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CONTEXT AND TARGET SEARCH REVERSAL: IMPLICIT FLEXIBILITY AND

RAPID ADAPTATION OF RELATIONAL MEMORIES USING VISUAL SEARCH

by

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ABSTRACT
CONTEXT AND TARGET SEARCH REVERSAL: IMPLICIT FLEXIBILITY AND
RAPID ADAPTATION OF RELATIONAL MEMORIES USING VISUAL SEARCH

by

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Under the Supervision of Professor Anthony Greene

Repeated perceptual exposure leads to increased accuracy and decreased response latency – referred to as perceptual facilitation or priming – and generally occurs in the absence of conscious memory experience. One example of a priming task which depends upon contextual relations is termed contextual cuing. It has long been held that context-dependent relations can only be acquired with deliberative or explicit processes. While context learning has historically been attributed to declarative memory, the existence of implicit context learning tasks may be better explained as an implicit relational learning process. Although implicit memories have long been characterized as relatively rigid, such tasks raise the possibility of implicit flexible learning. If relational learning entails flexibility in memories and it is possible to encode relations implicitly, then the contextual cuing task should demonstrate implicit flexibility.

The current experiments further investigate the idea that relational learning is possible in the absence of awareness by examining a series of three-phase contextual cuing protocols. Using this visual search task, memory for target location in a repeated context is established and then manipulated by altering target location in repeated arrays

by moving the target different locations (reversal/switch). If implicit flexibility is possible, then reversing contextual contingencies should only transiently disrupt visual search latencies. As such, these reversals should produce little in the way of a behavioral cost. While reversing contingencies has historically been shown to produce behavioral costs, the consequences of doing so in this type of visual search task has not been attempted. Overall, this study hopes to show an overall greater efficiency in visual search by way of rapidly adapting implicit learning processes.

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Introduction

Characterization of explicit and implicit memory. Functional long term memory depends on an individual's ability to recall specific experiences learned under particular circumstances. Recognition, or recall, involving deliberative recovery of learned experiences is referred to as explicit memory because it occurs with awareness. Explicit memory can further be divided into episodic and semantic memory. The later refers to knowledge about the world that has been encountered and used frequently and, as such recall does not involve recollection of personal experience(Tulving, 1985). Semantic memory can be demonstrated by observing reaction time, such that, faster reaction times for accurate responses to true or false questions during a sentence verification task, demonstrates greater knowledge, while slower reaction time indicates less knowledge (Kounios & Holcomb, 1992).

Episodic memory is referred to as autobiographical memory for specific events and is dependent upon personal experiences. For example, in a free-recall experiment, a participant may first be asked to study a list of words, and then later asked to recall only those items that are frequently encountered (Squire & Zola, 1998; Tulving & Markowitsch, 1998; Yonelinas, 2001). Episodic memory provides a chronicle of our daily activities, bonding the complexities of our experiences together in meaningful ways. In fact, recall is more robust for related items than it is for items presented in isolation (Blumenfeld, Parks, Yonelinas, & Ranganath, 2011; Bobrow & Easton, 1972).

On the other hand, memory that influences behavior covertly is described as implicit memory and occurs in the absences of awareness (Cohen, Eichenbaum, Deacedo, & Corkin, 1985). Implicit memory is often broken down into procedural learning and

priming. Procedural memory, or skill learning, is observed though enhanced speed and accuracy when performing, for example, sensory motor tasks like mirror tracing. Perceptual priming is described as enhanced recognition for previously experienced items. For example, a picture completion test would involve exposure to a complete drawing and later, at test, partial drawings created from previously primed items are presented. If the partial drawing is experienced early as a whole (primed), it will be identified more rapidly than non-primed pictures (H. Eichenbaum, 1997; Squire, 1998). Both procedural learning and priming show how behavior is modifiable through repeated exposure of stimuli.

Extant view of exclusivity for flexibility in memory. To function in an ever-changing environment, experiences learned in one circumstance must be applied to novel circumstances, which are thereby flexible. This malleability allows for previously learned information to be recalled and applied to novel situations when presented with a subset of the original material (Postman, 1951). This function of memory is adaptive, as it allows for the binding of novel information to established mnemonic traces (Hunt & Einstein, 1981). Therefore, a memory system suited for flexibility possesses the propensity for predictability and discrimination. In other words, a parsimonious explanation involving a "dual-process" memory system is preferred to two "single-process" models separately specializing in flexibility and specificity (Koen & Yonelinas, 2010).

Research is rife with support for mnemonic flexibility for both implicit and explicit memory. Implicit memory, for example, has historically been thought of as insensitive to context and highly specific to surface features, due to its rather limited

capacity and inflexibility (Luck & Vogel, 1997). In fact, priming diminishes when discrepancies between the learning and test episode arise (Tulving & Schacter, 1990). Further evidence supporting this rigidity shows that priming is specific to stimulus features, such that changes in shape or size between study and test items result in decreased priming (Roediger & Blaxion., 1987). Collectively, these results suggest that events encoded implicitly are thought to be encoded as a unitized whole and, as such, are described as being fragile and impervious to rapid adaptation (Dienes & Berry, 1997).

The argument against implicit flexibility has been championed by the proposal that adaptable manipulation of contingencies requires deliberation, particularly as the complexity of the relationship between items increases (Clark & Squire, 1998). By this account, all complex memories must be explicit, because implicit memory lacks the flexibility required for adaptable reorganization of contingencies. Accordingly, it has previously been shown that as tasks become more elaborate and require more effortful study, task contingencies tend to become explicit. Furthermore, elaborative processing facilitates learning new explicit associations, and its prevention leads to poor recall (Schacter, 1987).

