PSYCHE

an interdisciplinary journal of research on consciousness

Change Detection: Paying Attention To Detail

Erin Austen & James T. Enns<1>

Department of Psychology
University of British Columbia
2136 West Mall
Vancouver, B.C., Canada V6T 1Z4

jenns@psych.ubc.ca

PSYCHE, 6(11), October 2000
http://psyche.cs.monash.edu.au/v6/psyche-6-11-austen.html

KEYWORDS: change blindness, local perception, global perception, visual search, attention.

ABSTRACT: Changes made during a brief visual interruption sometimes go undetected, even when the object undergoing the change is at the center of the observer's interest and spatial attention (Simons & Levin, 1998). This study examined two potentially important attentional variables in change blindness: *spatial distribution,* manipulated via set size, and *detail level,* varied by having the change at either the global or local level of a compound letter. Experiment 1 revealed that both types of change were equally detectable in a single item, but that global change was detected more readily when attention was distributed among several items. Variation of target level probability in Experiment 2 showed further that observers could flexibly set the detail level in monitoring both single and multiple items. Sensitivity to change therefore depends not only on the spatial focus of attention; it depends critically on the match between the detail level of the change and the level-readiness of the observer.

1. General Introduction

There has been a recent explosion of interest within the psychophysical community in the role of attention in perception (e.g., change blindness, inattentional blindness, repetition blindness, the attentional blink, masking by object substitution, amnesic visual search). A central theme in this research is that perception of the visual world is not as rich as our subjective experience gives us to believe. In the present study, we examined the role of an attentional variable, *detail level*, which has not yet been studied systematically in this context. We believe that its consideration is at least as important as other factors that have been studied and that it may hold the key to some puzzles that currently beset the relationship between attention and perception.

Much credit for the current interest in attention goes to Mack and Rock (1998), who reported a series of experiments in which they cleverly distinguished between perception with and without expectation. What they demonstrated was that observers were often unaware of otherwise salient visual stimuli if these stimuli were presented unexpectedly along with expected stimuli on which observers performed a difficult perceptual judgment. Even some unexpected stimuli presented to the fovea went undetected in these tasks, prompting the authors to coin the apt term "inattentional blindness."

Research involving a related phenomenon, "change blindness," took this idea one step further in reporting that some changes to a scene go undetected even when the object undergoing the change is the focus of attention (Simons & Levin, 1998). On the surface, this finding is disturbing, since it implies that even focused attention on an object does not guarantee accurate perception. It is one thing to learn that unexpected and unattended objects are not always seen (Mack & Rock, 1998). But is even our subjective experience of seeing a fully attended object only an illusion? To help understand the claim that change to an attended object can go undetected, we review the background research briefly.

Interest in change blindness began with reports that observers did not notice image changes made during a saccade in the inspection of a picture (e.g., a switch in hats worn by two gentlemen), although these same changes were easily detected when they occurred during a fixation (e.g., Grimes, 1996, McConkie & Currie, 1996). Other reports indicated that similar results could be obtained if the changes occurred during a brief visual interruption in the scene (Rensink, O'Regan & Clark, 1997), if the changes occurred during a 'cut' in a movie sequence of real-world actions (Levin & Simons, 1997; Simons, 1996), and even if they occurred during a real-world conversation between an unwitting participant and an actor. In this case it was the actor who exchanged places with another actor when a door being carried by other actors briefly interrupted the conversation (Simons & Levin, 1998).

In was clear from the outset that attention to the relevant portion of a scene is a *necessary* component of successful change detection. Changes are detected more readily when they occur to objects that are of interest to the observer (Rensink, 1999; Rensink et al, 1997), and when they occur in locations that have had attention drawn to them by a salient cue such as a local visual transient or a unique color (Rensink et al, 1997; Scholl, 1999). However, attention to an object is also not *sufficient* to prevent change blindness. For example, in the study in which real-world participants failed to notice the change in an actor, there was every indication that participants were fixating the actor both before and after the change, and that the actor was the visual focus of interest in the scene (Simons & Levin, 1998). Similarly, in studies of movie cuts, the change involved a single moving actor in the scene approaching a telephone (Levin & Simons, 1997). Findings such as these indicate that focused attention does not guarantee detection of changes to the attended object. Or do they?

We began our thinking on this issue by differentiating three different aspects of spatial attention, following Coren, Ward and Enns (1999; Chapter 15). Attention to a scene or an object can be understood in terms of: the *locus* of the attention (where in the visual field is the center of attention?), the extent or *distribution* of attention (how widely is attention spread over space?), and *detail level* (is attention set for the 'forest' or the 'trees'?). From this perspective, it is clear that studies of change blindness to date have manipulated the locus (e.g., Scholl, 1999) and distribution of attention (e.g., Rensink, 1999; Smilek, Eastwood & Merikle, in press). However, none have systematically varied the detail level. Before describing such a study, we will briefly summarize some of the past research on global-local perception in order to provide a context for the present study.

