acquired threat value by virtue of its association with CS. Thus,

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the neutral stimulus in Schmidt et al.'s (2015b) study functionally assumed the role of a CS50. Based on this work, we might expect to see similar capture effects to a CS100 and CS50 in a standard fear conditioning capture task. A future study might utilize search displays similar to the ones used here in the context of a standard capture paradigm to address the question of how the presence of a CS50 distractor in a search display affects eye movement behaviors and the deployment of attention.

It has been suggested in previous associative preconditioning work that an association between two stimuli must be sufficiently strong for a conditioned response to transfer from one stimulus to its associate (Vansteenwegen et al., 2000). We do not suspect that our lack of capture effects to the colored associates were a result of insufficiently strong memory representations of the scene-object associations because participants accurately identified the pairs 85% of the time in a recognition test at the end of the experiment. Additionally, Wimmer and Shohamy (2012) demonstrated that, following an incidental encoding phase, CRs (i.e., decision biases) occurred to arbitrarily-paired associates of previously rewarded stimuli, even in the absence of intact memory representations for the image pairs (i.e., memory accuracy for image pairs was no different than chance). However, neuroimaging results of the same study did indicate that decision biases were predicted by hippocampal activity and the reactivation of category-specific visual regions during reward learning (Wimmer & Shohamy, 2012).

It is possible that the *pre-existing* strength of the relationship between stimuli, before they are paired together during an encoding session, may also play a role in the later emergence of conditioned responses to an associate of a CS. One previous study has shown that the magnitude of a CR may depend on the conceptual similarity of the pre-associated stimuli (Dunsmoor, White, & LaBar, 2011). In this study, participants either studied conceptually similar pairs of

images (i.e., a spider with a web, a wasp with a nest), conceptually unrelated pairs of images (i.e., a spider and a wasp with a waste drum or a hospital corridor), or conceptually mismatched pairs of images (i.e., a spider with a nest, a wasp with a web). Following a conditioning procedure, in which one image from each pair was either paired with shock (CS+) or was not (CS-), participants were then re-exposed to the associates of the conditioned stimuli. Those in the conceptually similar group showed a larger SCR to the CS+ relative to the conceptually unrelated group, although both groups showed evidence of standard preconditioning effects (i.e., enhanced SCRs to the CS+ vs. the CS-). These results suggest that pre-existing conceptual knowledge can modulate the transfer of a conditioned fear response to an associated, unconditioned stimulus.

In the current study, because the association of scenes and objects was novel, it is likely that the transfer of affective value to the colored associates may have been smaller relative to other reports of flexible conditioned responses in the human literature (e.g., generalization to conceptually similar images – Dunsmoor et al., 2011; to objects in a category – Dunsmoor et al., 2012; to semantically related words – Boyle et al., 2015). Incidentally, it is the case that conditioned responses to associates of a CS are typically much smaller than first-order conditioned responses (Gewirtz & Davis, 2000). Thus, the absence of capture effects to the associates of a CS in the current study, despite an abundance of first-order conditioning studies that have demonstrated robust capture effects to a CS (e.g., Hopkins et al., 2016; Mulckhuyse & Dalmaijer, 2016; Nissens et al., 2017), may not be so surprising.

There were several limitations of the work presented here. First, our methods of contingency awareness (i.e., discrete button press responses, a remotely administered PEQ) may have been insensitive to subtle changes in awareness. Future work should address this

shortcoming by using a continuous measurement of online awareness (i.e., a joystick or a mouse scroll wheel; Dunsmoor et al., 2012; Schultz & Helmstetter, 2010). Furthermore, the current study did not measure physiological arousal (i.e., SCR) during search, so we cannot determine with any certainty whether our null effects arose because 1) a conditioned response successfully transferred to the associates and associates of a CS+ simply do not impact eye movement behavior to a significant degree or because 2) a conditioned response did *not* transfer to the associates. In future work, it would be useful to include another trial type, in which the CS+ itself was occasionally presented as a distractor in the search display (in addition to trial types with just its associate), and to measure SCR during search. In this type of design, direct conclusions could be drawn about the transfer of fear responses on two different measures of conditioned fear (i.e., SCR and capture effects). Finally, during search in the current study, the fixation cross re-appeared with the onset of the visual search display. The sudden presence of the central fixation cross may have inhibited participant's ability to disengage their attention from the center of the screen (Saslow, 1967), and, thus, may have slowed all saccade latencies across all conditions (baseline, CS100, CS50, and CS0). Because the quickest saccades during search were made toward the salient circle associates, it is possible that the overall percentage of capture was lessened as a result of this design flaw.