Environmental demands dictate flexibility in implicit and explicit memory. Relational learning provides a more modern account of flexibility in memory. The relational memory model describes the environment as the binding of items in context. In this way, the target and relevant surrounding items are bound together based on their associations to one another (Eichenbaum, et al., 2007). This binding remains robust during retro and proactive interference, across varieties of visual complexity, and during high capacity demand (Jiang, Song, & Rigas, 2005). As such, the relational learning

view argues that episodic memory is a type of associative learning, and is therefore

indistinct in its characterization as implicit or explicit (Manns & Eichenbaum, 2006).

Neurological results also support this model by indicating that explicit and implicit

memory processes occur concurrently, suggesting possible interactions during encoding

and retrieval (Voss & Paller, 2008).

It has recently been argued that the characterization of explicit and implicit

memory is misleading. While it has long been shown that episodic memories are subject

to novel application, a rapidly expanding body of evidence suggests that implicit memory

is also capable of encoding context flexibly (Greene, Gross, Elsinger, & Rao, 2007;

Kristjánsson & Campana, 2010; Ostreicher, Moses, Rosenbaum, & Ryan, 2010).

Moreover, recent experiments have shown that the two depend on similar mnemonic

processes (Voss, Lucas, & Paller, 2010). In fact, when explicit memory is compromised

due to decreased attention during encoding, recognition remains highly accurate in the

absences of awareness (Voss, Baym, & Paller, 2008). More specifically, when explicit

recognition is made to fail, implicit knowledge can produce accurate recognition (Voss &

Paller, 2010). Furthermore, recent evidence suggests that implicitly learned information

can be context independent and applied to novel situations (Greene, 2007; Greene,

Spellman, Dusek, Eichenbaum, & Levy, 2001; Greene, Gross, Elsinger, & Rao, 2007;

Gross & Greene, 2007; Leo & Greene, 2008). Altogether, these results argue against the

view that implicit and explicit memory is mutually exclusive on the basis of flexibility.

Instead, emerging evidence favors the view that contextual relations are elaborately

encoded and available to implicit processes. Yet despite the growing body of research

consisting of properties once thought to be exclusive to explicit memory, little is known about how to characterize similar contributions by implicit memory.

The contextual cuing task. One example of a context-dependent experiment is the contextual cuing task. Initially described by Chun & Jiang (1998), the contextual cuing effect is an implicit learning and memory process that facilitates visual search. The protocol involves finding a rotated target "T" among an array of distractor "Ls" (See Figure 1). Half of the arrays are repeated throughout the experiment, while the other half are novel. The contextual cuing task involves two distinct types of learning. Procedural learning occurs as a result of persistent practice with the task. Reaction time decreases rapidly during the first experimental blocks and then nears asymptote. This form of learning occurs for both novel and repeated arrays. Decreased reaction time for target search in repeated arrays surpasses the benefits bestowed by procedural practice alone (See Figure 2). Contextual information, imparted by the configuration of distractors in repeated arrays, is believed to cue target location. In this way, memory for the spatial configurations is reinforced across experimental blocks and reaction time decreases as the contextual traces strengthen (Chun & P., 1999; Chun & Nakayama, 2000). Participants learn the predictive value of repeated arrays, which facilitates visual search in the contextual cuing paradigm.

Recognition tests measuring explicit memory support the implicit nature of the contextual cuing effect. As mentioned, participants benefit from exposure to repeated arrays without explicit memory of having experienced the displays previously. In fact, recognition tests asking participants to predict the quadrant of target locations results in chance performance (Chun & Jiang, 1998; Chun & P., 1999; Chun & Jiang, 2003; Gross

& Greene, 2007). Even when participants are informed of the repeated displays during instruction, identification of target location during recognition tests is performed at chance (Chun & Jiang, 2003). These results are further supported by the fact that awareness remains elusive despite drastically increased recognition trials that include probes after each block (Geyer, Shi, & Müller, 2010). Even without explicit evidence for elaborate rehearsal of these contextual contingencies, the contextual cuing effect is stable and enduring, persisting for at least one week (Chun & Jiang, 2003). Implicit knowledge governs the contextual cuing effect despite many efforts to increase deliberative processing.

Flexibility in implicit contextual learning has been tested using various stimulus manipulations. While most versions use the standard block-type letter shapes for stimuli, the task can be made more difficult when more ambiguous stimuli are presented and, as a result, reaction time suffers and contextual cuing takes longer to develop (Chun & Jiang, 1998). The color of the stimuli has also been manipulated in an attempt to elucidate the cognitive mechanisms surrounding contextual cuing. Unless explicitly explained, grouping stimuli by color offers no additional benefits to visual search (Y. Jiang & Chun, 2001; Olson & Chun, 2002). However, in a modified protocol using color to produce the spatial context, visual search is facilitated. Similarly, contextual cuing is present even in displays that lack color but vary in luminance, though the effect is less pronounced (Huang, 2006). While color and shape impart certain stimulus features, the greatest predictive benefits to visual search are spatial. The implicit knowledge gained throughout the contextual cuing task is capable of enduring stimulus manipulations, like

color and font type, suggesting that these rather arbitrary features fail to significantly contribute to relational learning.

