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Inattention and the perception of visual features *

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Subjects selectively attended to one of two interleaved, novel figures while ignoring the other figure. In subsequent tests administered to determine the extent to which the ignored figure was perceived, recognition of shape and the location of contour gaps was at the chance level. Moreover, recognition of the presence of contour gaps was significantly below the chance level. These results indicate that preattentive visual processing of unattended objects is too crude to encode global shape and local features such as contour gaps. It is suggested that preattentive processing creates visual representations of unattended objects that contain very limited information about features.

It is possible to look directly at a visual scene but not perceive many of its properties. For example, when looking through a window at night, sometimes both the scene on the other side of the window and a reflection of the scene on the viewer's side of the window are simultaneously visible. Either scene can be attended to, but usually only the details of the attended scene are perceived. While the viewer is aware of both scenes because they are spatially superimposed, the perception of detailed scene properties appears to require focused attention.

Several researchers have recreated similar conditions in the laboratory to determine the role of focused attention in perception. For

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example, Neisser and Becklen (1975) optically superimposed two videotapes in which two different kinds of activities were being carried out. Subjects were required to attend to the events of one tape while ignoring the events of the other. They could do this easily, but they rarely noticed unusual events of the ignored tape despite the complete spatial overlap of both activities in the visual field. Similar results were also found with static scenes (Goldstein and Fink 1981). In particular, when subjects were required to attend to one of two superimposed line drawings, their recognition of the attended drawings in a subsequent test was significantly better than that of the unattended drawings. Thus, observers appear to perceive information primarily about scenes on which attention is explicitly focused.

We define perception as the level of processing that entails awareness. Thus, when we state that the perception of scene properties appears to require focused attention, we imply that the awareness of scene properties appears to require focused attention. Note, however, that some degree of perceptual processing is also carried out on stimuli that are not attended to. This processing appears to be very limited relative to that carried out on stimuli that are attended to, but some aspects of unattended stimuli are perceived.

Rock and Gutman (1981) conducted a study to determine whether shape is one of the properties of unattended stimuli that is perceived. On each trial, subjects saw a pair of novel figures, one red and one green. These figures were approximately equal in style and complexity. Subjects were required to attend to only one of the figures on the basis of its colour (e.g., the red one) and to process this figure by rating its aesthetic appeal (we refer to this as the *overlapping figures task*). Thus, on each trial, subjects looked at both figures because they were spatially superimposed, but directed their attention only to the figure to be rated. Rock and Gutman found that the shape recognition accuracy of attended figures was significantly better than that of unattended figures. Moreover, the shape recognition accuracy of unattended figures was not significantly better than that of previously unseen figures. They concluded that the perception of an object's shape appears to require focused attention (see also, Butler and McKelvie 1985).

Rock and Gutman's study raises questions about whether the effect of inattention in this type of task concerned a failure of perception or memory. In particular, poor recognition test performance could indicate inadequacies in the initial perception or in the retention of what was perceived. However, these researchers presented additional evidence that poor recognition performance due to memory failure was unlikely. To elaborate, they conducted another experiment in which familiar shapes (christmas tree, house) were presented in two of the ten trials. When these shapes were attended to, recognition accuracy was 85%. On the other hand, when these shapes were *not* attended to, recognition accuracy was only 10%. This suggests that the familiar shapes were not initially perceived (as opposed to initially perceived but forgotten). It is reasonable to expect that in such a task, if they were initially perceived, they would also be recognized. Rock and Gutman also conducted a similar experiment in which trials involving the familiar shapes were immediately followed by a blank field. When this blank field was presented, subjects were required to report all that they could remember about both figures on the previous trial. Even when memory effects were eliminated with this immediate-report technique, 89% of subjects did not report seeing the familiar shapes. Moreover, even when subjects were shown these shapes, they said that they had not seen them. Therefore, it appears that the shapes of the unattended figures were not initially perceived.

Rock and Gutman also examined the extent to which other properties of unattended figures are perceived and found that subjects were able to notice large size differences. Thus, some global properties of figures appear to be perceivable under conditions of inattention. The extent to which local properties of unattended figures are perceived is less clear, and particularly those properties that appear to be detected preattentively when other tasks such as visual search are performed.

