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Interference from irrelevant colour-singletons during serial search depends on visual attention being spatially diffuse

Bryan R. Burnham, James H. Neely, Peter B. Walker, and W. Trammell Neill

Department of Psychology, University at Albany, State University of New York, USA

Theeuwes (2004) argued that when a target appears in a visual search display with heterogeneous distractors, observers will narrow their attentional window and conduct a serial search (resulting in positive RT/number-of-display-items slopes). Theeuwes argued that during serial search, the presence of a salient singleton distractor does not capture attention (i.e., does not slow RTs relative to when it is absent), because the narrowed attentional window precludes it from being simultaneously perceived with other items, thereby concealing its status as a (salient) singleton. However, Theeuwes and Burger (1998) demonstrated this was true only if the observer has explicit, top-down attentional control over what colour should be attended and what colour should be ignored in the display. Specifically, when the target-relevant and the singleton-distractor colours are fixed across trials, a colour-singleton does not capture attention; but when either one (or both) of those colours is randomized across trials, a colour-singleton does capture attention, even when there is serial search. Theeuwes and Burger explained this capture effect as due to incomplete top-down knowledge as to what features to expect in the search display. Thus, when top-down control is strong and search is serial, a colour-singleton does not capture attention.

It is noteworthy that the items in Theeuwes’ (2004) and Theeuwes and Burger’s (1998) displays always appeared around the circumference of an imaginary circle. Because the item locations were predictable, observers may not have spread their attention over the complete display prior to beginning serial search. This initially narrowed attention (and the subsequent serial search) would have precluded the singleton-distractor from being perceived as a (salient) singleton before search initiation, thereby preventing it from capturing attention.

Address correspondence to: Bryan R. Burnham, Department of Psychology (SS 369), University at Albany, SUNY, 1400 Washington Ave., Albany, NY 12222, USA. Tel: (518) 442-4817; E-mail: bb7090@albany.edu
In the present research, we sought to (1) replicate the absence of capture from a colour-singleton during serial search when observers could exert strong top-down control against shifting attention toward a singleton and when the display items were presented in a “circular” arrangement (circle-display group), and (2) show that when the same items and procedures are used (such that top-down control should still be exerted), a colour-singleton can capture attention when observers are induced to maintain a diffuse state of attention prior to beginning their serial searches. We encouraged observers to maintain an initially diffuse state of attention by varying randomly across trials which locations, defined by the cells in a 5 × 5 hidden grid, the display elements appeared in (“random”-display group). (We put “random” in quotation marks because the target and singleton-distractor were always placed at locations within the grid that had the same eccentricity as the item-locations in the circular display, whereas the other items received random placement.)

Our design was a 2 (Configuration: Circle vs. “random”) × 2 (Target: A vs. R) × 3 (Set size: 5, 7, or 9) × 2 (Distractor: Present vs. absent) factorial, with configuration manipulated between subjects and the other variables randomized within subjects. Participants indicated by a key press whether the target “A” or “R” appeared among four, six, or eight featurally similar letters drawn without replacement from the set “E”, “H”, “S”, “N”, “Z”, “U”, “K”, and “T”. (These were the same procedures used by Theeuwes & Burger, 1998.) On half of the trials, all letters were red (or green—manipulated between subjects), but on the other half, one of the nontargets (i.e., the singleton distractor) was an “oppositely” coloured singleton from the other letters. Because each letter was unique and because the target had no distinguishing feature relative to nontargets, we expected to find positive set-size slopes for both display configurations.

Error rates were low (<4.0% in all cells) and are not considered further. Only RTs associated with correct responses were analysed and effects called significant are associated with two-tailed ps < .05. Each participant’s geometric mean RT for each cell (collapsed on target) was computed and entered into a 2 (Configuration: Circle vs. “random”) × 2 (Distractor: Present vs. absent) × 3 (Set size: 5, 7, or 9) mixed-model ANOVA. The results are presented in Table 1. For both the distractor-present and distractor-absent conditions there were significant and similar set size effects for both configurations, suggesting a serial search.

Most important, the Configuration × Distractor interaction was significant, due to a significant 13.7 ± 12.7 ms distractor effect in the “random”-display group and a nonsignificant −4.3 ± 12.0 ms distractor effect in the circle-display group. Hence, the colour-singleton captured attention in the “random”-display, but not in the circle-display group.
We believe the “random”-display results are the first to demonstrate a singleton-distractor capturing attention during serial search when observers can exert strong top-down control because the target and singleton colours did not vary across trials. We think this capture effect occurred because, unlike the repeated circular display configuration, the random display configuration induced observers to maintain a diffuse attentional state so they could determine the to-be-searched item locations, prior to initiating serial search. This diffuse attentional state allowed the distractor to be perceived as a (salient) singleton and capture attention.

We believe this capture of attention was stimulus-driven (rather than strategic or contingent) for three reasons. First, the singleton was irrelevant to locating the target. Second, the target was not a singleton and was not related to the distractor by sharing the abstract property of “singletonness”, which Bacon and Egeth (1994) showed can produce a “contingent” attentional capture effect (cf. Folk, Remington, & Johnston, 1992). Third, the deployment of top-down control, which our procedures should have encouraged, would have acted against our observing any capture effect. Although our distractor effect could have been due to a filtering cost (cf. Folk & Remington, 1998) rather than a capture of spatial attention, we nevertheless believe that spatial uncertainty for the display elements induced a diffuse state of attention that allowed stimulus-driven attentional capture to occur even under conditions that Theeuwes (2004) and Theeuwes and Burger (1998) suggested should preclude capture, that is, when observers must use a serial search and also have top-down control over what colour to attend to and what colour to ignore.

<table>
<thead>
<tr>
<th>Display configuration</th>
<th>Distractor condition</th>
<th>5 items</th>
<th>7 items</th>
<th>9 items</th>
<th>Overall</th>
<th>Slope</th>
</tr>
</thead>
<tbody>
<tr>
<td>Circle</td>
<td>Present</td>
<td>736</td>
<td>824</td>
<td>886</td>
<td>815</td>
<td>36.5*</td>
</tr>
<tr>
<td></td>
<td>Absent</td>
<td>741</td>
<td>831</td>
<td>887</td>
<td>820</td>
<td>37.5*</td>
</tr>
<tr>
<td></td>
<td>Distractor effect</td>
<td>−5</td>
<td>−7</td>
<td>−1</td>
<td>−5</td>
<td></td>
</tr>
<tr>
<td>Random</td>
<td>Present</td>
<td>730</td>
<td>801</td>
<td>862</td>
<td>798</td>
<td>33.2*</td>
</tr>
<tr>
<td></td>
<td>Absent</td>
<td>712</td>
<td>788</td>
<td>852</td>
<td>784</td>
<td>35.2*</td>
</tr>
<tr>
<td></td>
<td>Distractor effect</td>
<td>18</td>
<td>13</td>
<td>10</td>
<td>14*</td>
<td></td>
</tr>
</tbody>
</table>

RTs are rounded to the nearest ms. RTs in the Overall column are averaged over set size. Values in the Slope column are the RT/item slope measured in ms/item. The distractor effect was computed by subtracting the absent condition from the present condition, which should result in positive effects if the singleton captured attention.

*p < .05 (two-tailed).
REFERENCES


The unlikely perception of figural shape from 3-D concavities

Anthony Cate
*University of Western Ontario, London, Ontario, Canada*

Marlene Behrmann
*Carnegie Mellon University, Pittsburgh, PA, USA*

“A hole is nothing at all, but it can break your neck.” In a similar fashion to the danger pointed out by this folk paradox, holes also pose difficulties to theories of visual shape perception. We can readily identify the shape of well-bounded concavities, although according to models of how observers distinguish figure/ground relationships and part boundaries, concavities should not be perceived to have figural shape. Therefore, the question of how we perceive shape from holes is central to the problem of how the perceptual
organization of a scene influences how the visual system interprets the scene’s information.

Three experiments investigated the process by which figural shape is perceived in 3-D concavities. Shape from shading images were used in all experiments, which allowed the same image to appear concave or convex depending on its orientation in the picture plane (Figure 1). The experiments investigated how concavity alters the perception of three aspects of a figural shape, compared with observers’ performance with solid shapes: (1) The perceptual grouping between local surface elements; (2) the perception of the part structure of the figural shape; and (3) the global features of the figural shape.

Experiment 1 addressed the central paradox of perceiving shape from holes: If the local features of a 3-D concavity are so different from those of the equivalent convexity, why is the same global figure perceived? Hoffman and Richards’ (1984) minima rule predicts that reversing an image’s 3-D structure from convex to concave will reverse the perceived part boundary locations as well, an idea that has been confirmed experimentally for the case of holes in 2-D planar surfaces by Bertamini and Croucher (2003). Experiment 1 used an attentional flanker task to assess the degree of perceptual grouping between pairs of surfaces in concave and convex shapes. Participants indicated the colour of a cued surface while ignoring the colour of the second surface, and the RT difference between trials when the two surfaces had the same or different colours formed the dependent measure of cueing effect. When the two surfaces had a local relationship (contiguous)

![CONCAVE](image1.png) ![CONVEX](image2.png)

*Figure 1.* Examples of concave and convex images from the experiments. All images in the study were rendered based on a 3-D concave model in MATLAB. Convex images were created by rotating the convex images 90° in the picture plane, in order to exploit the shape from shading illusion described by Ramachandran (1988).
there was no difference in the grouping effects for convex and concave images. However, when the two surfaces were distant and related only by the fact that they occupied the same figure, the surfaces were strongly grouped in convexities (cueing effect 66 ms; \( SEM \ 39 \) ms) but showed no grouping effects at all in concavities (–68 ms; 24 ms). This result confirms the above paradox by suggesting that in terms of low-level attention, figural shape really has no perceptual consequences with concavities; it adds no perceptual organization above those inherent to the local surface features.

Since Experiment 1 showed a lack of global object-based attention effects with concavities, Experiment 2 tested whether the figural shape that is perceived from a concavity is also perceived in a less holistic and more parts-based fashion. A Garnerian “orthogonal insertion” interference task (Lederman, Klatzky, & Reed, 1993) was used to measure how well observers could attend to a single lobe of a shape while ignoring changes to a different part. During a baseline block only the attended part changed from trial to trial, while during subsequent blocks the irrelevant part changed as well. With concave images, RT did not increase from baseline to interference blocks (750 vs. 807 ms; 49 vs. 44 ms), but it did with convex images (786 vs. 1005 ms; 32 vs. 78 ms). The main effects of stimulus type, \( F(1, 43) = 4.60, p = .003 \), and block, \( F(1, 43) = 28.34, p < .001 \), were significant, as well as the two-way interaction, \( F(4, 43) = 3.79, p = .010 \). This suggests that the figural shape that is perceived from concavities is perceived as a collection of perceptually independent parts, to a greater extent than with convexities.