In conclusion, we examined, for the first time, whether capture effects may transfer to the learned associate of a CS in the absence of a pre-existing (e.g., semantic) relationship between a CS and its associate. Across three different measures of eye movement behavior (i.e., percent of overt capture, time course of oculomotor capture effects, and target-directed saccade latencies), capture effects did not differ as a function of CS condition, suggesting that fear-conditioned capture effects to a CS may not flexibly transfer to their learned associates. Future studies in this

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domain may consider simplifying shock contingencies (e.g., by eliminating the CS50 category) to boost contingency awareness and might collect two conditioned responses (i.e., both SCR and eye movement behavior) to determine whether capture effects represent a sensitive measure of conditioned responses to CS associates. Because fear conditioning represents a gold-standard laboratory model for the development of anxiety (Mineka & Zinbarg, 2006; Öhman & Mineka, 2001) and because higher-order conditioning procedures, in particular, are thought to contribute to fear and avoidance behaviors in clinical anxiety (Foa et al. 1989), the circumstances under which fear responses may transfer to unconditioned associates should continue to be examined in basic scientific studies.

References

American Psychiatric Association. (2013). *Diagnostic and Statistical Manual of Mental Disorders* (5th ed.). Arlington, VA: American Psychiatric Publishing.

Anderson, B.A. (2016). The attention habit: How reward learning shapes attentional selection. *Annals of the New York Academy of Science, 1369,* 24-39.

Anderson, B.A. & Kim, H. (2019). On the relationship between value-driven and stimulus-driven attentional capture. *Attention, Perception, & Psychophysics, 81,* 607-613.

Anderson, B.A., Laurent, P.A., & Yantis, S. (2011). Value-driven attentional capture. *Proceedings of the National Academy of Sciences, 108,* 10367-10371.

Armstrong, T. & Olatunji, B.O. (2012). Eye tracking of attention in the affective disorders: A meta-analytic review and synthesis. *Clinical Psychology Review, 32,* 704-723.

Awh, E., Belopolsky, A.V., & Theeuwes, J. (2012). Top-down versus bottom-up attentional control: A failed theoretical dichotomy. *Trends in Cognitive Sciences, 16,* 437-443.

Bacon, W.F. & Egeth, H. E. (1994). Overriding stimulus-driven attentional capture. *Perception & Psychophysics, 55,* 485-496.

Belopolsky, A.V. (2015). Common priority map for selection history, reward and emotion in the oculomotor system. *Perception, 44,* 920-933.

Belopolsky, A.V. & Theeuwes, J. (2009). When are attention and saccade preparation dissociated? *Psychological Science, 20,* 1340-1347.

Bennett, K.P., Dickmann, J.S., & Larson, C.L. (2018). If or when? Uncertainty's role in anxious anticipation. *Psychophysiology, 55,* e13066.

Bouton, M.E. (2004). Context and behavioral processes in extinction. *Learning and Memory, 11,* 485-494.

Boyle, S., Roche, B., Dymond, S., & Hermans, D. (2015). Generalization of fear and avoidance along a semantic dimension. *Cognition and Emotion, 30,* 340-352.

Brogden, W.J. (1939). Sensory pre-conditioning. *Journal of Experimental Psychology, 25,* 323-332.

Cisler, J.M. & Koster, E.H.W. (2010). Mechanisms of attentional biases towards threat in anxiety disorders: An integrative review. *Clinical Psychology Review, 30,* 203-316.