Relational learning in the contextual cuing effect has been noted during various spatial manipulations as well. To this point, reaction time suffers when target location and predictive distractors are spatially separated by noise. Olson and Chun (2002) examined whether contextual cuing is the result of associative learning or local contextual priming by altering the predictive environment of the target. Reaction time was measured using four array configurations; repeated (arrays repeat), a novel configuration (arrays are variant), short range context (array split with the half containing the target repeating), and long range context (array split with the half not containing the target repeating). If the target location is embedded within invariant distractors, even when the other half of the stimulus field consists of novel distractors, reaction time resembles the classic repeated benefit (Olson & Chun, 2002). Further, the contextual cuing effect remains robust in situations wherein the invariant context is restricted to the quadrant shared with the target. This attention to the local context persists even when the entire display is predictive. On the contrary, it has been shown that shuffling the distractors, thus disrupting the associative relationships among the global context, diminishes the contextual cuing effect (Chun & Jiang, 1998). As such, when the predictive quadrant becomes variable the contextual cuing effect vanishes (Brady & Chun, 2007). Collectively, these results suggest that local contextual priming drives the contextual cuing effect, but suggests that global associations can also play a contributing role.

The resilience of the contextual cuing effect has also been tested under conditions that change the contingencies under which the arrays are originally learned. Contextual cuing is diminished in many instances of relational change, suggesting that the items in the search environment provide a predictive advantage(Chun & Jiang, 1998; Y. Jiang, Chun, & Olson, 2004; Makovski & Jiang, 2010; Manginelli & Pollmann, 2009). For example, when repeated targets are relocated to previously empty space at least 4.32° away from the originally learned location, contextual cuing is abolished. Similarly, when previously learned targets switch with repeated distractors, a slight cost is incurred as search for the target continues to utilize misleading cues (Makovski & Jiang, 2010). Similar studies have found contextual cost in similar situations, and have also indicated that the misleading cues are only transiently disruptive as contextual cuing is rapidly reestablished (Manginelli & Pollmann, 2009). Research has also shown that constantly changing target locations results in the failure to develop the contextual cuing effect in the absence of previous experience in a repeated search environment (Chun & Jiang, 1998). Recent pilot data from our lab supports the former mentioned results that relocation of the target with a distractor eliminates the contextual cuing effect for a short period of time. However, this preliminary data also suggests that after targets are again returned to the originally learned location the contextual cuing effect continues, uninterrupted. This implies that the contextual cuing effect is capable of rapid adaptation to changed contingencies and remains an implicit mnemonic process despite increased contextual complexities. Overall, this indicates that implicit memory is associative in nature and, as such, is capable of flexibility.

Research questions

The primary goal for this experimental endeavor is to determine the effect of multiple modifications to target location and observe the resulting impact on the contextual cuing effect. As mentioned, manipulating target locations within repeated displays disrupts the associations between items resulting in decreased search speed. Thus, while target manipulation seems to produce a behavioral cost in search speed, there is little evidence as to why this cost only disrupts search transiently. The momentary cost to, and rapid return of, the contextual cuing effect could be due to an improved global search strategy. It is also possible that memory for repeated local contexts makes it easier to reacquire cues that guide search. The effect that target manipulations have on reaction time should help elucidate the governing search strategy. This experiment is also expected to provide evidence to the claim that implicit memories can be flexibly applied to changed contexts. There are many examples of implicit relational learning, and relational learning views are supportive of flexibility, however there is little evidence of implicit memory accommodating relational changes. The relational learning theory can account for the contextual cuing phenomenon, an implicit example of relational learning, and therefore it should be possible to demonstrate flexibility using this task.

Method

Participants

The participant pool for this project consisted of University of Wisconsin-Milwaukee students aged 18 to 30. For all experiments, $N = 122$ students participated. Compensation for participation included course extra credit and $10 campus giftcards ($5 per hour). Power analyses were performed for 2x3 (Type by Time) repeated measures design, using $\alpha = 0.05$, and desired power $= 0.8$. These analyses revealed that

approximately 30 participants per experiment will provide sufficient power to detect a significant result (Lenth, 2006). This analysis compliments previous research by Chun & Jiang (1998) and Green et al. (2007) who found significant results with $n = 16$ and 26, respectively.

All participants completed an informed consent (approved by the University of Wisconsin-Milwaukee Institutional Review Board) upon arriving in the lab. After completion, the principal investigator or research assistant provided oral instruction to the participant. Instruction included basic experimental procedures and response directions. Particularly stressed during this instruction period was to respond as fast and accurately as possible and to keep still. The instructions were sufficiently vague, omitting terms such as "memory" and "remember" which would otherwise bias the subject to the underlying theoretical goals of the experiment. After consenting, participants were seated at the experimental computer.

Experimental setup

Stimuli were presented on a 17 inch LCD color monitor (resolution of 1280 by 1024). The program "Presentation" (Version 14.6) was used to produce all stimuli as well as record reaction times, behavioral responses, and the timing of all experimental events. Experiments were presented on a Dell™ Optiplex 755 Intel ® Core™ 2 Duo CPU with 2.33 GHz, 1.95 GB RAM, running Microsoft Windows XP Professional Version 2002, Service Pack 3. Behavioral responses were made using a Dell™ two-button mouse.

Procedure

Participants were seated, unrestrained, in a chair approximately 24 inches from the monitor. Experimental instruction was provided by a researcher and as part of an on-screen tutorial. Afterwards a brief (approximately 10 minutes) training phase took place, allowing the participant to become oriented with the response methods and experimental procedure. Each experimental block was separated by one minute rest periods. Each array was presented for 3000 ms, though most reaction times occured before 1500 ms. During array presentation, reaction time and accuracy was recorded. After completion participants performed a short 12 trial recognition test, asking to predict target location in arrays missing an actual target.