Because of the consistent biases to local features found in concavities in Experiments 1 and 2, Experiment 3 tested whether global figural shape is, in fact, perceived equally well from concavities and convexities. Observers judged whether two successively presented shapes were the same or different, and observers were instructed to attend to the whole shape. There was no main effect of concavity/convexity, showing that observers perceived shape from concavities well. However, there was a significant interaction between concavity/convexity and the way in which pairs of shapes differed from each other on “different” trials, \( F(2, 18) = 5.70, p < .02 \). When pairs of shapes had identical aspect ratios but different sizes, RTs were higher for convexities than for concavities (1079 vs. 970 ms; 53 vs. 42 ms), suggesting that concave shapes are not encoded in as much of a scale-invariant way as convexities. When pairs of shapes were made different by distorting only the major axis length (which altered the figure’s aspect ratio), RTs were lower for convexities than for concavities (986 vs. 1106 ms; 45 vs. 78 ms), suggesting that the global dimensions of a concave shape are encoded independently, rather than via the holistic dimension of aspect ratio. In summary, the same
shape perception performance may be achieved even though it is the result of encoding different features of figural shapes.

In conclusion, this study found that the same figural shape can be perceived by means of significantly different local features. 3-D concavities do not evoke the same object-based perceptual grouping, holistic part integration, or scale-invariance that 3-D convexities do, even when they describe the same 2-D outline shape. These results may indicate that there are two routes to perceiving figural shape. The first would be a holistic process by which local image elements are perceptually grouped early in the process of shape perception, which makes the global aspects of the figure more salient, the local elements harder to perceive independently, and the specific metric dimensions of the figure less salient. The second would be a process that essentially provides a “second chance” for certain scenes to be perceived as figures even when their local elements violate gestalt grouping and figure/ground principles. 3-D concavities appear to be a special case of such “poorly organized” scenes, since we perceive figural shape from them so readily. Future experiments will have to address whether in fact holes rely on a distinct process for shape perception or whether observers perceive holes by enforcing a figure–ground reversal (as suggested by Nelson & Palmer, 2001). The consistent local/global biases found between concavities and convexities in this study suggest that the two-process case is more likely.

REFERENCES
Does emotion systematically influence visual perception?

Arieta Chouchourelou
Department of Psychology, Rutgers University, Newark, NJ, USA

Toshihiko Matsuka
Howe School of Technology Management, Stevens Institute of Technology, Castle Point on Hudson, Hoboken, NJ, USA

Kent Harber and Maggie Shiffrar
Department of Psychology, Rutgers University, Newark, NJ, USA

Previous research has shown that visual sensitivity to a human action is defined by an observer’s motor and visual experience with that action. The goal of the current research is to examine whether another factor, namely, emotional processes, also shape visual sensitivity to human action. The potential impact of emotional processes on action perception is suggested by several neurophysiological findings which indicate that: (1) The neural circuitry involved in emotion perception (e.g., Heberlein, Adolphs, Tranel, & Damasio, 2004) overlaps with the neural areas involved in the visual analysis of human motion in the Superior Temporal Sulcus or STS (e.g., Puce & Perrett, 2003), (2) STS activity is modulated by angry facial expressions, and (3) numerous feedback and feedforward pathways connect the STS and emotional centres in the amygdala (Adolphs, 1999; Baron-Cohen, 1995; Brothers, 1997). To the extent that these connections serve functional purposes, we hypothesize that emotional processes might shape the visual detection of human action in profound ways. This hypothesis is tested in the psychophysical studies described below. Specifically, we examine whether an observer’s ability to detect an action is modulated by the emotional content of that action.

In Experiment 1, two professional actors individually walked within a motion capture system while expressing a variety of emotions. The resultant spatiotemporal coordinates were converted into 3 s point-light movies of human gait. Each point-light walker displayed one of five possible emotional
states: neutral, sad, happy, afraid, and angry. The point-light movies were shown to eight naïve observers who categorized each action as one of the five possible emotions. Overall, observers were able to categorize the emotional expression of the walkers with a mean accuracy of 79% correct ($SD = 0.41$, chance = 20%). This replicates previous findings that observers are able to determine an actor’s emotional state from point-light displays of bodily motion (Atkinson, Dittrich, Gemmell, & Young, 2004; Dittrich, Troschianko, Lea, & Morgan, 1996). The results of Experiment 1 allowed us to identify those movies that reliably conveyed a particular emotion by computing the interobserver agreement for each stimulus. We selected a set of 15 walker stimuli, three instances for each of the five emotional classes, for which interobserver agreement was at least 83%. This set of stimuli was used in subsequent action detection studies.

In Experiment 2, we used the above stimulus set to conduct a standard psychophysical discrimination task. Our goal was to test whether the emotional content of a human movement affects the detection of that movement. For each stimulus, a mask of positionally scrambled but otherwise identically moving points was created. For each stimulus, the same motions made up both the walker and the mask. Therefore, the presence of a walker could only be determined from a global analysis of the relative locations of the points. Two types of trials were designed. In the walker-present trials, a coherent walker was present in the mask. In the walker-absent trials, the points defining the walker were scrambled. Thirteen naïve observers watched each movie on a 14-inch computer monitor. Following a within-subjects design, each subject saw 120 3-s displays in each of two blocks. Each block contained walker-present and walker-absent trials in equal presentations for all five emotional states. Point-light actors appeared to walk towards, away, leftward, and rightward relative to observers. Observers reported, by pressing one of two buttons, whether or not a walker was present in the mask. The results were analysed for sensitivity to the signal ($d'$-primes computed as the relative difference between the standardized hit rate minus standardized false alarm rate), response bias ($C$), and response latency (reaction time). Importantly, walker detection was found to be emotion dependent, $F(4, 12) = 2.925$, $MSE = 0.216$, $p < .05$. Observers were significantly more likely to detect the presence of angry walkers ($p < .05$). Furthermore, a five-level (walker emotional state) repeated measures ANOVA indicated that decision criteria, $c$, were significantly shifted for angry displays, $F(4, 12) = 5.786$, $MSE = 0.11$, $p < .05$, as a result of the high rate of false alarms in the angry walker condition, all $ps < .001$ (Figure 1). A 5 (emotional states) $\times$ 2 (trial types) repeated measures ANOVA on the reaction time data suggests that participants’ response times were significantly modulated by emotion,
These results suggest that action detection is emotion dependent. Because life-sized point-light walkers might be perceived as potentially more interactive and thus engaging, we hypothesized that walker size might modulate walker detection. Therefore, Experiment 3 replicated the previous experiment with life size displays. Observer stood 2 m from a rear projector screen and performed the same walker detection task. When analysed for overall sensitivity, the results indicate no modulation of walker detection by emotion. However, when examined with respect to the direction in which each point-light actor walked relative to the observer, detection sensitivity is significantly enhanced to the angry people walking toward the observer, \( F(4, 96) = 5.107, p < .05 \). A 5 (emotional states) \( \times 2 \) (trial types) repeated measures ANOVA on the reaction time data suggests that participants’ response times were significantly modulated by emotional information in the gaits, \( F(4, 24) = 2.804, p < .05 \). These results are consistent with the finding that STS responsiveness can be coded in an observer relative coordinate space (Puce & Perrett, 2003).

Taken together, these data support a significant interdependence of action perception and emotion analyses and may reflect the substantial interconnections between higher order visual processes in the STS and the limbic system. The amygdala is involved in the perception of threat (e.g., Anderson, Christoff, Panitz, de Rosa, & Gabrieli, 2003). Angry people, especially when they approach an observer, are clearly threatening. Enhanced detection of

\[ F(4, 24) = 3.046, p < .05, \]
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threatening actions may represent an important condition under which emotional processes impact perceptual analyses.

REFERENCES


Recognizing novel deforming objects

Lewis L. Chuang

*Max Planck Institute for Biological Cybernetics, and Graduate School of Neural and Behavioral Sciences, Tübingen, Germany*

Quoc C. Vuong

*Max Planck Institute for Biological Cybernetics, Tübingen, Germany*

Ian M. Thornton

*Department of Psychology, University of Wales Swansea, Swansea, UK*

Heinrich H. Bülthoff

*Max Planck Institute for Biological Cybernetics, Tübingen, Germany*

Visual object perception is dynamic as the result of an active observer or movement in the environment. Nonetheless, contemporary theories of object
recognition commonly focus on how objects are represented in terms of their static properties, e.g., shape. When the contribution of motion has been considered, it has typically been with regards to how rigid rotation in depth could facilitate the reconstruction of an object’s static 3-D shape (e.g., Ullman, 1979). Here, we propose that human observers represent an object’s dynamic properties as a cue to its identity, independent of its contribution to shape perception. This information may facilitate recognition when shape information is less reliable, e.g., viewpoint variations.

Stone (1998) introduced a method that allowed the role of object motion to be studied, independent of static recognition cues. In this study, participants learned to discriminate between rigid amoeboid objects that were rotating in depth. After training, recognition performance was impaired when the rotation of the learned objects was reversed (i.e., by playing the frame sequence in reverse order). From this, Stone suggested that humans represented object motion during learning, as the motion reversal manipulation selectively distorted an object’s learned motion but not its shape. That is, object representations that are solely defined by shape properties should not be affected by motion reversal. Several studies have replicated Stone’s finding across a variety of novel rigid objects and learning paradigms (Liu & Cooper, 2003; Stone, 1999; Vuong & Tarr, 2004).

The work reported here extends these previous findings by investigating the visual learning of non-rigidly deforming shapes and how this learning generalizes to novel viewpoints of dynamic objects. We used amoeboid objects similar to those used by Stone (1998, 1999). However, our objects moved with characteristic patterns of nonrigid deformations instead of rigid rotations in depth. Samples of these stimuli can be viewed at http://www.kyb.mpg.de/~chuang. Unlike rigid rotations, nonrigid deformations are less likely to provide useful cues to 3-D shape. Experiments 1 and 2 investigated whether object learning is generally sensitive to nonrigid motion sequences, as it is to rigid motion. Experiment 3 examined whether learned motion can compensate for changes in viewpoint that distorts shape properties.

