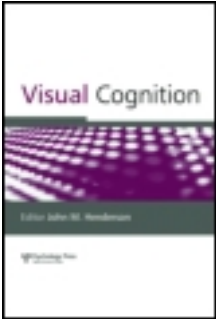


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**Object Perception, Attention, and Memory (OPAM)
2011 Conference Report
19th Annual Meeting, St. Louis, Missouri, MO, USA**

Organized by Brian Levinthal, Tim Vickery, Carly Leonard,
and Melissa Võ

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Individual differences in controlled attention and susceptibility to inattention blindness

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Inattention blindness (IB) is the failure to notice an unexpected object when attention is focused elsewhere (Mack & Rock, 1998). Many studies have explored how the stimuli and task affect this phenomenon, but few have explored individual differences in noticing. In light of evidence that IB plays a role in problems outside the laboratory (e.g., car accidents), it is important to explore factors that might make certain people more vulnerable to experiencing it.

Since controlled attention is a critical aspect of executive functioning (EF; McCabe, Roediger, McDaniel, Balota, & Hambrick, 2010), individual differences in EF might influence whether a person notices an unexpected object. A few studies have examined the relation between IB and certain aspects of EF (e.g., working memory), but have yielded inconsistent findings (Richards, Hannon, & Derakshan, 2010; Seegmiller, Watson, & Strayer, 2011). Meanwhile, both anxiety and depression are associated with attention control deficits (Eysenck, Derakshan, Santos, & Calvo, 2007; Mialet, Pope, & Yurgelun-Todd, 1996), but no published research has explored the relation between emotional distress and IB.

To this end, we examined whether individual differences in dimensions of EF and/or distress predict IB in two samples. In our first sample, 134

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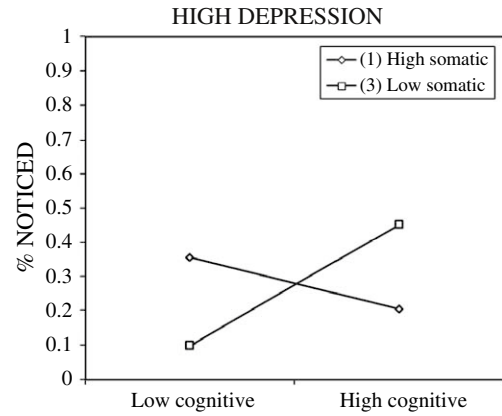
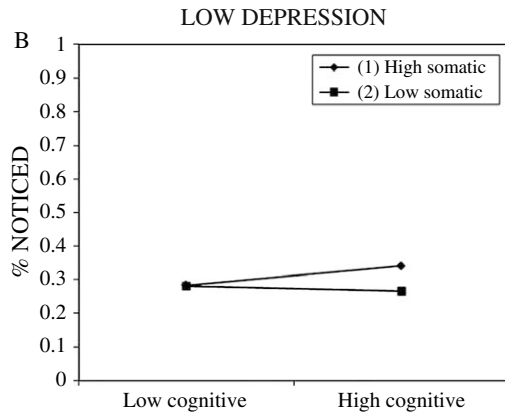
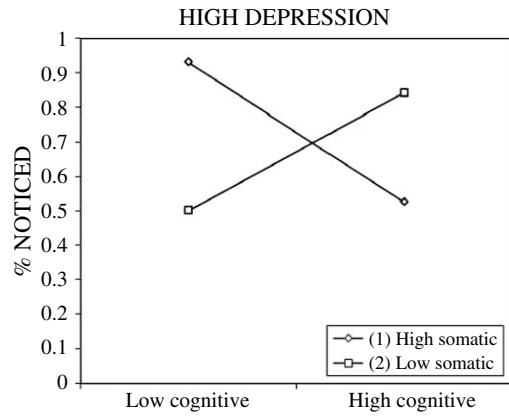
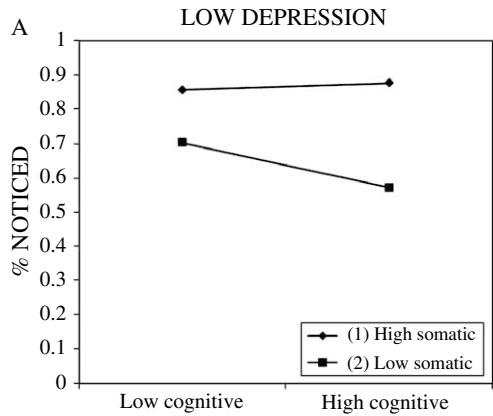
college students were tested individually. Each participant completed: (1) Questionnaires designed to measure levels of depression, cognitive anxiety, and somatic anxiety; and (2) verbal and spatial versions of a two-back (working memory) task. Then, participants completed a sustained attention task in which they counted the number of times that four white shapes touched the sides of a window centred on a computer monitor while ignoring four black shapes. Counts were treated as accurate if they were within 20% of the actual number. Each trial lasted 12 s. After four trials with no unexpected events, participants completed one critical trial in which a grey cross entered the display from the right, moved horizontally across the display for 4 s, and exited on the left. Participants were asked, “Did you see anything other than the black and white Ls and Ts?”

Eighty-eight participants reported noticing (and provided an adequate description of) the unexpected cross. To test whether scores from the tasks or questionnaires predicted noticing the grey cross, we conducted logistic regression analyses. We found that working memory scores did not predict noticing, Wald statistic = 1.08, $p = .30$, even when excluding participants who did not perform the tracking task accurately on the critical trial, Wald statistic = .48, $p = .49$. Working memory did predict tracking performance on the noncritical trials, $r = .28$, $p < .01$, suggesting that this task requires controlled attention.

Depression, cognitive anxiety, and somatic anxiety also did not predict noticing when considered separately. However, exploratory analyses revealed a significant three-way interaction between these variables predicting IB, $B = -0.95$, $p = .03$. The nature of this interaction is shown in the top panel of Figure 1. In participants with elevated levels of depression, there was a crossover interaction between cognitive and somatic anxiety, such that individuals with diminished or elevated levels of both had the highest rates of IB. In participants with low levels of depression, somatic anxiety was positively associated with noticing, independent of cognitive anxiety.

In summary, although individual differences in working memory did not predict IB, emotional distress did, though this association was more complex than anticipated. To see if these findings would replicate, we collected data from another sample. Furthermore, in the second study we administered: (1) A more rigorous measure of tracking ability; (2) an additional, well-validated measure of working memory; and (3) tasks to measure other dimensions of EF (inhibition, shifting).

In our second sample, 196 college students were tested individually. Participant completed the same questionnaires and two-back tasks used in the first sample, as well as: (1) The automated operation span task (as an additional measure of working memory); (2) the stop-signal task (to measure inhibition); and (3) the plus/minus task (to measure shifting). The sustained



attention task was comparable to the version used for the first study, but included a block of trials in which object speeds were adjusted based on accuracy (to determine the speed at which each participant could count accurately on 75% of trials; see Simons & Jensen, 2009). Immediately after this block, participants completed four trials on which the items moved at a fixed speed, followed by one critical trial. The order of the tasks was randomized.

Fifty participants noticed the unexpected cross. Once again, two-back performance did not predict IB, Wald statistic = .09, $p = .77$, though it did predict tracking ability, $r = .21$, $p < .01$. Extending these findings, performance on the operation span task and the other EF tasks did not predict noticing (all $ps > .15$). In contrast, depression, cognitive anxiety, and somatic anxiety again interacted to predict noticing, $B = -0.40$, $p = .05$. Importantly, the pattern of this interaction was quite comparable to the pattern from the first sample (see Figure 1B).

In summary, across two samples and multiple measures, we found that individual differences in EF did not predict IB. This suggests that one's capacity to control attention, though important for performing tasks in the face of distraction, doesn't play a prominent role in the capture of awareness by unexpected objects. Our findings are inconsistent with recent reports that individuals with reduced working memory capacity are more likely to exhibit IB (e.g., Richards et al., 2010). The methodology used in these other reports differed from ours in some important ways (e.g., age range). Future research should test which of these differences accounts for the discrepancy between our findings and previous reports, in order to identify factors that might moderate the relation between working memory and IB.

Although EF did not predict IB, emotional distress did. Specifically, self-reported levels of depression, cognitive anxiety, and somatic anxiety interacted to predict IB. This suggests that attention control deficits associated with anxiety and depression extend to the capture of awareness by unexpected objects, which may have important implications for understanding how anxiety and depression impact daily functioning. Moreover, our findings suggest that the *pattern* of symptoms an individual is experiencing is critical, at least in terms of IB, though more research is needed to determine the basis for this.

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Exposure to an urban environment alters the local bias of a remote culture

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The present study examined the Himba, a remote tribe of Northern Namibia, who have been found to have more local (analytic) visual processing than Westerners (Davidoff, Fonteneau, & Fagot, 2008; de Fockert, Davidoff, Fagot, Parron, & Goldstein, 2007). Typically, local visual processing has been attributed to (1) individualistic societies (the dominant account; Nisbett, Peng, Choi, & Norenzayan, 2001) or (2) the low clutter of the visual environment (Miyamoto, Nisbett, & Masuda, 2006). The first account cannot explain the Himba local bias as their society promotes interdependent, rather than individualistic, behaviour: Their society is structured around large family compounds and social position is allocated rather than achieved. We assessed the second account by examining whether exposure to an urban (cluttered) environment decreased the local bias of the Himba.

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Opuwo, a town nearby the Himba, provides an urban environment for its 12,000 inhabitants. Some of its inhabitants are Himba who have spent their early life in traditional villages before moving to Opuwo permanently in early adulthood. These urbanized Himba were compared to traditional Himba, urban British, and urban Japanese on their performance at two tasks that index global/local processing: The Ebbinghaus illusion (Experiment 1; de Fockert et al., 2007) and the global/local matching task (Experiment 2; Davidoff et al., 2008). We investigated whether living in an urban environment would cause the Himba to process more globally like British and Japanese. In addition, we investigated the degree of exposure to an urban environment required to affect the local bias in traditional Himba, by recording the change in their visual processing as a function of their number of visits to Opuwo. Most traditional Himba tested had visited Opuwo between 0 and 3 times in their lifetime.

METHOD

In Experiment 1, participants compared two targets and decided which one was bigger. The targets were surrounded by irrelevant inducers that affected their perceived size (i.e., a target surrounded by big inducers appeared smaller; Ebbinghaus illusion; see Figure 1a). In Experiment 2, participants compared two Navon-like figures (i.e., big shapes made of small elements; bottom of Figure 1b) and decided which of them most resembled a target figure (top of Figure 1b). One of the comparison figures matched the target figure at the local level and the other at the global level.

In Experiment 1, traditional Himba were predicted to be less affected by irrelevant inducers and, in Experiment 2, to choose global-similarity matches less often than Japanese, British, and urbanized Himba. The difference between traditional Himba and other groups was predicted to decrease the more often they had visited Opuwo.

Four populations were tested: (1) 63 Japanese (31 females, mean age 20 years, range 18–23); (2) 62 British (35 females, mean age 24 years, range 18–37); (3) 70 urbanized Himba (31 females, mean estimated age 27 years, range 17–46); and (4) 241 traditional Himba (107 females, mean estimated age 27 years, range 16–45). Traditional Himba were separated into four subgroups: Those who had been to Opuwo once (82 individuals), twice (63 individuals), three times or more (62 individuals), or those who had never been there (34 individuals).

In Experiment 1, stimuli and procedure were similar to those used in de Fockert et al. (2007) and, in Experiment 2, to those used in Davidoff et al. (2008).