Craske, M.G., Rauch, S.L., Ursano, R., Prenoveau, J., Pine, D.S., & Zinbarg, R.E. (2009). What is an anxiety disorder? *Depression and Anxiety, 26,* 1066-1085.

Deubel, H. & Schneider, W.X. (1996). Saccade target selection and object recognition: Evidence for a common attentional mechanism. *Vision Research, 36,* 1827-1836.

Devue, C., Belopolsky, A.V., & Theeuwes, J. (2011). The role of fear and expectancies in capture of covert attention by spiders. *Emotion, 11,* 768-775.

Dunsmoor, J.E., Kragel, P.A., Martin, A., & LaBar, K.S. (2013). Aversive learning modulates cortical representations of object categories. *Cerebral Cortex, 24,* 2859-2872.

Dunsmoor, J.E., & LaBar, K.S. (2013). Effects of discrimination training on fear generalization gradients and perceptual classification in humans. *Behavioral Neuroscience, 127,* 350-356.

Dunsmoor, J.E., Martin, A., & LaBar, K.S. (2012). Role of conceptual knowledge in learning and retention of conditioned fear. *Biological Psychology, 89,* 300-305.

Dunsmoor, J.E. & Murphy, G.L. (2015). Categories, concepts, and conditioning: How humans generalize fear. *Trends in Cognitive Sciences, 19,* 73-77.

Dunsmoor, J.E., White, A.J., & LaBar, K.S. (2011). Conceptual similarity promotes generalization of high order fear learning. *Learning & Memory, 18,* 156-160.

Dymond, S., Dunsmoor, J.E., Vervliet, B., Roche, B., & Hermans, D. (2015). Fear generalization in humans: Systematic review and implications for anxiety disorder research. *Behavior Therapy, 46,* 561-582.

Egeth, H. E., & Yantis, S. (1997). Visual attention: Control, representation, and time course. *Annual Review of Psychology, 48,* 269-297.

Failing, M.F. & Theeuwes, J. (2014). Exogenous visual orienting by reward. *Journal of Vision, 14,* 6.

Failing, M.F. & Theeuwes, J. (2015). Nonspatial attentional capture by previously rewarded scene semantics. *Visual Cognition, 23,* 82-104.

Failing, M.F. & Theeuwes, J. (2017). Don't let it distract you: How information about the availability of reward affects attentional selection. *Attention, Perception, & Psychophysics, 79,* 2275-2298.

Fan, J.E. & Turk-Browne, N.B. (2016). Incidental biasing of attention from visual long-term memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 42,* 970-977.

Ferrante, O., Patacca, A., Di Caro, V., Della Libera, C., Santandrea, E., & Chelazzi, L. (2018). Altering spatial priority maps via statistical learning of target selection and distractor filtering. *Cortex, 102,* 67-95.

Foa, E.B., Steketee, G., & Rothbaum, B.O. (1989). Behavioral cognitive conceptualization of post-traumatic stress disorder. *Behavior Therapy, 20,* 155-176.

Fox, E., Russo, R., Bowles, R., & Dutton, K. (2001). Do threatening stimuli draw or hold visual attention in subclinical anxiety? *Journal of Experimental Psychology: General, 130,* 681-700.

Franconeri, S.L. & Simons, D.J. (2003). Moving and looming stimuli capture attention. *Perception & Psychophysics, 65,* 999-1010.

Gaspelin, N., Leonard, C.J., & Luck, S.J. (2017). Suppression of overt attentional capture by salient-but-irrelevant color singletons. *Attention, Perception, & Psychophysics, 79,* 45-62.

Gaspelin, N. & Luck, S.J. (2018). The role of inhibition in avoiding distraction by salient stimuli. *Trends in Cognitive Sciences, 22,* 79-92.

Gewirtz, J.C. & Davis, M. (2000). Using Pavlovian higher-order conditioning paradigms to investigate the neural substrates of emotional learning and memory. *Learning & Memory, 7,* 257-266.