The visual stimuli follow those used by Chun & Jiang (1998). Each stimulus display will contained one target "T" and 11 distractor "Ls" for a total of 12 stimuli per array. The target was displayed at either 90° or 270° while distractors were displayed at 0°, 90°, 180°, and 270°. The direction of the target's tail (the stem of the "T") and the orientation of the distractors were randomized during each trial. Similarly, the color of both the target and distractor were randomly assigned for each trial, and include blue, green, red, and yellow. Each color was equally represented in each array. The location of each item was determined by placing it on an arm of an imaginary 8 by 6 grid that extends approximately 37.2° by 28.3° in visual angle. All stimulus items were presented on a gray background.

This study employed a block design consisting of multiple sets. All experiments consisted of 27 blocks, each containing 24 trials for a total of 648 array presentations. The 27 blocks were divided in to nine block sets, creating a 9 by 9 by 9 design. Like the aforementioned contextual cuing experiments, this experiment used two array types.

During each experimental block 12 repeated and 12 novel arrays were presented. Unlike novel arrays, whose target and distractor items are continuously being reconstructed into new organizations, repeated arrays maintain target and distractor location throughout the experiment. For example, array type repeat "1" (of 12) presented in block one looked exactly like array type repeat "1" of block 7. The order of novel and repeat arrays was random within each block. These traits were present in all three experiments. Each trail was separated with a varying inter trial interval (ITI). Breaks of one minute occurred every three blocks. Participants were told to remain seated during these breaks. Testing took place over a single 105 minute session.

Experiment 1 was a replication of the pilot work discussed earlier. It is best described as an ABA design, where the alphabet letters represent sets of target locations (See Figure 3). The first nine blocks are intended to replicate the contextual cuing design described in Chun (1998), wherein repeated displays are randomly inserted into blocks along with novel displays. During the following set of nine blocks, repeated arrays were modified by switching the target positions with a distractor. In this way, a new set of 12 repeated arrays were created during block 10 and continued to be presented, randomly along with novel arrays, for the middle group of nine blocks. Beginning during block 19 the repeated arrays were again altered by switching the target location back to the original position presented during blocks 1 through 9. Experiment 2 followed an ABC design. Epochs 1 and 2 mimicked the design laid out in Experiment 1. During phase 3 ("C") the target locations for repeated arrays was again be switched with a distractor and maintained this new position for the remainder of the experiment (See Figure 4). This experiment, therefore, contained three sets of repeated arrays. Experiment 3 is an

ABRandom (ABR) design. This experiment, too, follows the design of Experiment 1 and 2 for the first two epochs. During the third phase the target location of repeated arrays continually switched places with distractors. As such, target location will not be maintained during this third set (See Figure 5). All three experiments test the flexibility of implicit memory by subtly modifying target location within repeated arrays.

Similar to the procedures found in Conci, et. al (2011), participants had to demonstrate contextual cuing during the initial phases of the experiment to be considered in the final analyses. Participants demonstrating contextual cuing at least 50% of the time (based on accuracy and reaction time) were included in further analyses. Sample sizes are described below within the results section of each experiment.

Expected outcomes

The proposed experiments are expected to replicated and produce novel outcomes. First, the contextual cuing effect will be replicated during the initial set of Experiment 1, 2, and 3. As mentioned, the procedure mimics historically robust protocols used to produce this effect. In this way, repeated and novel reaction times will separate to significant levels after approximately five blocks. Repeated measures ANOVA will test for main effects of array type and time as well as an interaction for type (repeated or novel) by time (block). Participants are expected to show enhanced performance as a function of experience with the procedure, faster reaction time for repeated versus novel arrays and, more specifically, an interaction between time and array type (i.e. the more exposure a participant has with the repeated arrays the lower the latency to find the target). Accuracy for detecting tail orientation is expected to be nearly perfect with an error rate of approximately 2 to 3 percent.

During the reversal phases of the experiments (Blocks 10-18 and 19-27 or the beginning of sets 2 and 3) the contextual cuing effect is expected to be compromised. Reaction time for old displays is likely to return to a novel-like rate; however, this is expected to be transient. After approximately three blocks the contextual cuing effect is expected to reestablish. This temporary increase in reaction time is proposed to be the result of misleading contextual cues. The relational trace for the old arrays may erroneously guide attention to the previously learned location during the reversed trials. Adaptation to target manipulation is expected, with the contextual cuing effect reestablishing itself shortly after target switching.

Relatively new to the misleading cue discussion is the outcome of reversals. All experiments are designed to test the flexibility of implicit memory by first examining the effect of single reversals. Reversals likely create a new learning environment by manipulating contextual contingencies among stimuli. If reaction time is unaffected during the ABA protocol and the contextual cuing effect persists, it may indicate that the trace for old displays is still intact and capable of coexisting with the new target location. This would indicate that similar associative traces for oft-experienced environments show little competition and can be recalled rapidly. On the other hand, reaction time could increase to novel-like rates, implying that a misplaced target is sufficient in producing a new learning environment. In this way, the predictive nature of the context must be reevaluated. This reevaluation process is likely to occur rapidly, which is an idea supported by the literature (Chun & Jiang, 1998; Y. Jiang, Chun, & Olson, 2004; Makovski & Jiang, 2010; Manginelli & Pollmann, 2009). Similarly, but undocumented in current literature, a behavioral cost could be incurred causing reaction time to be

greater than novel trials. Perhaps participants search the display using the relational trace learned during the original contextual environment and, upon failing to find the target, employ search strategies consistent with random environments, which will likely require additional time.