These three experiments observed the same design. Participants first learned to discriminate between two novel deforming objects and subsequently tested on their ability to recognize these learned targets from two distracters under testing conditions that differed across the three experiments. During testing, targets and distracter objects were presented in either forwards or reverse frame order. The reversed frame order introduced a motion reversal of the learned deformation pattern for the targets and was not expected to influence perception of the distracters. This manipulation defined the main independent variable of motion-type. The influence of motion-type on object recognition was indexed by performance decrements induced by this manipulation.
In Experiment 1, 12 participants were tested with an old–new recognition task after training. Motion reversal impaired accuracy performance of the targets, indicated by a comparison of sensitivity (d') for forwards ($M_{d'} = 2.62$, $SE_{d'} = 0.23$) against reversed motion ($M_{d'} = 1.70$, $SE_{d'} = 0.31$). This difference was significant, $F(1, 11) = 6.44$, $\eta^2 = 0.37$, $p < .05$. In Experiment 2, we used a two-interval forced-choice (2IFC) task. Twelve participants selected the learned object from a pair of target and distractor. Here, motion reversal of the targets impaired performance for both accuracy, $F(1, 11) = 12.7$, $\eta^2 = 0.54$, $p < .01$ and reaction time, $F(1, 11) = 12.3$, $\eta^2 = 0.53$, $p < .01$. Overall, participants were faster and more accurate in identifying the learned objects deforming in the learned sequence ($M_{RT} = 478$ ms, $SE_{RT} = 71$; $M_{acc} = 89.8\%$, $SE_{acc} = 2.9$) than in the reverse sequence ($M_{RT} = 551$ ms, $SE_{RT} = 77$; $M_{acc} = 83.1\%$, $SE_{acc} = 3.9$). In conjunction with past experiments that used rigid objects, Experiments 1 and 2 demonstrate that observers encode the manner in which an object changes over time, irrespective of motion type (i.e., rigid vs. nonrigid motion).

Finally in Experiment 3, 20 participants were tested in a 2IFC task similar to Experiment 2 except that targets and distractors were now presented from different viewpoints during testing ($0^\circ$, $\pm 10^\circ$, $\pm 20^\circ$, $\pm 30^\circ$ about the azimuth, relative to the learned viewpoint). It is commonly found that changing the viewpoint affects visual object recognition, as this manipulation changes the appearance of an object. This viewpoint effect was replicated here: Accuracy decreased as a function of increasing viewpoint, $F(3, 57) = 25.0$, $\eta^2 = 0.57$, $p < .001$. Importantly, there was also a main effect of motion type across the different viewpoints, $F(1, 19) = 13.7$, $\eta^2 = 0.42$, $p < .01$. That is, observers were more accurate for forwards than reversed motion (see Figure 1c). Finally, there was an interaction between viewpoint and motion type, $F(3, 57) = 2.83$, $\eta^2 = 0.13$, $p < .05$. This interaction is illustrated in Figure 1(c) and appears to be the result of a lack of difference between forward and reverse motion at $0^\circ$. Removing the data point eliminates the interaction, $F(2, 38) = 0.993$, $\eta^2 = 0.50$, $p = .38$. These results indicate that the benefit from learned object motion is maintained despite changes in viewpoint. It is not clear why this is not the case at $0^\circ$ when multiple viewpoints are presented. This remains an open question for future research.

The results presented here help extend previous findings on the role of motion in object recognition. First, visual object learning involves the representation of characteristic object motion and this includes nonrigid deformations. Second, this benefit of learned object motion is robust across viewpoints and, in this aspect, different from the role of shape cues in object recognition. It should also be noted that the role of nonrigid motion in learning is not confined to novel objects. Recent experiments in face learning found that the presence of facial motion, e.g., emotional expressions, can facilitate subsequent face recognition, particularly when static cues were
rendered less informative or when task demands were increased (Knappmeyer, Thornton, & Bülthoff, 2003; Pilz, Thornton, & Bülthoff, in press). A question that remains to be answered is how dynamic information is represented. Some theorists may argue that object motion is a complex feature that requires a combination of both spatial and temporal inputs (Giese & Poggio, 2003). Alternatively, our present findings can also be explained by associative learning through the temporal contiguity of static features (Miyashita, 1988). A resolution of this debate presents potential for future research in object recognition.

REFERENCES


The distinctiveness effect reverses when using well-controlled distractors

Nicolas Davidenko and Michael J. A. Ramscar

Stanford University, Stanford, CA, USA

The distinctiveness effect in memory holds that distinctive items (e.g., unusual objects, infrequent words, or atypical faces) have a recognition advantage over typical items (e.g., Geraci & Rajaram, 2002; Schmidt, 1991; Valentine, 1991). The recognition advantage is usually operationalized as a higher hit rate and lower false alarm rate for distinctive items. Although the effect has been replicated numerous times in various domains, the conclusion that distinctive items are remembered better than typical items seems at odds with other findings in cognitive psychology. In particular, typicality effects, such as the recognition advantage for prototypical colours (Lucy & Shweder, 1979) and the improved discrimination of own-race faces (e.g., Walker & Tanaka, 2003), suggest that we have better mental representations for frequently encountered, typical items.

A key factor that is often overlooked in studies on distinctiveness is the role of foils, or distractors. In face recognition experiments, subjects study a set of target faces and later try to pick the target faces from among distractor faces, either in a forced-choice or old/new paradigm. Although experimenters usually select distractors randomly, this does not guarantee an equitable comparison between the two types of faces. The central distribution of face space (see Valentine, 1991) actually predicts a systematic relationship between the distinctiveness of a face and its overall similarity to randomly chosen distractors. A simple geometric analysis shows that random distractors will be statistically more similar to typical faces (located more centrally in face space) than to distinctive faces (located more peripherally). This asymmetry implies that distinctive faces will be overall more distinguishable from random distractors, and therefore more recognizable when pitted against them.

We propose that the well-reported distinctiveness advantage in face recognition is primarily due to this asymmetry. We further propose that if the asymmetry is eliminated, typical faces should be recognized more accurately than distinctive faces, consistent with other typicality effects. To this aim, we describe two studies that measure the accuracy of face

Address correspondence to: Nicolas Davidenko, Psychology Department, Building 420, Jordan Hall, Stanford University, Stanford, CA, USA. E-mail: ndaviden@psych.stanford.edu
recognition. The stimuli for these studies are parameterized face silhouettes (see Figure 1) that have been previously validated as psychologically legitimate face stimuli (Davidenko, 2004). The use of a fully parameterized face space allows us to create precisely controlled face stimuli and examine the role of distractor choice.

STUDY 1: REPLICATION OF THE STANDARD DISTINCTIVENESS EFFECT

Twelve Stanford undergraduates completed an old/new task with parameterized face silhouettes. Using Matlab, we constructed 210 silhouettes by sampling randomly from a multinormally distributed silhouette face space derived from 48 actual face profiles (see Davidenko, 2004). Silhouettes were designated as typical or distinctive based on their distance in face space from the overall norm (typical silhouettes being closer to the norm). Of the 105 typical silhouettes, 70 were randomly designated as targets and 35 as distractors, and likewise for the 105 distinctive silhouettes.

Participants completed 35 trials in which they observed a sequence of four “training” silhouettes, followed by an 8-s retention interval. They then observed a sequence of four “test” silhouettes (two targets and two distractors, in random order) which they judged as “old” or “new”. Each response was coded as a hit, miss, false alarm, or correct rejection. Consistent with previous studies using front-view face images (e.g., Shepherd, Gibling, & Ellis, 1991), distinctive silhouettes yielded significantly higher hit rates (0.63 vs. 0.54; two-tailed paired $t$-test $=2.78$, $p < .05$) and significantly lower false alarm rates (0.21 vs. 0.33; two-tailed paired $t$-test $=2.57$, $p < .05$) than typical silhouettes. We conclude that the classic distinctiveness effect replicates with face silhouettes.
As mentioned above, the centrally dense distribution of faces in face space predicts that randomly chosen distractors will be on the whole more similar to distinctive faces than to typical faces. To test whether a recognition advantage for distinctive faces persists in the absence of this asymmetry, we conducted a study that used equally spaced distractors for every target silhouette.

**STUDY 2: DECONFOUNDING DISTINCTIVENESS AND ISOLATION FROM DISTRACTORS**

Sixteen Stanford undergraduates participated in a short-delay recognition task using a three-alternative forced-choice paradigm. Using Matlab, we constructed 50 typical and 50 distinctive target silhouettes in the same way as in Study 1. Two distractors were constructed specifically for each target silhouette by translating the target silhouette a small distance in silhouette face space. The magnitude of these translations was kept constant for all targets, while the direction was allowed to vary randomly.

Participants completed 100 trials in which they observed a target silhouette for 2.5 s, a random line mask for 2 s, and a test set of three silhouettes from which they attempted to identify the target. Performance was coded as percentage correct identification of target silhouettes. Mean performance across participants was 61% for typical silhouettes and 56% for distinctive silhouettes, revealing a significant disadvantage for distinctive silhouettes (two-tailed paired t-test = 2.20, \( p < .05 \)). We thus report a “reverse distinctiveness effect”, whereby typical face silhouettes are recognized more accurately than distinctive face silhouettes.

In a variation of this study, we equated the sizes of the face space regions corresponding to typical and distinctive silhouettes to avoid the possibility of preferential online learning of typical silhouettes during the experiment. The results were consistent with Study 2, again revealing a recognition disadvantage for distinctive silhouettes.

Together, these studies provide evidence that prior experience with central regions of face space (corresponding to typical faces) improves our ability to discriminate and represent these faces in short-term memory. The choice of distractors in recognition tasks, which is often overlooked and rarely manipulated, clearly influences performance in recognition tasks. By constructing distractors that were equally spaced from typical and distinctive targets, we were able to more fairly compare performance on the two types of faces. Consistent with other typicality effects, we found that typical face silhouettes are remembered more accurately than distinctive faces silhouettes. We suggest that this “reverse distinctiveness effect” will generalize, not only to standard front-view face stimuli, but also to other object categories with centrally dense distributions.
REFERENCES


Velocity cues improve visual search and multiple object tracking

David E. Fencsik

Brigham and Women’s Hospital, and Harvard Medical School, Cambridge, MA, USA

Jessenia Urrea

Boston Latin High School, Boston, MA, USA

Skyler S. Place

Brigham and Women’s Hospital, Cambridge, MA, USA

Jeremy M. Wolfe and Todd S. Horowitz

Brigham and Women's Hospital, and Harvard Medical School, Cambridge, MA, USA

Early stages of visual processing are thought to rapidly extract a number of basic perceptual attributes from a visual stimulus, including object bound-

Address correspondence to: David E. Fencsik, Visual Attention Laboratory, Brigham and Women’s Hospital, 64 Sidney St., Ste. 170, Cambridge, MA 02139, USA. Tel: 617-768-8812; Fax: 617-768-8816; E-mail: fencsik@search.bwh.harvard.edu
aries, orientations, and colours, among others. One major topic of research in vision has been to specify which attributes can be extracted by this early stage of processing, and which attributes require limited capacity processing by later stages (e.g., Treisman & Gelade, 1980; Wolfe, 1994). Many previous studies have used visual search tasks to make this categorization. However, if an early processing stage exists, its output should be used by all later processes to perform any visual task.