When subjects perform a visual search task, target objects that possess unique features not shared with other distractor objects appear to be detected preattentively (e.g., Treisman and Gelade 1980). On the other hand, targets that do not possess unique features but are instead defined by a unique conjunction of features shared by the distractors are not usually detected preattentively (although this is not always the case; cf., Cave and Wolfe 1990; Mordkoff et al. 1990; Nakayama and Silverman 1986; Wolfe et al. 1989). Treisman and Souther (1985) found that when a visual search target was a circle with a gap in its contour and the distractor items were closed circles without gaps, target detection times indicated that the target's contour gap was detected preattentively. Presumably, when this type of task is performed, information about features that are available preattentively is stored in some form in a visual representation. The purpose of the current experiment was to determine whether contour gaps in unattended figures would also be available preattentively when an overlapping figures task was performed, and whether this information would be stored in a visual representation to enable subsequent recognition of gap presence and location.

Method

Subjects

Fifty-one University of Western Ontario undergraduates participated in this experiment. All subjects had normal or corrected-to-normal vision, and none were aware of the purpose of the study.

Apparatus and stimuli

Stimulus displays were viewed at a distance of 50 cm on IBM colour monitors. Data collection and experimental control were carried out with IBM PS/2 Model 25 microcomputers. Each trial began with a 1 second presentation of a white fixation cross in the centre of a black (unlit) background. The fixation cross subtended $1.13 \times 1.13°$ of visual angle. This was followed by a 1 second blankscreen interstimulus interval (ISI) and then the onset of the stimulus display. Each display consisted of two interleaved figures, one red and one green, presented in the centre of the display. Stimuli subtended $6.8 \times 6.8°$ on average and were composed of horizontal, vertical,

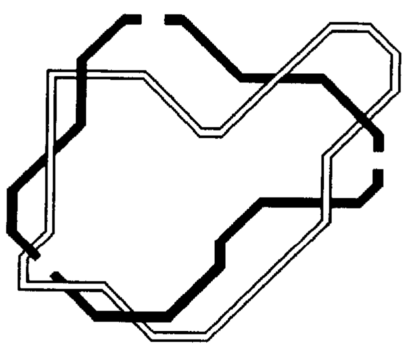

Fig. 1. An example of the overlapping stimulus figures. The white outline shape represents the green figure that subjects rated the pleasingness of, and the black, gapped shape represents the red figure that was not attended to.

and diagonal contours one pixel wide (see fig. 1). As was the case in the original Rock and Gutman (1981) experiments, all figures were novel and approximately equal in style and complexity. Red figures (with the exception of those for practise trials) always had three contour gaps 0.6° in length. In addition, at least one gap in the red figure was always in the interior region of the green figure, and at least one gap in the red figure was always outside the green figure on each trial. Therefore, the pattern of results could not be attributed to red figure gap locations always being inside or outside of the focus of attention on the green figure. The exposure duration of the stimulus display was 1 second, and the duration of the blankscreen ISI between the stimulus display and the onset of a display rating query (described in the next paragraph) was 2 seconds. Responses to this query were made by pressing appropriate keys on the microcomputer keyboards.

Procedure

Subjects were told that we were interested in how people make aesthetic judgments about the shape properties of figures. On each trial, they were required to rate how pleasing the green figure was on a five-point scale. The scale was as follows: *one* was very displeasing, *two* was displeasing, *three* was mildly pleasing, *four* was pleasing, and *five* was very pleasing. Two seconds after the rating was made, the next trial began. Thus, the green figures were always the figures that were attended to (the foreground figures), and the red figures were always the figures that were not attended to (the background figures). Since we were interested in the degree to which gaps were noticed when attention was directed elsewhere, it was desirable to present foreground figures with continuous (non-gap) contours. [1] There were five practice trials to allow subjects to become accustomed to the task, and then ten data trials.

The rating task was immediately followed by a two-alternative, forced-choice recognition test involving 10 test trials in which each of the previously presented background figures was paired with one of a set of novel red figures. Following this were 10 test trials in which each of the previously presented foreground figures was paired with one of a set of novel green figures. Subjects were told to choose the figure that they had seen before during the rating task – the one on the left or the one on the right. The choice was made by pressing one of the keyboard keys corresponding to either the left or the right figure. The procedure of this experiment was similar to the overlapping figure experiments (Rock and Gutman 1981) that indicated that recognition performance differences in this type of task reflect differences in perceptual as opposed to memory processes. In particular, the same number of data trials and the same level of complexity of the overlapping novel figures were used in this experiment and those conducted by Rock and Gutman.

[1] In a similar study involving overlapping figures, subjects recognized the presence or absence of a textured pattern in foreground figures but not background figures (Wright and Katz 1991). Therefore, the features of attended figures were processed in more detail than those of unattended figures. Based on the similarity of this experiment and the current experiment, it is clear that the presence of gaps would have been perceived in foreground figures of the current experiment.