The effect of a second target manipulation is unclear and unprecedented.   While a second reversal presents another form of interference from previous learning environments, the contextual cuing effects develops rapidly (Chun, 1998). This suggests that even with the added interference, disruptions in reaction time are likely to be transient. The various planned experiments will all test implicit flexibility; however, the second target displacement portion is different for each manipulation. Experiment 1 will measure how rapidly the original visual search strategies are reacquired when the final reversal again places targets back to the parent positions. If the initial relational trace remained intact during the second target displacement, the contextual cuing effect will quickly recover. However, if the initial target displacement degrades the original relational trace, then the contextual cuing effect will likely be transiently disrupted similarly to the effects of the single displacement. The contextual cuing effect will rapidly redevelop as the predictive value of the arrays is reacquired from the original learning environment. Experiment 2 will test the limits of implicit flexibility when a third set of repeated arrays must be learned. The contextual cuing effect will likely be disrupted similarly to a single displacement. If implicit flexibility reaches some limit, the contextual cuing effect will likely take longer to redevelop following a second displacement. On the other hand, reaction time could respond similarly to single displacements, suggesting that implicit flexibility rapidly adapts and is relatively resistant

to the influence of previous learning environments. Finally, Experiment 3 will further measure the effects of target displacement on implicit memory by persistently displacing the target location. With the target location of repeated arrays constantly changing, participants should be incapable of learning the new relational configurations. This is likely to lead to repeated trial reaction time resembling novel search. In the absence of any predictive value to be gleaned from repeated arrays, the contextual cuing effect will likely be abolished. However, continued exposure to the repeated arrays, as a whole, will likely produce consistently faster reaction times, beyond what is to be expected from procedural learning, have been adopted. While still faster than novel searches, reaction times during the final phase of the ABC design will be greater than those in the ABA and ABC designs. Also, in accordance with previous results, recognition for old displays is predicted to be at chance levels. Despite the extended exposure to the experimental condition, this task is likely to remain an implicit learning experience.

Results

Experiment 1: ABA

A total of $n = 20$ participants were included in the analyses for Experiment 1. The mean reaction times (RT) for both array types within a block were computed and were aggregated into 3-block runs. The RTs are graphed by run and array type, and presented in Figure 6. The aggregated runs were entered into a repeated measures ANOVA in a 2 (type: repeated vs. novel) by 9 (time: runs 1-9) structure. The repeated measures ANOVA reveled significant main effects for display type, $F (1, 19) = 29.859$ (p < .001), and time, $F (8, 152) = 18.043$ (p < .001). The interaction between these variables was also significant, $F (8, 152) = 2.357$ (p = .020). The significant interaction confirms the

contextual cuing effect, suggesting that RT speeds depend on the array configuration. Pairwise comparisons confirm that repeated arrays were searched faster than random arrays, $MD = 47.269$ (p < .001).

The effect of switching target location within repeated arrays was further explored within the interaction. Pairwise comparisons show that at Run 3 the contextual cuing effect is present $MD_3 = 73.953$ ($p_3 = .006$), is abolished during Run 4 after the target switch ($MD_4 = 29.097$ ($p_4 = .225$)), and reestablishes and maintains itself following the reversal to the original location in Runs 7, 8, and 9 ($MD_7 = 58.560$ ($p_7 = .004$); $MD_8 = 79.885$ ($p_8 < .001$); $MD_9 = 78.494$ ($p_9 = .001$)). To determine whether the contextual cuing effect immediately returned, an individual block comparison was performed between random and repeat arrays for block 19. Unfortunately, repeat array targets were not located significantly faster than random array targets immediately following the second switch, $MD_{19} = 28.469$ ($p_{19} = .338$). However, by block 20, repeat search times significantly differ from random array search times, $MD_{20} = 74.060$ ($p_{20} = .002$). These results are similar to pilot studies, suggesting that switching target location creates search interference. It was expected that a brief relearning phase would accompany the reversal to the original target location. However, the nearly instantaneous return to pre-reversal search facilitation was unexpected. This rapid return could indicate reinstatement of the previously learned contextual contingencies after only 1 block of re-exposure. Pairwise comparisons of repeat array search times for block 9 (prior to the first switch) and block 20 (the first appearance of the contextual cuing effect following the second switch) was not significant, $MD_{9 - 20} = 58.045$ ($p_{9 - 20} = .163$). This seems to imply that relearning, as opposed to novel learning, is occurring following the switch back to the originally

encoded target positions. A significance difference between block 9 and 20 would suggest that initial learning was taking place but, because only 1 block is needed before search times resemble end-of-A-phase times, these results suggest that memory for the repeated arrays is being reinstated. Experiment 2 and 3 explore this premise by further manipulating target location in repeated arrays.

Experiment 2: ABC

The ABC protocol contained data from $n = 25$ participants. The ABC main effects mimic those of the ABA design. Similarly, the type by time interaction was also found to be significant, $F(8, 192) = 4.404$ (p < .001). This interaction implies that a reduction in RT across the experiment depends on the type of array type.The mean differences for the pairwise comparisons of the array type by time interaction are presented in a graph of RTs by run and coded by array type in Figure 7. RT comparisons suggest that the contextual cuing effect develops by Run 3, is abolished following the target location switch by Run 4, is reestablished and maintained by Run 5 (a pairwise comparison array type for block 15 indicates the first significant difference between random and repeated arrays, $MD_{15} = 69.986$ (p = .041) through 6, but is eliminated following the second switch. Unfortunately, block by block comparisons confirm the abolishment of the contextual cuing effect by failing to show a significant separation of random and repeated arrays during the C epoch.The results of experiment 2 imply that implicit learning of contextual contingencies has limits. Compared to the reversal phase of the ABA design, which failed to produce lasting interference, learning another new set of relations seems to impose a greater burden for visual search.