Godijn, R. & Theeuwes, J. (2002). Programming of endogenous and exogenous saccades: Evidence for a competitive integration model. *Journal of Experimental Psychology: Human Perception and Performance, 28,* 1039-1054.

Hannula, D.E., Ryan, J.D., Tranel, D., & Cohen, N.J. (2007). Rapid onset relational memory effects are evidence in eye movement behavior, but not in hippocampal amnesia. *Journal of Cognitive Neuroscience, 19,* 1690-1705.

Hickey, C., McDonald, J.J., & Theeuwes, J. (2006). Electrophysiological evidence of the capture of visual attention. *Journal of Cognitive Neuroscience, 18,* 604-613.

Hopkins, L.S., Helmstetter, F.J., & Hannula, D.E. (2016). Eye movements are captured by a perceptually simple conditioned stimulus in the absence of explicit contingency knowledge. *Emotion, 16,* 1157-1171.

Horner, A.J., Bisby, J.A., Bush, D., Lin, W., & Burgess, N. (2015). Evidence for holistic episodic recollection via hippocampal pattern completion. *Nature Communications* 6:7462.

Hovland, C.I. (1937). The generalization of conditioned responses: I. The sensory generalization of conditioned responses with varying frequencies of tone. *Journal of General Psychology, 17,* 125-148.

Hunt, A.R., Cooper, R.M., Hungr, C., & Kingstone, A. (2007). The effect of emotional faces on eye movements and attention. *Visual Cognition, 15,* 513-531.

Irwin, D.E., Colcombe, A.M., Kramer, A.F., & Hahn, S. (2000). Attentional and oculomotor capture by onset, luminance and color singletons. *Vision Research, 40,* 1443-1458.

Jasnow, A.M., Lynch III, J.F., Gilman, L., & Riccio, D.C. (2016). Perspectives on fear generalization and its implications for emotional disorders. *Journal of Neuroscience Research,* jnr.23837.

Jonides, J. (1980). Voluntary vs. automatic control over the mind's eye's movement. In J.B. Long & A.D. Baddeley (Eds.), *Attention and performance IX* (pp. 187-203). Hillsdale, NJ: Erlbaum.

Karpicke, J.D. & Blunt, J.R. (2011). Retrieval practice produces more learning than elaborative studying with concept mapping. *Science, 331,* 772-775.

Koster, E.H.W., Crombez, G., Van Damme, S., Verschuere, B., & De Houwer, J. (2004). Does imminent threat capture and hold attention? *Emotion, 4,* 312-317.

LeDoux, J. (1998). Fear and the brain: Where have we been, and where are we going? *Biological Psychiatry, 44,* 1229-1238.

Le Pelley, M.E., Pearson, D., Griffiths, O., & Beesley, T. (2015). When goals conflict with values: Counterproductive attentional and oculomotor capture by reward-related stimuli. *Journal of Experimental Psychology: General, 144,* 158-171.

Lipp, O.V. (2006). Of snakes and flowers: Does preferential detection of pictures of fear-relevant animals in visual search reflect on fear-relevance? *Emotion, 6,* 296-308.

Lissek, S. (2012). Toward an account of clinical anxiety predicated on basic, neutrally mapped mechanisms of Pavlovian fear-learning: The case for conditioned overgeneralization. *Depression and Anxiety, 29,* 257-263.

Lissek, S., Biggs, A.L., Rabin, S.J., Cornwell, B.R., Alvarez, R.P., Pine, D.S., & Grillon, C. (2008). Generalization of conditioned fear-potentiated startle in humans: Experimental validation and clinical relevance. *Behaviour Research and Therapy, 46,* 678-687.

Lissek, S., Powers, A.S., McClure, E.B., Phelps, E.A., Woldehawariat, G., Grillon, C., & Pine, D.S. (2005). Classical fear conditioning in the anxiety disorders: A meta-analysis. *Behaviour Research and Therapy, 43,* 1391-1424.

Ludwig, C.J.H. & Gilchrist, I.D. (2003). Goal-driven modulation of oculomotor capture. *Perception & Psychophysics, 65,* 1243-1251.