The debate over whether visual analysis begins with the details (the 'trees') or with the larger configuration (the 'forest') has a long history (see review by Kimchi, 1992). Most modern studies of this issue rely on the logic outlined by Navon (1977), who presented observers with compound letters (a large or 'global' letter made up of many smaller or 'local' letters). The letters could be the same at each level (consistent) or different (inconsistent). Response time (RT) was recorded for the detection of a specified target letter that could occur at either the local or global level. The main findings were first, that RT to global targets was generally faster than to the local targets and second, that RT to local targets were slowed down more by a conflicting global letter than was RT to a global letter made up of inconsistent local letters. These patterns were interpreted as evidence for a more rapid analysis of the 'forest', or *global precedence.*

Numerous studies since Navon's (1977) have examined various stimulus factors (Amirkhiabani & Lovegrove, 1996; Grice, Canham, & Boroughs, 1983; Hughes, Layton, Baird, & Lester, 1984; Kimchi, 1992; Kinchla & Wolfe, 1979; Martin, 1979; Navon & Norman, 1983) and observer expectations (Boer & Keuss, 1982; Lamb & Robertson, 1989; Miller, 1981; Robertson, Egly, Lamb & Kerth, 1993; Ward, 1982; 1983), leading to a large and confusing set of results. While there are certainly some conditions that favor global precedence (e.g., small local letters densely arrayed), others favor the local level (large local letters sparsely arrayed). Most notably, the attentional set of the observer (e.g., which level is expected) is often a more important predictor of the RT pattern than are the specific stimulus parameters that are used (Ward, 1982; 1983). Accordingly, the research focus in this area seems now to have shifted from the question of "which level is analyzed first?" to the more useful question of how sensory factors of stimulus registration (bottom-up) interact with internal mechanisms of selection and decision making (top-down) to bias perception toward one or the other level in a given situation.

In what follows, we report two experiments examining the role of detail level in successful change detection. Experiment 1 found equally successful detection of global and local changes under focused attention, but superior global change detection when attention was spatially distributed. This pattern of results raised a number of questions, including (a) whether the results for focused attention were subject to ceiling effects, (b) whether the results for focused attention implied rich representations of attended objects or merely a probability matching strategy, and (c) whether the global detection advantage under distributed attention was primarily a sensory or attentional effect. These questions were addressed by the design of Experiment 2, where the probability of change at each level was manipulated. The results showed that change detection depends critically on the expectancy of the observer, for both focused and distributed attention conditions.

2. Experiment 1

Our first experiment varied independently both the spatial distribution of attention and the detail level of the target of change. It was important to vary the spatial distribution of attention because of the claims that change blindness is possible even when the observer's spatial attention is narrowly focused on the object of change in the experiment (Levin & Simons, 1997; Simons & Levin, 1998). We chose a set size manipulation in the flicker version of a change detection task as a convenient way to do this (Rensink, 2000). When there was only a single item in the flickering display, spatial attention could be devoted fully to that item. In contrast, when the display contained multiple items, spatial attention had to be distributed widely across the display because the target (the changing item) was equally likely to be any one of the items.

The detail level of display items was manipulated by using compound letters similar to those of Navon (1977). Two large letters (E and S) were formed by arranging smaller letters (also E and S) into appropriate configurations, as shown in Figure 1. This meant that there were four possible different items in any display, large Es made of smaller Es, large Es made of smaller Ss, large Ss made of smaller Es, and large Ss made of smaller Ss. On one half of the trials, one of the letters changed from frame to frame; either a local or a global letter. There were two main questions: (1) Would change be detected more easily at the local or global level? and (2) Would any detail level effects we observed differ, depending on whether attention was focused (set size =1) or distributed (set size > 1).

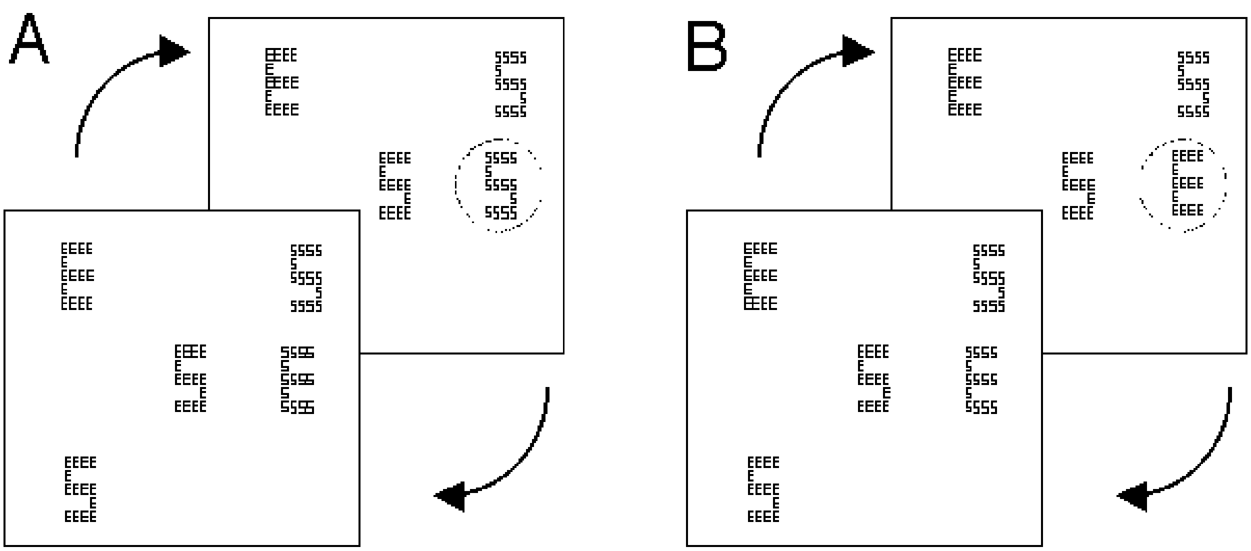

Figure 1.
Schematic illustration of the visual displays. A letter that changes from frame to frame is indicated with a dashed circle (which did not appear in displays shown to observers). (A): Change at the global level of the target item. (B): Change at the local level of the target item.