Experiment 3: ABR

The ABR experiment contained $n = 27$ participants. The average RTs were calculated for each 3 block aggregate and graphed in Figure 8. Repeated measures ANOVA revealed a significant main effect for type ($F (1, 26) = 43.299$ (p < .001)) and time ($F (8, 208) = 8.598$ (p < .001)). The interaction was found to be insignificant. Because the first 2 phases of the ABR experiment are the same as the previous two experiments, this result is unexpected. While a block by block analysis shows that contextual cuing is present beginning in block 4 and lasting, albeit somewhat inconsistently, until block 9 (p4 = .023, p5 = .026, p6 = .063,p7 = .057,p8 = .007, p9 = .055), the effect fails to reliably reestablish itself for the duration of the experiment.

Discussion

This study examined how readily new relational contingencies can be learned or reinstated in the presence of interference. In each experiment participants viewed arrays of distractor "Ls" with the goal of finding a target "T". Unbeknownst to the participant, a set of 12 arrays are repeated throughout the 27 trial experiment. After repeated exposure to the recurring arrays, RT to finding the target is lower compared to randomly generated arrays (the contextual cuing effect). Target locations were manipulated in three different ways: a target switch and reversal (ABA), two switches (ABC), and a single switch followed by continuous switching within repeated arrays (ABR). By manipulating target location the flexibility of implicit memory was examined.

Altering the contextual relations among distractor and target locations tended to produce disruptions in visual search. Participants in the ABA and ABC experiments developed contextual cuing during the first phase of each protocol. However, after the target location switched positions during phase 2 ("B" phase), and the distractors no

longer provided a predictable advantage to target acquisition, the contextual cuing effect was abolished. However, this disruption is relatively transient and contextual cuing redeveloped following repeated exposure to the new target locations, similarly to what others have reported (Conci, Sun, & Müller, 2011; Makovski & Jiang, 2010; Manginelli & Pollmann, 2009). If the relations among distractors and the target location are learned throughout phase one, then the behavioral cost associated with miscuing following target relocation is plausibly attributed to interference from previously learned relations. The regenerative return of the contextual cuing effect suggests that new learning can occur in the face of interference. One explanation for relearning relational cues following a switch concerns a prioritization according to the relevance of the distractors-to-target link (Conci, Sun, & Müller, 2011). However, the results of the following experiments shows that altering the target location may interfere with the prioritization of these links.

Interestingly, and previously unexplored in the literature, are the aftereffects of a second switch of target location. Experiment 1(ABA) showed no behavioral cost when target locations were switched backed to the originally learned locations. This suggests that the originally learned relations remain intact despite the new learning, reorganization, or reprioritization that occurred during phase 2 ("B"). The effects of a second switch during experiment 2("C" phase) to yet another distractor location resulted in a more enduring disruption. The persistent abolishment of the contextual cuing effect during phase 3 suggests a limit to implicit relational learning. While the contextual cuing effect did reestablish during the final (9) block, the cost associated with the switch suggests that implicitly learning 3 contextual relations is quite difficult. It may be the case that the originally encoded location (A) is weighted, or becomes more important,

than other locations. Even though faster (compared to random RTs) search times were observed during other phases, the originally encoded location seems to be, at least initially, prioritized until new learning of the relations occurs

Experiment 3 (ABR) sought to further examine the effects of manipulation previously learned contextual relations by continually switching the target location to learned distractor locations during phase 3. Unfortunately, a small sample size is likely to blame for the variance between this experiment and the other two. Visually examining the block by array type reaction times (Figure 8) suggests a similar result as that observed during the ABC experiment; cost to switching, reestablishment of CC, a more persistent cost following a second switch, and a late resurgence of the contextual cuing effect. The ABR design requires further examination to draw further conclusions.

This set of experiments did contain limitations. The length of study may have contributed to the elimination of so many participants. If attention waned during the beginning phases of the experiment the contextual cuing effect would be stunted or delayed throughout the experiment. This lead to the fairly liberal exclusion criteria outlined above. It might be possible to shorten the experiment by implementing a training phase, which then leads to target manipulation phases. This training phase could replace the full 9 run "A" phase by, for example, only using repeated arrays. Also contributing to the shortcomings of the study is the absence of recognition data. While this data corroborates the implicit nature of the experiments, it is historically documented that this procedure is implicit. While a programming error was the result of this missing data, there is no evidence to suggest that these results are due to explicit memory. Finally the rather limited sample size of the experiments limits the generalizability of the results.

The AB version of all three experiments should be the same and mimic the trends of previous pilot work. However, the sensitivity of these results have likely been effected by the small sample size. Despite the aforementioned limitations, these experiments show that implicit relational learning is capable of flexibility by way of rapid relearning.

Taken together, the results of this study make a case for implicit flexibility by showing that the contextual cuing effect, a type of relational learning, can adapt to changing contextual contingencies. While this flexibility appears to have limits, lasting efficient visual search is possible following contextual interference.