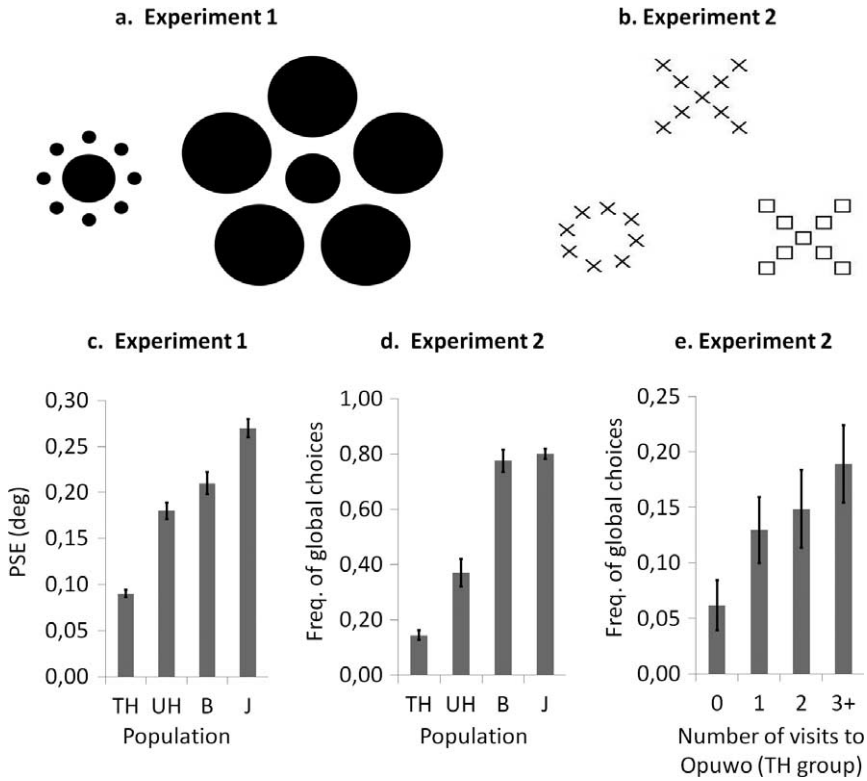


Figure 1. (a,b) Stimuli of Experiments 1 and 2. (c-e) Results of Experiments 1 and 2: PSEs and global-choice frequencies as a function of group of participants (TH = traditional Himba; UH = urbanized Himba; B = British; J = Japanese) or number of visits to Opuwo (0, 1, 2, or 3+ visits, in traditional Himba group).

RESULTS

In Experiment 1, the point of subjective equality (PSE; i.e., the threshold for deciding that a target surrounded by large inducers was the larger one) was significantly affected by population, $\chi^2 = 194.7$, $df = 3$, $p < .001$ (see Figure 1c). A large PSE indicated a large Ebbinghaus illusion (i.e., large effect of irrelevant inducers). The PSE was larger in Japanese (0.27° , $SEM = 0.010$) than British (0.21° , $SEM = 0.012$), $\chi^2 = 11.0$, $df = 1$, $p < .005$, equivalent in urbanized Himba (0.18° , $SEM = 0.009$) and British, $\chi^2 = 3.2$, $df = 1$, $p > .1$, and smaller in traditional Himba (0.09° , $SEM = 0.004$) than British, $\chi^2 = 74.9$, $df = 1$, $p < .001$. In the traditional Himba group, there was no effect of number of visits to Opuwo.

In Experiment 2, the frequency of global choices was significantly affected by population, $\chi^2 = 187.9$, $df = 3$, $p < .001$ (see Figure 1d). The latter was equivalent in Japanese (0.80, $SEM = 0.019$) and British (0.77, $SEM = 0.28$), $\chi^2 = 0.5$, $df = 1$, $p > .1$, smaller in urbanized Himba (0.37, $SEM = 0.049$) than British, $\chi^2 = 25.5$, $df = 1$, $p < .001$, and smaller in traditional Himba (0.14, $SEM = 0.018$) than urbanized Himba, $\chi^2 = 22.5$, $df = 1$, $p < .001$. In addition, in the traditional Himba group, the frequency of global choices decreased with decreasing number of visits to Opuwo (3+ visits: 0.19, $SEM = 0.040$; 2 visits: 0.15, $SEM = 0.035$; 1 visit: 0.13, $SEM = 0.029$; 0 visit: 0.06, $SEM = 0.022$; see Figure 1e), Jonckheere-Terpstra statistic = 2.1, $p = .037$.

DISCUSSION

Our study showed, using two different paradigms, that the strong local bias of traditional Himba varies systematically as a function of their degree of exposure to an urban environment. Thus, the Ebbinghaus illusion (Experiment 1) strikingly increased in urbanized Himba to reach a level similar to that observed in urban British. Second, the frequency of global choices in a global/local matching task (Experiment 2) increased in traditional Himba with increasing numbers of visits to the urban environment and increased even more in urbanized Himba.

The increase in global processing with urbanization cannot be explained by the classical social organization account which suggests that collectivist societies promote global processing (Nisbett et al., 2001). Indeed, the Himba did not become more local with exposure to an urban (individualistic) environment. Our preferred interpretation is that the more cluttered visual environment in Opuwo caused a shift towards more global visual processing in the Himba (Miyamoto et al., 2006).

Future research will need to determine the processes by which cluttered visual input and/or other aspects of the urban environment comes to change perceptual foci of interest in the dramatic way observed here but parsimony suggests that these effects of the urban environment should also contribute to the global bias in Japanese and British.

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Holding on and letting go: The allocation of attention to space and objects is constricted and slowed near the hands

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Perception, attentional control, and working memory are remarkably influenced by the proximity of the hands to viewed objects. For example, items near the hands receive perceptual, attentional, and memorial priority relative to other objects in the environment (Abrams, Davoli, Du, Knapp, & Paull, 2008; Cosman & Vecera, 2010; Reed, Grubb, & Steele, 2006; Tseng & Bridgeman, 2011). This enhanced processing near the hands has been theorized to be adaptive, given that the hands afford direct interaction with nearby items and that the decision to grasp or avoid can be determined by relatively minor differences in visual detail (Abrams et al., 2008; Graziano & Cooke, 2006). Nevertheless, it remains unclear what mechanism underlies these effects. Here, we propose that the priority given to information near the hands arises because (1) attention is less susceptible to information outside of hand-space, and (2) shifts of attention within objects confined by the hands are relatively slow and inflexible. To test this hypothesis, we conducted two experiments that compared space- and object-based control of attention near to, and far from, the hands. In Experiment 1, we show that the hands confine the spotlight of attention to the area within their grasp. In

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Experiment 2, we show that shifts of attention between global and local aspects of objects are slowed when those objects appear between the hands.

EXPERIMENT 1

Thirty-six participants performed an Eriksen-type flanker task, in which they identified a target (H or S) flanked by two congruent letters (same identity as target), two incongruent letters (identity of the alternate but incorrect response), or two neutral flankers (X) not associated with any response. Stimuli were presented on an LCD monitor laid horizontally on a desk. In the hands-near condition, participants placed their hands on the display between the target and flankers with palms facing each other (Figure 1A). In the hands-far condition, participants oriented their hands similarly, but placed them to the side of the monitor, away from the letter displays (Figure 1B). In the barrier condition, the hands remained to the side of the display while two wooden blocks analogous in length, height, width, and shape to a typical pair of hands were placed on the display between the target and either flanker (Figure 1C). This mimicked the physical and visual segregation apparent in the hands-near condition. In all conditions, response buttons were positioned under the tips of the ring fingers. If the hands restrict the breadth of spatial attention, compatibility effects should be smaller in the hands-near condition compared to the hands-far and barrier conditions.

Compatibility effects were defined by the mean difference between incongruent and neutral response times (RTs), although similar results were obtained by comparing congruent and incongruent conditions. Compatibility effects in the hands-far condition averaged 27 ms. The barrier did not alter these effects (23 ms), $t(35) = 0.58$, $p = .57$. Interference was greatly reduced, however, in the hands-near condition (4 ms) compared to both the barrier, $t(35) = 2.12$, $p < .05$, and hands-far, $t(35) = 2.51$, $p < .02$, conditions. These results indicate that the hands restrict the spatial breadth of attention, which notably was not achieved by physical barriers of similar size and shape.

EXPERIMENT 2

Eighteen participants identified stimuli based on their local elements (square, rectangle) or global form (square, rectangle). Participants saw two stimuli on each trial (S1, S2) and made a response to each (R1, R2). Stimuli were presented on a CRT display. Participants attended to the global dimension of S1 and the local dimension of S2, or vice versa. Thus, trials involved a time-consuming shift of attention between responses (Robertson, 1996). The elapsed time between R1 and S2 (response-to-stimulus interval; RSI) ranged from 0 to 232 ms. As RSI increases, more of the attentional shift

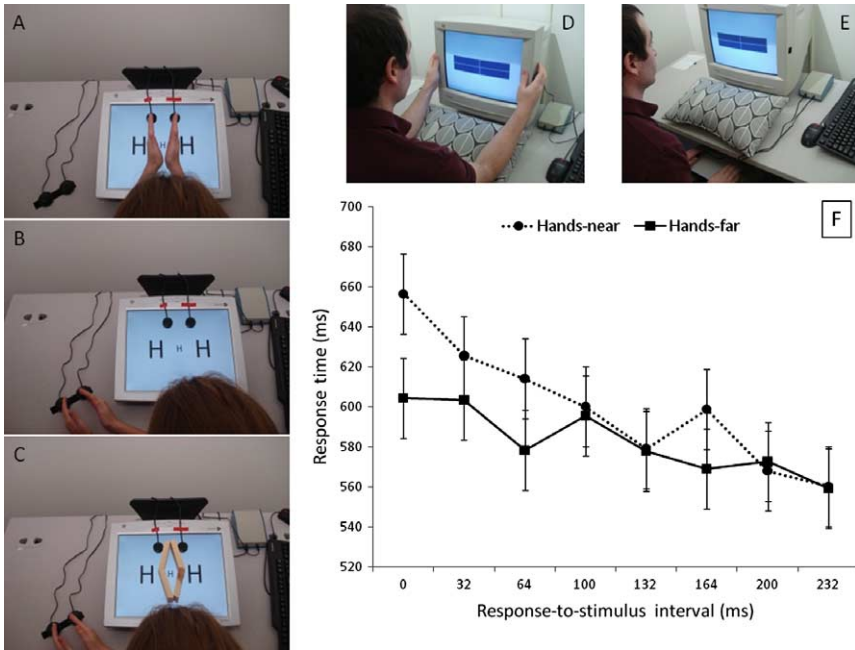


Figure 1. The hands-near (A), hands-far (B), and barrier (C) conditions of Experiment 1, and the hands-near (D) and hands-far (E) conditions of Experiment 2. Mean RTs (collapsed across direction of switch) across the response-to-stimulus interval for the hands-near and hands-far conditions from Experiment 2 (F). To view this figure in colour, please see the online issue of the Journal.

can be completed prior to the presentation of S2 (Brockmole, Carlson, & Irwin, 2002). As a result, R2 should decrease as RSI increases. The slope of this decrease reveals the speed with which attention can be shifted. Half of the participants placed their hands over response buttons fixed to the sides of the monitor so that the objects appeared between their palms (hands-near condition; Figure 1D). The other half placed their hands in their laps (hands-far condition; Figure 1E) and pressed response buttons fixed to a lightweight board. If shifts of attention between global and local levels of form are slowed by hand proximity, the RT profile for S2 should be steeper in the hands-near compared to the hands-far condition.

RTs to S1 and S2 were submitted to separate 2 (switch direction) \times 2 (hand posture) \times 8 (RSI) mixed-factor analyses of variance, with hand posture as a between-subjects factor. RT for S1 was not affected by RSI or hand position ($F_s < 2.57$, $p_s > .13$), indicating that shape identification was equivalent across hand postures. As expected, RTs for S2 decreased as RSI increased, $F(7, 112) = 20.03$, $p < .001$. Most importantly, S2 was also affected by hand posture (Figure 1F), such that participants in the

hands-near posture were slower to switch their attention across object dimensions, $F(7, 112) = 3.84, p < .005$. To ensure that hand position affected shifts of attention rather than some general component of S2 processing, an additional experiment was conducted where observers made global or local judgements to both stimuli (no switch of attention necessary) using RSIs of 0 and 225 ms. Here, hand posture was unrelated to RTs.

