Selective looking with minimal eye movements

DAVID LITTMAN and ROBERT BECKLEN
Cornell University, Ithaca, New York 14853

Neisser and Becklen (1975) showed that one of two visually superimposed events could be followed without interference from the other. Neisser and Becklen allowed their subjects to move their eyes without restriction. The present experiment eliminated the possibility that the tracking eye movements of the subjects, which could have been used to maintain the stability of the event on the retina, were instrumental in following the desired event. The experiment of Neisser and Becklen was essentially replicated with one exception: subjects were required to fixate a spot in the center of the visual field during one-half of the trials. It was no more difficult for subjects to follow either a single event or one of two superimposed events when fixation was required. The suggestion was made that eye movements do not initiate a perceptual act, but rather are dependent upon perceptual anticipations.

In a recent paper, Neisser and Becklen (1975) described a method for the study of selective attention to visually specified events. Subjects were shown two "superimposed" videotapes and instructed to pay attention to one and ignore the other. The tapes were presented through television monitors, the images of which were optically superimposed by means of half-silvered mirrors. One videotape showed three persons tossing a basketball back and forth to one another at irregular intervals while moving about fairly unpredictably. The other showed the hands and parts of the arms of two individuals involved in the traditional "hand-slap" game in which one player tries to hit the backside of the other player's hands, who in turn tries to avoid being hit by pulling away his hands quickly. The subjects responded to predefined target events in the attended episode by pressing a button. The critical targets in the ball game were "passes" or "ball exchanges" and in the hand-game "attempted slaps." The study showed that, under these conditions, selective attention was easy even for unpracticed subjects. Error rates were only slightly higher in the "superimposed" condition than in a control condition where only one videotape was shown. Moreover, the subjects picked up very little information about the fully visible, but unattended, episode, failing even to notice strikingly incongruous events.

It appears, then, that selection was both efficient and relatively complete. However, it is not clear exactly how it was accomplished. Neisser and Becklen considered the possibility that selection could be explained by eye movements alone. They rejected this hypothesis on a priori theoretical grounds, but it seems important to test it empirically as well. This was the aim of the present study. In the case of the ball game, there is a plausible attentional strategy involving eye movements which might be supposed to underlie the selection

process, viz, simple tracking of the ball. Such tracking would hold the image of the ball stationary with respect to the retina, while details not sharing the motion patterns of the ball would move with respect to or "smear" across the retinal surface. The image of a given player would be relatively stationary while he was in possession of the ball. The "unattended" hand game, however, would rarely be stationary and foveated at the same time. Thus, simply tracking the ball and responding every time a player's image becomes stationary would provide a reasonably adequate strategy for selectively attending to ball throws. Such a hypothetical process would fit well with the prevalent theoretical view that attention depends on the existence of special mechanisms which selectively filter or attenuate unwanted information. Pursuit eye movements of the type described above could serve as a peripheral filtering mechanism which accepts stationary "images" and rejects smeared ones.

The present study was carried out to demonstrate that this view is incorrect. Although eye movements certainly are both natural and useful in performing the selection task in the Neisser and Becklen situation, this does not imply that they constitute *the* mechanism of selection. By demonstrating that selection of a ball game superimposed on a hand game is possible without any eye movements at all, we hope to make more plausible the argument that eye movements are one of the *consequences* of visual selectivity rather than its *cause*. To this end, we repeated certain conditions of Neisser and Becklen with fixation instructions, and monitored the subjects' eye positions to evaluate the degree to which these instructions were followed.

METHOD

Subjects

Eight Cornell University students, with vision corrected to normal, participated in the experiment. Each was paid \$4.20 for the work.

Contributions by both authors were equal.