Figure 1

Example contextual cuing array

Figure 2

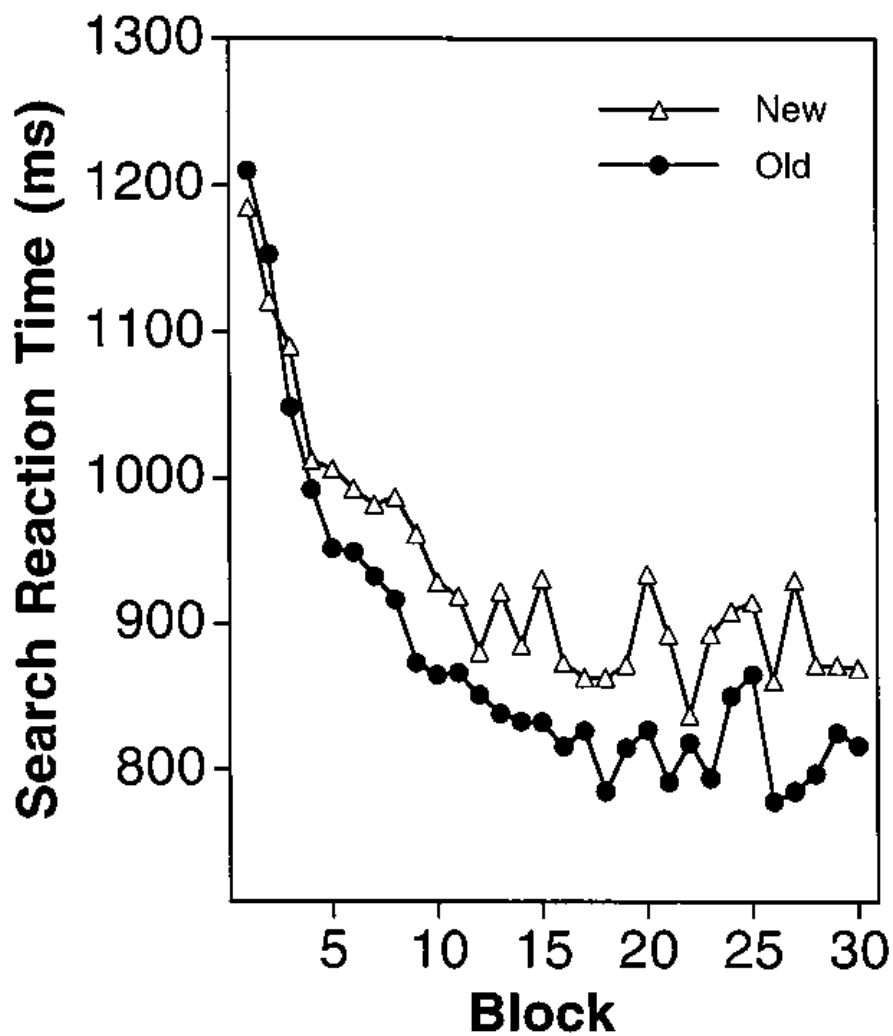Example reaction times in contextual cuing experiment

Figure 3

Sample ABA array

Figure 4

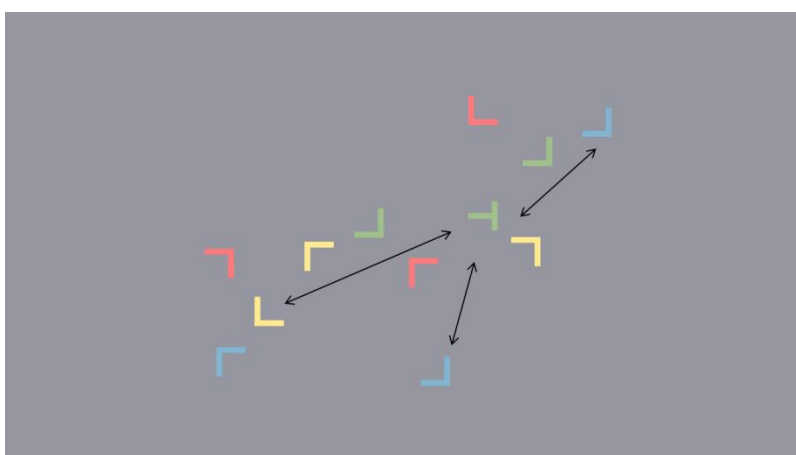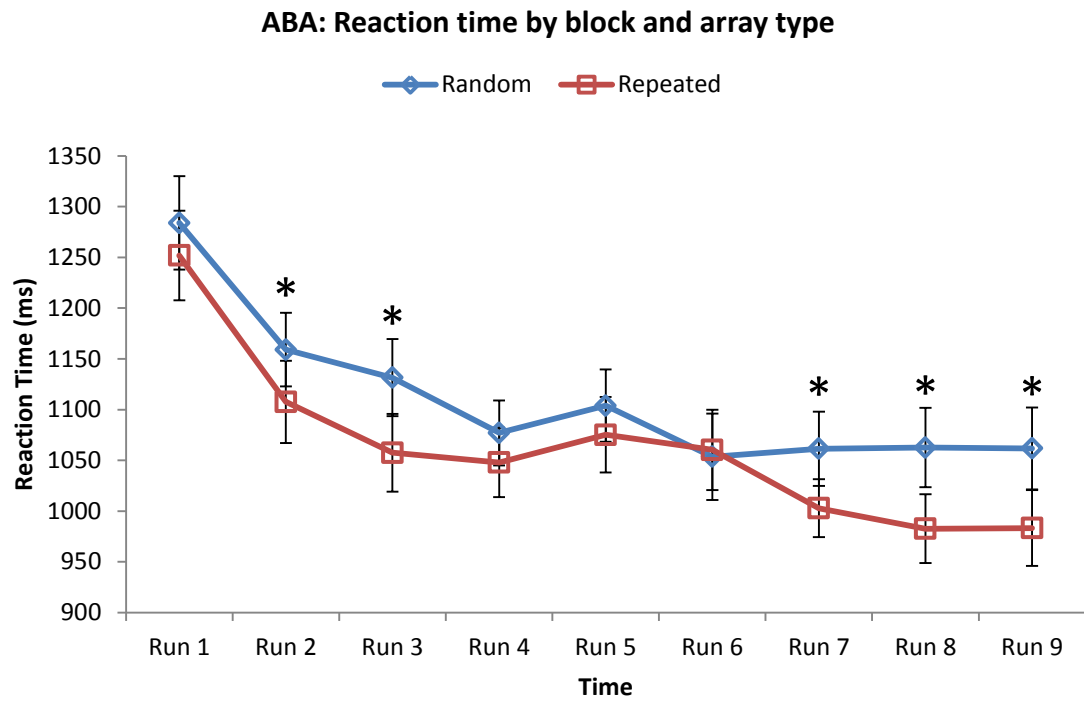Sample ABC array