In this paper, we seek evidence that basic attributes, thought to support the detection of a target in visual search, also facilitate segregation of targets from distractors when observers track a subset of randomly moving, identical objects—the multiple-object tracking (MOT) task. If a common stage of processing serves as input to both tasks, then objects with properties that are easy to search for should also be easy to track, while objects that are difficult to search for should be harder to track. We tested this prediction by comparing the results of a search experiment and an MOT experiment conducted on the same observers.

Here we investigated the role of speed. Ivry and Cohen (1992) performed a set of visual search experiments using oscillating dots. The target was a dot moving either slower or faster than the distractors. When targets moved more slowly than distractors, target-detection time increased as a function of the number of stimuli in each display (“set size”). However, when targets moved faster than distractors, target-detection time was minimally affected by set size. Thus, it is easier to find targets moving more quickly than distractors (i.e., they “pop out”) than targets moving more slowly than distractors. It may be that this asymmetry is due to the way that the early stage computes velocity (Ivry & Cohen, 1992; Rosenholtz, 1999).

We hypothesized that an analogous asymmetry would be observed in MOT. That is, it should be easier to track targets that move more quickly than the distractors, compared to targets moving more slowly than distractors. This prediction might be somewhat counterintuitive. While it is easier to track targets that differ from distractors in speed (Yantis, 1992), all else being equal, tracking slower objects is easier than tracking fast objects (Alvarez & Franconeri, 2005).

We began by replicating Ivry and Cohen’s (1992) visual search experiment. However, instead of oscillating stimuli, we used a motion pattern that could be compared to MOT. Stimuli were white disks measuring 1.33° visual angle with black borders. Disks were assigned random initial directions, then moved in straight lines, except when they bounced off the edges of the display (20° × 20°). On 50% of the trials, one target disk moved at a different speed from the rest. Observers made a speeded detection response to either a fast (6.4°/s) target among slow (3.2°/s) distractors, or vice versa, in separate blocks.
The same observers then ran in a MOT task using identical stimuli. Observers tracked five targets out of 12 total disks (given an equal number of targets and distractors, observers might have cheated when target tracking was difficult by tracking distractors instead). There were five conditions in the MOT task: All stimuli moved fast (“all-fast”); all stimuli moved slow (“all-slow”); all targets moved fast and all distractors moved slow (“targets-fast”); all targets moved slow and all distractors moved fast (“targets-slow”); and a mixed condition in which the two speeds were evenly distributed among targets and distractors.

When targets and distractors are not completely identical, the observer might be tempted to not track at all, but simply use target-distractor differences to recover targets at the end of the trial. We took two precautions to thwart such a strategy. First, trial duration was unpredictable, varying randomly between 6 s and 8 s. Second, condition varied randomly from trial to trial, and observers were not informed of the speed manipulation.

Figure 1A shows a clear asymmetry between fast and slow targets in visual search, replicating the results of Ivry and Cohen (1992). Both the mean RTs and the slope of the RT by set size functions were smaller when the targets were faster. Our MOT results, shown in Figure 1B, replicated Yantis’ (1992) finding that tracking was easier when targets and distractors could be discriminated by speed, as indicated by the difference between the mixed condition on the one hand, and the targets-fast and targets-slow conditions on the other, $F(1, 7) = 47.1, p < .001$. Tracking performance was
better in the all-slow condition than in the all-fast condition, confirming that tracking difficulty increases with speed (Alvarez & Franconeri, 2005), $F(1, 7) = 44.9, p < .001$. However, when targets and distractors were segregated by speed, we observed the opposite pattern: Tracking performance was better in the targets-fast condition than in the targets-slow condition, $F(1, 7) = 11.9, p = .011$.

Thus, we observed an asymmetry in MOT analogous to the one observed in the visual search task. This asymmetry is predicted on the outcome of the search experiment even though previous results from MOT might seem to suggest that tracking fast targets should always be more difficult than tracking slow targets.

These results tentatively support the hypothesis that a common representation serves as input to search and MOT. This was not the only possible outcome. Texture segmentation and pop-out search were initially thought to tap into the same processes, but we now know that some attributes that support rapid texture segmentation do not support efficient search and vice versa (Wolfe, 1992). More work will be necessary to determine whether or not the same holds true for search and MOT, and whether or not MOT can serve as a tool for investigating the properties of early visual processing.

REFERENCES


Executive load in working memory induces inattentional blindness

Daryl Fougnie and René Marois

Vanderbilt Vision Research Center, Center for Integrative and Cognitive Neuroscience, Vanderbilt University, Nashville, TN, USA

Attending to an event in the visual world improves its processing (Luck, Hillyard, Mouloua, & Hawkins, 1996). However, this benefit is likely to come at a cost; namely the inability to detect other events in that same visual scene (Mack & Rock, 1998; Simons & Chabris, 1999). This is evidenced by the inattentional blindness (IB) phenomenon, which occurs when an unexpected stimulus is not consciously perceived, even if it is in plain sight, because attention is diverted away to another event or stimulus. In a classic example of IB, a substantial proportion of observers failed to detect an easily perceptible visual stimulus, such as a black square, when it was presented while their attention was engaged in an unrelated line-length judgement task (Mack & Rock, 1998).

What causes IB? Inattentional blindness is thought to result from the inability of unexpected, task-irrelevant stimuli to attract attention, thereby preventing them from reaching awareness. Although attentional engagement in a primary task is thought to be crucial for the generation of IB (Mack & Rock, 1998), it is much less clear how such engagement prevents awareness of the unexpected stimulus. Does IB occur because the primary task engages visuospatial attention, or can IB result from the withdrawal of more central, amodal sources of attention? The current evidence regarding IB is conflicting in this regard (Mack & Rock, 1998; Rees, Russell, Frith, & Driver, 1999; Ruz, Worden, Tudela, & McCandliss, 2005, Strayer, Drews, & Johnston, 2003, Todd, Fougnie, & Marois, 2005).

The goal of the current study was to determine whether manipulations that affect only late stages of information processing are capable of inducing IB. Specifically, we assessed whether the engagement of a central executive function, i.e., manipulation of information held in verbal working memory (WM), would be sufficient to impair the ability to detect an unexpected, task-irrelevant visual stimulus. To assess this, we compared IB during two verbal WM tasks that differed only in the involvement of executive
functions. One group of participants performed a memory task that simply involved rehearsing five consonants (maintain condition). By contrast, a second group was required not only to rehearse the five letters, but also to rearrange them in alphabetical order (manipulate condition). Since the two verbal WM tasks differed only in their involvement of executive functions, any differences in IB performance between these two tasks should originate at executive stages of processing. To assess IB during the verbal WM task, on the fourth experimental trial, an unexpected task-irrelevant stimulus (the critical stimulus) briefly appeared 500 ms into the WM retention period in one of the four quadrants of the display. Detection of the critical stimulus was assessed immediately afterwards by interrupting the trial with questions presented on the computer monitor. Participants were considered to have seen the critical stimulus if they reported having noticed something unexpected in the display and correctly identified the quadrant in which it appeared.

Thirty-eight per cent of the participants in the maintain condition failed to detect the critical stimulus. Importantly, more participants failed to detect the critical stimulus in the manipulate condition (64%) than in the maintain condition (Figure 1A, \( p = .02 \)). By contrast, almost all participants were able to detect the critical stimulus when the verbal WM task was ignored, indicating that the critical stimulus could be easily perceived with undivided attention.

A second experiment demonstrated that the IB difference between the maintain and manipulate conditions specifically results from the processing demands of alphabetizing rather than from differences in general task demands between the two conditions. When the unexpected critical stimulus was presented after alphabetization was complete (7500 ms into the retention period of the verbal WM task) there was no longer any difference in detection ability between the maintenance and manipulate conditions (Figure 1B, \( p = 1 \)). Thus, while these two conditions still led to largely different verbal WM performance, they yielded similar incidences of IB.

The main finding of this study is that alphabetizing in verbal WM can induce IB. We therefore conclude that the engagement of an executive process is sufficient to impair the ability to detect unexpected, task-irrelevant visual stimuli. By directly implicating executive processes as a source of IB, these results are consistent with studies suggesting that cognitive demands affect IB (Simons & Chabris, 1999; Strayer et al., 2003). Since manipulations of the observer’s visuospatial attentional set are also known to strongly modulate the strength of IB (Most, Scholl, Clifford, & Simons, 2005), we conclude that IB can arise when attentional demands of the primary task take place either at early or late stages of information processing. Together with a previous study demonstrating that a visual WM load can impair the detection of an unexpected, task-irrelevant visual stimulus (Todd et al.,
our findings also demonstrate that each of the two major operations of working memory—maintenance and manipulation of information—can independently induce IB. Thus, not only can a WM load interfere with the simultaneous performance of a goal-directed task (e.g., Jolicoeur & Dell’Acqua, 1998; Oh & Kim, 2004), it can also interfere with stimulus-driven perception.

What could be the mechanism by which manipulation of information in verbal WM affects the explicit detection of a visual stimulus? One possibility

![Figure 1. Effect of verbal WM maintenance (left) or manipulation (right) on the percentage of participants who detected an unexpected visual stimulus that appeared (a) 500 ms after letter presentation (Experiment 1) or (b) 7500 ms after letter presentation (Experiment 2).](image)
is that executive load reduces activity in visual cortex. Alternatively, executive processes could suppress the neural circuit involved in attentional orienting, so as to prevent task-irrelevant stimuli from interfering with ongoing behavioural goals (Todd et al., 2005). A final possibility is that the neural substrates underlying alphabetizing are also involved in the perception of task-irrelevant stimuli. For example, the process of shifting the serial position of letters during alphabetizing may have much in common with shifting of attention towards novel, task-irrelevant stimuli. Engagement of that process in the manipulate condition may prevent its simultaneous involvement in other cognitive functions, such as the reorienting of attention. Clearly, distinguishing exactly how executive load induces IB will be an important goal of future research.

REFERENCES


Spatiotemporal cues for tracking multiple objects through occlusion

S. L. Franconeri
University of British Columbia, Vancouver, Canada

Z. W. Pylyshyn
Rutgers University, New Brunswick, NJ, USA

B. J. Scholl
Yale University, New Haven, CT, USA

As we move about the world, and objects in the world move relative to us, objects constantly move in and out of view as they are occluded by other objects. Given such disruptions, how does the visual system maintain attention on objects of interest? We used a multiple object tracking task (Pylyshyn & Storm, 1988) to explore the spatiotemporal cues used to track objects through occlusion. Observers tracked four target objects moving among four identical distractor objects, as all objects frequently passed behind static vertical occluders. Across three experiments, we manipulated the way that objects behaved under occlusion, and observed the effect on tracking performance.