Maljkovic, V. & Nakayama, K. (1994). Priming of pop-out: I. Role of features. *Memory & Cognition, 22,* 657-672.

Maltzman, I., Langdon, B., Pendery, M., & Wolff, C. (1977). Galvanic skin response-orienting reflex and semantic conditioning and generalization with different unconditioned stimuli. *Journal of Experimental Psychology: General, 106,* 141-171.

Maren, S. (2001). Neurobiology of Pavlovian fear conditioning. *Annual Review of Neuroscience, 24,* 897-931.

Mineka, S. & Zinbarg, R. (2006). A contemporary learning theory perspective on the etiology of anxiety disorders. *American Psychologist, 61,* 10-26.

Mulckhuyse, M. (2018). The influence of emotional stimuli on the oculomotor system: A review of the literature. *Cognitive, Affective, & Behavioral Neuroscience, 18,* 411-425.

Mulckhuyse, M., Crombez, G., & Van der Stigchel, S. (2013). Conditioned fear modulates visual selection. *Emotion, 13,* 529-536.

Mulckhuyse, M. & Dalmaijer, E.S. (2016). Distracted by danger: Temporal and spatial dynamics of visual selection in the presence of threat. *Cognitive, Affective, & Behavioral Neuroscience, 16,* 315-324.

Mulckhuyse, M., Van der Stigchel, S., & Theeuwes, J. (2009). Early and late modulation of saccade deviations by target distractor similarity. *Journal of Neurophysiology, 102,* 1451-1458.

Myers, K. & Davis, M. (2002). Behavioral and neural analysis of extinction. *Neuron, 36,* 567-584.

Nickel, Hopkins, Minor, & Hannula (2019). *Attention capture by episodic long-term memory.* Manuscript submitted for publication.

Nissens, T., Failing, M., & Theeuwes, J. (2017). People look at the object they fear: Oculomotor capture by stimuli that signal threat. *Cognition and Emotion, 31,* 1707-1714.

Notebaert, L., Crombez, G., Van Damme, S., De Houwer, J., & Theeuwes, J. (2011). Signals of threat do not capture, but prioritize, attention: A conditioning approach. *Emotion, 11,* 81-89.

Öhman, A., Flykt, A., & Esteves, F. (2001). Emotion drives attention: Detecting the snake in the grass. *Journal of Experimental Psychology: General, 130,* 466-478.

Öhman, A., Lundqvist, D., & Esteves, F. (2001). The face in the crowd revisited: A threat advantage with schematic stimuli. *Journal of Personality and Social Psychology, 80,* 381-396.

Öhman, A. & Mineka, S. (2001). Fears, phobias, and preparedness: Toward an evolved module of fear and fear learning. *Psychological Review, 108,* 483-522.

Pfautz, P.L., Donegan, N.H., & Wagner, A.R. (1978). Sensory preconditioning versus protection from habituation. *Journal of Experimental Psychology: Animal Behavior Processes, 4,* 286-295.

Pinto, Y., Olivers, C.N.L., & Theeuwes, J. (2005). Target uncertainty does not lead to more distraction by singletons: Intertrial priming does. *Perception & Psychophysics, 67,* 1354-1361.

Posner, M. (1980). Orienting of attention. *The Quarterly Journal of Experimental Psychology, 32,* 3-25.

Preciado, D., Munneke, J., & Theeuwes, J. (2017). Was that a threat? Attentional biases by signals of threat. *Emotion, 17,* 478-486.

Quinlan, P.T. (2013). The visual detection of threat: A cautionary tale. *Psychonomic Bulletin Review, 20,* 1080-1101.

Raine, L.B., Lee, H.K., Saliba, B.J., Chaddock-Heyman, L., Hillman, C.H., & Kramer, A.F. (2013). The influence of childhood aerobic fitness on learning and memory. *PLoS One, 8,* e72666.

Raio, C.M., Carmel, D., Carrasco, M., & Phelps, E.A. (2012). Nonconscious fear is quickly acquired but swiftly forgotten. *Current Biology, 22,* 477-479.