Figure 5

Sample ABR array

Figure 6

ABA: Reaction time by block and array type

Figure 7

ABC: Reaction time by block and array type

Figure 8

ABR: Reaction time by block and array type
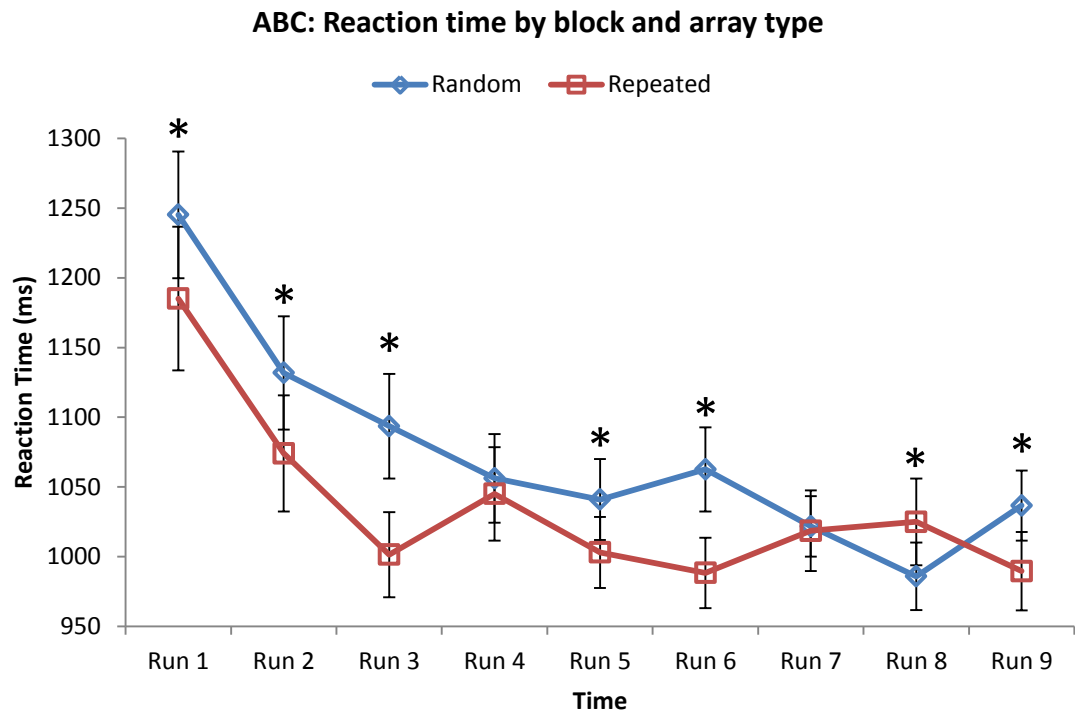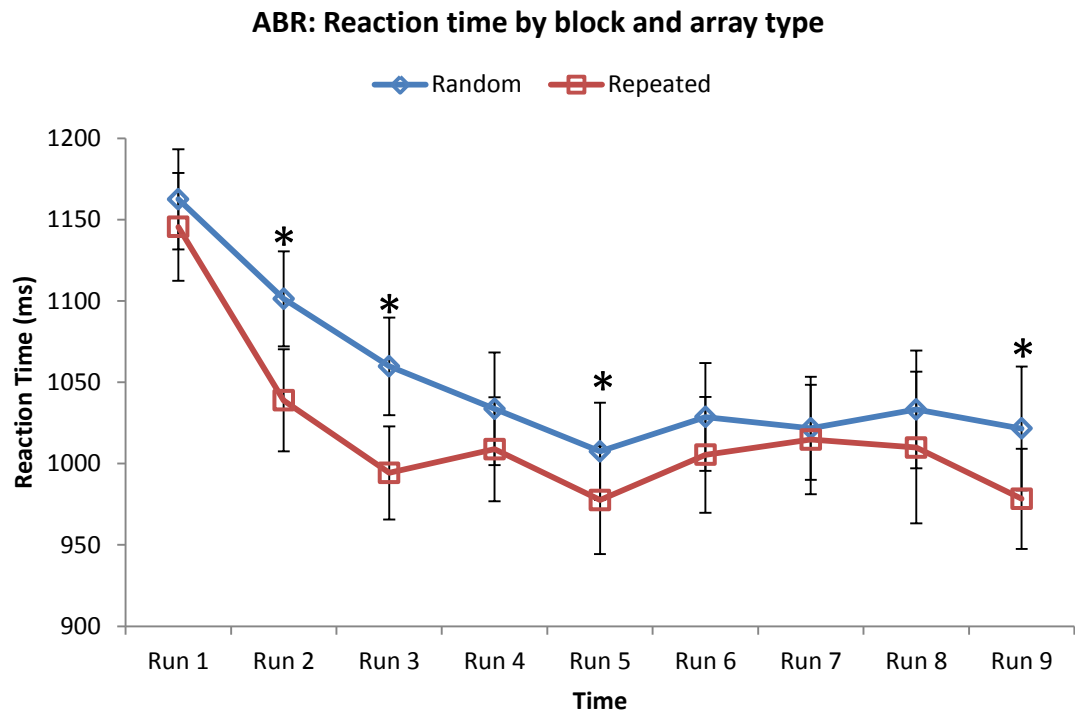
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