When an object passes behind an occluder, the observer must link the preocclusion object to the postocclusion object across a brief disappearance. There are at least two major spatiotemporal features that could be important for making this link. First, the location where the object first disappears might be critical. When an item becomes occluded, a "marker" could be placed at the location where the object disappeared (the marker might also be placed on the expected location of the object’s reappearance, based on an extrapolation of the object’s path). When an object disoccludes near this marker, it could signal the object’s link to the original object. Additionally, the history of the object’s motion could be an important feature that could be used to link the two views of the object across the disruption. We might expect a similar angle of disocclusion to be important for establishing this
link. Furthermore, we might also expect that the object disocclude on the opposite side of where it occluded.

Across three experiments, we tested whether each of these cues was used to link two views of an object across an occlusion. In Experiment 1, objects exited the occluders at the “wrong” location along the occluder’s edge (the object reappeared either 2 or 4 object diameters higher or lower than expected). If the linking of the preocclusion object to the postocclusion object requires a marker of the location of the object’s disappearance, then increasing this distance should impair performance. In Experiment 2, objects exited the occluders at the “wrong” angle (by turning either 30 or 60 degrees under the occluder). If the pre- and postocclusion objects are linked by matching the new trajectory to the old, then larger angle deviations should lead to a greater impairment in performance. In Experiment 3, objects exited the occluders at the “wrong” side (by either bouncing or reversing direction). If the process linking the pre- and postocclusion objects also relies on a representation of which side of the occluder an object should reappear, then these manipulations should also impair performance.

METHODS

See Figure 1 for a depiction of the displays and manipulations used in each experiment. Subjects were presented with a black computer display containing eight blue circles outlined in white. In Experiments 1 and 2, two vertical occluders spanned the vertical extent of the screen, eight degrees apart. Because Experiment 3 included a manipulation where objects bounced off the occluders, occluders in this experiment were broken into 12 pieces (four columns of three small occluders each) in order to minimize objects getting ‘stuck’ bouncing between two occluders. In each trial of each experiment, four randomly selected objects flashed several times, and all objects began moving randomly around the display. In each experiment, manipulations of an object’s behaviour under occlusion were manipulated across blocks, and subjects were fully informed of the presence, and size of the manipulations present in a block of trials. At the end of each trial, subjects clicked the four objects that they believed corresponded to the flashed targets.

RESULTS

The results of each experiment are depicted in Figure 1. In Experiment 1 ($N=21$), tracking performance was significantly higher (84%) when objects made only small locations shifts under the occluder, compared to trials where objects made large shifts (72%), $t(20) = 6.3, p < .001$. In Experiment 2 ($N=16$), there was no difference between trials where objects made small
angle changes under the occluder (87%) compared to trails where the angle changes were large (86%), \( t(15) > 0.5, p = .65 \). In Experiment 3 \((N = 16)\), while tracking performance on trials with no manipulations was high (86%), performance on trials where the objects bounced (81%) or reversed direction (82%), was only slightly, but significantly, impaired, \( t(15) > 3, p < .01 \).

CONCLUSION

Experiment 1 showed that when target objects were occluded, performance remained high if the object’s location was shifted only slightly during the occlusion, but dropped abruptly if the shift was large. The distance between the original object occlusion and the location of the object’s disocclusion appears to be a critical factor in determining whether the two instances are perceived as the same object. Experiment 2 showed that angle changes have no effect on performance, suggesting that the direction of motion of an object was not used to link the pre- and postocclusion instances of an object. Experiment 3 extended this result, showing that when objects reappeared on the wrong side of the occluder (which could be considered an even larger angle change), performance was only mildly impaired. Together, these results suggest that when an object is occluded, the location of the occlusion, but not the angle of motion or side of occlusion, is a critical factor in linking the
pre- and postocclusion instances as the same object across occlusion. This simple trick could underlie much of our perception of persisting objecthood when an object disappears from view. These results are consistent with other recent findings suggesting that observers do not extrapolate the motion paths of objects that become temporarily invisible during multiple object tracking. For example, when all moving objects in a display temporarily disappear for short durations (e.g., 200–400 ms), tracking performance is better when the objects reappear near the same location as the disappearance, relative to when they reappear as if they had continued moving while invisible (Fencsik, Horowitz, Klieger, & Wolf, 2004; Keane & Pylyshyn, 2003, 2004).

REFERENCES


Attentional enhancement along the path of a sequence of saccades

Timothy M. Gersch and Brian S. Schnitzer

Department of Psychology, Rutgers University, Piscataway, NJ, USA

Priyesh S. Sanghvi

Department of Electrical and Computer Engineering, Rutgers University, Piscataway, NJ, USA

Barbara Dosher

Department of Cognitive Sciences, University of California, Irvine, CA, USA

Eileen Kowler

Department of Psychology, Rutgers University, Piscataway, NJ, USA

One of the central questions concerning the role of attention in saccadic control is the relationship between the selective filter that determines the effective target of a saccade and the attentional filter that serves perception. Results from several studies employing dual-task methods have shown superior perceptual performance at the location that contains the target of a saccade, implying that a single attentional filter is used both by saccadic and perceptual systems (Godijn & Theeuwes, 2003; Kowler, Anderson, Dosher, & Blaser, 1995). Recently, Gersch, Kowler, and Dosher (2004) examined the links between attention and saccades executed as part of repetitive sequences of several eye movements, rather than as single eye movements programmed in isolation. Perceptual performance, which was tested during the pauses between saccades, was better at the target of the next saccade in the sequence than at other extrafoveal locations. Locations that were targets of any subsequent saccades in the sequence showed no perceptual enhancement, and thus were not treated differently by the perceptual system than locations that never were to be fixated at all.

Linking extrafoveal visual attention exclusively to the goal of the next saccade would seem to place a severe limit on the ability to sample...
information across the visual field. Such a state of affairs would imply that any such sampling would require interrupting or altering the saccadic sequence. The goal of the present experiment was to determine whether broader distributions of attention could be achieved without hindering saccadic accuracy or timing. A dual-task paradigm was used in which a visual test stimulus (Gabor patch) was presented briefly during selected intersaccadic pauses. This visual task is known to be sensitive to attention (Dosher & Lu, 2000) and thus can be used to determine the strength of attention at different locations on or near a saccadic path. Unlike prior work (Gersch et al., 2004), nonrepetitive saccadic sequences were used.

METHODS

The display was a $5 \times 5$ array of $1^\circ$ coloured outline circles. Beginning at one of the four sides of the array, the observer made a brisk sequence of five oblique saccades across the array to each of the five circles that constituted the saccadic path. Eight different saccadic paths were used. The paths were designated by a colour difference or by instructions displayed prior to execution of the sequence. An oriented Gabor patch (2.2 c/d) with a superimposed visual noise field appeared briefly (90 ms) at a random time during a randomly selected intersaccadic pause at one of the central nine locations. The location of the Gabor either was or was not cued in advance. Visual noise fields were presented in all circles. Contrast of the Gabor was chosen to obtain $\sim 75\text{--}85\%$ correct reports in a two-alternative forced-choice (2AFC) orientation discrimination task. A postcue, displayed after the saccadic sequence was completed, always disclosed the location of the Gabor. Sessions were also run in which perceptual performance was tested while the eye remained fixated at different locations in the display in order to evaluate the effects of retinal eccentricity on discrimination.

RESULTS

Observers were able to perform both the saccadic and perceptual tasks concurrently. The accuracy and timing of saccades was about the same as observed in control trials, when saccades were made without the concurrent perceptual test. The current methods revealed a novel and complex distribution of attention (Figure 1) that was not apparent in prior findings with repetitive saccadic paths (Gersch et al., 2004) or single saccades (Kowler et al., 1995). Perceptual performance overall suffered during intersaccadic intervals but was much better on than off the saccadic path. Performance was especially poor at locations that neighboured saccadic targets. The enhancement of saccadic targets extended not just to the next
location in the sequence but to locations that had already been fixated and locations that were to be fixated in the future. Another unique finding was that performance improved overall over time as the saccadic path was completed. This improvement in performance applied particularly to

Figure 1. Perceptual performance (proportion correct) obtained during pauses between saccades (Boxes A, B, and C) and during steady fixation (Boxes D, E, and F). Performance was measured for the central 9 circles in the display when the eye was at 3 different locations. In Boxes A, B, and C, these 3 locations represent 3 locations along the saccadic path as it is executed. In Boxes D, E, and F, the eye remained stationary on these same 3 locations. The lighter the interior of the circle, the better the orientation discrimination at that location. Light grey outlined circles represent locations on the saccadic path. Dashed circles represent the current position of the eye. Dark grey outlined circles denote locations off the saccadic path. Arrows point to the target/s of the next saccade/s. These results are from one subject (EC) for the condition in which the location of the perceptual target was cued prior to its appearance.
locations off the saccadic path. This pattern of results (Figure 1) was observed for all three subjects and when the perceptual target was or was not cued prior to its appearance. This pattern of performance was also obtained for saccadic sequences when the saccadic path was not marked with a colour cue and the saccadic path was executed from memory, with one important exception. Performance along the saccadic path was good at the goal of the next saccade but was relatively poor (similar to nontargets) at future saccadic target locations when targets were no longer distinguished by a colour difference.

**DISCUSSION**

The results showed new links between attention and saccadic planning, but the links were not simple. Perceptual performance was poorer during intersaccadic pauses than during steady fixation, suggesting that saccadic sequences may suppress visual performance. The magnitude of the suppression may be related to saccadic planning. Suppression was greater off the path and when the sequence was just getting underway. Suppression was least at the target of the next saccade. Increasing the saccadic workload (memorized path) increased the suppression, especially for the location later in the path (i.e., not the very next location). Carrying out saccadic sequences produces fundamental changes in the quality of vision. These changes may directly reflect the attentional distributions that are needed to ensure accurate placement of saccades.

