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Identifying Objects Across Saccades: Effects of Extrafoveal Preview and Flanker Object Context

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Two object-naming experiments explored the influence of extrafoveal preview information and flanker object context on transsaccadic object identification. Both the presence of an extrafoveal preview of the target object and the contextual constraint provided by extrafoveal flanker objects were found to influence the speed of object identification, but the latter effect occurred only when an extrafoveal preview of the target object was not presented prior to fixation. The context effect was found to be due to facilitation from related flankers rather than inhibition from unrelated flankers. No evidence was obtained for the hypothesis that constraining context can increase the usefulness of an extrafoveal preview of a to-be-fixated object.

The current study was designed to explore the role that extrafoveal contextual information can play during object identification. Previous work has shown that the constraint provided by an appropriate scene context can increase the accuracy of detecting a target object within a tachistoscopically displayed scene (e.g., Biederman, Mezzanotte, & Rabinowitz, 1982; Boyce, Pollatsek, & Rayner, 1989; Masson, 1991) and can also influence object processing when the scene is viewed over multiple fixations (Antes, 1974; Boyce & Pollatsek, 1992; De Graef, Christiaens, & d'Ydewalle, 1990; Friedman, 1979; Loftus & Mackworth, 1978). The prevalent explanation of these semantic context effects is the schema hypothesis, according to which stored memory representations of scenes are used to develop expectations about objects likely to appear in a particular scene (Biederman et al., 1982; Friedman, 1979; see Henderson, in press-b, for a critical review). These expectations then affect identification of individual objects. For example, in the most general schema hypothesis, the identification of a horse in a farm scene involves recognizing that the entire scene constitutes a farm, activating a memory schema for *farm,* using the schema to generate likely objects (and possibly spatial relations) to be found in a farm scene, and feeding this information top-down to object identification routines, thus facilitating recognition of the horse.

An additional potential source of contextual facilitation in scenes is intralevel interactions between object representations (Henderson, Pollatsek, & Rayner, 1987; Henderson, in press-b). For example, in a farm scene, the horse may be identified more rapidly because a cow or a barn was recently (or is simultaneously) identified. Consistent with this intralevel priming hypothesis, Henderson et al. (1987; Henderson, in press-a) found that object identification (as assessed by naming latency and fixation duration) in nonscene arrays of objects was speeded when a related object in comparison with an unrelated or neutral object had been seen during an immediately preceding fixation. Furthermore, when fixation duration was the dependent measure, the magnitude of the facilitation effect was similar to the effects observed in studies examining fixation durations in full scenes (e.g., Antes & Penland, 1981; Loftus & Mackworth, 1978). Therefore, Henderson et al. (1987) concluded that the context effects observed in scenes might be due to object-to-object or intralevel priming between foveal and extrafoveal objects.

A second possible source of object-to-object priming in scene processing derives from related objects occupying nearby extrafoveal locations. For example, suppose the viewer is attempting to acquire information from an object that is not currently at the center of fixation but that is about to be fixated. Would the time needed to identify that object after fixation be influenced by the other extrafoveal objects that had been present in the visual field prior to fixation? If so, then this result would provide evidence for an additional source of contextual facilitation in scenes due to the presence of individual objects. To date, however, there is no evidence that extrafoveal flanker objects can provide contextual facilitation, even in simple displays. For example, Henderson et al. (1987) found that only the context provided by an object fixated on the immediately preceding fixation affected fixation time on the currently fixated object; flanker objects seen either prior to the saccade to the target object or during fixation on the target object did not influence fixation time. Similarly, De Graef (1990, 1992) presented subjects with arrays containing five extrafoveal objects equidistant from the initial fixation point. Subjects could make a single eye movement to an object; any additional eye movements terminated the display. Unlike the study conducted by Henderson et al. (1987), subjects in De Graef's experiment were allowed to make the initial saccade to any object in the display that they wished.

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De Graef found that the presence of extrafoveal flankers that were related to the object fixated first had no effect on fixation duration. Consistent with Henderson et al. (1987), De Graef found that if a related object were present at the initial fixation point prior to the eye movement, then first fixation duration was reduced on the object that was the target of the saccade. The first purpose of the current study, then, was to explore whether extrafoveal flanker objects related to a to-be-fixated target object can facilitate identification of that target object.

A second purpose of this study was to determine whether extrafoveal flanker context might increase the amount of information acquired from the extrafoveal target prior to fixation on it. During natural visual tasks such as scene viewing, objects falling on or near the center of gaze are identified, but because acuity falls off rapidly with increasing retinal distance from the fovea, objects beyond the point of fixation are often not fully analyzed (Nelson & Loftus, 1980; Parker, 1978), though they are typically partially analyzed. The partial analysis of an extrafoveal object provides the information necessary for programming an eye movement to an informative area of a scene (Antes, 1974; Loftus & Mackworth, 1978; Mackworth & Morandi, 1967; Parker, 1978) and also provides the object identification system a head start in identifying an object prior to fixation. The preview of an object acquired extrafoveally can then be integrated with information acquired foveally after fixation on the object, speeding identification of an object once it is fixated (Henderson et al., 1987; Henderson, Pollatsek, & Rayner, 1989; Pollatsek, Rayner, & Collins, 1984; Pollatsek, Rayner, & Henderson, 1990; see also Irwin, 1991).