CONCLUSION

This research indicates that placing the hands around an object has two major consequences. First, the spotlight of spatial attention is constricted, reducing the likelihood that information away from the hands will influence behaviour. Second, the flexibility with which attention can be reallocated is diminished. Combined with past studies showing delayed attentional disengagement from objects near the hands (Abrams et al., 2008), our results suggest that the allocation of selective attention is fundamentally altered near the hands, and that these alterations may provide the mechanistic basis for enhanced perception of, and memory for, held objects.

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Interference in visual memory can obscure explicit awareness of statistical relationships: The influence of location–identity binding mismatches

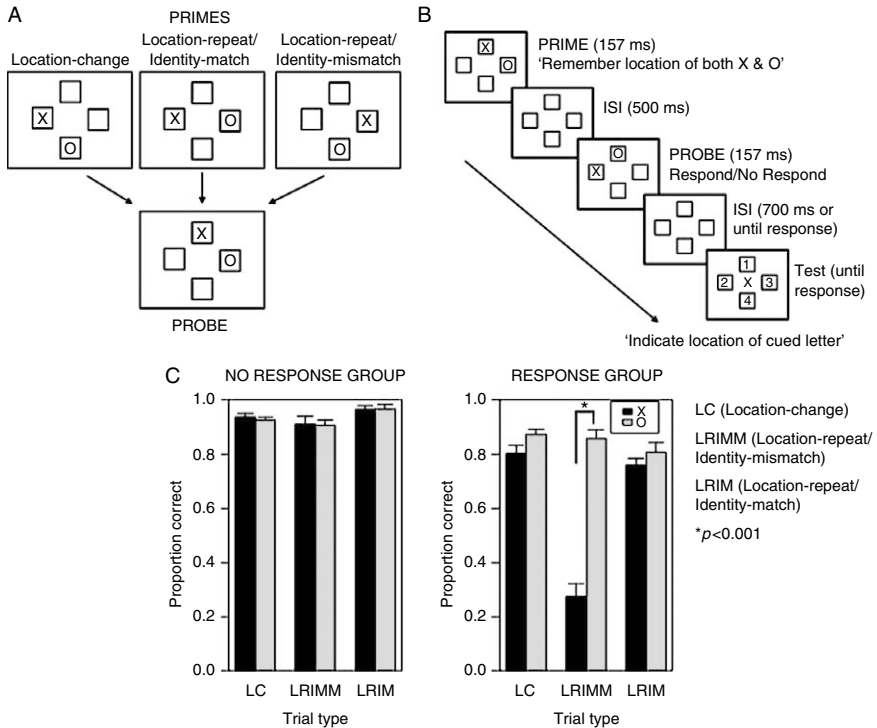
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The ability to note relations among successive events is one of the most fundamental human abilities. While previous research has looked at the extent to which human behavior is sensitive to such relations (Nissen & Bullemer, 1987), relatively little work has been directed at the question of how we are able to verbalize these relations explicitly. The purpose of the current study is to better understand the processes that underlie the creation of conscious, explicit knowledge of visual patterns.

Our investigation stems from earlier work (Fiacconi & Milliken, 2011; Vaquero, Fiacconi, & Milliken, 2010) using a simple priming procedure. Participants were required to observe passively a prime stimulus containing two different letter characters appearing in two of four demarcated locations (see Figure 1A for a depiction of the various trial types). Following the prime, a probe display appeared and participants were instructed to localize a target character as fast as possible. A contingency was introduced such that the probe target letter (O) appeared in the same location as one of the two prime letters (either the X or O in separate experiments) on 75% of the trials. After the experiment was completed, participants were asked to report their subjective estimate of the percentage of trials in which this critical trial type occurred. Strikingly, when the identity of the predictive character in the prime mismatched the identity of the probe target (location-repeat/identity-mismatch trials), almost all participants were unable to verbalize the strong contingency that had been introduced (Experiment 1). However, when there

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was a match in identity (location-repeat/identity-match trials) between the predictive character in the prime and the probe target (Experiment 2), nearly all participants were able to verbalize the strong contingency accurately.

The purpose of the current study is to better understand the mechanism by which mismatches in location-identity bindings (location-repeat/identity-mismatch trials) obscure contingency awareness. Our approach to answering this question was guided by some recent work in the visual memory literature. Traditional conceptions of visual memory distinguish between a brief, high capacity store known as iconic memory (Sperling, 1960), and a longer lasting, durable, low capacity store known as visual working memory (VWM; Phillips, 1974). Because of its durable nature, representations in VWM are thought to be resistant to masking, or interference from subsequent information. This characteristic of the VWM system, however, has been recently called into question (Alvarez & Thompson, 2009; Makovski, Sussman, & Jiang, 2008; Sligte, Scholte, & Lamme, 2008). These studies have shown that representations in VWM are indeed quite vulnerable

to subsequent interference. Furthermore, there is evidence to suggest that bound featural information is particularly susceptible to interference in the absence of attention (Wheeler & Treisman, 2002).

Given the recent work in the visual memory domain, it is possible that the contingency blindness we observed in prior studies reflects a profound interference effect in visual memory caused by location-identity binding mismatches. By this view, participants' inability to accurately verbalize the contingency reflects the cumulative result of many trials in which visual memory interference made participants unaware that two different identities appeared at the same location one after the other. If one assumes that mismatches in location-identity bindings are a potent source of interference, then it follows that contingency awareness should be very poor when it hinges on memory for a particular location-identity binding that is subject to this interference.

The basic procedure for the current experiment can be seen in Figure 1B. Upon onset of the prime display, participants were told to remember the locations of both the X and O because at the end of each trial they would be asked to indicate the location in which either the prime X or prime O had appeared (they did not know in advance which letter would be queried). Following the prime display, the probe display appeared. There were an equal number of location-change, location-repeat/identity-mismatch, and location-repeat/identity-match trials. One group of participants was instructed to respond to the location of the probe O (as in previous experiments); another group of participants was told simply to attend to the probe display and make no response. Following the probe display, a test display appeared. In the centre of the screen was a letter cue (either X or O) and participants were instructed to indicate the location in which that letter had appeared during the prime display. Therefore, this experiment consisted of a 2 (response, no response) \times 3 (location-change, location-repeat/identity-mismatch, location-repeat/identity-match) \times 2 (X cue, O cue) factorial design.

The results from this experiment were quite clear. Figure 1C depicts the means for each condition. An omnibus ANOVA revealed a significant main effect of response, $F(1, 20) = 18.4$, $p < .001$, with poorer accuracy when participants must respond to the probe target (O). Most important, however, was the significant three-way interaction, $F(2, 40) = 33.5$, $p < .001$. This interaction was driven primarily by the finding that for the response group, accuracy was much poorer when participants were asked to indicate the location of the prime X relative to the prime O for the critical location-repeat/identity-mismatch trials, $t(10) = 8.6$, $p < .001$. This result provides strong evidence in favour of the view that contingency blindness can result from interference in visual memory produced by mismatches in location-identity bindings. Moreover, the present findings suggest an interesting boundary condition for this effect. Interference due to binding mismatches is

not an obligatory process—rather it seems to occur only when selective attention is needed to direct some form of action/response to the mismatching stimulus.

Our work is consistent with the notion that representations in VWM are susceptible to substantial interference from subsequent inputs. Such interference likely explains why we found such low levels of explicit contingency awareness in the presence of binding mismatches in our previous experiments. We conclude that our ability to learn about and explicitly describe statistical information in our environment can be intimately linked with the processes that update visual representations in memory.

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Multiple-target search increases workload but enhances incidental learning: A computational modelling approach to a memory paradox

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When people search a display for a single target, they are typically adept at locating it (Wolfe, 2010) or performing an exhaustive search. By contrast, multiple-target search incurs an accuracy cost: People are more likely to miss and to false-alarm when searching for several potential targets simultaneously (Menner, Cave, & Donnelly, 2008). In both cases, however, searchers retain a great deal of information about the objects they encounter, even without effortful encoding (Williams, 2009). In prior experiments, we found a paradoxical pattern wherein, despite the increased workload of multiple-target search (shown by costs in search accuracy and response times, relative to single-target search), it creates robust incidental memory for distractor objects, with greater learning of “background” objects as the number of potential targets increases (Hout & Goldinger, 2010, Hout & Goldinger, 2011).

In the current investigation, we had participants perform visual search for new targets, embedded among repeated distractors; stimuli were photographs of real-world objects. We employed a rapid serial visual presentation task (RSVP; see Figure 1A), wherein participants maintained a variable number of potential targets in working memory (WM), and then passively viewed streams of images (centrally presented for 250 ms each), after which they made target-present versus target-absent decisions (if present, only one target appeared in the stream). This procedure ensured that all items received the same opportunity for encoding (i.e., each distractor was shown the same number of times, for the same duration). After search concluded, we tested memory for the distractors using a surprise two-alternative forced-choice

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(2AFC) recognition memory procedure with semantically matched foils (e.g., a previously seen “old” coffee cup was matched with an unseen, “new” cup).

In Experiment 1, we examined conditions in which WM was overloaded (i.e., search for as many as five potential targets) and people viewed varying stream lengths (5–15 items). We found a 10% drop in search accuracy from single- to five-target search (see Figure 1B), but a 6% increase in recognition memory (both $ps < .01$; see Figure 1C). In Experiment 2, we examined how well participants could vary their “search strength” (i.e., the degree to which incoming search items are encoded) online, by giving them a modified task wherein target identities were presented after the search stream. Participants were informed regarding the number of targets they would later be asked about; thus, they could tune the level of scrutiny that was applied to incoming items. Incidental memory was again greater when searching for more, relative to fewer, potential targets, even though search accuracy was worse (for single- and triple-target search, we found a 4% increase and a 6% decrease in recognition and search accuracy, respectively; both $ps < .01$).

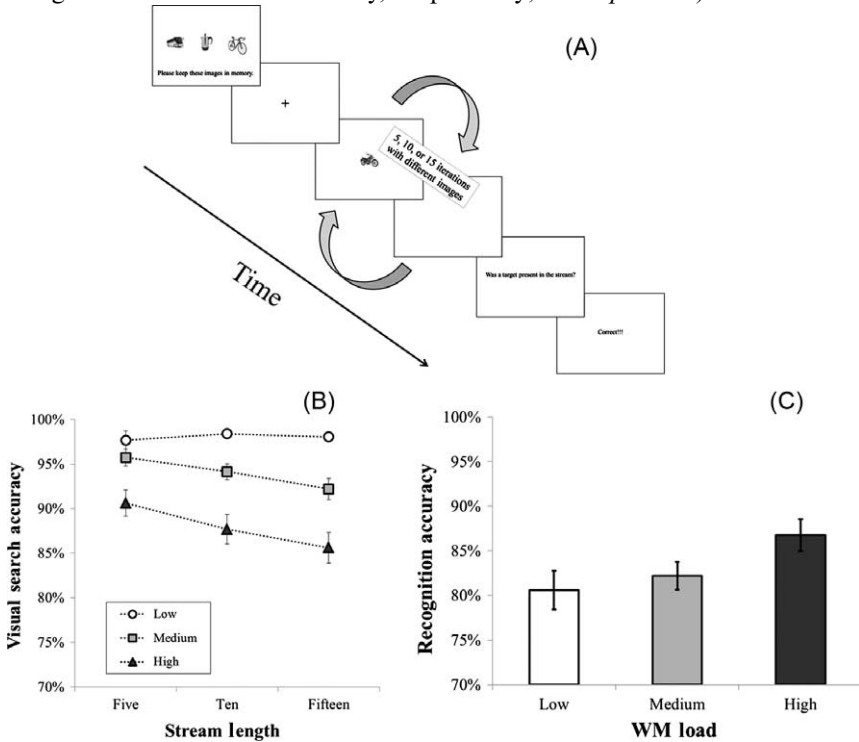


Figure 1. (A) Progression of events in a search trial, from Experiment 1. (B) Visual search accuracy from Experiment 1, plotted as a function of WM load and stream length. (C) Recognition memory performance, from Experiment 1.