**REFERENCES**


Affective consequences of attentional inhibition of faces depend on selection task

Brian A. Goolsby, Jane E. Raymond, and Kimron Shapiro

*University of Wales, Bangor, UK*

Two major brain systems that prioritize the processing of information needed to guide human action are a *selective attention system*, which preferentially facilitates processing of task-relevant information and suppresses processing of task-irrelevant information, and an *emotion system*, which interprets information in terms of the consequences of current and future goals. Although the body of evidence indicating an influence of emotion on attentional processing is substantial (e.g., Bush, Luu, & Posner, 2000; Eastwood, Smilek, & Merikle, 2001; Vuilleumier, Armony, Driver, & Dolan, 2001; etc.), little is known about the influence of attention on emotional processing. Raymond and colleagues (Fenske, Raymond, & Kunar, 2004; Raymond, Fenske, & Tavassoli, 2003; Raymond, Fenske, & Westoby, 2005) have shown that previously ignored Mondrians (colourful abstract patterns) or faces in a visual search task are rated more negatively than previously attended or novel items. Fenske, Raymond, Kessler, Westoby, & Tipper (2005) reported that social-emotional preference judgements are biased against faces paired with a no-go cue (i.e., “inhibit responding”) in favour of simultaneously presented but uncued faces. This suggests that the devaluation of an ignored stimulus results from inhibition associated with this stimulus. When an emotional judgement is required on subsequent presentation, the inhibition applied at encoding may exert some negative influence on emotional processing.

One might predict from this account that for inhibition to be encoded as part of a memory representation of a previously ignored stimulus, the ignored stimulus must compete for target selection on a feature dimension that can identify the object on later exposures, at least implicitly. This was the case in previous studies using Mondrian stimuli (Fenske et al., 2004; Raymond et al., 2003); target selection was based on features (e.g., element colour or shape) that were identifying of a particular Mondrian. In Fenske et al. (2005), inhibition was purely location-based and the location of the cued face was always maintained between encoding and evaluation. In the present...
study, participants selected one of two colourized faces in a speeded task and then rated greyscale versions of the selected, the ignored, or a novel face for trustworthiness. Stimulus location was never maintained between encoding and evaluation, thus only face-specific properties linked a to-be-rated (TBR) item with the events of its initial exposure. Target selection was by colour (not a face-specific attribute) or by gender (a face-specific attribute). If merely ignoring the distractor face is sufficient for devaluation, distractor devaluation should be equivalent in the two selection conditions. If selection must be based on an object-relevant feature, then distractors should only be devalued relative to targets in the gender selection condition.

METHOD

Each trial consisted of two tasks. In the attention task, observers selected the target from a two-face bilateral array for a discrimination response. Some observers selected the target face based on colour (the faces were colourized to appear with a blue or yellow tint) and discriminated its gender, while other observers selected the target face based on gender and discriminated its colour. Following this response, observers saw a single, central face and rated its trustworthiness. This TBR face was always presented in greyscale and was either the target or the distractor from the preceding attention phase, or it was a novel face. Observers rated trustworthiness (or untrustworthiness) on a 1–5 scale with a manual key press.

Each of the 40 observers participated in one selection condition—select colour/report gender or select gender/report colour. The valence of the rating scale and the order of selection feature (blue or yellow first; male or female first) were varied between subjects. The selection feature, target hemifield, and motor congruency were counterbalanced within subjects. Each subject completed 120 experimental trials.

RESULTS AND DISCUSSION

Data from four observers was removed from the analysis due to accuracy below 80% or mean response times (RT) greater than 4 SE outside the group mean in the selection task, leaving 19 observers in the select colour group and 17 observers in the select gender group. RT did not differ significantly for the select colour (1348±73 ms) and the select gender (1411±85 ms) groups, t(34)=0.569, ns, though accuracy was better for the select colour group (96% vs. 92% correct), t(34)=3.782, p < .001. There was no effect of block order or rate valence in either the RT or ratings data.

In the select colour task, there was no difference in trustworthiness ratings for the attended, ignored, or novel faces (Figure 1A), F(2, 36) < 1.
However, in the select gender task, there was a marginally significant effect of prior attention (Figure 1B), $F(2, 32) = 3.155$, $p = .056$. Both distractor and novel ratings were reduced relative to targets, but not relative to each other. This pattern of results differs from that first reported in Raymond et al. (2003). A median split analysis revealed that on select gender trials for which the response was faster than the median RT, the ratings data exhibited a nonsignificant mere exposure pattern (targets and distractors higher than novels; Figure 1C), $F(2, 32) < 1$. However, for responses slower than the median, the ratings data exhibited a devaluation pattern (targets and novels higher than distractors; Figure 1D), $F(2, 32) = 5.11$, $p < .05$. Accuracy was also worse for slower than median trials (94.7% vs. 97.5% correct), $t(16) = 4.344$, $p < .001$.

These results clearly demonstrate that the affective consequences of attention depend on the selection task and are consistent with the hypothesis that the selection feature must be object relevant. The devaluation on slower than median trials might reflect a relatively slow time course (>$1$ s) for this inhibitory encoding. However, given that overall accuracy in the selection task was worse in the select gender condition and that accuracy in this condition was worse for slower than median RTs (when devaluation was observed) than faster than median RTs (when mere exposure was observed),

**Figure 1.** These graphs plot the mean trustworthiness ratings (corrected for scale valence) as a function of prior attention to the to-be-rated (TBR) face. (A) Select colour, report gender condition. (B) Select gender, report colour condition. (C) Faster than median RTs in the select gender, report colour condition. (D) Slower than median RTs in the select gender, report colour condition. In each graph, ratings of target faces are represented by white bars, ratings of distractor faces are represented by black bars, and ratings of novel faces are represented by grey bars. Error bars represent $±1$ SEM.
the strength of inhibition, and thus devaluation, may be determined by task difficulty alone. Future work will disentangle these possibilities.

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REFERENCES


Contingent capture: A visuospatial effect? Evidence from electrophysiology

Émilie Leblanc, David Prime, and Pierre Jolicoeur

Centre de Recherche en Neuropsychologie et Cognition, Université de Montréal, Montréal, QC, Canada

Recent research has demonstrated that attentional capture, that is, the allocation of attention to a task-irrelevant but salient item, may be contingent on top-down attentional control settings (e.g., Folk, Remington, & Johnston, 1992). Although several behavioural and imaging studies provide evidence suggesting that attentional capture reflects a visuospatial effect (e.g., de Fockert, Rees, Frith, & Lavie, 2004; Folk & Remington, 1998; Remington, Folk, & McLean, 2001; Serences et al., 2005), as proposed by the contingent capture hypothesis, there remains the possibility that it is due to other, nonspatial mechanisms (Folk & Remington, 1998; Ghorashi, Zuvic, Visser, & Di Lollo, 2003; Remington et al., 2001).

In order to provide more direct neural evidence as to whether contingent attentional capture is due to a shift of visuospatial attention to the location of the distractor, we recorded event-related potentials (ERPs) while subjects performed an attentional capture task. We focused on the N2pc component, a greater negativity at posterior electrode sites over the hemisphere contralateral to the attended stimulus, typically observed between 180 and 280 ms after stimulus onset, and taken to reflect millisecond-by-millisecond orienting of visuospatial attention (Luck & Hillyard, 1994; Woodman & Luck, 2003).

We used Leblanc and Jolicoeur’s (2005) paradigm, adapted from Folk, Leber, and Egeth (2002), in which participants searched for a target-coloured digit embedded in a stream of coloured distractor digits presented in rapid serial visual presentation (RSVP) at fixation. Attentional capture is induced by presenting two irrelevant peripheral distractors, one of which can match the target colour or not. Behavioural results showed a reduction in target identification accuracy, indicating attentional capture, only when one of the peripheral distractors was presented in the target colour (Folk et al., 2002; Leblanc & Jolicoeur, 2005). If attentional capture by the target-colour distractor is the result of a shift of visuospatial attention to the location of
the peripheral distractor, an N2pc should be observed in the target-colour distractor condition, but not in the nontarget-colour distractor condition, which does not produce capture. On the other hand, if capture reflects a nonspatial process such as filtering costs or interference at decisional stages, no N2pc should arise in either condition.

**EXPERIMENT 1**

The stimuli were equiluminant coloured digits embedded in a RSVP stream at fixation, at a rate of 117 ms per item, without blank intervals. One colour was designated as the target colour for each subject, counterbalanced between subjects. Only one item in the RSVP stream—the target digit, to be reported at the end of the trial—bore the target colour. Along with the item preceding the target digit, two ‘‘#’’ distractors were presented 2º left and right of the central stream. One of the peripheral distractors was always grey, and the other was shown either in the target colour or one of the remaining colours (target-colour and nontarget-colour distractor conditions).

**RESULTS**

Twenty-one subjects participated in this study, but five had to be excluded due to the presence of artefacts or technical difficulties. Mean accuracy was 74.55% in the nontarget-colour distractor condition, and 64.91% in the target-colour distractor condition, $F(1, 15) = 17.21$, $MSE = 0.004$, $p < .001$ in a repeated measures ANOVA.

The ERPs were time-locked to the distractor onset. The N2pc was quantified as the subtraction of the averaged ipsilateral waveforms from the averaged contralateral waveforms in a 170–270 ms postdistractor onset time window, using the data from three electrode pairs: O1/O2, PO3/PO4, and PO7/PO8. Mean amplitudes in this time window were entered into an ANOVA with electrode site and distractor condition as within-subjects factors. Only the main effect of distractor condition was significant, $F(1, 15) = 6.52$, $MSE = 0.38$, $p < .05$, with a greater N2pc observed for target-colour distractors than for nontarget-colour distractors, as can be seen in Figure 1A.

**EXPERIMENT 2**

The experimental design in Experiment 2 was the same as in Experiment 1, except that the RSVP stream and peripheral distractors could be comprised of either digits or letters, counterbalanced across subjects. One grey
nontarget-category distractor was always present, and the second distractor could be a member of the target or nontarget category, and shown in the target or nontarget colour, yielding four distractor conditions. With the category manipulation, we wanted to investigate if the effect observed in Experiment 1 could be modulated according to whether there was a stimulus to process at the peripheral location where the attention was captured.

RESULTS

Again, from a total of 21 subjects who took part in the experiment, 5 had to be excluded, leaving the data from 16 participants to be analysed. The behavioural analysis revealed main effects of distractor colour (mean accuracy: 69.56% for target-colour; 75.87% for nontarget-colour), $F(1, 15) = 7.89, \ MSE = 0.008, p < .05$, and category conditions (mean accuracy: 71.77% for target-category; 73.66% for nontarget-category), $F(1, 15) = 5.47, \ MSE = 0.001, p < .05$, showing attentional capture for both distractor dimensions. The interaction was not significant.

The N2pc for each distractor condition were computed in the same way as for Experiment 1, using a 170–270 ms postdistractor onset time window in Experiment 1, and of 180–280 ms postdistractor onset in Experiment 2.

![Figure 1](image-url)

Figure 1. Contralateral–ipsilateral subtraction waveforms for each distractor condition, time-locked to distractor onset, in Experiments 1 (A) and 2 (B). The N2pc analyses were performed using a time window of 170–270 ms postdistractor onset in Experiment 1, and of 180–280 ms postdistractor onset in Experiment 2.
target-colour nontarget-category distractor condition, $F(1, 15) = 7.05$, $MSE = 0.51$, $p < .05$.