Given that partial analysis of an extrafoveal object can take place prior to fixation on the object, the second question addressed in this study was whether this partial analysis can be facilitated by the contextual constraint provided by related flanker objects. This type of increased acquisition of extrafoveal information with contextual constraint has been found in word identification studies with both single-word foveal context (Balota & Rayner, 1983) and sentence context (Balota, Pollatsek, & Rayner, 1985; McClelland & O'Regan, 1981). On the other hand, an attempt to find a similar effect with objects was not successful (Henderson et al., 1987). The following experiments were designed to test the hypothesis that context might increase the usefulness of an extrafoveal preview of an object prior to an eye movement to that object.

Experiment 1

The purpose of Experiment 1 was to examine the influences of extrafoveal flanker context and extrafoveal preview on object identification. The paradigm used was modeled after Pollatsek et al. (1984, 1990) and Henderson et al. (1987): Subjects executed an eye movement to a target object that appeared extrafoveally. The subject's task was to name the target object as quickly as possible after the eye movement. Prior to the movement, the target object was either present or absent, and the target location was flanked above and below by either a related object or a neutral stimulus. When a preview of the target object was present, the preview was identical to the target. When the preview was absent, a large plus sign was presented in place of the target to give the subject a target toward which to move his or her eyes. An estimate of the *preview benefit,* or savings in object identification time produced by an extrafoveal preview of the object, could be derived by comparing naming latency on an object as a function of whether it had been available extrafoveally prior to fixation. More specifically, preview benefit equals naming latency in the preview-absent condition minus naming latency in the preview-present condition.

To examine the influence of flanker objects on extrafoveal information use and integration across saccades, I used two context conditions. In the related condition, the target object was flanked above and below by an object semantically related to the target object. In the neutral context condition, the flanking object was replaced at both locations by the same plus sign as was used in the preview-absent condition. An estimate of the effect of context could be derived by comparing naming latencies in the neutral and related conditions. Specifically, the facilitation due to related flanking objects equals naming latency in the neutral condition minus naming latency in the related condition. Figure 1 presents an example of the related flanker, preview-present condition.

The distance of the target object (along with the flankers) from the initial fixation point was also manipulated. Previous research has shown that the magnitude of the effect of context on object identification differs depending on the distance of the target object from the current fixation point (e.g., Antes, 1974; Friedman, 1979; Henderson et al., 1987; Parker, 1978). Furthermore, the amount of extrafoveal preview benefit derived from a target object also differs depending on distance (Henderson et al., 1987; Nelson & Loftus, 1980; Pollatsek et al., 1984, 1990). Therefore, I also varied this factor in the present experiment such that the target object was either about 9.5° or 18.3° from fixation prior to the eye movement to the target.

Method

Subjects. Ten University of Alberta undergraduates were paid $6.00 to participate in the experiment. All subjects had normal vision or wore contact lenses. The subjects were naive with respect to the hypotheses being tested.

Materials. The stimuli were 40 line drawings of common objects drawn from Snodgrass and Vanderwart (1980), all of which were easily identified and named. The drawings were digitized with a scanner. At the viewing distance of 36 cm, the visual angles of the objects ranged from 5° 15′ to 7° 37′ along the longest axis. Of these 40 objects, 20 were designated targets, and 20 were designated contextual flankers. The objects from each group were combined to form 20 displays in which the flankers were related to the target. In each display, the same flanker object appeared both above and below the target object (see Figure 1), with 9° 18′ separating the objects from center to center. In addition, a large plus sign replaced the objects in the no-context and no-preview control conditions. This cross subtended about 9° of visual angle horizontally and vertically, which was larger than the diameter of the circle needed to surround the largest object.

Subjects were asked to name each of the objects before the experiment. If necessary, the experimenter corrected the subject with the names given by Snodgrass and Vanderwart (1980). Subjects had no difficulty accepting the names used.

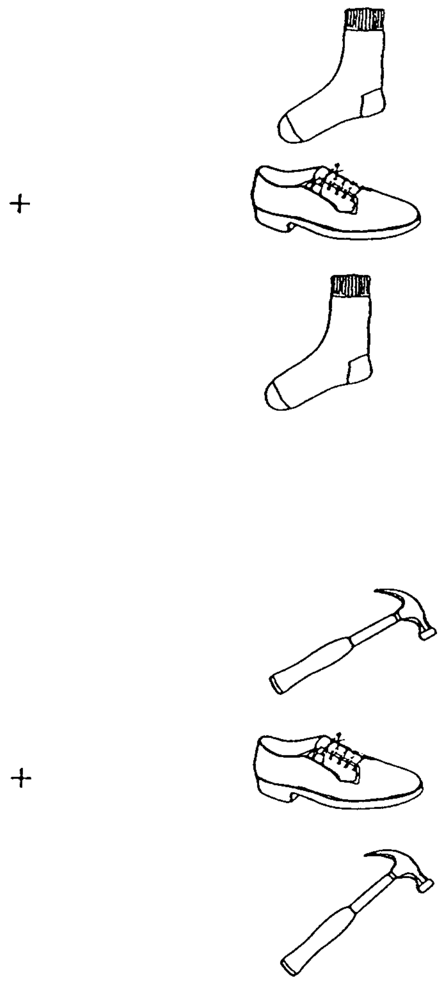

Figure 1. Example of the spatial layout of the displays in the preview-present related condition (Experiments 1 and 2) and the preview-present unrelated condition (Experiment 2). (Each object subtended about 6° of visual angle vertically and horizontally, with about 9° between the centers of adjacent objects.)