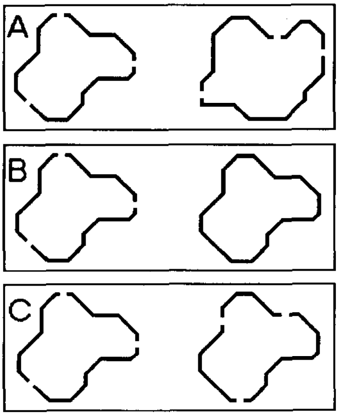

Fig. 2. Examples of the three unattended figure recognition test conditions. For purposes of illustration, the figure that had been previously presented to subjects is on the left in all three cases. (A) In the Shape Condition, the alternate choice also had contour gaps, but its shape was different from that of original. (B) In the Gap Presence Condition, the alternate choice had the same shape as the original, but did not have contour gaps. (C) In the Gap Location Condition, the alternate choice had the same shape as the original and also contour gaps, but the gap locations were different.

The purpose of the forced-choice recognition task was to isolate the relative availability of contour gaps in the unattended figures. More specifically, the presence of gaps in the contours of the unattended figures raised questions about whether or not subjects ever perceived these gaps (determined by making forced-choice decisions about identically-shaped unattended figures, one with gaps and one without gaps) and whether or not subjects perceived the locations of the gaps (determined by making forced-choice decisions about identically-shaped unattended figures, both with gaps, but only one with gaps at the same locations as had occurred at study). There were three recognition test conditions with 17 subjects in each condition (see fig. 2). These were:

The Shape Condition: The original red *background* figure was paired with a novel red figure that had gaps in its contour but had a different shape. This task was intended to indicate whether or not the overall shape of the unattended pattern was perceived.

The Gap Presence Condition: The original red *background* figure was paired with a novel red figure that was the same shape as the original but had no gaps in its contour. This task was intended to indicate whether or not any gap information had been perceived.

The Gap Location Condition: The original red *background* figure was paired with a novel red figure that was the same shape as the original and also had gaps in its contour. However, the gaps were at different locations than those of the original figure. This task was intended to indicate whether or not gap location information was perceived.

The recognition test for the foreground figures was the same in all three conditions. That is, the previously presented green figures were paired with other non-gapped green figures with novel shapes. Note that we refer to the recognition tests of the foreground figures as the Shape Condition, Gap Presence Condition, and Gap Location on the basis of the background figures that they were paired with. In all foreground figure recognition tests, however, no gaps were present and the figures differed only in terms of their shape (original vs. novel). The three identical foreground conditions provided a measure of the robustness of foreground figure recognition. In addition, the order in which the figures were tested for recognition was randomized relative to the order of their initial presentation.

Results

A two-way ANOVA was carried out on the mean recognition accuracy rates for all subjects (foreground/background × 3 conditions). Recognition accuracy for foreground figures (65.49%) was significantly greater than that for background figures (39.61%), $F(1,96) = 48.84$, $p < 0.0001$. On test trials with foreground figures, subjects responded with 69.41% accuracy in Shape Condition, 61.18% accuracy in Gap Presence Condition, and 65.88% accuracy in Gap Location Condition (see fig. 3). Post

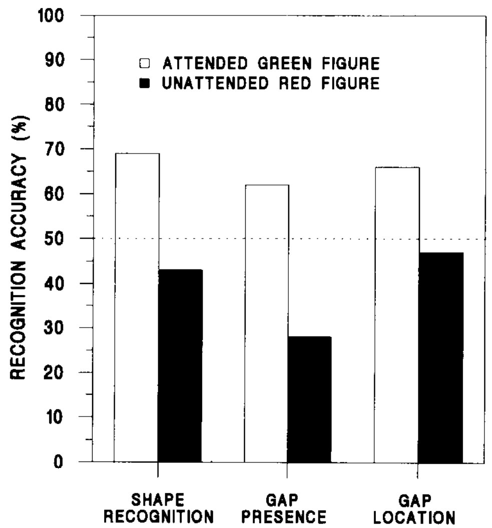

Fig. 3. Recognition performance for the three test conditions. Note that each of the attended figure recognition test conditions involved shape recognition (choosing between original vs. novel ungapped figure). For purposes of simplicity, however, the attended figure tests are labeled Shape Condition, Gap Presence Condition, and Gap Location Condition on the basis of the unattended figure they were paired with.

hoc comparisons between the mean recognition accuracy rates of the foreground figures showed that they did not differ significantly across conditions. However, post hoc comparisons did indicate that these means were significantly above the chance level in all three conditions (i.e., $t(32) = 6.41$, $p < 0.001$ in the Shape Condition; $t(32) = 3.17$, $p < 0.05$ in the Gap Presence Condition; and $t(32) = 3.50$, $p < 0.05$ in the Gap Location Condition). The equivalence across conditions of the recognition of foreground figures is evidence of the robustness of this effect.