CONCLUSIONS

The electrophysiological results of the present study, that is to say the observation of an N2pc wave in conditions inducing attentional capture, provide strong evidence in favour of a visuospatial account of the contingent capture effect. Moreover, it is very interesting to note that the N2pc is larger under conditions in which the peripheral distractor shares the target category in addition to the target colour. This suggests that it then takes longer to disengage visuospatial attention from the location where it has been captured. However, processing of the distractor is not necessary for capture to occur, as the results from the target-colour (Experiment 1) and target-colour nontarget-category distractor conditions (Experiment 2) demonstrate. This interpretation is consistent with the time course of the contingent capture described by Leblanc and Jolicoeur (2005).

REFERENCES


Effects of object-based visual attention: Sensory enhancement or prioritization?

Ashleigh M. Richard, Hyunkyu Lee, and Shaun P. Vecera

*Department of Psychology, University of Iowa, Iowa City, IA, USA*

Studies of object-based attention have convincingly demonstrated that attention can be *controlled* by objects. However, the *effects* of object-based attention have been studied much less (see, for exceptions, Shomstein & Yantis, 2002; Vecera et al., 2006). There are two possible effects of object-based attention: Sensory enhancement and prioritization. Sensory enhancement proposes that perceptual processes are improved through attending to a particular location or object, whereas prioritization accounts propose that attention affects the order in which locations are analysed, not the perceptual quality of attended items.

Which of these two views best accounts for effects of object-based attention? Shomstein and Yantis (2002) addressed this question using a flanker task. Participants viewed three rectangles overlaid with three letters, one target letter in the centre and two in flanking locations. The flankers were either on the same object as the target or different objects. Sensory enhancement and prioritization make different predictions in this paradigm. Sensory enhancement predicts that attending to the object containing the target letter will enhance the representation of that object relative to unattended objects. Participants would show greater flanker interference when the letters appear on the same object as the target, as opposed to on different objects. Prioritization predicts that regions of the display will be ordered in search. Because the location of the target is always known and no search is required, there should be no effect of whether the flankers appear on the same object as the target or different objects. The results demonstrated that the flanker effect was unaffected by whether the flankers appeared on the same object or on different objects. These results were taken as evidence of a prioritization effect.

Although previous results have suggested a prioritization effect of object-based attention, sensory enhancement effects can explain many of the effects of spatial attention (see Luck & Vecera, 2002, for review). Because of the close connection between space-based and object-based attention under some theories of object-based attention (e.g., a “grouped array”; Vecera,
1994; Vecera & Farah, 1994), we reexamined the effects of object-based attention.

A close inspection of Shomstein and Yantis’ (2002) procedure suggested that sensory enhancement may have been put at a disadvantage for several reasons. First, in their studies, the task-relevant stimuli were highly familiar letters, and these stimuli might not require any perceptual-level enhancement processing to distinguish among the stimuli. Additionally, these task-relevant letters appeared abruptly and were presented after the task-irrelevant objects (rectangles). Such displays give the impression of stimuli occurring at two depth planes—a near surface of letters and a more distant surface of the background objects. Finally, because the task-relevant letters were not integral to the objects but instead appeared on top of (and monocularly in front of) the objects, the letters and objects may have been perceptually segregated from one another, allowing the objects to be effectively ignored; thus, attentional priority may have been given to the visual surface of the letters, not the background objects.

To further test between sensory enhancement and prioritization effects of object-based attention, we modified Shomstein and Yantis’ (2002) paradigm to include targets that were intrinsic to the objects, minimizing difficulty in establishing target and object correspondence. The targets were “bites” taken out of the objects, in either a rectangular or a circular shape. Our targets and objects appeared simultaneously on the screen. The predictions of the two attentional effects are identical to those outlined above.

In Experiment 1, displays consisted of a central, target bite and two flanking bites, either on the same object or on different objects as the target. The large rectangle (same object) extended $1.5^\circ \times 10^\circ$ and small rectangles (different object) extended $1.5^\circ \times 3^\circ$. The task was to determine if the centre bite was circular or rectangular. We investigated the difference between the flanker compatibility effect on same-object trials and different-object trials. We found a significant effect of flanker interference only on those trials in which the flankers appeared on the same object as the target (Figure 1A). These results are consistent with our hypothesis that if the attentional effect observed in object-based attention is sensory enhancement, the flanker compatibility effect should be reliably higher on trials in which flankers appear on the same object as the target. Therefore, our results support a sensory enhancement view of object-based attentional effects.

In order to understand the difference in our findings and those supporting prioritization effects, we conducted two additional experiments. In Experiment 2, we replicated Shomstein and Yantis (2002) using letter stimuli that appeared 1000 ms after the rectangles. In Experiment 3, we eliminated the time gap between the presentation of the rectangles and the letters. In neither experiment did we observe an object-based advantage (Figure 1B–C). These results suggest that enhancement effects arise when the task-relevant targets
are intrinsic to the stimulus objects. Previous prioritization effects might have been produced by attention being prioritized toward the letter stimuli and not the background objects used to assess object-based attention.

Finally, in Experiment 4, we sought to measure sensory enhancement using a secondary probe detection task. On half of the trials, a small, pointed probe appeared at one end of our stimuli. If the entire object is enhanced by object-based attention, the probe should be more rapidly detected in the same object conditions than different object conditions. Prioritization would assign highest priority to the target location and participants should only be attending to that location because it is the known target location. In support of sensory enhancement, detection times were faster when the probe appeared on an attended object (Figure 1D).

We have provided evidence supporting a sensory enhancement effect of object-based attention. The current findings suggest that results from cuing paradigms (Egly, Driver, & Rafal, 1994; Vecera, 1994) are likely to be the result of attention spreading throughout an attended object and enhancing the perceptual representation of that object rather than a reflection of
prioritization of objects to be searched. Future research will be required to
determine the conditions under which the different effects of object-based
attention operate.

REFERENCES
Egly, R., Driver, J., & Rafal, R. D. (1994). Shifting visual attention between objects and
locations: Evidence from normal and parietal lesion subjects. *Journal of Experimental
Psychology: General, 123*, 161–177.


Shomstein, S., & Yantis, S. (2002). Object-based attention: Sensory modulation or priority
setting? *Perception and Psychophysics, 64*(1), 41–51.


Experimental Psychology: General, 123*, 146–160.

enhancement or uncertainty reduction? *Manuscript in preparation*.

Axes versus averages: High-level representations of
dynamic point-light forms

Javid Sadr

*Department of Psychology, Harvard University, Cambridge, MA, USA*

Nikolaus F. Troje

*Department of Psychology, Queens University, Kingston, Ontario, Canada*

Ken Nakayama

*Department of Psychology, Harvard University, Cambridge, MA, USA*

Even when simultaneously masked by a large number of similar moving
points of light, one can almost effortlessly extract a small number of dots
whose coherent global motion depicts the moving limbs or joints of a person.

Address correspondence to: Javid Sadr, Vision Sciences Laboratory, Department of
Psychology, Harvard University, 33 Kirkland St., Rm. 740, Cambridge, MA 02138 USA.
Tel: 617.495.3884; Fax: 617.495.3764; E-mail: sadr@wjh.harvard.edu
Just as face perception, as a special case of visual object perception, has lent itself to the study of recognition, categorization, memory, expertise, attention, etc., so may this form of biological motion perception be plumbed as an extremely rich and fruitful example of complex object processing. Moreover, it may be studied using visual stimuli whose low-level spatiotemporal properties are amenable to quantitative analysis and systematic manipulation.

We are able to digitally capture, analyse, and model whole-body human movement and subsequently depict it using a small number of discrete points of light. Further, we are able to manipulate these stimuli in important ways, creating synthetic individuals whose movement and/or form are produced through, e.g., averaging or exaggeration of real individuals (Troje, 2002). The stimuli thus produced not only retain a very natural appearance, they also inspire exciting new approaches to the study of the mechanisms and representations underlying this intriguing and important perceptual process.

Starting with some relatively high-level perceptual questions that can be studied with these dynamic point-light displays, we first asked whether the seemingly straightforward categorical judgement of a walker’s gender (i.e., male/female discrimination) relies on representations that are prototype/norm based (e.g., distance from the average of each category) or if these may be better described as an opponent-style axis, explicitly coding the transformation (i.e., high-dimensional “direction”) between two categories.

Hypothesizing that the latter opponent system should exhibit a marked rebound effect following adaptation to a given gender, we tested subjects’ gender ratings with point-light walkers of varying masculinity/femininity, following viewing of clearly male, female, or neutral adapting stimuli (Troje, Sadr, Geyer, & Nakayama, 2006). The results strongly support the idea that these perceptual categories are represented in an adaptive opponent-like fashion, as seen in a directional shift of the psychophysical functions in this simple forced-choice task.

Subsequently, we further investigated this perceptual gender “axis” in relation to the more subtle dimension of attractiveness. These point-light stimuli drive such a vivid and rich percept that we find subjects can indeed provide reliable judgements of point-light walkers’ attractiveness, prompting some very interesting questions in relation to the current state of the surprisingly analogous study of face processing. In that literature, the predominant theory suggests that facial attractiveness and mating strategy are strongly driven by tendency toward the mean, such that the group prototype or average is what is considered the most attractive (e.g., Langlois & Roggman, 1990). A contrasting notion, however, is that sexual dimorphism is an important signal for attractiveness (e.g., Perrett et al., 1998). Following this latter theory, we hypothesized that not only would attractiveness ratings in biological motion be highly correlated with gender ratings (see also Troje, 2003), but also that manipulating these ratings by system-
atically varying the form and kinematics of walkers could explicitly contradict the “averageness” theory of attractiveness—specifically, that the most attractive individuals would not be those closest to the group mean but rather individuals exaggerated along the gender axis, perhaps far from the norm or prototype.

Our results bear out the above hypothesis quite clearly. Compared to a set of original female walkers, synthetically averaged walkers did receive slightly greater attractiveness ratings from male and female subjects, perhaps due in part to increased symmetry (e.g., Penton-Voak et al., 2001). However, as indicated in Figure 1, synthetically feminized walkers were rated as far more attractive than these averages. (NB Averaging and feminization were performed using very similar arithmetic procedures, differing mainly in the direction of the morphing.) These findings, as we hypothesized, show a strong connection between the two complex perceptual dimensions of gender and attractiveness (as in Perrett et al., 1998) and simultaneously augment our gender adaptation results to provide a sketch of the high-level coding of these stimuli; we see, for instance, that exemplars are better members of a category (e.g., “female”) not due to greater proximity to an averaged norm of that category but by something akin to a dot product with a vector describing the differences between categories.