Apparatus. The stimuli were displayed on a Zenith VGA monitor, with the contours of the objects appearing black (pixels off) against a white (pixels on) background.

Eye movements were monitored by means of an ISCAN RK-416 high-speed eyetracker. The eyetracker and display monitor were interfaced with a Zenith 80286 microcomputer that controlled the experiment. The computer recorded saccade latencies and naming latencies. Signals were generated by the eyetracker at a frequency of 120 Hz, and the computer changed the display contingent on detecting an eye movement of greater than 0.5°. Because a saccade directed to a target 9.5° away (to the nearest target) generally requires over 45 ms (e.g., Abrams, Meyer, & Kornblum, 1989) and because the longest display change required about 25 ms (8.33 ms to detect the saccade and 16.66 ms to refresh the monitor), the display change was accomplished during the saccade when vision was suppressed. Subjects reported that they were aware display changes were taking place, but they were unable to see the actual changes.

Procedure. On arriving for a session, each subject was seated comfortably with his or her head resting on a chin and forehead rest to minimize head movements. The calibration of the eyetracker then took place. After calibration, subjects participated in two blocks of 80 test trials each. A trial consisted of the following events: First, a fixation display appeared consisting of several test fixation points and a small cross that indicated the computer's estimate of the current fixation position. If the calibration was satisfactory, the experimenter initiated the trial. The calibration display was then replaced by a preview display consisting of three extrafoveal objects to the right of fixation. The subject immediately initiated a rightward horizontal eye movement to the center object.[1] In the short-distance condition, the distance from the fixation cross to the center of the target object was 9° 27′, and in the long-distance condition, the distance was 18° 17′. During the saccade, the preview display was replaced by the target display, consisting of the target object alone, and the subject named this object as quickly as possible. The computer recorded the latency of the eye movement and the latency of the vocal response (timed from when the eye crossed the 0.5° boundary). The experiment was completed in a single session that lasted about 45 min.

Each subject participated in two blocks of trials. In the first block, the subject saw all 80 displays in a random order at one eccentricity. After a short rest, the subject received the second block, which consisted of the same displays in a new random order at the other eccentricity. Five subjects participated in the short eccentricity block first, and 5 subjects participated in the long eccentricity block first. In each block, the 80 trials were produced by the within-subjects factorial combination of 20 target objects and four extrafoveal preview conditions (preview of target with related or neutral flankers, and no preview of target with related or neutral flankers).

Results

Mean corrected naming latencies are presented in Figure 2. These means exclude trials on which an anticipatory eye movement occurred (defined as a movement with a latency less than 100 ms) and trials on which the naming latency was less than 100 or more than 1,500 ms. Corrected latencies excluded 5.6% of the trials. The pattern of corrected latencies did not differ from the pattern prior to correction.

For the analyses reported below, order (short distance followed by long distance, or vice versa) was a between-subjects factor, and distance (short vs. long), preview (present vs. absent), and context (related vs. neutral) were within-subjects factors. In an initial omnibus analysis, a significant interaction among the four factors was found, $F(1, 8) = 5.563$, $p < .05$, $MS_e = 495$. Therefore, separate analyses of variance were conducted on each block.

Considering just the trials from the first block viewed by each subject (shown in Figure 2), naming latencies were 563 ms with a preview and 724 ms without a preview, leading to a 161-ms preview benefit, $F(1, 8) = 90.55$, $p < .001$, $MS_e = 2877$. No effects involving distance were significant (all ps > .15). There was no main effect of context, $F(1, 8) = 2.180$, $p > .15$, $MS_e = 799$. However, the interaction between preview and context was significant, $F(1, 8) = 7.679$, $p < .05$, $MS_e = 915$. As can be seen in Figure 2, the Preview × Context interaction indicates that the context provided by related flankers was not useful with a preview of the target (−13 ms) but was useful when the preview was absent (40 ms). The

[1] Previous studies have indicated that in this paradigm, eye movement direction does not affect the acquisition of extrafoveal object information or the use of this information across fixations (Henderson et al., 1987; Pollatsek et al., 1984, 1990).

pattern was also in opposition to the prediction generated from the hypothesis that contextual constraint will increase the preview benefit. The preview benefit was 188 ms with neutral flankers but decreased to 135 ms with related flankers.