With regard to the second question, it is worth noting that there are two different positions in the literature concerning the relation between spatial distribution and detail level of attention. The position we take is that these are qualitatively different aspects of selective attention. An alternative position is given by Nakayama (1990), who described a theoretical framework in which a wide spatial distribution is tantamount to a visual analysis of global scene characteristics, whereas a narrow spatial focus is invariably tied to local visual analysis. Furthermore, the attentional focus for a new scene always begins at wide/global and moves to narrow/local as required. In our view, the former position has the most empirical support, because of studies showing a clear dissociation between factors that influence spatial aspects of performance separately from the detail aspects (Enns & Kingstone, 1995, Lamb, 1999). As we will argue later, it is also supported by the results of the present study.

2.2. Method

2.2.1. Participants

Ten undergraduate psychology students from the University of British Columbia were recruited to take part in a 1 hr session in return for partial course credit. Each participant reported having normal or corrected-to-normal vision.

2.2.2. Stimuli and Apparatus

Displays were generated by a Macintosh computer and viewed on a 17" Applevison monitor in black and white mode. A chin rest was used to maintain a viewing distance of 86 cm. Two possible large letters, E and S, were formed by arranging one of two smaller letters, also E and S, as shown in Figure 1. One half of the letter combinations were consistent (i.e., identical global and local letters), the other half inconsistent (i.e., different global and local letters). (Note. There is no point in analyzing the consistency factor in this design, since a 'target' always involves a change from a consistent to an inconsistent item across repeating frames). Letters were black (all pixels off) on a white background (all pixels lit). Local letters were 5 x 10 pixels (0.2 x 0.4 degrees); global letters measured 35 x 70 pixels (1.4 x 2.8 degrees).

Displays consisted of alternating frames of 1, 3, or 5 items (225 ms), followed by a blank frame (225 ms), followed again by the same number of items in the same locations (225 ms), followed by a blank frame (225 ms). This continued until the observer pressed one of the keys, indicating that a change had been detected in one of the items. Half of the trials contained a different item in one of the two frames of items, with the difference being equally likely to involve the local letters in an item or the global configuration. Feedback in the form of a plus (correct) or minus (incorrect) sign was presented at the center of the screen following each response. This also served as fixation and warning symbol for the start of the next trial. Maximum allowable display time without a response was set to 14 s.

Items appeared randomly in one of nine squares of an imaginary 3 x 3 matrix (10.8 x 11.4 degrees overall, each square measured 3.6 x 3.8 degrees). Items were jittered with the constraint that a minimum distance of 1 degree separated items.

2.2.3. Procedure

Participants indicated whether a change was present in one of the items by pressing a designated key with an index finger as quickly as possible. If no change was detected they pressed a different key with the other index finger. Participants were told that a change was present in one of the items on half of the trials, that the change would equally often at the local and global level. The three display sizes of 1, 3 and 5 items were also randomly intermixed in a block of trials. Participants were given printed and verbal instructions, before beginning a practice block of 10 trials. A testing session consisted of eight blocks of 60 trials. At the end of each block, a dialogue box on the screen indicated the error rate, and a warning message was presented if errors exceeded 10%. Participants were instructed to slow down if this warning message was presented.

2.3. Results

Correct response time (RT) and error data were analyzed in all conditions. RT has been demonstrated to be a reliable and valid measure of change detection in a visual search task, despite the fact that the displays consist of discrete images separated by blank intervals (Rensink, 2000).

2.3.1. Change Detection During Focused Attention

There were no differences in change detection for global and local changes when set size was equal to one. Mean RT for detecting a global change was 1381 ms (SE = 54 ms) while that for detecting local change was 1376 ms (SE = 71 ms), $F(1, 9) < 1$. Mean errors in detecting global and local changes also did not differ, both conditions yielded 3.2% (SE = 0.01%). A repeated-measures ANOVA examining no-change trials along with the two kinds of change trials (local, global) indicated that RT was significantly longer when no change was detected, 1605 ms (SE = 106 ms), $F(2, 18) = 54.65$, $p < .001$. This is the expected pattern in a visual search task, where only one target needs to be detected in order to respond positively, but where all items must be checked in order to respond negatively. The same analysis of errors showed no difference, $F(2, 18) < 1$.

2.3.2. Change Detection During Distributed Attention

Global change detection was considerably easier than local change detection when set size exceeded one item. Mean correct RT and mean errors for set sizes 3 and 5 are shown in Figure 2. Repeated-measures ANOVAs examining Display Size (3 and 5) and Change Type (none, global and local) were conducted on both measures and all effects (main and interaction) were statistically significant at the $p < .01$ level.