Ratcliff, R. (1979). Group reaction-time distributions and an analysis of distribution statistics. *Psychological Bulletin, 86,* 446-461.

Rizley, R.C. & Rescorla, R.A. (1972). Associations in second-order conditioning and sensory preconditioning. *Journal of Comparative and Physiological Psychology, 81,* 1-11.

Rudy, J.W. & Pugh, C.R. (1996). A comparison of contextual and generalized auditory-cue fear conditioning: Evidence for similar memory processes. *Behavioral Neuroscience, 110,* 1299-1308.

Saslow, M.G. (1967). Latency for saccadic eye movement. *Journal of Optical Society of America, 57,* 1030-1033.

Sawaki, R. & Luck, S.J. (2010). Capture versus suppression of attention by salient singletons: Electrophysiological evidence for an automatic attend-to-me signal. *Attention, Perception, and Psychophysics, 72,* 1455-1470.

Schmidt, L.J., Belopolsky, A.V., & Theeuwes, J. (2012). The presence of threat affects saccade trajectories. *Visual Cognition, 20,* 284-299.

Schmidt, L.J., Belopolsky, A.V., & Theeuwes, J. (2015a). Attentional capture by signals of threat. *Cognition and Emotion, 29,* 687-694.

Schmidt, L.J., Belopolsky, A.V., & Theeuwes, J. (2015b). Potential threat attracts attention and interferes with voluntary saccades. *Emotion, 15,* 329-338.

Schmidt, L.J., Belopolsky, A.V., & Theeuwes, J. (2017). The time course of attentional bias to cues of threat and safety. *Cognition and Emotion, 31,* 845-857.

Schultz, D.H. & Helmstetter, F.J. (2010). Classical conditioning of autonomic fear responses is independent of contingency awareness. *Journal of Experimental Psychology: Animal Behavior Processes, 36,* 495-500.

Shohamy, D. & Wagner, A.D. (2008). Integrating memories in the human brain: Hippocampal-midbrain encoding of overlapping events. *Neuron, 60,* 378-389.

Theeuwes J. (1989). Effects of location and form cueing on the allocation of attention in the visual-field. *Acta Psychologica, 72,* 177-192.

Theeuwes, J. (1991). Exogenous and endogenous control of attention – The effect of visual onsets and offsets. *Perception & Psychophysics, 49,* 83-90.

Theeuwes, J. (1992). Perceptual selectivity for color and form. *Perception & Psychophysics, 51,* 599-606.

Theeuwes, J. (1994). Stimulus-driven capture and attentional set: Selective search for color and visual abrupt onsets. *Journal of Experimental Psychology: Human perception and performance*, *20*(4), 799.

Theeuwes, J. (2018). Visual selection: Usually fast and automatic; seldom slow and volitional. *Journal of Cognition, 1*(1), 29.

Theeuwes, J. & Belopolsky, A.V. (2012). Reward grabs the eye: Oculomotor capture by rewarding stimuli. *Vision Research, 74,* 80-85.

Theeuwes, J., De Vries, G.J., & Godijn, R. (2003). Attentional and oculomotor capture by static singletons. *Perception & Psychophysics, 65,* 735-746.

Theeuwes, J. & Godjin, R. (2001). Attentional and oculomotor capture. In C.L. Folk & B.S. Gibson (Eds.), *Attraction, distraction, and action: Multiple perspectives on attentional capture*. New York: Elsevier Science.

Theeuwes, J., Kramer, A.F., Hahn, S., & Irwin, D.E. (1998). Our eyes do not always go where we want them to go: Capture of the eyes by new objects. *Psychological Science, 9,* 379-385.

Theeuwes, J., Kramer, A.F., Hahn, S., Irwin, D.E., & Zelinsky, G.J. (1999). Influence of attentional capture on oculomotor control. *Journal of Experimental Psychology: Human Perception and Performance, 25,* 1595-1608.