For the second block of trials (shown in Figure 2), naming latencies were 146 ms faster with a preview of the target (524 ms) than with no preview (670 ms), $F(1, 8) = 77.90, p < .001$, $MS_e = 2{,}746$. Latencies were also faster given a near target (534 ms) than given a far target (660 ms), $F(1, 8) = 6.090$, $p < .05$, $MS_e = 26{,}008$. There was no effect of context and no interaction between preview and context (Fs < 1). No other interactions were significant (all Fs < 1).

Discussion

The first question addressed in this experiment was whether the contextual constraint provided by related flanker objects seen only extrafoveally prior to an eye movement could influence the time needed to identify an object fixated after the eye movement. In contrast to prior studies (De Graef, 1990; Henderson et al., 1989), this experiment showed a clear effect of extrafoveally viewed flankers. However, the flanker context effect was found to be mediated by two factors. First, evidence for a flanker effect was found only when the target object was unavailable for processing prior to the eye movement (i.e., in the preview-absent condition). Second, the effect of context was found to be greater in the first block of trials when the targets were not as well known. These results suggest that contextual facilitation increases when the target object cannot be easily identified, as is the case when a preview is absent and when the target is less familiar.

The second question addressed in this experiment was whether the preview benefit derived from an extrafoveally viewed target object prior to fixation on the object could be increased by related context. The answer to this question was clearly negative. The preview benefit was actually smaller with a related context than with a neutral context in the first block of trials (135 vs. 188 ms) and was the same in the second block of trials (149 vs. 144 ms). This same underadditive interaction between context and preview was found in two experiments reported by Henderson et al. (1987) using foveal primes, although in those experiments the interaction was only marginally significant. Thus, in both cases a related context tended to reduce the preview benefit.

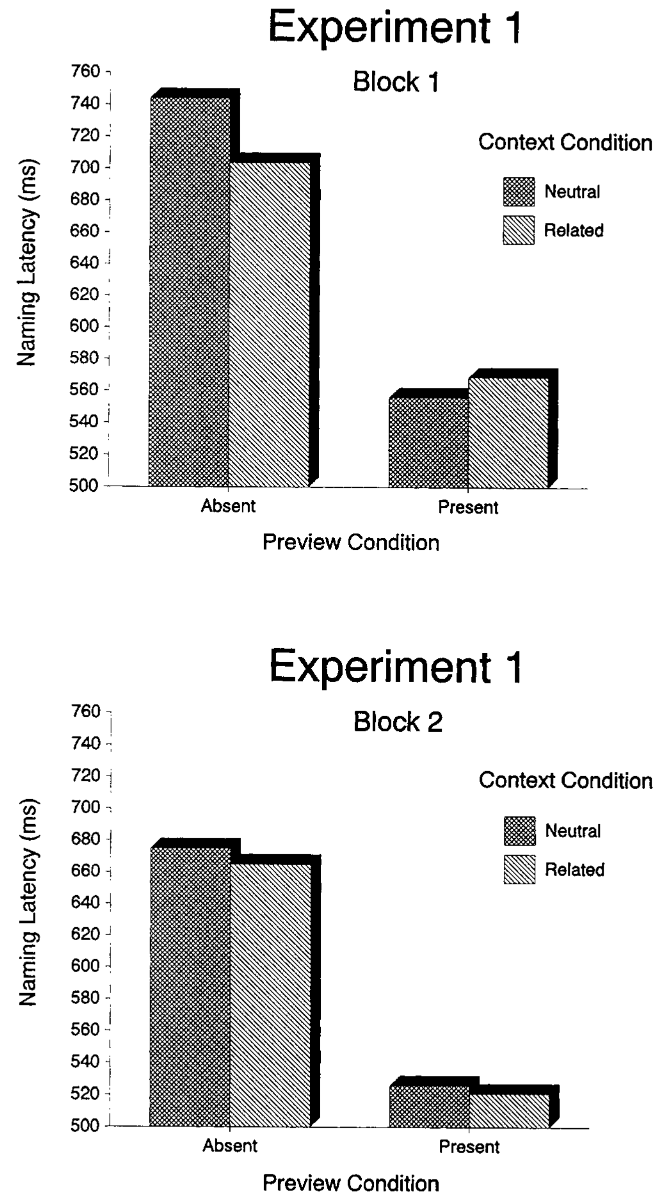

Figure 2. Mean naming latencies (in milliseconds) as a function of parafoveal preview and flanker object context in Experiment 1. Data are shown from Blocks 1 and 2, respectively.

Experiment 2

In contrast to previous studies (De Graef, 1990; Henderson et al., 1987), the results of Experiment 1 suggest that context from nearby extrafoveal objects may be used to aid identification of an extrafoveal target object once it is fixated, particularly when the target object is difficult to identify.