Apparatus and Procedures

The subjects were shown some of the videotaped episodes used by Neisser and Becklen. *Ball game* episodes showed three men, all simultaneously in the camera's field of view, passing a basketball back and forth to each other. Though throws occurred rather irregularly, the total number during each 1-min episode was always around 20 or 40. Similarly, in the *hand-game* episodes, the total number of attempted slaps was held at 20 or 40, although the players tried to make the occurrence of any particular slap as unpredictable as possible. In the present experiment, the subjects were always attending to the ball game, pressing the button whenever the ball was passed from one player to the next. The hand game was used only as a distractor. Responses were recorded by an event recorder on moving paper tape and later scored against master tapes prepared by the experimenters. Subject responses within a 1-sec interval, from ¼ sec before to ¾ sec after the master response, were scored as correct. If no response occurred within such an interval, a miss was scored; responses occurring outside any such interval were labeled false alarms.

The subjects viewed two 9-in. Panasonic television monitors, binocularly, with the head placed in a chinrest. A half-silvered mirror, approximately 6 in. in front of the subject's head, was positioned in such a way that the transmitted image of one monitor, placed directly in front, precisely overlapped the reflected image of the other monitor, 90° to the subject's left. From the subject's point of view, this resulted in the impression of a single TV screen located straight ahead. This virtual screen subtended 7° of the subject's field of view, at an optical distance of 35 in. During experimental trials, a video camera, directly above and behind the subject's left shoulder, recorded an image of his left eye, reflected from a small mirror placed at an appropriate angle just in front of the head. Thus, a videotape record of each subject's eye movements during the various conditions of the experiment was obtained.

The primary independent variable was the viewing condition, free or restricted (fixation). During free (F) trials, the subjects viewed ball games either alone (A) or in superimposition (S) with hand games, responding to each throw by pressing the button. No restrictions were placed on their eye movements. During restricted (R) trials, the subjects performed the same task but were, in addition, required to fixate on a small black spot in the middle of the TV screen. Since pilot work had established that performance in the restricted condition improves greatly with a little training, practice trials were given prior to the experimental trials. No eye-movement recordings were made during practice trials.

The experiment was run in two sessions on consecutive days. On Day 1, the subjects were given six practice trials (AF, AR, SF, and three SR) followed by four experimental trials (AF, AR, SF, and SR), all with an event rate of 20/min. On Day 2, with the event rate at 40/min, four experimental trials (AF, AR, SF, and SR) were followed by an eye-movement calibration test.

Eye-Movement Calibration

The principal aim of the experiment was to show that selective looking can occur without eye movements. To demonstrate this, it was necessary to show that our fixation instructions were effective i.e., that eye movements rarely occurred in the R conditions. This demonstration, in turn, could only be satisfactory if our method of recording was, in fact, accurate enough to detect any substantial eye movements that might occur. A check on the accuracy of the method seemed particularly important since it was a somewhat unorthodox one: we simply inspected the videotape of the subject's eye and noted whatever movement took place. Because the sensitivity of this method may vary slightly with the characteristics of the particular eye being observed, it seemed best to carry out such a check with each subject individually.

The calibration was performed with the aid of a specially prepared videotape, which showed a hand holding a pointer as it moved slowly and steadily (3 in./sec) to various positions in the camera's field of view. Movements were always made in one of four possible directions (up, down, left, or right) from a central resting position, and extended over one of three possible path lengths, subtending 0.5°, 0.9°, or 2.5° at the subject's eye. About 4 sec separated successive movements. The tape also included a number of "catch-trials" on which no movement occurred.

During the calibration, the subject was instructed to follow the pointer with his eyes, as well as pressing the response key when a movement took place. He notified the experimenter orally if he lost fixation on the marker; such trials were repeated. Each subject was given three trials at each possible direction and path length as well as four no-movement trials, for a total of 40 trials; they were randomly ordered. The subject's remarks and keypresses were recorded on the audio track of the videotape.

Later, one of us (D.L.) viewed the silent video record of the subject's eye during this procedure and reported the occurrence and direction of the eye movements as he saw them. Comparison of his reports with the actual stimulus sequences and the audio tapes of the same sessions indicate that he detected 95% of the 2.5° movements, 93% of the 0.9° movements, and 68% of the 0.5° movements (each percentage is based on 96 trials, 12 from each of eight subjects. The judge never responded to catch trials.