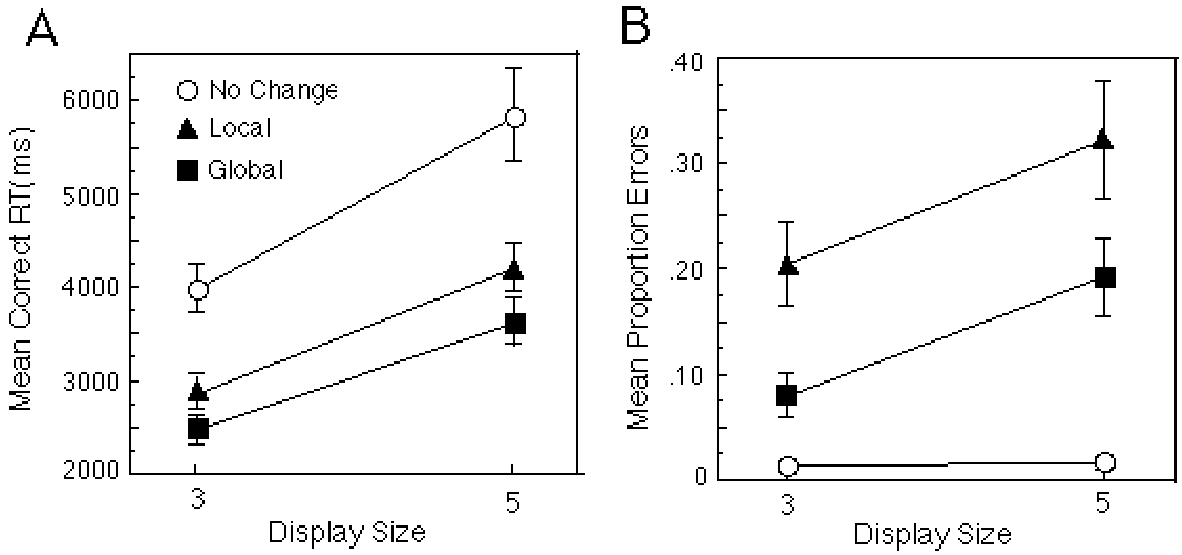

Figure 2.
Results of distributed spatial attention in Experiment 1 for 10 participants. (A) Mean correct RT and (B) Mean proportion correct. Error bars refer for 1 SE.

A more detailed analysis of only local and global change RT revealed that global change was detected more rapidly than local change, $F(1, 9) = 13.38$, $p < .01$, and that change was detected more rapidly in 3 items than in 5 items, $F(1, 9) = 80.37$, $p < .001$. The interaction between these factors did not reach significance, $F(1, 9) = 3.12$, $p > .05$. The same analysis involving errors revealed the same pattern. Global change was detected more accurately than local change, $F(1, 9) = 16.73$, $p < .01$, and accuracy was higher when set size was three than when it was five, $F(1, 9)=19.55$, $p < .01$. There was no significant interaction, $F(1, 9) < 1$.

2.4. Discussion

The results showed that under conditions of focused attention to a single item, changes at the local level were detected as rapidly and accurately as changes at the global level. This finding establishes that, at least under conditions of full attention and central fixation, changes at either the local or the global level were detected equally readily in these displays. This baseline will be important in the interpretation of results from larger set sizes and from the Experiment 2.

The results also showed that when attention was distributed among multiple items, changes at the global level were detected more rapidly and accurately than changes at the local level. This finding is therefore consistent with many previous reports of a global processing advantage (Hughes et al., 1984; Navon, 1977), especially with those indicating that the advantage for the global level is more pronounced under conditions of distributed attention and/or greater visual field eccentricity (Amirkhiabani & Lovegrove, 1996; Navon & Norman, 1983). What is novel about the present finding is that the global advantage does not only apply to the identification of a static object, but extends to the detection of change in an object. This is potentially important to global-local researchers because the ease of feature detection in static displays does not always correlate with the ease of detection in feature change displays (Rensink, 2000).

It is clear from these results that the ease of detecting change at different detail levels depended on the spatial distribution of attention. Why might this be? It is helpful to break this larger question down into two smaller ones: Why was there no detail level effect when set size was one? And, Why was there a global advantage for detecting change in larger set sizes? There are at least three possibilities to consider for the first question. First, the result may have been a ceiling effect; the task may have been too easy to measure any differences in perception.

Second, it may reflect the well-supported position that visual representations of attended objects are rich and complete (e.g., Duncan, 1984; 1993a; 1993b; Baylis, 1994; Baylis & Driver, 1992). This would mean, for example, that many of the attributes of a briefly-viewed attended object are available, at least for a short time, for report by the observer. There should be little cost in performance when asked to report one versus two attributes of the attended object (Duncan, 1993a; 1993b). From this perspective, the observer in Experiment 1 had complete and equal perceptual access to both levels of the compound item that was attended when set size was equal to one.

The third possibility is that global and local levels of a single attended item were not processed equally. Perhaps, as might be predicted based on Ward (1982, 1983), observers were only optimally prepared for one or the other level prior to the onset of a trial. Switching from one level, when no change was detected there, to the other level, would incur a cost in RT and accuracy. If this view is correct, then it is possible that observers were matching the probabilities of the experiment, switching levels from trial to trial in order to match their expectations to the equal probabilities of local and global changes.