There would appear to be several possible mechanisms through which the extrafoveal object context could exert an influence on target object processing. First, the presence of the context might have allowed subjects to generate expectations or predictions about what the target object would be. On the other hand, the context may have produced its effect through an automatic priming process such as that proposed in spreading activation theories (e.g., Anderson, 1976; Collins & Loftus, 1975). One piece of evidence against the expectancy explanation is the finding that the context effects observed in Experiment 1 were larger in Block 1 than in Block 2. Presumably, subjects would be better able to generate expectations about the target objects in the second block, when they would have been more familiar with the prime-target contingencies, and therefore according to the expectancy explanation should have shown a larger context effect in the second block. However, this contrast across blocks is at best indirect. A more straightforward way to distinguish between these two possibilities would be to use a cost–benefit analysis (Neely, 1977; Posner & Snyder, 1975; Stanovich & West, 1983). An expectancy-based account predicts that a related context should produce facilitation and an unrelated context should produce inhibition in relation to a neutral condition. An automatic spreading activation mechanism, however, predicts facilitation in a related condition but no inhibition in an unrelated condition. One purpose of Experiment 2 was to try to distinguish between an expectancy account and a priming account of the results of Experiment 1. An unrelated condition was therefore added to determine whether inhibition would be observed. Inhibition would support an expectancy account, whereas similar performance in the neutral and unrelated conditions would support a priming account.

The second purpose of Experiment 2 was to provide another test of the hypothesis that more preview benefit can be acquired from a contextually constrained extrafoveal preview. No evidence supporting this hypothesis was found in Experiment 1. However, it could be argued that comparing preview benefit in the neutral and related conditions was inappropriate; more preview benefit might be expected in the neutral condition because there is only one extrafoveal object present. It could be that the presence of extrafoveal flankers in the related condition decreased preview benefit because of, for example, attentional capture, name retrieval interference, or visual complexity effects. The addition of the unrelated condition allowed a test of these possibilities. In both the related and unrelated conditions, two objects flanked the target object, thus equating the displays in terms of information to be attended, number of potentially interfering names, and overall visual complexity. If contextual constraint can increase the usefulness of an extrafoveal preview, then more preview benefit should be found in the related than in the unrelated condition.

Method

Subjects. Twelve University of Alberta undergraduates participated in the experiment for credit toward their introductory psychology course. None of the subjects had participated in Experiment 1, and all subjects were naive with respect to the hypotheses being tested. All subjects had normal vision or wore contact lenses.

Materials. The stimuli were the same 40 line drawings of common objects used in Experiment 1. Again, 20 of the objects were designated targets, and 20 were designated contextual flankers. In addition to the related and neutral flanker conditions as described in Experiment 1, the flanker and target objects were re-paired to form 20 displays in which the flankers were unrelated to the target (see Figure 1). The same unrelated flanker object appeared above and below its associated target. Again, subjects were asked to name each of the objects before the experiment, and they had no difficulty accepting the names used.

Apparatus. The apparatus was identical to that used in Experiment 1.

Procedure. The procedure was similar to Experiment 1. Each subject again participated in two blocks of trials. In the first block, the subject saw all 120 displays in a random order at one eccentricity. After a short rest, the subject received the second block, which consisted of the same displays in a new random order at the other eccentricity. Six subjects participated in the short eccentricity block first, and 6 subjects participated in the long eccentricity block first. In each block, the 120 trials were produced by the within-subjects factorial combination of 20 target objects and 6 extrafoveal preview conditions (preview of target with related, unrelated, or neutral flankers and no preview of target with related, unrelated, or neutral flankers). The experiment was completed in about 60 min.

Results

Mean corrected naming latencies are presented in Figure 3. Computation of these means excluded trials on which an anticipatory eye movement occurred (defined as a movement with a latency less than 100 ms) and trials on which the naming latency was less than 100 or greater than 1,500 ms. Corrected latencies excluded 7.3% of the trials. The pattern of corrected latencies did not differ from the pattern prior to correction.

For the following analyses, order (short distance followed by long distance, or vice versa) was a between-subjects factor, and distance (short vs. long), preview (present vs. absent), and context (related, unrelated, and neutral) were within-subjects factors. A significant three-way interaction among block order, preview, and context was found, $F(2, 20) = 4.90$, $p < .05$, $MS_e = 406$. However, because block order did not interact with distance (the blocked factor) in either the two-way or any higher level interaction (all $ps > .10$), analyzing the individual blocks was not warranted. There was no obvious interpretation for the three-way interaction, and importantly, the interaction did not change the general interpretation of the data reported below.

Naming latencies were 563 ms with a preview and 692 ms without a preview, leading to a 129-ms preview benefit, $F(1, 10) = 355$, $p < .001$, $MS_e = 1678$. The preview effect was mediated by distance, $F(1, 10) = 16.8$, $p < .005$, $MS_e = 168$, indicating that the preview benefit was larger when the preview was close (152 ms) than when it was more distant (105 ms). No other effects involving distance were significant (all $ps > .15$).