The results of the calibration procedure demonstrate that we can accurately detect very small eye movements. The smallest eye movements made during the calibration (0.5) corresponded to 1/14 the width of the screen. Throws made in the ball game itself, on the other hand, rarely traveled less than 1.5°. Moreover, the subjects used pursuit movements to follow the calibration marker, whereas they tended to saccade from point to point when following short throws in the ball game. Since pilot studies indicate that saccades are easier to detect than pursuit movements, we are confident that we know when subjects moved their eyes from the fixation point in order to follow the ball.

RESULTS

Accuracy of Selective Looking

Misses and false alarms occurred very rarely in any condition. Miss rates are presented in Table 1. It is evident that though fixation produced a light drop in accuracy compared to free viewing, the subjects performed at about 95% accuracy in the most difficult conditions (SE) for both target rates. The means are higher than the medians because of relatively high miss rates by two subjects. False alarms were negligible: the median rate was 0 in every condition except SR, Day 1, where it was 1.

Table 1
Number of Target Events Missed by the Median Subject
(of Eight) in Each Condition

		Day 1		Day 2	
		20 Target Events (F)	(R)	40 Target Events (F)	(R)
Alone	(A)	0 (.12)	0 (.50)	.5 (.84)	1.5 (2.20)
Superimposition	(S)	0 (.25)	1 (1.26)	0 (.62)	2.0 (2.84)

Note—Means per subject in parentheses.

Table 2
Number of Eye Movements in the Restricted Viewing Conditions
by the Median Subject (of Eight) for the Two Target Rates

		Day 1 20 Target Events	Day 2 40 Target Events
Alone	(AR)	1 (2.1)	2 (2.0)
Superimposed	(SR)	2.5 (3.1)	2 (3.1)

Note—Means per subject in parentheses.

Effectiveness of Fixation Instructions

Table 2 shows that the subjects followed fixation instructions quite well, the median subject making only about two eye movements even in the most taxing conditions. By comparison, typical nonfixation conditions would yield well over 100 eye movements *per subject per episode*. Furthermore, Figure 1 shows that those subjects who were most successful in following the fixation instructions also tended to miss the fewest targets.

DISCUSSION

The results show clearly that visual selection in a task such as that of Neisser and Becklen (1975) can be

Figure 1. The relationship between eye movements and errors in the fixation conditions. Each point represents one subject; eye movements and misses summed over the four fixation conditions.

easily accomplished while inhibiting the natural tendency to follow the target events with one's eyes. Since eye movements are not necessary, visual selection can hardly be said to depend on them. This is not to deny the usefulness and frequent necessity for *foveation*. If foveal acuity is required to detect critical features, as for example in reading fine print, eye movements are obviously helpful. However, in such a case, the "filter" metaphor would be misleading since the purpose of the eye movements is to *pick up* rather than *exclude*. Evidently, the information necessary for following the ball game in our experiment is gross enough that foveation is not necessary. At least when the brightnesses of the superimposed events are equal, selection does not occur because some images are foveated while others are smeared, but by virtue of the flow of movements itself.

The slight drop in accuracy in the fixation condition (from 100% to 95%) was probably due to the increased complexity of the subject's task. For inexperienced subjects, fixation is something that requires attention in its own right. That is, the restricted viewing conditions created a divided attention task, namely following the action in the ball game *and* fixating the black spot. If the subject's eyes had a tendency to automatically flick away from the fixation spot, he had to pay more attention to the fixation task itself, and so missed more targets in the ball game. On the other hand, the subjects who were good at the fixation task made very few errors in following the ball game. We would expect that, with practice, accuracy of performance on both tasks would eventually approach 100%.

REFERENCE

- NEISSER, U., & BECKLEN, R. Selective looking: Attending to visually specified events. *Cognitive Psychology*, 1975, 7, 480-494.

(Received for publication February 19, 1976;
revision received April 30, 1976.)