Our memory results may be explained by postulating that multiple-target search enhances the fidelity of encoding for incoming search items. By this account, when a person must search for any of several possible targets, he or she will increase the effort devoted to processing each object. The paradox, however, is that if multiple-target search causes viewers to more carefully scrutinize each object, it becomes difficult to simultaneously explain decrements in search accuracy incurred by looking for extra targets. That is, the mechanism that is suggested to explain increased memory performance would also be expected to increase search accuracy, as people essentially become more careful searchers. To reconcile this apparent conflict, we developed a computational model intended to simultaneously simulate RSVP search performance, and subsequent recognition memory for the objects encountered.

The model, dubbed SQuEaL (Scanning QUIet Echoes and Learning), is derived from Hintzman's (1988) MINERVA2 multiple-trace memory model. Like MINERVA2, each object is represented by a vector of feature loadings (+1, 0, -1); we assume that each experienced event is represented by its own memory trace. In the model, targets are held in a WM buffer for the duration of a trial. As search items are "shown" to the model, these probes are sent to WM, wherein they return a single composite echo. More specifically, the probe activates all memory traces (i.e., all potential targets) in parallel, and to the extent that a probe vector is similar to one of the memory traces, the echo intensity is increased. Thus, when an incoming search item is a distractor, the echo intensity will be low, but when the item matches one of those held in WM, the intensity increases. When intensity reaches a certain threshold, the model responds "target-present"; otherwise, a "target-absent" response is generated. Critically, each probe is also weakly encoded in a long-term memory store. Following visual search, this accumulated long-term memory structure is used to simulate 2AFC performance. The model is presented with old distractor probes, and new foils. These items each generate echo intensities, emanating from long-term memory; the model responds by choosing the probe with the higher intensity.

Two of SQuEaL's parameters are particularly important: Target decay and search strength. Target decay represents the extent to which information is lost from WM during a trial, and is simulated by "losing" elements of the target vectors (i.e., setting them to zero) with some probability. Because encoding is never assumed to be perfect, search strength represents the scrutiny applied to incoming search items, and is simulated by varying the probability that incoming features will be encoded. We matched the simulations to our findings by increasing both target decay and search strength parameters as a function of WM load. Importantly, this suggests a potential strategy shift from single- to multiple-target search. We suggest that when participants look for a single target, their locus of control may be internal. That is, they devote effort to maintaining the identity of the target held in WM, and apply relatively weak

scrutiny to incoming search items. By contrast, when searching for multiple-targets, the locus shifts externally. In effect, it becomes too difficult to faithfully maintain several targets in WM. Instead, people “ramp up” the degree to which incoming items are encoded, which causes targets to fade from WM, but allows incoming items to more successfully “pop out” of the search stream, and subsequently, to be better remembered later.

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Is the lateral occipital complex necessary for haptic object recognition? Object shape representation in a visual agnosic with bilateral occipitotemporal lesions

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Both the visual and haptic systems provide information about the three-dimensional geometric structure of objects. When an object cannot be seen,

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somatosensory inputs provide a rich source of information about object identity, including structural cues about three-dimensional shape, surface features such as texture, and compliance. Converging evidence from behavioural priming, lesion studies, and functional imaging in humans indicates that the visual and haptic systems may share a common neural representation. A central but as yet unresolved issue concerns whether such object representations are confined to a localized region within human cortex, or whether they are cortically distributed (James, James, Humphrey, & Goodale, 2005). Case studies in visual agnosia patients indicate that the lateral occipital complex (LOC) is critical for visual object recognition (James, Culham, Humphrey, Milner, & Goodale, 2003; Konen, Behrmann, Nishimura, & Kastner, 2011). The LOC has also been consistently implicated in studies of haptic object recognition. For example, haptic object exploration has been shown to directly activate spared LO cortex in a visual agnostic, without mediation from visual recognition (Allen & Humphreys, 2009). Similarly, neuroimaging studies in healthy observers typically show LOC activation in response to objects explored by touch, in addition to vision (Amedi, Jacobson, Hendler, Malach, & Zohary, 2002; Amedi, Malach, Hendler, Peled, & Zohary, 2001; James, Humphrey, Gati, Servos, Menon, & Goodale, 2002; Naumer, et al., 2010).

In a series of studies, we examined the extent to which LOC is necessary for object recognition in a patient (MC) with extensive bilateral lesions in visual and temporal cortices, importantly including LOC. Although MC has visual agnosia, she shows some residual visual abilities for perceiving motion and performing visually guided actions. In a series of studies we investigated whether MC, despite her bilateral LOC lesions and severe agnosia, would show preserved haptic object recognition and spared activation in other brain regions, particularly in parietal areas known to be involved in haptic processing.

We first examined patient MC's ability to recognize familiar and novel objects using touch. Object recognition and memory was excellent for familiar everyday objects that could be discriminated using multiple cues to object identity, such as differences in surface texture and compliance. Both MC and controls rapidly and accurately identified a set of 50 common objects using touch alone. MCs performance was comparatively poorer than controls for learning novel unfamiliar shapes that differed only with respect to their three-dimensional geometric structure, although she was able to reliably make simple same/different judgements on the same items.

We subsequently used fMRI to investigate activation levels for familiar, everyday objects versus textures and fMRI adaptation to investigate object-selective responses in patient MC and an age-matched neurologically intact control group. The fMRI participants were presented with somatosensory

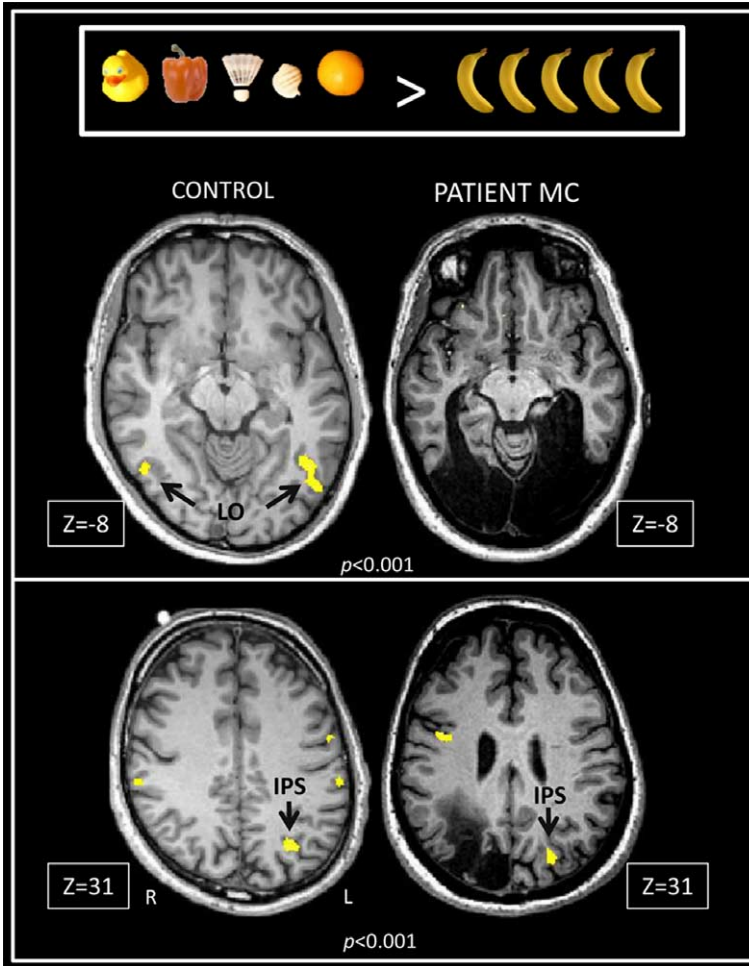


Figure 1. Haptic object-selectivity in patient MC and a representative control participant. Controls, but not patient MC, showed fMRI adaptation to repeated haptic object identity within LOC (upper panel). Both controls and MC, however, showed similar haptic adaptation effects within dorsal networks, particularly around the intraparietal sulcus (IPS) (lower panel). $p < .001$. To view this figure in colour, please see the online issue of the Journal.

sequences involving different textured materials or objects. Object stimuli comprised a set of 50 solid three-dimensional real-world natural and man-made objects that could be grasped using one hand (e.g., pacifier, toothbrush, lemon). Textures were nonrigid amorphous sheets of material (e.g., fur, leather, cotton). The experiment was run in a block design with three somatosensory conditions: Touching different textures (texture

different condition), touching different objects (object different condition), and repeatedly touching the same object (object same condition). Each 20 s block of trials consisted of five consecutive somatosensory objects or textures (4 s each). Somatosensory blocks were followed by 20 s of rest. Participants were instructed to passively identify each of the objects. Brain areas showing haptic object responsivity were identified by contrasting activation for object different versus texture different conditions. Brain areas showing haptic object selectivity were identified by contrasting activation in the object different condition with the object same condition. This contrast utilized the logic of fMRI adaptation designs whereby neural populations that encode object identity are expected to show a reduced fMRI response (i.e., adaptation) on blocks of trials where object identity is repeated compared to blocks in which object identity changes.

First, comparing activation for objects compared to textures, we found that haptic object perception in the control group produced strong bilateral activation within the lateral occipital complex (LOC). Patient MC showed no activation in this area. Conversely, both patient MC and controls showed a typical pattern of activation within parietofrontal areas involved in haptic exploration and somatosensation. Haptic object perception for MC and controls activated a network of regions outside the LOC, including the superior parietal lobe (SPL), intraparietal sulcus (IPS), anterior parietal area (AIP), motor areas in the postcentral gyrus, and somatosensory areas in the precentral gyrus. Controls also showed object activation within the collateral sulcus and parahippocampal gyrus, a region recently implicated in the processing of visual textures (Cant & Goodale, 2007). MC also showed a small but significant cluster of activation in the same region in the right hemisphere. Unlike controls, patient MC showed a small additional region of object activation in the right hemisphere around the posterior superior temporal sulcus (pSTS).

Next, we examined areas that showed adaptation to repeated haptic object identity. Controls showed significant adaptation effects within bilateral LOC, whereas MC showed no adaptation effects within this area. For MC, however, adaptation effects were observed within the same pSTS cluster identified in the different objects versus textures contrast. Both the control group and MC showed a strikingly similar pattern of identity-selective responses within a network of areas similar to those revealed in the objects vs textures contrast, most notably within parietal and parahippocampal cortex.

Taken together, the results of the behavioural and fMRI studies reported here suggest that a distributed network of object-selective areas including parietal, ventromedial temporal, and frontal cortex can be activated by haptic sensory input, without input from LOC. These same areas respond not only to objects over textures, but also show selectivity

to object identity (adaptation). That neural populations in the spared cortex of MC were able to support object recognition is corroborated by her behavioural performance on object recognition and matching tasks. Although LOC may be critical for visual recognition of objects, our data indicate that it is not a necessary substrate for object recognition via haptics.

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Perception in obesity: Does physical or perceived body size affect perceived distance?