All three of these possibilities are examined in Experiment 2. If the third possibility is supported, it would help us understand why an object that is at the center of spatial attention, can undergo a salient change that is sometimes undetected (Levin & Simons, 1997; Simons & Levin, 1998). It might be because the change is at a *detail level* for which the observer is currently unprepared. Such a result would go against both the possibilities of ceiling effects and rich representations as accounts of the equal performance for focused attention in Experiment 1.

With regard to the second question, concerning a global advantage for change detection when there are multiple items, we think there are two interesting possibilities. One is that the two levels of detail are quite unequal in their discriminability when these items are presented outside the fovea. Given the distribution of receptors across the retina, and corresponding cortical neural distributions, global letters may simply be more visible in the parafovea than local letters in this view (Kinchla & Wolfe, 1979).

Another possibility, however, is that the limit on the visibility of local letter changes in the parafovea is not only a low-level one, as might be expected on the basis of the decreasing spatial resolution that accompanies increasing visual eccentricity. Instead, the limit may also be set by one's readiness to see a given level of detail or other. The key difference between this view and the first, that global information is simply better represented in the visual periphery, is that the attentional view allows for the possibility of visual representations that are sensitive to the demands of the task. For example, if we found that the pattern of global-local change detection under distributed attention was influenced by the nature of the task, it would suggest that a difference in parafoveal visual acuity could not, on its own, account for the observed differences in global and local change detection. Change detection, even under distributed attention conditions, may depend on the detail set of the observer.

3. Experiment 2

The critical modification in Experiment 2 was variation in target level probability. One group of observers performed the same task as in Experiment 1 with the exception that a local change occurred 75% of the time and a global change occurred only 25% of the time. A second group experienced the reverse arrangement: a global change occurred 75% of the time, and a local change 25% of the time.

This probability manipulation permitted us to answer the questions that raised by the results of Experiment 1. For example, if the equal detection of local and global change for an attended item reflected either ceiling effects or the rich representations of attended objects (Duncan, 1984; 1993a; 1993b), varying target level probability should have very little effect. Similarly, if the global advantage seen when attention was distributed reflected primarily parafoveal acuity, then varying target level probability should also have no effect.

It is important to note that this manipulation of target level probability could not alter response biases. In each condition, no change and change trials were still randomly presented and equally divided among the trials (50% change). The probability factor concerned only the type of change (local or global) that was present in a change trial.

3.2. Methods

Twenty undergraduate psychology students volunteered to participate in return for partial course credit. Participants were randomly assigned to either the local bias (local change 75%) or the global bias conditions (global change 75%). All reported normal or corrected-to-normal vision. With the exception of varying the target level probability for the two groups, the stimuli and procedure were identical to Experiment 1.

3.3. Results

3.3.1. Change Detection During Focused Attention

Target type was involved in a crossover interaction with detail level when set size was equal to one. Mean correct RT and mean errors for each bias condition are shown in Figure 3. The data from Experiment 1 (No Bias) are included for comparison purposes. In the Local Bias group, both RT and errors favored detection of local change, whereas in the Global Bias group RT and errors favored global change detection. ANOVAs for RT and errors showed both interactions to be significant, $F(1, 18) = 11.5$, $p < .01$, and $F(1, 18) = 7.63$, $p < .05$, respectively.

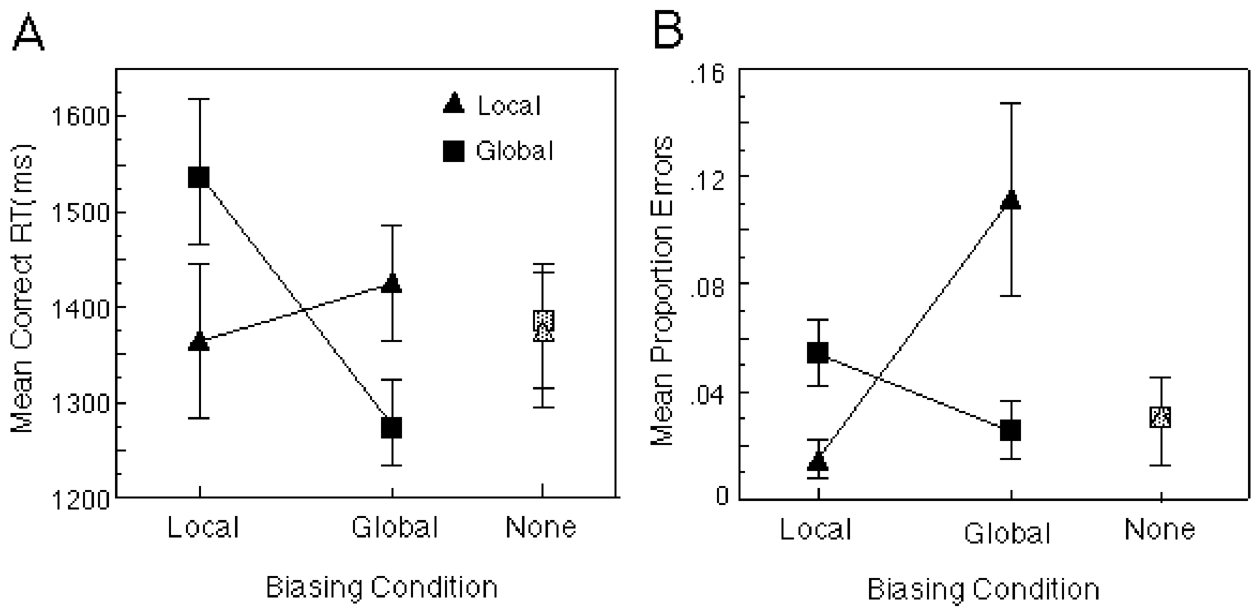

Figure 3.
Results of focused spatial attention in Experiment 2 for 10 participants in each of two biasing conditions. (A) Mean correct RT and (B) Mean proportion correct. Error bars refer for 1 SE. The No Bias condition is Experiment 1 and is presented for comparison purposes.