**Figure 1.** Attractiveness ratings ($z$-score; $n=9$) as a function of point-light walkers’ “averageness” or femininity, manipulated here by morphing original female walkers towards gender prototypes (i.e., average female or male) or towards an exaggerated female.
In conclusion, subtle properties of the position and motion of a few dots can provide us with a rich percept not only of a single, coherent object (i.e., human actor) but also of complex, interrelated characteristics of this object and its actions (gender and attractiveness, not to mention identity, emotional expression, etc.; e.g., Cutting & Kozlowski, 1977). Here, perceptual hysteresis and the relative influences of prototypicality and exaggeration further demonstrate important properties on the mechanisms and representations underlying such a compelling and important perceptual experience.

REFERENCES

fMRI reactivation of the human lateral occipital complex during delayed actions to remembered objects

Anthony Singhal, Liam Kaufman, Ken Valyear, and Jody C. Culham
Department of Psychology, University of Western Ontario, London, Ontario, Canada

We employed a delayed reaching and grasping paradigm to investigate brain areas involved in delayed hand actions to 3-D objects. The two brain areas of

Address correspondence to: Anthony Singhal, Department of Psychology, Social Science Centre, University of Western Ontario, London, Ontario, Canada N6A 5C2. Tel: 519-661-2111 × 88190; Fax: 519-661-3961; E-mail: asingha@uwo.ca
primary interest were the lateral occipital complex (LOC) in the ventral stream, which processes information about object properties during visual recognition (Grill-Spector, Kourtzi, & Kanwisher, 2001), and the anterior intraparietal sulcus (AIP) in the dorsal stream, which processes information about object properties to guide actions such as hand preshaping during grasping (Binkofski et al., 1998; Culham, 2003). Neuropsychological work has shown that a patient, DF, who has LOC lesions, but an intact AIP (James, Culham, Humphrey, Milner, & Goodale, 2003), cannot recognize objects but can accurately grasp them when they are visible in real-time (Goodale, Milner, Jakobson, & Carey, 1991). However, when a delay is introduced between viewing and grasping, DF can no longer perform accurately (Goodale, Jakobson, & Keillor, 1994), suggesting that LOC may be an important area for delayed action. Furthermore, patient, IG, with optic ataxia and posterior parietal cortex (PPC) damage, but an intact LOC, cannot accurately grasp objects in real-time, but with practice can do so after a delay (Milner et al., 2001). In contrast, single unit recording work in macaque monkeys has shown that AIP neurons remain active during delays (Murata, Gallese, Kaseda, & Sakata, 1996) raising the possibility that AIP stores object information for delayed actions. Based on this, we investigated the activation patterns in LOC and AIP during the three phases of a delayed action paradigm: Visual stimulus presentation, memory maintenance, and action execution: This paradigm allowed for the visual and action responses to be separated in time, while the delay interval provided information about which brain areas are involved in the storage of information necessary for action, and action preparation.

**METHODS**

Twenty healthy right-handed participants were auditorily cued to encode the location and the object properties of a briefly illuminated 3-D stimulus in order to prepare to act on the object (reach or grasp). Following an 18 s delay in complete darkness, participants were auditorily cued to perform the action (go), or to stop (no-go), thereby preventing the action and ending the trial. We employed an event-related design where the reaching and grasping events were randomly interleaved. Images were collected with a 4 Tesla MRI system (Siemens-Varian) using a full head coil and a voxel size of 3 mm × 3 mm × 5 mm. Half of the subjects were scanned with a slice orientation covering parietal and frontal cortices and half were scanned with a slice orientation covering parietal and temporal cortices. Each experimental scan session consisted of at least four functional runs and a high-resolution anatomical scan. Participants’ heads were tilted inside the coil to permit
direct viewing, without mirrors, of 3-D objects above their torsos. A general linear model was used to estimate each of four components separately for the reaching and grasping trials: (1) Activation associated with the initial visual presentation of the 3-D object; (2) activation associated with the delay period; (3) activation associated with the go signal; and (4) activation associated with the no-go signal. A region of interest (ROI) approach with independent tasks was used to localize LOC and AIP. LOC was localized by selecting voxels in the ventral lateral part of occipital cortex that were significantly activated by the presentation of 2-D images of objects. AIP was localized in each participant by selecting voxels in the anterior part of the intraparietal sulcus (IPS) that were significantly more active for grasping than reaching.

RESULTS

The most interesting finding in this experiment was that LOC was reactivated at the time of action despite the fact that no visual stimulus was presented at this time. As expected, LOC was activated during the visual presentation phase, but it did not show activation during the delay phase. A second finding of interest was that AIP showed greater activation for grasping than reaching for both the visual presentation and action phases. In addition, AIP showed delay phase activation, which was equivalent in magnitude for grasping and reaching. The data also showed that the delay phase was significantly correlated with activation of a network of brain regions that included parts of the frontal and parietal cortices, as well as the supplementary motor area. Finally, as expected, the initial presentation of the 3-D object was associated with widespread brain activation, including visual cortex.

CONCLUSIONS

The reactivation in the ventral object-selective area, LOC, during the action phase suggests that LOC is important for delayed action, and processes higher order information about the target object required by the dorsal stream. The nature of this processing may involve the extraction of object features from memory in order to complete the action following a delay, and/or the mental imagery of the object. This finding supports the neuropsychological evidence from patient, DF who has LOC lesions and cannot grasp objects accurately after a delay. Furthermore, the finding that AIP was activated during the delay phase supports the monkey neurophysiology work that this region stores information necessary for action after a delay. However, the delay phase activation in AIP was not greater for grasping than
reaching, which is more consistent with the optic ataxia patient data suggesting that PPC regions may not be essential for accurate delayed grasping (Milner et al., 2001).

REFERENCES


Control of speed and accuracy set point in visually guided manual-pointing movements

Joo-Hyun Song and Ken Nakayama

*Harvard University, Cambridge, MA, USA*

Motor actions directed toward one object are influenced by the presence of other nontarget objects. When an odd-colour target was presented with two distractors, we previously observed two types of strategies. Subjects sometimes waited a bit longer and initiated direct movements to the target,

Address correspondence to: Joo-Hyun Song, Department of Psychology, Harvard University, 33 Kirkland Street 710, Cambridge MA 02138, USA. E-mail: jhsong@wjh.harvard.edu
showing straight trajectories, or initiated movements quickly toward distractors and then shortly after corrected them to the target, showing curved trajectories. Yet, when a single target is presented without distractors, movements were initiated quickly and directly to the target (Song & Nakayama, 2005). Compared to single target trials, odd-colour target search trials are relatively difficult. The range of movement strategies demonstrates influences of trial difficulty on speed and accuracy criteria in visually guided actions.

In the current study, we asked how intermixing trials of varying difficulty influences speed and accuracy criteria of each trial, what mechanism adjusts these criteria, and how speed and accuracy criteria adjust the time course.

We conducted two experiments, where single target and odd-colour target search trials are mixed in various ways. Nine right-handed subjects participated in each experiment. Polhemus Fastrack recorded 3-D finger movement trajectories at a rate of 120 Hz. On each trial, subjects were required to touch the lone or odd-coloured target with their index fingers as quick and accurately as possible. The target colours were randomly switched between red and green. If the target was red, two distractors were green, and vice versa. The target location was randomly chosen from three possible locations: 4, 8, and 12 o’clock from the centre. The display was presented until subjects touched the target. Response–stimulus interval (RSI) was 1.5 s.

We considered two sources that may affect adjustment of speed and accuracy criteria: Predictability for the upcoming trial type and repetitions of the same trial type. To pit predictability for upcoming trial against trial type repetition, we mixed the two types of trials in three ways in Experiment 1: Blocked, mixed, and alternating conditions. In the blocked condition, single and odd-colour target trials were presented in separate blocks. In contrast, in the mixed condition, the two types were randomly mixed. Finally, in the alternating condition, single and odd-colour target trials would be alternating and subjects were informed about the alternation in advance.

Both accounts commonly predict that optimally differentiated speed and accuracy criteria would be adopted for the two trial types in the blocked condition either due to cognitive knowledge for upcoming trials or cumulative learning based on repetition of the same type, but this would not occur in the mixed condition. Of interest is the alternating condition, where diverging results are predicted. According to the predictability account, the alternating condition would be similar to the blocked condition, whereas according to the cumulative learning account, it should be similar to the mixed condition.
Our results showed that initiation latencies were significantly shorter for single target (245 ms) than odd-coloured target trials (329 ms) in the blocked condition, indicating that latencies were adjusted appropriately for the level of trial difficulty. However, there was no latency difference in the mixed (285 vs. 296 ms) and alternating conditions (286 vs. 284 ms). Single target trials became significantly slower and odd-colour target trials became faster compared to those in the blocked condition. Thus, in contrast to the blocked condition, the mixed and alternating conditions demonstrate the failure of optimal criteria adjustment for difficulty level.

The cost of suboptimal initiation criteria, especially faster initiation of odd-colour target trials, is reflected in curved movement trajectories. More curved trajectories toward distractors were observed in the mixed and alternated conditions compared to the blocked condition though conventional final accuracy indexes such as correctness of target selection, touching locations and their variances indicate that subjects successfully fulfilled their ultimate task goal.

To examine how latency criteria are adjusted trial-by-trial, trials were categorized into three groups based on the number of same trial type repetition in the mixed condition: 0, 1, and over 2 repetitions. Results show that, with increasing the number of repetitions, the difference between single and odd-colour target trials also increased. This supports the view that the latency criteria are incrementally adjusted by recent experience.

In Experiment 2, we further investigated the time course of the adjustment of latency criteria based on cumulative learning, using predictable sequences. In this task, five single and five odd-colour target trials were regularly switched (Allport, Styles, & Hsieh, 1994; Rogers & Monsell, 1995). Subjects had perfect cognitive knowledge for the upcoming trial type since they were informed about the five-trial-switch rule and visual cues for trial type and which trial in the sequence (first, second, etc.) were also presented in each trial.

Latencies for the two difficulty levels were gradually differentiated as the number of repetitions increased. The latency differences between single and odd-colour target trials were statistically significant except for in the 0 repetition condition, where the response for the type of trials was reversed. The difference emerged only after one (35 ms) or two repetitions (50 ms), and gradually increased up to 62 ms. Thus, it again supports the cumulative learning account by trial type repetition. In addition, the lack of latency difference at the switching point (0 repetitions) shows that cognitive knowledge is not directly involved in this adjustment.

In the current study, therefore, we suggest that an essential mechanism responsible for adjusting visuomotor criteria is cumulative learning based on very recent events.
REFERENCES