Context did not produce a main effect ($F < 1$). However, the Preview × Context interaction was significant, $F(2, 20) = 7.70$, $p < .005$, $MS_e = 406$. When a preview of the target was present, context did not produce a significant effect, $F(2, 20) = 2.83$, $p > .05$, $MS_e = 420$. When the preview was absent,

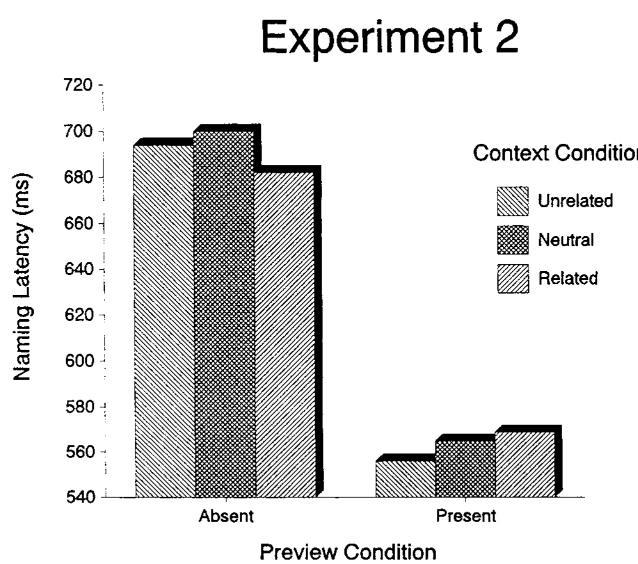

Figure 3. Mean naming latencies (in milliseconds) as a function of parafoveal preview and flanker object context in Experiment 2.

however, there was a significant effect of context, $F(2, 20) = 4.35$, $p < .05$, $MS_e = 494$. For the preview-absent condition, there was a significant 18-ms advantage for the related over the neutral condition, $F(1, 10) = 5.78$, $p < .05$, $MS_e = 721$, but the 6-ms difference between the unrelated and neutral conditions was not significant, $F(1, 10) = 1.21$, $p > .10$, $MS_e = 402$.

The interaction between context and preview was not consistent with the hypothesis that contextual constraint increases the benefit of an extrafoveal preview. As can be seen in Figure 3, the preview benefit was 144 ms with neutral flankers but decreased to 113 ms with related flankers. Importantly, the preview benefit was smaller with related flankers (113 ms) than with unrelated flankers (129 ms), $F(1, 10) = 5.49$, $p < .05$, $MS_e = 283$. Thus, there is no evidence that a related context can increase the usefulness of an extrafoveal preview, even when the displays are equated on the number of objects present in the visual field. Instead, it appears that less information is acquired with the presence of contextual constraint.

Discussion

Experiment 2 replicated the main result of Experiment 1. An effect of the extrafoveally viewed context objects was observed, but only when a preview of the target object was not available for processing. The new finding was that the effect of context was due to facilitation of object recognition in the related condition rather than inhibition in the unrelated condition. Objects were named faster when surrounded by related rather than unrelated or neutral flankers, and naming latencies in the latter two conditions did not differ. Thus, the context effect is consistent with an automatic priming rather than a subject expectancy or prediction account. Finally, there was no evidence that the amount of information acquired from an extrafoveal preview increased as a function of context. The amount of information acquired from a preview when the flankers were related was a significant 16 ms less than the amount acquired when the flankers were unrelated.

General Discussion

Two main questions were addressed in this study. First, would the contextual constraint provided by extrafoveal flanker objects speed the identification of a to-be-fixated extrafoveal target object after fixation? Second, if extrafoveal flanker objects can influence target object processing, how would this effect combine with the effect of an extrafoveal preview of the target object? Each of these issues is addressed here.

Effects of Extrafoveal Context

As discussed earlier, the results of several previous studies have suggested that the contextual constraint provided by extrafoveal flanker objects does not facilitate object identification across saccades (De Graef, 1990; Henderson et al., 1987). In contrast to those earlier studies, the experiments reported here provide evidence that extrafoveally viewed flanker objects can, under certain conditions, influence target identification time. There are several differences in the prior studies and the current set of experiments that may account for the different results, as considered next.

First, in the earlier studies examining flanker object context, the target object was relatively distant from the contextual flankers. Previous research has suggested that prior to an eye movement, attention is allocated to the location about to be fixated next (Henderson, 1992; Henderson & Ferreira, 1990; Henderson et al., 1989; McConkie, 1979; Morrison, 1984; Rayner, McConkie, & Ehrlich, 1978; Shepherd, Findlay, & Hockey, 1986). In addition, research indicates that the spatial distribution of visual attention, once allocated to a location, may become highly spatially constrained (Downing & Pinker, 1985; Eriksen & Yeh, 1985; Henderson, 1991; LaBerge & Brown, 1989; Posner, 1980). Therefore, flanker objects that are relatively distant from the location about to be fixated might not exert an influence on target processing because they themselves have not been attended. Second, both of the prior studies finding no effect of flanker object context (De Graef, 1990; Henderson et al., 1987) used fixation durations as a reflection of object identification time, whereas this study used naming latencies. It may be that the difference in the effects of flanker context found across studies is due to differences in sensitivity between these dependent measures. Contrary to this explanation, however, studies that have used both of these measures have tended to find context effects of very similar magnitude (Henderson et al., 1987). Comparing across experiments that used the same sets of objects and the same display equipment, I found that the effects of contextual constraint with fixation durations (Henderson, 1988) and with naming latencies (Henderson et al., 1987) were virtually identical. A final explanation for the difference between the previous studies and this study rests on the observation that both of the prior studies included previews of the target objects prior to fixation. It is clear that an effect of flanker context was observed in this study only when the target object was not displayed prior to fixation. Therefore, the results of all of the studies can be seen as consistent in showing that flanker objects do not have an effect when the target is available for extrafoveal processing but do have an effect when the target is not available prior to fixation.