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According to the action-specific perception account (e.g., Witt, 2011), a person's ability to perform an action affects their perception of the environment. For example, targets were judged as farther away to those who threw a heavy ball than to perceivers who threw a light ball (Witt, Proffitt, & Epstein, 2004). Similarly, chronic pain patients judged distances to be farther compared with age-matched controls (Witt et al., 2008). Thus, as changes occur in both short-term and long-term potential, perceptual experiences reflect these changes. In the current experiment, we examined whether one's physical body size, according to Body Mass Index (BMI) classifications, influences perceptual distance judgements. We predicted that people with a higher BMI would see targets as farther away due to increased energetic requirements to walk to the target. In addition, we also examined whether perceived body size among overweight individuals affected perception of distances. In particular, we examined whether the environment is scaled relative to one's physical body size or one's perceived body size, and some people who are obese experience a disconnection between the two.

In this experiment, 18 normal weight (mean BMI = 23.23) subjects (nine females) age 20–30 years ($M = 23.1$), 16 overweight (mean BMI = 27.02) subjects (nine female) age 19–33 years, and 10 obese (mean BMI = 33.41) subjects (five females) age 18–32 years ($M = 24.8$), were recruited in front of Wal-Mart to participate in the experiment. Participants made four distance judgements (10, 15, 20, 25 m) in a randomized order along a nearby sidewalk. Participants were instructed to “verbally estimate the distance to a cone in feet and inches”. After making all distance estimates, participants were asked to complete a questionnaire about their perceived body size (e.g., “How

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would you categorize your body type?’). Finally, the experimenter obtained measures of the subject’s weight and height to determine their BMI.

Subjects were categorized as normal or obese according to BMI classification. We ran repeated-measures ANOVA with distance (10, 15, 20, and 25 m) as a within-subjects factor and weight group (normal, overweight, and obese) as a between-subjects factor. Target distance significantly affected estimated distance, $F(3, 41) = 148.68, p < .001, \eta_p^2 = .78$. The effect of weight group on estimated distance was trending significance, $F(2, 41) = 2.632, p = .084, \eta_p^2 = .114$. Interestingly, however, there is a significant difference in distance estimates between obese and normal weight subjects, $F(3, 26) = 4.77, p = .038, \eta_p^2 = .155$. The interaction between age and distance was not significant. As apparent in Figure 1, obese individuals estimated distances to be farther than normal weight and overweight subjects. Normal weight and overweight individuals underestimated distances, which is a typical finding in literature (Loomis, Da Silva, Fujita, & Fukushima, 1992; Philbeck & Loomis, 1997; Proffitt, Stefanucci, Banton, & Epstein, 2003; Witt et al., 2004). Thus, obese subjects may have overestimated target distance compared to typical underestimation of normal weight subjects. An interesting possibility is that obese individuals made more accurate estimates and therefore are seeing the world more veridically; however, we see no reason why this should be the case.

In a follow-up analysis, among those who classify as either obese or overweight, we examined whether their perceived body image would influence distance estimates. Out of 21 subjects who were classified as overweight or obese, 12 (seven females) had an accurate body image and 14 (seven females) had an inaccurate body image. Subjects’ body image was

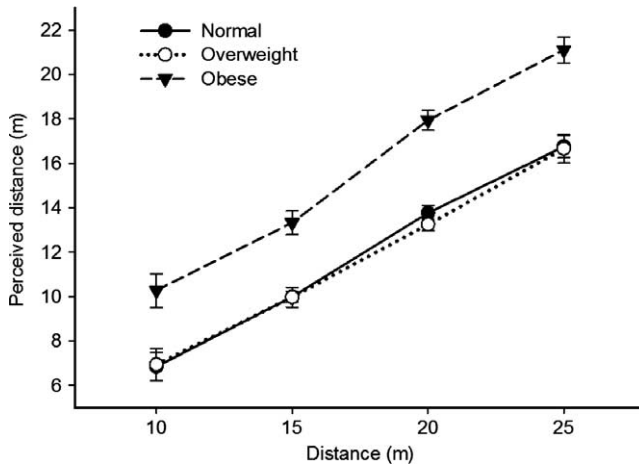


Figure 1. Estimated distance as a function of actual target distance for obese, overweight, and normal weight subjects. Error bars represent 1 SEM.

categorized as “inaccurate” if they reported their body size as either normal or slim/fit when in fact BMI reveals them to be either overweight or obese. On the other hand, their body image was classified as “accurate” if they reported their body as overweight when BMI does reveal them as overweight. We ran a repeated-measures ANOVA with distance (10, 15, 20, 25 m) as a within-subjects factor and body image (inaccurate vs. accurate) as a between-subjects factor. Target distance significantly affected estimated distance, $F(3, 24) = 86.14$, $p < .001$, $\eta_p^2 = .78$. Body image did not affect estimated distance, $F(1, 24) = 0.127$, $p = .725$, $\eta_p^2 = .005$. The interaction between body image and distance was also not significant.

In these experiments, we found that those who are obese judged distances to be farther than normal weight subjects. However, there is no difference between overweight and normal weight subjects. These results may suggest that only certain weight extremes begin to impede action ability and as a result influence perception. Obese individuals have poor physical fitness levels and as a result find many everyday activities to be more strenuous and exhausting compared to fitter individuals. These poorer fitness levels associated with weight may affect action relevant spatial perception. One study already shows that this may be the case. Hills were judged as steeper by people who were fatigued or had poor physical fitness levels (Bhalla & Proffitt, 1999). Furthermore, judgements of perceived egocentric distance increased for people encumbered by a heavy backpack (Proffitt et al., 2003). These findings are consistent with and expand on the action-specific perception approach, which argues that the environment is scaled relative to an observer’s action abilities (Witt, 2011).

Given that increased anticipated effort for walking leads to increased judgement of distances (Proffitt et al., 2003; Witt et al., 2004; Witt, Proffitt, & Epstein, 2010), the current experiments also address whether physical or perceived body size influences anticipated action ability. It is unclear what specific components—conscious or unconscious image of self—influence action abilities. Therefore, to address this we examined whether the environment is scaled relative to perceived body size or physical body size. We found no difference in perceived distance to targets between overweight individuals with an accurate and an inaccurate body image. Results suggest that actual body size—not perceived body size—influences perceived distance.

The current results propose that one’s belief about their body size does not influence spatial perception; rather, physical body size is the main determinant of distance perception. Additional research is needed to determine whether obesity, and differences in perceived body size among those who are overweight, also influences other aspects of spatial perception such as slant perception and width aperture. It seems to be adaptive for a perceptual system to be tuned to physical body size and actual abilities rather than one’s beliefs about their potential for action.

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Properties of spatial attention during conscious and nonconscious processing of visual features and objects

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Attention and consciousness are closely related, yet recent work indicates that they do not share identical underlying neural processes (Koch & Tsuchiya, 2006). Attending to stimuli may be necessary for their conscious registration but it is not sufficient, since space-based and feature-based attention can be deployed to and at the processing of stimuli that

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nevertheless do not register in consciousness (Finkbeiner & Palermo, 2009; Kieffer & Brendel, 2006; Tapia, Breitmeyer & Shooner, 2010). Although attention can modulate nonconscious levels of processing, little is known about how it is allocated and how it affects visual processing at nonconscious as compared to conscious levels. Recent reports (Tapia et al., 2010) indicate that effects of feature-based attention at nonconscious and conscious levels of processing are distinct. The properties and gradient of spatial attention, on the other hand, have been shown to be equivalent for consciously and nonconsciously processed form features (Tapia, Breitmeyer & Broyles, 2011). Here we examine and compare interactions between feature-based and spatial attention at conscious and nonconscious levels.

Participants responded to the shape (Experiment 1), colour (Experiment 2), or shape and colour (Experiment 3) of the probe while ignoring two flanking shapes. The probe and the flankers could have one of two shapes (diamond or square) and one of two colours (green or blue), resulting in four probe-flanker congruency conditions: All-congruent (e.g., green diamond probe and green diamond flankers), form-incongruent (e.g., green diamond probe and green square flankers), colour-incongruent (e.g., green diamond probe and blue diamond flankers), and form-and-colour-incongruent (e.g., green diamond probe and blue diamond square flankers).

As long as the flankers fall within the spatial gradient of attention centred at the probe location (Cave & Bichot, 1999; LaBerge, 1995), significant flanker compatibility effects (FCE), defined as differences between choice reaction times (RTs) to incongruent and congruent probe-flanker pairs, are expected. These compatibility effects ought to decrease with increasing separation between flankers and the attended probe location (Eriksen & Eriksen, 1974). Moreover, task-relevant incongruent features should yield larger FCEs than task-irrelevant features (Tapia et al., 2010). For example, significantly larger form-incongruent FCEs are expected in Experiment 1 (where response to the shape of the probe is required), whereas FCEs in colour-incongruent trials should be minimal. Identical trends in FCEs even when flankers are suppressed from visual awareness are also expected, particularly when participants respond to a single feature (Tapia et al., 2011). Additionally, we explore the interaction between feature and spatial attention at conscious and nonconscious levels by examining FCE trends across probe-flanker separations and different congruency levels. Because feature conjunctions are processed only at the conscious but not the nonconscious level (Tapia et al., 2010), the gradient of spatial attention may differ between these two levels.

METHOD

Flankers were positioned symmetrically to the left and right of the probe on an imaginary half-circle centred at fixation so that the distance from the fixation to any stimulus was always 6.2° (Figure 1a). The probe was always centred directly above the fixation, while the centre-to-centre distance between the flankers and the probe varied. The flankers were form-and-colour-(all-)congruent, form-incongruent, colour-incongruent, or all-incongruent with the probe. The probe was presented 53 ms after the flankers. In the flanker-visible (conscious processing) condition only the probe followed the flankers; in the flanker-invisible (nonconscious processing) condition, the

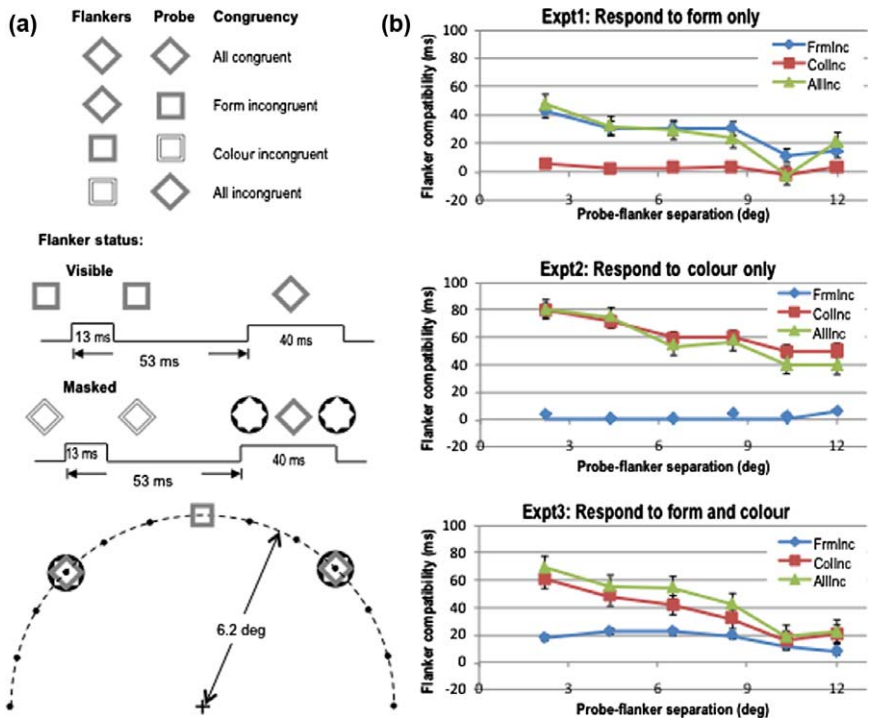


Figure 1. (a) Upper panel: Examples of four probe-flanker congruency conditions (different types of lines represent two different colours of stimuli). Middle panel: Temporal parameters of trial sequences. Shown here is form-incongruent trial with visible and colour-incongruent trial with masked flankers. Lower panel: Spatial layout of the stimuli. Relative to the probe position, flankers (and masks) could be placed at one of 6 symmetric spatial separations, indicated by the black dots. Illustrated are flanker and mask locations at a 4.6° separation from the probe when flankers were followed by metacontrast masks. (b) Upper panel: FCEs in Experiment 1 (task-relevant feature: Form). Middle panel: FCEs in Experiment 2 (task-relevant feature: Colour). Lower panel: FCEs in Experiment 3 (task-relevant features: Form and colour). Error bars correspond to *SEM*. To view this figure in colour, please see the online issue of the Journal.

probe was accompanied by two flanking circular metacontrast masks that, at an SOA of 53 ms, suppressed the visibility of the flankers. In RT trials, participants were instructed to respond to the shape (Experiment 1), colour (Experiment 2), or the shape and colour (Experiment 3) of the probe. In a separate block of trials, the visibility of masked flankers was assessed by asking participants to identify their shape (Experiment 1), colour (Experiment 2) or shape and colour (Experiment 3).