A one-way ANOVA was also carried out on the mean recognition accuracy rates for all subjects for the background figures. Subjects were correct on 42.94% of test trials in the Shape Condition, on 28.82% of trials in the Gap Presence Condition, and on 47.06% of trials in the Gap Location Condition. The difference between these means was significant ($F(2,48) = 3.38$, $p < 0.05$). Post hoc tests indicated that the difference between the Gap Presence Condition and Gap Location Condition means was also significant ($t(32) = 2.38$, $p < 0.05$) and that the difference between the Gap Presence Condition and Shape Condition means was marginally significant ($t(32) = 1.77$, $p = 0.086$). More important, these tests indicated that recognition accuracy for background figures did not differ significantly from the chance level (50%) in the Shape Condition ($t(32) = 1.48$, $p > 0.05$) and in the Gap Location Condition ($t(32) = 0.70$, $p > 0.05$). However, recognition accuracy for background figures in the Gap Presence Condition was significantly lower than chance ($t(32) = 3.30$, $p < 0.05$). Thus, subjects in Gap Presence Condition consistently chose the novel red figure that *did not* have gaps as opposed to the original red background figure of the same shape that did have gaps.

Discussion

Subjects perceived the shapes of the figures they attended to during the rating task, but not the shapes of the unattended figures. This result is consistent with Rock and Gutman's (1981) data. In addition, subjects did not perceive the locations or even the presence of contour gaps in the unattended figures. This failure to perceive contour gaps is evident in the Gap Presence Condition, in which participants 'falsely recognized' the (nonpresented) solid contour figure as opposed to the (actually presented) gapped figure. We assume that these data reflect a decision process whereby participants know that the attended figure was solid. If gap information is not perceived at all, then the 'best guess' a participant can make is to choose a figure that might have occurred, and in this case that would be a solid figure. This suggests that the processing of the unattended figures was very limited, and that the information stored in representations of the overlapping figure displays did not include information about gap features even though such features can be detected preattentively in visual search tasks.

The apparent discrepancy between our results and those of Treisman and Souther (1985) deserves comment. The visual search task and the overlapping figures task differ in several ways. In particular, when performing a visual search task, the participant can set up a 'template' sensitive to a specific feature. However, when performing an overlapping figures task, such a template cannot be set up. It is possible then that visual search tasks are most informative about the complexity of the template that can be processed preattentively (e.g., template complexity less than that required when targets are defined by feature conjunctions). On the other hand, the overlapping figures task may be more informative about the features of the display that preattentively 'capture' processing capabilities. [2]

One account of these results is that focused attention is required for the shape of figures to be perceptually encoded in sufficient detail to be recognized. Thus, the limited perceptual encoding of unattended figures may be why shape recognition is not possible. Ullman (1984) proposed a scheme for the perceptual encoding of visual information about object shapes and spatial relations that is consistent with our results. In particular, he argued that sequences of basic visual operations called *visual routines* can be put together in different combinations to enable the visual system to establish a wide variety of object shape and relational information. According to Ullman, *universal routines* are the first to be carried out and they provide crude shape and relational information about objects in the visual field that cannot be provided by the predominantly local, parallel processes of early vision. After universal routines have been invoked, specialized routines are then said to be assembled in accordance with a computational goal and/or the crude information provided by the universal routines. These specialized routines provide *detailed* shape and rela-

[2] As such, the overlapping figures task appears to be related to the recent work of Yantis and Jonides (1984, 1990). These researchers found that abrupt-onset stimuli appeared to capture visual attention in some cases, including situations in which stimuli with unique visual features (features detectable preattentively in a visual search task) did not capture attention (Jonides and Yantis 1988). These researchers concluded that only abrupt-onset stimuli appear to be preattentively indexed. If true, then perhaps when an overlapping figures task is performed, the presence of gaps in the unattended figures would be perceived if the gaps have an abrupt onset a brief period of time after the figures were presented.

tional information about the objects initially processed by universal routines.

If this proposal is valid, then it is reasonable to assume that when the overlapping figures task is performed, the perceptual encoding of the rated figure is detailed and the encoding of the unattended figure is crude. As a result, a visual representation of the figure pair would primarily consist of information about the rated figure and information about the shape of the ignored figure would be limited. Furthermore, information about the ignored figure's more local features such as contour gaps may not be available at all. Thus, it seems that some properties of unattended figures are perceived but that information about these properties is limited and does not include shape or features that can be detected preattentively in visual search tasks. The perception of objects under conditions of inattention warrants further study which, in turn, could indicate the processes involved and the visual representations created by these processes.

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