3.3.2. Change Detection During Distributed Attention

Global change detection was again generally easier than local change detection when set size exceeded one item. However, there was also clear evidence that target level probability had a strong influence on the magnitude of the global advantage. Mean correct RT and mean errors, averaged over set sizes 3 and 5, are shown in Figure 4. The data from Experiment 1 (No Bias) are again included for comparison purposes. Repeated-measures ANOVAs examining Display Size (3 and 5), Change Type (local, global) and Bias (local, global) were conducted on RT and errors.

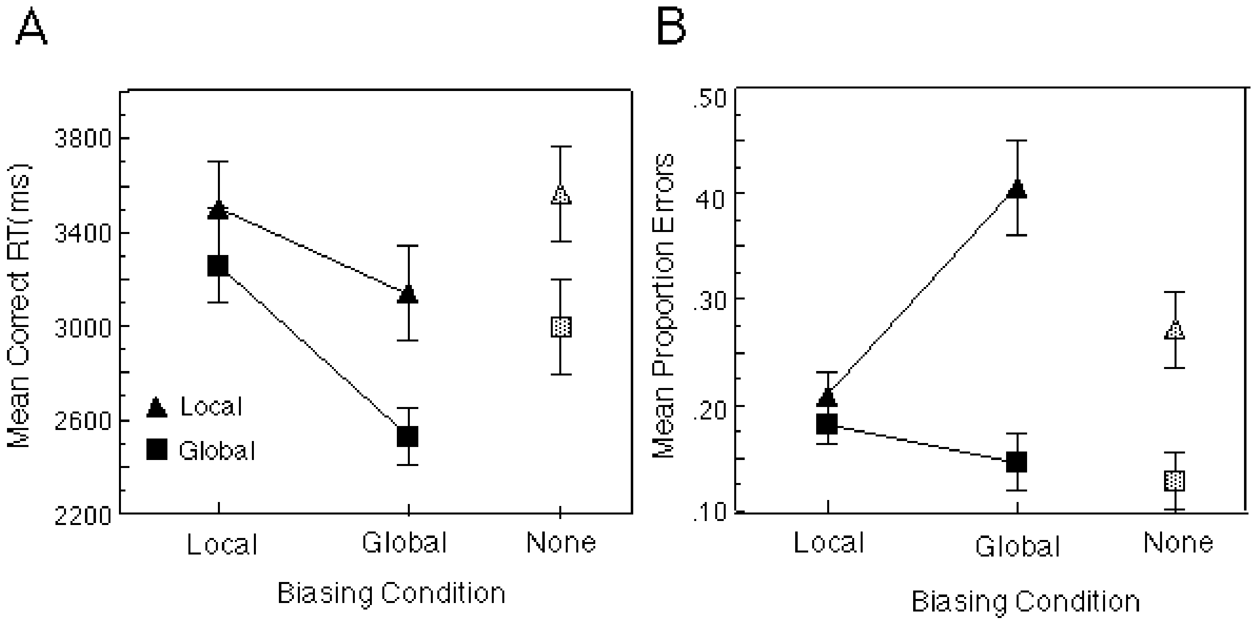

Figure 4.
Results of distributed spatial attention in Experiment 2 for 10 participants in each of two biasing conditions, after averaging over the display sizes of 3 and 5. (A) Mean correct RT and (B) Mean proportion correct. Error bars refer for 1 SE. The No Bias condition is Experiment 1 and is presented for comparison purposes.

The analysis of RT revealed significant main effects of Display Size, ($F(1, 18) = 105.7$, $p < .001$, and Change Type, $F(1, 18) = 9.75$, $p < .01$. The main effect of Bias approached significance, $F(1, 18) = 3.99$, $p < .07$. The Change Type x Bias interaction was not significant, $F(1, 18) = 2.68$, $p > .10$. There were no other significant effects, all p's > .10.

The analysis of errors revealed significant main effects of Display Size $F(1, 18) = 41.65$, $p < .001$, and Change Type ($F(1, 18) = 21.83$, $p < .001$. The main effect of Bias Condition was not significant, $F(1, 18) = 3.30$, $p < .09$. However, in this analysis, Change Type x Bias was significant, $F(1, 18) = 17.10$, $p < .001$. There were no other significant effects, all p's > .20. Pairwise comparisons of accuracy in the local bias condition revealed no significant difference between local and global targets, $F(1, 9) < 1.0$. In contrast, the global bias condition revealed a significant global advantage, $F(1, 9) = 40.05$, $p < .001$.

The high rate of errors for local targets in the Global Bias suggests that the correct RT in that condition underestimated the interaction between change type and bias. That is, only 60% of the trials contributed to the RT in that condition (40% were errors) and therefore many of them were lucky guesses. Thus, if participants had maintained an accuracy level comparable to the other conditions, their RT would also have been much longer.