Regardless of the reason for the null results reported by De Graef (1990) and Henderson et al. (1987), this study constitutes the first demonstration that extrafoveally viewed, contextually constraining flanker objects can exert an influence on the identification of a subsequently fixated object. It is important to note that this context effect must have been due to contextual constraint derived from parafoveally viewed objects; the context objects were no longer present once the saccade had been executed to the target object. In addition, the results of Experiment 1 suggest that the more easily information can be acquired from the target object prior to fixation (e.g., due to familiarity and the presence of a preview), the smaller the effect of the flanker context. The results of Experiment 2 also indicate that the context effect was due to facilitation from the related flankers rather than interference from the unrelated flankers, consistent with an automatic priming account.

Context and Extrafoveal Information Use

The results of the experiments reported here indicate that information acquired from an extrafoveal preview of an object during fixation *n* can be integrated with foveal information acquired from the same object during fixation *n* + 1, producing a robust preview benefit. Similar preview benefits during object identification have been found previously using both naming latency (Henderson et al., 1987; Pollatsek et al., 1984, 1990) and fixation duration (Henderson et al., 1989) measures of object identification processes.

The results of both experiments reported here showed that although a constraining context can influence overall identification time, it does not produce this effect by increasing the amount of information acquired from a preview of the object. If context were able to increase the usefulness of an extrafoveal preview, then a larger extrafoveal preview benefit should have been observed in the related context condition than in the unrelated and neutral conditions. There was no support for such an effect. Instead, the magnitude of the preview benefit was generally smaller in the related condition than in the neutral (Experiment 1) and unrelated (Experiment 2) conditions. This finding replicates a similar underadditivity observed by Henderson et al. (1987), for which context was defined by a foveal object prime.

The underadditivity between context and preview observed in this study, along with the Henderson et al. (1987) study, stands in contrast to the results obtained in several studies examining similar issues in word recognition. For example, Balota and Rayner (1983) showed that although preview benefits can be observed for unconstrained parafoveal words viewed prior to fixation, larger preview benefits are found when these words are contextually constrained through a single foveal prime word. Balota et al. (1985) and McClelland and O'Regan (1981) showed a similar increase in parafoveal preview benefit for words in highly constraining sentence contexts.

How is the difference to be resolved between contextual influences on the preview effect observed with objects and that observed with words? One possibility is that there is a fundamental difference between preview benefits obtained during object and word processing. For example, perhaps context can influence the speed with which information is acquired from extrafoveal word stimuli but can only influence the required amount of information that must be acquired for identification with object stimuli. While this is a logical possibility that will ultimately have to be tested, there does not seem to be an independently motivated theoretical reason to believe that such a fundamental difference between word and object processing should exist.

A second possibility is that the experiments investigating word recognition and those investigating object recognition differed enough that different effects would be expected. The contextual effects produced in the object studies have been relatively small and based on brief exposure to the context-generating stimuli, whereas in the majority of the word studies, the context effects have been larger and produced by longer and more complete processing of the context. Consistent with this explanation, Balota and Rayner (1983) found that subjects were able to use extrafoveal word information more effectively only when the foveal context word was available to the subject for a large amount of time (750 ms exposure plus 500 ms blank time) prior to the display of the extrafoveal target. Otherwise, if the foveal word was available only 200 ms prior to the extrafoveal target, then the effects of context and preview were additive.

A clear difference between the experiments finding additivity (or underadditivity) between context and preview information and those finding more benefit from a preview given a constraining context, then, is the degree to which the context was processed. In the 200-ms context condition of Balota and Rayner (1983), the simultaneous context condition of Henderson et al. (1987), and the simultaneous context experiments reported here, the subject was primarily concerned with attending to the extrafoveal stimulus and was given little time or motivation to attend to the context stimulus. In the 1,250-ms context condition of Balota and Rayner (1983) and the sentence context experiments of Balota et al. (1985) and McClelland and O'Regan (1981), the subject either was given time to process the context stimulus alone or was actively constructing a representation that included the constraining context. One hypothesis, therefore, is that a constraining context may increase the benefit derived from an extrafoveal preview of both words and objects, but only if the context is sufficiently constraining and is given sufficient time to operate.

Taking this line of argument one step further, it is possible that overadditive effects will be observed only when the subject is given a sufficiently constraining context and sufficient time to allow active generation of possible target candidates. In other words, it could be that while automatic priming will produce an additive combination of context and preview, active prediction from context will allow increased preview benefit (Balota & Rayner, 1983). It is interesting to note in this regard that in the Balota and Rayner long-display experiment and in the sentence context studies (Balota et al., 1985; McClelland & O'Regan, 1981), subjects would have been able to generate likely target words with great accuracy.

Even assuming that the overadditivity between context and preview observed in the word identification studies (greater preview benefit with constraining context) can be explained by active prediction, an additional explanation must be sought for the underadditivity between context and preview observed in the present experiments and in Henderson et al. (1987). I will consider three hypotheses that might account for this underadditivity next.