Theeuwes, J. & Van der Burg, E. (2007). The role of spatial and nonspatial information in visual selection. *Journal of Experimental Psychology: Human Perception and Performance, 33,* 1335-1351.

Treisman, A.M. & Galade, G. (1980). A feature-integration theory of attention. *Cognitive Psychology, 12,* 97-136.

van Zoest, W., Donk, M., & Theeuwes, J. (2004). The role of stimulus-driven and goal-driven control in saccadic visual selection. *Journal of Experimental Psychology: Human Perception and Performance, 30,* 746-759.

van Zoest, W., Van der Stigchel, S., & Donk, M. (2017). Conditional control in visual selection. *Attention, Perception, and Psychophysics, 79,* 1555-1572.

Vansteenwegen, D., Crombez, G., Baeyens F., Hermans, D., & Eelen, P. (2000). Pre-extinction of sensory preconditioned electrodermal activity. *The Quarterly Journal of Experimental Psychology, 53,* 359-371.

Wang, B. & Theeuwes, J. (2018). Statistical regularities modulate attentional capture independent of search strategy. *Attention, Perception, & Psychophysics, 44,* 13-17.

Wimmer, G.E. & Shohamy, D. (2012). Preference by association: How memory mechanisms in the hippocampus bias decisions. *Science, 338,* 270-273.

Wolfe, J.M. (2010). Visual search. *Current Biology, 20,* R346.

Wolfe, J.M., Butcher, S.J., Lee, C., & Hyle, M. (2003). Changing your mind: On the contributions of top-down and bottom-up guidance in visual search for feature singletons. *Journal of Experimental Psychology, 29,* 483-502.

Wolfe, J.M. & Horowitz, T.S. (2004). What attributes guide the deployment of visual attention and how do they do it? *Nature Reviews Neuroscience, 5,* 495-501.

Wolfe, J.M. & Horowitz, T.S. (2017). Five factors that guide attention in visual search. *Nature Human Behaviour, 1,* article number 0058.

Yantis, S. & Jonides, J. (1984). Abrupt visual onsets and selective attention: Evidence from visual search. *Journal of Experimental Psychology: Human Perception and Performance, 10,* 601-621.

Yantis, S. & Jonides, J. (1990). Abrupt visual onsets and selective attention: Voluntary versus automatic allocation. *Journal of Experimental Psychology: Human Perception and Performance, 16,* 121-134.

Zhao, J., Al-Aidroos, N., & Turk-Browne, N.B. (2013). Attention is spontaneously biased toward regularities. *Psychological Science, 24,* 667-677.

APPENDIX A:

Hopkins et al. (2016)'s PEQ

Post-Experimental Questionnaire

1. What do you think our experiment was attempting to measure?

2. In the first part did you notice any association or pattern between the circles and the shock? Please circle one.

              No   Yes

3. If you answered 'yes' to question 2, which was the pattern you noticed?

4. If you had to guess, which circle would you say shocked you more?

Red   I got shocked   Green
                         The same amount by each

5. How would you rate the intensity of electrical stimulation at the end of the experiment on a scale 0-10?

    0   1   2   3   4   5   6   7   8   9   10

(0=no sensation)   (10=painful, but tolerable)

Post-Experimental Questionnaire

1. What do you suspect was the objective of the experiment?

2. Did you notice any association or pattern between the display characteristics (e.g., the colored circles, scenes – if they were used) and the delivery of the electrical stimulus? Please circle your response.

    No   Yes

3. If your response to Question 2 was 'yes,' then please describe the pattern you noticed.

4. If you had to guess, which circle would you say was most often associated with the electrical stimulus? Please circle your response based on the options below.

Blue	Orange	Green	All Colors Equally Often	Electrical Stimulus Not Related to Color

5. If you indicated in response to Question 4 that the electrical stimulus was not tied to color, do you believe that it was systematically related to something else? Explain.

6. How would you rate the intensity of the electrical stimulus at the end of the experiment on a scale 0-10?

    0   1   2   3   4   5   6   7   8   9   10

    0 = No Sensation   10 = Painful but Tolerable