3.4. Discussion

These results provided clear answers to the questions prompting this experiment. First, we found that biasing the observer to expect change at one level clearly influenced the results for a single attended item: a local bias led to a local detection advantage, whereas a global bias led to a global detection advantage. This finding rules out two interpretations for the equal detection of attended local and global targets in Experiment 1, namely, that the result reflected a ceiling effect, and that an attended item is represented so richly that both local and global information are equally accessible. Rather, these results indicate that change detection, even for an attended item, is influenced by the *detail level* to which the observers' attentional system has been set. Change detection in items that are fully attended depends, therefore, on the internal *level-readiness* of the observer (Ward, 1982; 1983).

Second, we found that biasing the *detail level* also influenced the detection of change in items viewed under distributed attention. This finding rules out one interpretation of the global advantage found in Experiment 1, namely that acuity for local detail is limited primarily by parafoveal acuity. We found instead that there was no significant difference between local and global change detection when observers were prepared to detect local changes, In contrast there were very large differences favoring global change detection when observers were prepared to detect global changes. So, in addition to the known factors which reduce visual acuity for local letters in the parafovea, this finding indicates that the attentional factor of *detail level* is influential enough so that, on the one hand, a local bias can virtually erase the benefits that normally accrue to the global level, while on the other, a global bias can render the local letters significantly less visible.

4. General Discussion

This study has demonstrated the importance of considering *detail level* in understanding change blindness. Sensitivity to change in a scene is a function not only of the *locus* of attention (Where is attention directed?, as in Rensink et al., 1997; Scholl, 1999), nor of its *extent* (How widely is attention distributed over space?, as in Rensink, 1999; Smilek et al, in press). It is equally important to characterize the *detail level* of attention in predicting whether change blindness will occur (At what level of visual detail is the scene processed?).

Most importantly, the present study brings clarity to one of the puzzles of change blindness, namely, that although attention may be focused on an object, blindness to large changes may still occur (Levin & Simons, 1997; Simons & Levin, 1998). It is our view, based on the interaction between target bias and detail level in Experiment 2 (Figure 3), that attention can be directed toward a given level of detail in much the same way as it can be directed to a given location in space. However, the neural mechanisms are probably different, with the spatial distribution under the control of parietal lobe function and the detail level under the control of temporal lobe function (Corbetta, Miezin, Dobmeyer, Shulman & Petersen, 1991; Kingstone, 1992).

This perspective suggests a clear prediction for future experiments in which change in an attended object may go unnoticed. Change detection in an attended object should be directly related to the match between the *detail level* of the change and the *level-readiness* of the observer (Ward, 1982; 1983). As an example, the detection of change in the emotional expression of an actor should occur more readily than the detection of change in the identity of an actor, if the perceptual task involves reading the emotional expression of the actor. Conversely, change in the identity of an actor should be detected more readily than change in the emotional expression, if the perceptual task involves individual identification (see Levin & Simons, 1998, control experiment for some support).

Our results for change detection when attention is distributed also speak to the nature of representations of unattended information. In comparison to the strong position of the "grand illusion" of perception (O'Regan, 1992), in which unattended objects in the scene are represented very crudely, if at all, the present results suggest that even the visual representations of unattended objects may be influenced by the nature of the perceptual task. This can be seen in the present study by comparing the two bias conditions in Experiment 2. Although the visual displays were identical in the two conditions on any given trial, visual search for the changing item was guided in one case by early (i.e., preattentive?) representations that were clearly biased in favor of one level over the other.

Finally, our results from the distributed attention conditions in both experiments suggest that the global level of representation may be a default for the visual system, either because of factors such as parafoveal acuity, and/or because that level coincides most readily with many tasks involved in everyday perception (e.g., eye movements, reaching, grasping). Future studies will be needed to address this question. One useful approach might be to vary the temporal lag between being informed of the task and the display presentation. For instance, at the two extremes, participants could either be told of the specific kind of change to search for prior to display onset, or they could be given such information only following display termination. If global representations are initiated by default (Nakayama, 1990), such an experiment would result in small or nonexistent temporal lag effects for global level change, but large lag effects for more local levels of information. The specific time course required for the optimal detection of various attributes would serve as a convenient tool for studying the reconfiguration of the visual system in response to changing task demands.

Note

<1>. To whom all correspondence should be addressed.

Author Note

The research reported in this paper was funded by an NSERC (Canada) Research Grant to J. T. Enns. The authors are grateful to Tony Saraon for help in collecting the data. Correspondence may be addressed to J. T. Enns, Department of Psychology, University of British Columbia, Vancouver, BC, Canada V6T 1Z4. Email: jenns@psych.ubc.ca.

References

Amirkhiabani, G., & Lovegrove, W.J. (1996). Role of eccentricity and size in the global precedence effect. *Journal of Experimental Psychology: Human Perception and Performance, 22,* 1434-1447.

Baylis, G.C. (1994). Visual attention and objects: Two-object cost with equal convexity. *Journal of Experimental Psychology: Human Perception and Performance, 20,* 208-212.

Baylis, G.C., & Driver, J. (1992). Visual parsing and response competition: The effects of grouping. *Perception & Psychophysics, 51,* 145-162.