One explanation for the underadditive interaction between preview and context appeals to the allocation of visual attention prior to the eye movement. As discussed above, there is considerable evidence that visual attention is allocated to the target location of an impending eye movement prior to that movement (e.g., Henderson, 1992; Shepherd et al., 1986). It could be that the gradient of attention surrounding the target location changes depending on whether there is an object at that location. More specifically, attention may be distributed over a greater region of space when no object is present at the target location but may be more narrowly focused on the location when an object is present. If attention is distributed over a greater region when the preview is absent, then the flanker objects would be more likely to fall under the focus of attention in the preview-absent condition. Thus, with this explanation, a greater context effect will be generated in the preview-absent condition because there would be a higher probability that the flanker objects would be processed. In addition, given this pattern of contextual effects (related is faster than unrelated with no preview, but there is little difference with a preview) and given that preview benefits are observed in both context conditions, an increase in preview benefit must also be observed in the unrelated condition in comparison with the related condition (because of the lack of degrees of freedom remaining to define the pattern of interaction). The problem with this attention explanation, however, is that it does not easily generalize to the Henderson et al. (1987) study, in which similar underadditivity was observed between the presence of a preview and a foveally presented prime. Given the current models of the relationship between visual attention and eye movement control (Henderson, 1992; Morrison, 1984; Rayner & Pollatsek, 1989), it does not seem likely that the presence of a preview would influence the amount of attention allocated to the foveal object.

A second and perhaps more parsimonious explanation for the interaction of preview information and contextual constraint appeals to the notion that identification can be conceptualized as activation within a network of recognition units (e.g., McClelland & Rumelhart, 1981; Morton, 1969; Paap, Newsome, McDonald, & Schvaneveldt, 1982). In this view, both preview and context might be thought to affect the activation level of the recognition unit for the target object. Furthermore, one might assume that the level of activation that a unit can attain prior to fixation is constrained by an upper limit. This limit may reflect the degree to which the object identification system is willing to commit to an object interpretation prior to fixation, or it may simply reflect full identification. In either case, as the activation level approaches its prefixation limit, further evidence for that object will cease to have an effect. (Note that a similar argument could be based on an asymptotic activation curve instead of an absolute activation limit.) Thus, given a constraining context that boosts the activation level of the target object, activation due to a preview will exert less of an influence than it would if no constraining context were present. From the other perspective, given a preview of the target object, activation due to constraining context will exert less influence than it would if no preview were given. Note that with this explanation, both context and preview exert an influence at the same level of representation, where activation is combined. This level of representation would have to be fairly abstract because it would need to encode information about semantic relations to account for the observed priming effects. Interestingly, the notion that an extrafoveal preview activates object representations at a fairly abstract level has recently been supported by studies investigating the integration of pictorial information across saccades (Pollatsek et al., 1990; see also Irwin, 1991). Note also that this explanation can account for underadditivity between preview and context from both flanker primes (these experiments) and foveally presented primes (Henderson et al., 1987).

One problem for the activation-limit hypothesis is that it predicts an increase in the flanker context effect given greater distance between the initial fixation position and the preview. This prediction follows because the preview was found to be less useful given the greater eccentricity. In neither of the experiments reported here was such an increase in contextual benefit with greater eccentricity found. However, it is important to note that the eccentricity of the target preview was perfectly correlated with the eccentricities of the flanker objects. Therefore, the increase in the influence of the flankers that would be expected because of the greater target eccentricity may have been offset by the decrease due to the lower visibility of the flankers. An earlier study, however, confirms that the effects of context are greater when the preview is less visible. Henderson et al. (1987) found that increasing the eccentricity of the preview from 5° to 10° increased the benefit due to a foveal priming object. In that study, the visibility of the foveal prime remained constant across extrafoveal preview eccentricity. Importantly, a preview benefit was observed in both eccentricity conditions. Thus, consistent with the activation-limit hypothesis, it appears that when less information is provided by the preview, activation provided by constraining context plays a greater role.

Implications for Scene Processing

The finding that extrafoveal flanker objects influenced the time to identify a target object suggests an additional mechanism beyond foveal priming (Henderson et al., 1987) by which simple priming can influence object identification in scenes. It is possible that related objects surrounding an extrafoveal object about to be fixated in a scene could increase the speed of identification of the extrafoveal object once it was fixated. That flanker priming was observed only when there was no preview of the target object in this study may undermine this possibility. It seems likely, however, that the eyes often move to fixate an object from which little or no information has yet been acquired but around which surrounding objects have been analyzed. Such a case would be functionally similar to the preview-absent condition examined here. Given that the flanker priming effect demonstrated is due to automatic priming, it would be expected to occur in scenes as well. Of course, studies using full scenes will be required to ensure that the effect does generalize.

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Neuropsychology to Be an APA Journal

In January 1993, *Neuropsychology*, which has been published by the Educational Publishing Foundation (a subsidiary publishing program of the American Psychological Association), will be published by the American Psychological Association. The Publications and Communications Board of the APA has appointed Nelson Butters as editor of *Neuropsychology*. As of January 1, 1992, manuscripts should be submitted to

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