RESULTS

Participants (four out of 31) who identified masked flankers at an above-chance level were excluded from analyses. A 2 (flanker visibility) \times 6 (separation) \times 3 (congruency) repeated-measures ANOVA on FCEs with task (Experiments 1–3) as a between-subjects factor was conducted. The main effect of flanker visibility, $F(1, 24) = 19.64, p < .001$, indicates that FCEs were overall larger when flankers were visible than when they were masked. The expected main effect of congruency, $F(2, 48) = 101.7, p < .001$, as well as the interaction between task and congruency, $F(4, 48) = 78.49, p < .001$, reflect significant FCEs to task-relevant incongruent probe–flanker pairs. For example, in Experiment 1, when participants responded to the shape of the probe, FCEs in form- and form-and-colour-(all-)incongruent trials were significantly larger than in the colour-incongruent as well as all-congruent trials, indicating that only the task-relevant feature was attended. The expected main effect of separation, $F(5, 120) = 10.64, p < .001$, reflects decreasing FCEs as the separation between probe and flankers increases. Moreover, the interactions between probe–flanker separation and congruency, $F(10, 240) = 5.24, p < .001$, as well as that between task, separation, and congruency, $F(20, 240) = 2.39, p = .001$, reflect decreasing FCEs in the task-relevant incongruent trials with increasing separation between stimuli (see Figure 1b). Notice that in Experiment 1, where form was task-relevant, significant FCEs were obtained only in form- and all-incongruent trials. Similarly, in Experiment 2, where colour was task-relevant, significant FCEs were obtained only in colour and all-incongruent trials. Finally, in Experiment 3, where both form and colour were relevant to the task, significant FCEs were obtained in all probe–flanker incongruency conditions (see Figure 1b). The lack of any significant interactions containing both factors of flanker visibility and probe–flanker separation (all $ps > .1$) suggests that FCEs decrease at a similar rate with increasing separation between stimuli regardless of visibility of the flankers.

CONCLUSION

The results of these experiments are: (1) Consciously and nonconsciously processed flankers interfere with processing of the probe; (2) flanker interference decreases with increasing separation between stimuli; (3) this occurs even when flankers are suppressed from awareness, indicating that spatial attention effects are expressed at the nonconscious level of processing; (4) the effects of feature-based attention at the nonconscious level are weaker than at the conscious level; (5) however, the spatial gradient of attention at the nonconscious level is similar to that found at the conscious level, even when stimuli are defined by more than one feature.

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The automatic encoding of distractors into visual working memory through overt, but not covert attention

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Visual working memory (VWM) refers to a limited-capacity storage system used for temporary maintenance of task-relevant visual information. An important issue in VWM research is the mechanism by which information is selected for encoding into VWM. Current evidence suggests that visual attention plays an important role in both encoding (Schmidt, Vogel, Woodman, & Luck, 2002) and maintenance of the items in VWM (Awh, Armstrong, & Moore, 2006). Further, some theories suggest that VWM and visual attention are simply two different terms to describe the same system (Theeuwes, Belopolsky, & Olivers, 2009), in which case attending to an object should be equivalent to its encoding into VWM.

In the present study, we investigated whether overtly or covertly attending to an object is sufficient for its consolidation into VWM. In three experiments, we used a change-detection task to measure participants' VWM capacities. On each trial, a memory array containing five coloured circles was presented on the circumference of a virtual circle. Spatial attention was manipulated during the retention interval by asking participants to either overtly (Experiment 1) or covertly (Experiments 2 and 3) attend to a distractor which was presented laterally (Figure 1A). At the end of each trial participants were presented with five coloured circles and asked to indicate whether all the colours were the same or one had changed. Encoding of the distractor object into VWM was measured by interference with colour memory; if the distractor is encoded into VWM, it should displace colour information.

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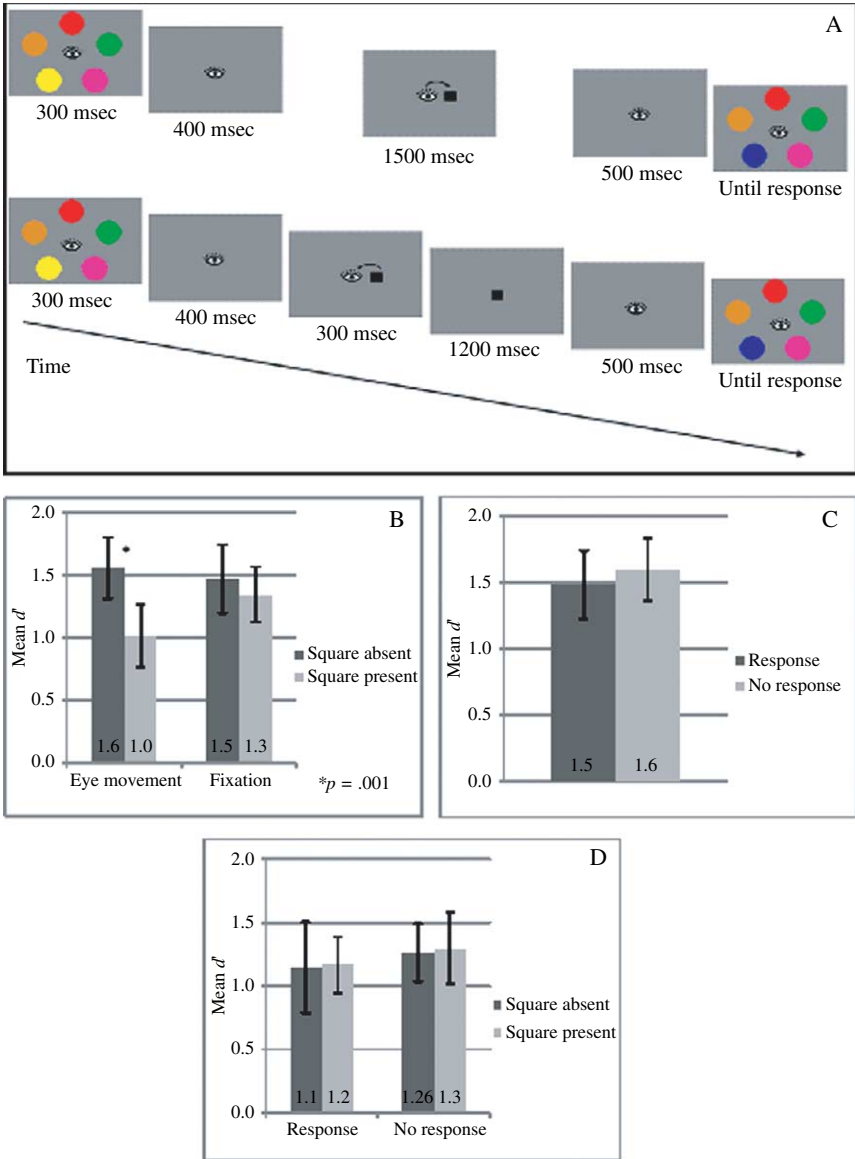


Figure 1. (A) Top: Sequence of events in an EM trial in Experiment 1. Bottom: Sequence of events in a fixation trial in Experiment 1. Figure not drawn to scale. (B–D) Mean sensitivity (d') values for Experiments 1, 2, and 3, respectively. Error bars represent 95% confidence intervals. To view this figure in colour, please see the online issue of the Journal.

If VWM and spatial attention reflect the same mechanism, both overt and covert shifts of attention would result in a significant decrease in change-detection performance. In contrast, if VWM and attention are dissociable then memory performance should not be affected by shifts of attention. This is because the attended item is always task-irrelevant to the primary VWM task. Alternatively, saccades may play a special role in VWM consolidation, because VWM is specialized to span the perceptual gaps created by each saccade (Hollingworth, Richard, & Luck, 2008). In this view, performance should decrease when participants execute a saccade to the distractor but not necessarily when they covertly shifted attention, as covertly shifting attention does not disrupt perceptual input.

EXPERIMENT 1

Experiment 1 has two conditions. In one block (eye movement), participants made a saccade to the distractor. In another block (fixation), the distractor first appeared laterally and then jumped to the fixation (Figure 1A). Participants were instructed to fixate on the central cross throughout the trial. In both blocks, the distractor was presented on two-thirds of the trials (square-present). The remaining trials did not contain the distractor (square-absent). We calculated participants' sensitivity to changes in the change-detection task (as measured by d' , Figure 1B). A 2 (condition: Eye movement vs. fixation) \times 2 (Object type: Present vs. absent) within-subjects ANOVA showed the main effect of condition was not significant, $F(1, 17) = 2.4$, $p > .05$. However, the main effect of object type was significant, $F(1, 17) = 17.8$, $p = .001$. Importantly, there was a significant interaction between condition and object type, $F(1, 17) = 6.8$, $p = .018$, indicating that making a saccade to a distractor reliably decreased change-detection performance whereas the same retinal events without a saccade did not.

EXPERIMENTS 2 AND 3

In Experiments 2 and 3, we investigated the role of covert attention on VWM consolidation. In both experiments, participants were instructed to fixate the central cross throughout the trial, and covertly attend to the distractor.

In Experiment 2, an outlined square was presented on every trial. In one block (no-response), participants were instructed to ignore the square. In another block (response), on one-third of the trials a low-contrast dot was presented in the square for 250ms (target-present); on the remaining trials, no dot was presented (target-absent). Participants were instructed to attend to the square and make a buttonpress response when they detected the dot.

Dot detection accuracy was high (96%), indicating that participants were attending to the square. We tested the role of covert attention by comparing no-response trials with response/target-absent trials (Figure 1C). There was no significant effect of block type, $t(17) = -1.19$, $p = .25$, suggesting that, unlike overt attention, covertly attending to a distractor did not interfere with memory performance.

Because the square was presented on every trial and it was an abrupt-onset object, participants might have attended to it in no-response trials. In order to eliminate this alternative explanation, in Experiment 3, we included square-absent trials. The dot appeared either in the square or on the opposite side of the screen. Participants were instructed to attend to the square but make a detection response in both cases. Dot detection accuracy was significantly higher when it appeared in the square than when it appeared on the opposite side, $t(16) = 1.8$, $p = .018$, confirming that participants were attending to the square. Only the target-absent trials were included in the analysis (Figure 1D). A 2 (condition: Response vs. no-response) \times 2 (object type: Present vs. absent) ANOVA was conducted. Neither the main effect of condition nor the main effect of object type was significant, $F(1, 15) = 1.2$, $p > .05$, and $F(1, 15) = 0.198$, $p > .05$, respectively. The interaction was also not significant, $F(1, 15) = .01$, $p > .05$, indicating that covertly attending to a distractor is not sufficient for its encoding into VWM.