Boer, L.C., & Keuss, P.J.G. (1982). Global precedence as a postperceptual effect: An analysis of speed-accuracy tradeoff functions. *Perception and Psychophysics, 31,* 358-366.

Corbetta, M., Miezin, F.M., Dobmeyer, S., Shulman, G.L. & Petersen, S.E. (1991). Selective and divided attention during visual discrimination of shape, color, and speed: Functional anatomy by positron emission tomography. *Journal of Neuroscience, 11,* 2383-2402.

Coren, S., Ward, L.M., & Enns, J.T. (1999). *Sensation & Perception* (5th Ed.). New York: Harcourt Bruce.

Duncan, J. (1984). Selective attention and the organization of visual information. *Journal of Experimental Psychology: General, 113,* 501-517.

Duncan, J. (1993a). Coordination of what and where in visual attention. *Perception, 22,* 1261-1270.

Duncan, J. (1993b). Similarity between concurrent visual discriminations: Dimensions and objects. *Perception & Psychophysics, 54,* 425-430.

Enns, J.T., & DiLollo (1997). Object substitution: A new form of masking in unattended visual locations. *Psychological Science, 8,* 135-139.

Enns, J.T., & Kingstone, A. (1995). Access to global and local properties in visual search for compound stimuli. *Psychological Science, 6,* 283-291.

Grice, G.R., Canham, L., & Boroughs, J.M. (1983). Forest before trees? It depends on where you look. *Perception & Psychophysics, 33,* 121-128.

Grimes, J. (1996). On the failure to detect changes in scenes across saccades. In K. Akins (Ed.). *Perception* (pp. 89-110). New York: Oxford University Press.

Hughes, H.C., Layton, W.M., Baird, J.C., & Lester, L.S. (1984). Global precedence in visual pattern recognition. *Perception & Psychophysics, 35,* 361-371.

Kimchi, R. (1992). Primacy of wholistic processing and global/local paradigm: A critical review. *Psychological Bulletin, 112,* 24-38.

Kinchla, R.A., & Wolfe, J.M. (1979). The order of visual processing: "Top-down," "bottom-up," or "middle-out". *Perception & Psychophysics, 25,* 225-231.

Kingstone, A.F. (1992). Combining expectancies. *Quarterly Journal of Experimental Psychology, 44A,* 69-104.

Lamb, M.R. (1999). Spatial frequency affects search slope but not attentional selection with hierarchically organized stimuli. *Abstracts of the Psychonomic Society, 4,* 424.

Lamb, M.R., & Robertson, L.C. (1989). Do response time advantage and interference reflect the order of processing of global- and local-level information? *Perception & Psychophysics, 46,* 254-258.

Levin, D.T., & Simons, D.J. (1997). Failure to detect changes to attended objects in motion pictures. *Psychonomic Bulletin and Review, 4,* 501-506.

Martin (1979). Local and global processing: The role of sparsity. *Memory & Cognition, 7,* 476-484.

McConkie, G.W., & Currie, C.B. (1996). Visual stability across saccades while viewing complex pictures. *Journal of Experimental Psychology: Human Perception and Performance, 22,* 563-581.

Miller, J. (1981). Global precedence in attention and decision. *Journal of Experimental Psychology: Human Perception and Performance, 7,* 1161-1174.

Nakayama, K. (1990). The iconic bottleneck and the tenuous link between early visual processing and perception. In C. Blakemore (Ed.), *Vision: Coding and efficiency* (pp. 411-422). Cambridge, UK: Cambridge University Press.

Navon, D. (1977). Forest before trees: The precedence of global features in visual perception. *Cognitive Psychology, 9,* 353-383.

Navon, D., & Norman, J. (1983). Does global precedence really depend on visual angle? *Journal of Experimental Psychology: Human Perception and Performance, 9,* 955-965.

O'Regan, J.K. (1992). Solving the "real" mysteries of visual perception: The world as an outside memory. *Canadian Journal of Psychology, 46,* 461-488.

Rensink, R. A. (2000). Visual search for change: A probe into the nature of attentional processing. *Visual Cognition, 7,* 345-376.

Rensink, R.A., O'Regan, J.K., & Clark, J.J. (1997). To see or not to see: The need for attention to perceive changes in scenes. *Psychological Science, 8,* 368-373.

Robertson, L.C., Egly, R., Lamb, M.R., & Kerth, L. (1993). Spatial attention and cuing to global and local levels of hierarchical structure. *Journal of Experimental Psychology: Human Perception and Performance, 19,* 471-487.

Scholl, B.J. (2000). Attenuated change blindness for exogenously attended items in a flicker paradigm. *Visual Cognition, 7,* 377-396.

Simons, D.J. (1996). In sight, out of mind: When object representations fail. *Psychological Science, 7,* 301-305.

Simons, D.J., & Levin, D.T. (1998). Failure to detect changes to people during a real-world interaction. *Psychonomic Bulletin and Review, 5,* 644-649.

Smilek, D., Eastwood, J. D., & Merikle, P. M. (in press). Does unattended information facilitate change detection? *Journal of Experimental Psychology: Human Perception and Performance.*

Ward, L.M. (1982). Determinants of attention to local and global features of visual forms. *Journal of Experimental Psychology: Human Perception and Performance, 8,* 562-581.

Ward, L.M. (1983). On processing dominance: Comment on Pomerantz. *Journal of Experimental Psychology: General, 112,* 541-546.