DISCUSSION

The present study examined the role of overt and covert attention on the consolidation of items into VWM. In line with previous studies which showed preferential encoding of the saccade-target object (Hoffman & Subramaniam, 1995), we found that executing a saccade to a distractor leads to its automatic consolidation into VWM (Experiment 1). However, we found no evidence for the automatic consolidation of a covertly attended object (Experiments 2 and 3). Together, these results are difficult to reconcile with accounts which hold covert attention and VWM constitute the same system. Instead, our results support the view that saccades play a special role in VWM consolidation. Executing a saccade to an object would lead to its automatic consolidation because saccades generate perceptual gaps that can be bridged only by a brief form of memory. In the absence of perceptual discontinuity (e.g., covert shifts of attention), the distractor can be strategically blocked from entry into VWM.

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Category learning for a (perceptual) purpose

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Our experience categorizing and recognizing objects in the world around us shapes their visual representations and affects how they are perceived. The current study investigated how the type of visual experience we have with an object affects these representations.

There is evidence that learning to categorize objects affects their visual representation through a process known as dimensional modulation. A model of object categorization by Nosofsky (1986) suggests that learning to categorize an object shifts the “attention weights” of the feature dimensions to exaggerate the importance of features that are diagnostic of category membership, while minimizing the importance of other features that are not diagnostic of category.

This exaggeration of the category diagnostic dimension can result in increased perceptual sensitivity to variations of that feature either along the entire dimension or near the category boundary (Goldstone, 1994; Gold-

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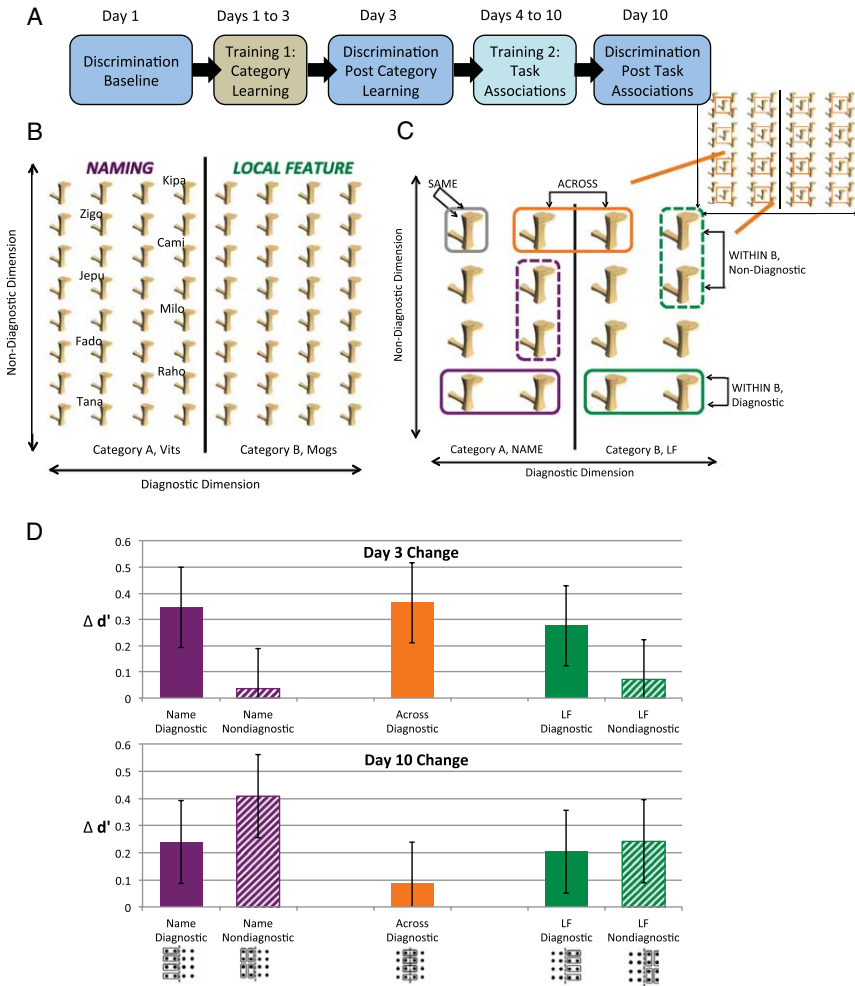


Figure 1. (A) Experimental design: Study design including discrimination test before training and after each training phase. (B) Training stimuli: Training stimuli divided into two categories with different tasks. (C) Test stimuli: Test object pairs, a 4 × 4 set within the training objects. (D) Discrimination test results: Results of discrimination test, Day 3 and Day 10 change by task and direction.

stone & Steyvers, 2001). Stretching may also occur more locally, for example in small clusters of a feature space to discriminate objects within a cluster (Aha & Goldstone, 1992). Goldstone (1994) demonstrated that this shift in “attention weights” of feature dimensions can be long lasting such that improvements in dimensions that were diagnostic for category learning can

be found outside of a categorization task. The nature of the category learning task has also been demonstrated to have an impact on which object features are attended to and encoded (Chin-Parker & Ross, 2002).

In previous work, the perceptual task has been uniform across the entire object space, thus requiring the same visual demands for all objects. In the real world, however, categories are often informative of different perceptual goals and can help us choose an appropriate perceptual strategy for these goals. The current study builds on previous work by creating categories of objects with different perceptual goals within the same feature space to better approximate real-world category learning.

In a 10 session, two part training study, participants learned to categorize a morphspace of complex novel objects into two categories, and then learned a different perceptual task, either individuation or local feature judgement, for each category (Figure 1A). A same/different discrimination test at three time points, before training, after category learning, and after category-task association training, allowed us to measure changes in sensitivity to feature dimensions of the object space as a result of each training.

A dimensional morphspace of Ziggerins made from four parents was created. The training set was an 8×8 space of Ziggerin morphs (Figure B), and the set used for the discrimination test was a 4×4 space of different Ziggerin morphs located between the training objects in the morphspace (Figure C). All of the stimuli also had a local feature in the same place, which was a pair of lines that were offset to one side or the other to allow a Vernier judgement.

In Sessions 1–3, participants learned to categorize objects into one of two categories, as Vits or Mogs. In Sessions 4–6, participants learned the category-specific tasks in separate blocks. For one category they learned to individuate eight training objects with unique names (e.g., Milo, Kipa). For the other category, participants learned to do a local feature task, which was a Vernier line task, in which they needed to judge if the top line was to the left or right of the bottom line. In Sessions 7–10, blocks were mixed with stimuli from both categories. Participants had to perform the category-specific task, either naming or local feature, without being told which category the object belonged to. In all of the training tasks, participants were able to achieve high accuracy although the naming task was more difficult than the local feature task. In the final stage of training we hoped to model real-world object categorization, where categorization serves recognition in a single, fluid process that dictates how an object is to be processed.

In the object discrimination test results, we saw that after category learning, there was an increase in sensitivity along the category diagnostic dimension on both sides of the space and also across the category boundary as predicted by previous work. After category-task association learning there was an increase in sensitivity on both sides of the space for both the category

diagnostic and category nondiagnostic dimensions. In an ANOVA of Δd for Sessions 3 and 10, there was a significant interaction of direction and session, $F(1, 23) = 6.585$, $MSE = 1.264$, $p = .0173$. This is interesting because the category nondiagnostic dimension is only relevant to the naming task but irrelevant for the feature task. The increase for the nondiagnostic dimension was slightly greater for the side of the space that participants learned to name (interaction of Session \times Direction \times Task), $F(1, 23) = 1.277$, $MSE = 0.168$, $p = .270$. The greater increase along the nondiagnostic direction for the naming side compared to other side suggests that these changes are not global across the feature dimension but are applied more locally within the space. This is also suggested by the fact that there was no further improvement in discrimination across the category boundary after the category–task association learning even though participants continued to improve slightly at categorization as indicated by their good performance selecting the appropriate task for the category.

The findings are consistent with previous work demonstrating that the relevance of object features changes with experience and alters object representations (Goldstone, 1994; Goldstone & Styvers, 2001). The results suggest that different perceptual strategies can be adopted on the two sides of a category boundary within a space of highly similar objects. This training paradigm bridges prior work in category learning with that on perceptual expertise (e.g., Wong, Palmeri, & Gauthier, 2009; McGugin, Tanaka, Lebrecht, Tarr, & Gauthier, 2011) and provides a useful model of how we create categories of objects that become associated with different perceptual strategies, such as in the “other race effect” for face recognition and in skills that require fine perceptual discriminations (e.g., radiology). Future work will address whether increasing the automaticity of the task associations will lead to sharpening of the category boundary, and whether objects from the two categories are processed qualitatively differently in the brain.

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Experience with an irrelevant singleton is necessary to prevent capture in feature search mode

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Selective attention during visual search allows us to devote processing to probable targets while limiting the same processing to nontargets. Although participants are skilled at constraining attention to task-relevant items, they are not perfect (Egeth, Virzi, & Garbart, 1984; Theeuwes, 1992). For example, Theeuwes (1992) demonstrated that a task-irrelevant colour singleton slowed participants' responses while they searched for a shape-defined target among homogeneous distractors. Because the colour singleton was never the target, attending to it was unhelpful; nonetheless, attention was captured by the irrelevant singleton.

Bacon and Egeth (1994) suggested Theeuwes' (1992) capture occurred because participants searched for a shape singleton, allowing any singleton (including the irrelevant colour singleton) to capture attention. Subsequently, Bacon and Egeth demonstrated that a colour singleton no longer captured attention when participants searched for a target shape among heterogeneous distractors. When the display contained heterogeneous distractors (the target was not a singleton), participants changed their attentional set and searched for a specific shape feature; thus, singleton distractors stopped capturing attention.

In the present experiment, we tested whether the lack of capture by the colour singleton during feature search mode results from a precise

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specification of the target shape or if capture is also affected by distractor properties. Specifically, we asked whether participants use a target template in isolation or in conjunction with inhibiting the colour singleton. For example, in Lamy, Leber, and Egeth (2004), participants searched for a colour-defined target among heterogeneous distractors. Before the search display appeared, a cue either matching or not matching the colour of the target appeared at one of the possible target locations. When the cue matched the target, participants detected the target at the cued location faster. Importantly, when the cue did not match the target, participants were slower to respond to targets appearing at the cued location. These results indicate that participants did more than simply ignore the nonmatching cue; they inhibited it.

Attentional tuning to distractors also occurs in other search tasks. For example, Maljkovic and Nakayama (1994) found that, when searching for a colour singleton, participants' responses became faster as the target and distractor colours repeated across trials. Although repeating target colour had a greater effect than repeating distractor colour, the shorter RTs (response times) in the later case indicates the role of attentional tuning to distractors.

Finally, a closer examination of Bacon and Egeth's (1994) results also suggests inhibition of the colour singleton. At large set sizes, RTs were shorter when the colour singleton was present, suggesting participants might have inhibited the singleton. However, the lingering question is what caused the observed distractor inhibition. Is the singleton inhibited from the outset of the task? Or, is the singleton inhibited based on long-term learning, specifically, experience with inhibiting singletons? Previous studies have not distinguished these possibilities because singletons remained constant and RTs were averaged across conditions. Therefore, we investigated whether feature search mode involves not only a precise target template, but also involves experience-dependent attentional tuning to distractor feature properties.

To encourage participants to learn a specific target template, we first trained participants to search for a green circle among green heterogeneous distractors (Figure 1A). Following this training phase, participants completed four blocks in which a colour singleton appeared on half of the trials. The singleton's colour differed in each block. If singleton capture is eliminated in feature search mode because of a precise target template alone, then varying the singleton's colour across blocks should not affect participants' RTs. This is because the target template suppresses distractors across all trials. In contrast, if participants learn to suppress the colour singleton in addition to using the target template, then the colour singleton should initially capture attention whenever its colour changes, and capture will diminish as participants learn to suppress irrelevant singletons.

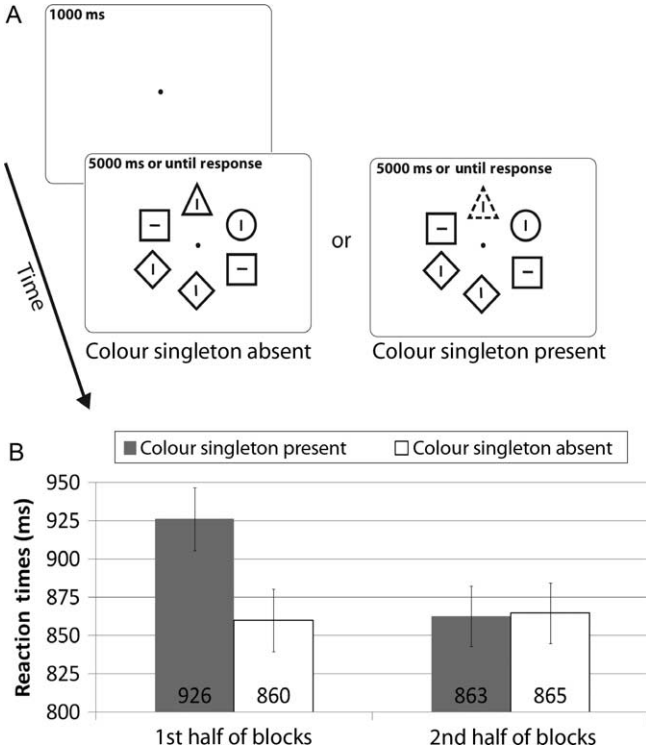


Figure 1. (A) Event sequence for a search trial. Different line patterns represent different colours. (B) Mean RTs as a function of colour singleton type (present vs. absent) and trial order (first half of blocks vs. second half of blocks). Error bars represent 95% confidence intervals (Loftus & Masson, 1994).

METHODS

Twelve University of Iowa undergraduates reported the orientation of a line appearing within a target green circle that appeared among five random heterogeneous distractors (Figure 1A). Stimuli appeared equally spaced around an imaginary circle with a radius of 4.2° . Each item was roughly $2.5^\circ \times 2.5^\circ$. The lines within the objects were $0.7^\circ \times 1^\circ$. Following the presentation of a fixation dot for 1000 ms, the search display remained on the screen for 5000 ms or until response. After completing 60 trials for the training phase without a colour singleton, participants completed four blocks of 48 trials. Each block had a different colour singleton (irrelevant to the shape search task) on half the trials. Block order was counterbalanced across participants. Participants were instructed to respond as quickly and accurately as possible.

RESULTS

A repeated measure analysis of variance (ANOVA) with colour singleton type (present vs. absent) and trial order (first half of blocks vs. second half of blocks) was performed on RTs of correct trials less than 2000 ms (see Figure 1B). Shorter RTs in the singleton absent condition led to a marginally significant main effect of singleton type, $F(1, 11) = 4.2, p < .066$. Shorter RTs in the second half of blocks led to a significant main effect of trial order, $F(1, 11) = 5.4, p < .05$. Most importantly, capture was observed in the first half of blocks, but not in the second half of blocks. This difference led to a significant interaction of colour singleton type and trial order, $F(1, 11) = 13.3, p < .005$. In fact, planned pairwise comparisons confirmed a significant effect of capture in the first half of blocks, $t(11) = 3.6, p < .006$, but not in the second half, $t(11) = 0.116, p = .91$. These results indicate that participants' attention was initially captured by a colour singleton, but this pattern disappeared with experience.

DISCUSSION

Our experiment demonstrates that, despite the fact that participants are in feature-search mode, a colour singleton captures their attention during the first half of blocks. Importantly, on subsequent trials, as expected in feature-search mode, capture disappeared. These results indicate that feature search mode is composed of not only a precise target template, but also an exclusionary template. Only after experience-dependent attentional tuning to distractor properties does an irrelevant singleton no longer capture attention.

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Dissociating the impact of emotion from the impact of attentional capture on conscious perception

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Research has revealed that emotional stimuli receive higher priority for limited-capacity perceptual processing than neutral stimuli do and that they can interfere with conscious perception of subsequent neutral stimuli. In large part, such studies have used rapid serial visual presentation (RSVP), where items are presented one at a time in the same spatial location at a high rate of speed (often 10 per second). In conventional nonemotional RSVP tasks, participants are asked to search for two targets in each RSVP stream and report both targets after the stream ends. Report accuracy for the second target often suffers if it is presented between 200 and 500 ms after the first one, a phenomenon known as the attentional blink (AB; e.g., Raymond, Shapiro, & Arnell, 1992). Theoretical accounts of the AB suggest that it stems from relatively late-stage, central bottlenecks in information processing, such as consolidation into working memory (e.g., Chun & Potter, 1995). In contrast, when participants search RSVP streams for only a single target, target perception remains intact because the distractors do not typically elicit such processing bottlenecks. However, in one such one-target RSVP task, emotional distractors that preceded the target induced greater target perception deficits than did preceding neutral distractors. This effect has been referred to as “emotion-induced blindness” (EIB; e.g., Most, Chun, Widders, & Zald, 2005). In short, emotional stimuli, although task-irrelevant, induced target perception deficits that resembled those found in the conventional AB studies. On the surface, it seemed that emotional stimuli simply induced spontaneous ABs through their ability to capture attention. This would be consistent with other recent findings that nonemotional, but

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attention-grabbing, distractors could spontaneously induce similar ABs (e.g., Spalek, Falcon, & Di Lollo, 2006).

However, we recently reported evidence suggesting that the spontaneous perceptual disruptions induced by emotional stimuli might stem from mechanisms different from those traditionally proposed to underlie the nonemotional attentional blink: Specifically, we found EIB to be spatially localized, a pattern that could not be accounted for by widely accepted suggestions that the AB reflects late-stage, central information processing bottlenecks (Most & Wang, 2011). In that study, participants searched for a target that could appear in one of two simultaneous RSVP streams, and an emotional distractor could appear either in the same stream as the target or in opposite stream. EIB was found only when target appeared at the location of the emotional distractor presented before the target. Could it be that such spatial localization reflects a mechanistically unique impact of emotion on conscious perception? We argued that it could, with emotional distractors outcompeting nonemotional targets for dominance at overlapping points in time and space (although the stimuli themselves appeared serially, their rapid rate of presentation could yield neural responses that temporally overlapped). The question remained, though, whether such a mechanism is truly unique to emotional distraction or whether perceptual disruptions caused by any attention-grabbing distractor would have the same spatially localized nature.

In the current experiments, we capitalized on the spatially localized nature of EIB to examine whether target perception impairments elicited by the emotional distractors and by the nonemotional, but attention-grabbing, distractors are based on common underlying mechanisms. If EIB stems simply from attentional capture by emotional stimuli, then target perception deficits caused by the nonemotional attention-grabbing distractors should also be spatially localized.

In Experiment 1, we first replicated the spatially localized effect of EIB. Two vertically arranged simultaneous RSVP streams were presented at a rate of 100 ms/item. Each stream contained 17 upright images depicting landscapes or architectures. The target was a picture that had been rotated 90° to the left or to the right. Depending on the trial, an emotional or neutral distractor picture containing people or animals appeared two items before the target, with equal probability of appearing in the same stream as the target or in the opposite stream (see Figure 1A). Participants were instructed to identify the orientation of the target and to ignore the distractors. EIB emerged only when targets and distractors appeared in the same stream as each other (p -value for Emotion \times Stream interaction = .014; see Figure 1B). We then examined whether nonemotional, but attention-grabbing distractors would elicit similarly localized perceptual impairments (Experiments 2 and 3). In Experiment 2, participants searched for a red letter that could appear

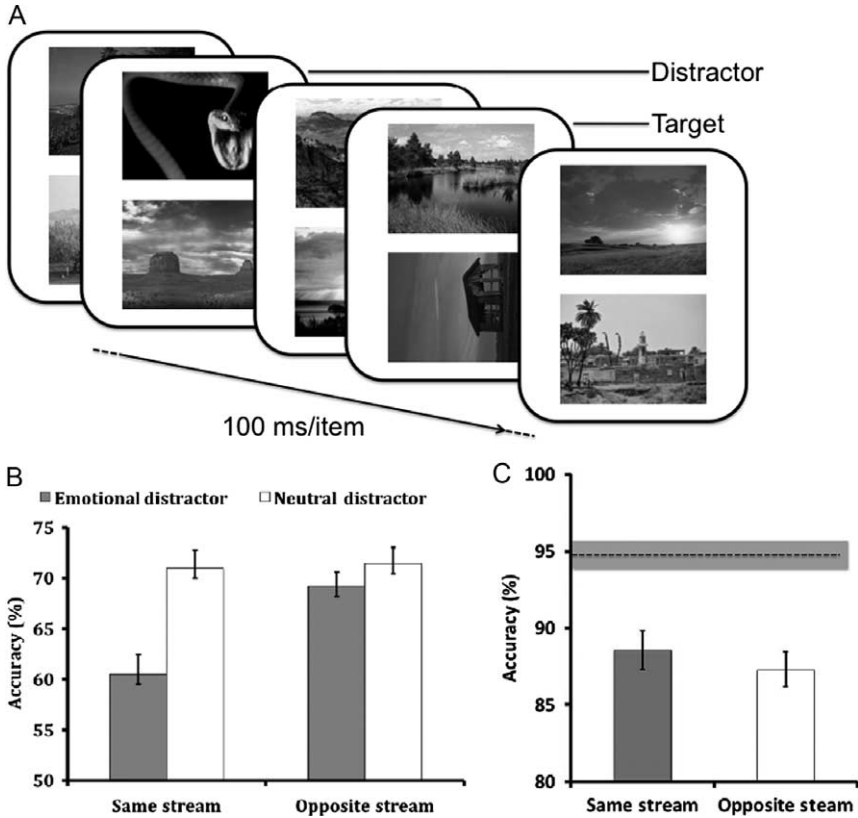


Figure 1. (A) Example of a partial trial in Experiment 1, with an emotional distractor appearing in the stream opposite the target. (B) Results from Experiment 1. (C) Results from Experiment 3, a nonemotional condition, where perceptual disruption was not localized. The dashed line indicates mean accuracy in the baseline condition.

within one of two simultaneous RSVP streams of 21 white letters, and in half of trials a task-irrelevant red digit appeared either two or eight items before the target, either in either the same or opposite stream as the target. The red digits impaired target perception both in the same stream ($p < .001$) and in the opposite stream ($p < .001$), and the impairments were equivalent across the two streams ($p > .72$). In Experiment 3, we further tested the impact of nonemotional distractors under conditions that more closely mimicked those in Experiment 1: All the stimuli were landscape and architectural photos. Participants searched through two simultaneous streams of upright greyscale photos for a rotated coloured target while trying to ignore a preceding upright, but coloured distractor that could appear two items before the target. Target perception was disrupted by the appearance of the coloured

distractor regardless of whether it appeared in the same stream as the target ($p < .002$) or the opposite stream ($p < .001$; p -value for interaction = .597; see Figure 1C).

In Experiments 2 and 3, the nonemotional distractors succeeded in capturing attention, as reflected by the fact that performance in their presence at early lags was worse than at longer lags or than in their absence. However, in contrast to Experiment 1, where emotional distractors elicited spatially localized perceptual disruptions, both types of nonemotional distractor elicited perceptual disruptions that were equivalent across the visual field. These results across the three experiments converge to suggest that emotional distractors impair target perception via mechanisms separable from those triggered simply by the nonemotional capture of attention, and that such mechanisms may involve spatiotemporal competition.

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