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Can attention be directed voluntarily to an eye?

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Abstract

Previous studies suggested that information indicating which eye received monocular stimulation is not available to consciousness. However, lack of awareness of eye-of-origin does not necessarily preclude subjects' ability to bias the processing of information presented to an eye. In the present experiment, subjects performed a target detection task under dichoptic viewing, using a precuing procedure. The target appeared above or below fixation and was presented to the right or left eye. The ability of subjects to utilize location cue and eye cue was examined. The results indicated that advance knowledge about the location of the to-be-presented stimulus facilitated performance, and invalid information had an inhibitory effect. In contrast, advance knowledge indicating which eye is more likely to yield the target had no effect whatsoever. These findings suggest that humans cannot direct attention voluntarily to an eye.

1. Introduction

In normal vision we view the world binocularly, with both eyes. Research efforts have been directed at understanding the cooperation between the two eyes using dichoptic viewing. This research has focused on revealing the conditions under which the inputs from the two eyes fuse into a single percept, sometimes producing stereopsis, and the conditions under which binocular rivalry arises (e.g., Levelt, 1965). A central question has been whether the mechanisms responsible for stereopsis and binocular rivalry are central or peripheral (see Arditi, 1986; Wolfe, 1986, for extensive reviews).

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The use of single-eye displays in operational environment, such as piloting a helicopter at night with a Forward Looking Infra-Red (FLIR) display, raises different issues concerning human performance under dichoptic viewing. In particular, operators under such situations often attempt to treat the information presented to the two eyes separately, rather than fusing it into a single percept. The question then arises whether the two eyes can function as separate information channels.

This question has not been directly addressed. Somewhat relevant to the issue at hand are studies on utrocular discrimination, the ability to judge which eye received monocular stimulation. The findings obtained in these studies are by no means conclusive. A number of studies suggest that some normal observers are able to distinguish monocular stimulation (e.g., Enoch et al., 1969). Several investigators attempted to identify a set of conditions under which observers perform utrocular discrimination successfully and found that normal observers were able to judge which eye received the pattern for low spatial frequency gratings, but not for high spatial frequency ones (Black and Cormack, 1979; Martens et al., 1981). On the other hand, other studies showed that human observers were unable to successfully perform utrocular identifications, suggesting that information about the "eye of origin" is not available to consciousness (e.g., Ono and Barbeito, 1985; Steinbach et al., 1985).

However, lack of awareness of eye-of-origin does not necessarily preclude the possibility that humans can use advance knowledge indicating which eye is more likely to yield the relevant information to bias the processing of information presented to this eye. There is quite a number of empirical findings demonstrating the facilitation and interference effects of information which is not consciously identified (e.g., "implicit memory", "unconscious perception"; see Jacoby, 1991, for a review).

Wolfe and Franzel (1988) showed that visual searches that rely only on information about eye-of-origin are not possible (Wolfe and Franzel, 1988, Experiment 9). In this experiment the target to be searched was defined exclusively by eye-of-origin. The distractors were identical to the target, except for being presented to the non target eye. Since the task actually required conscious identification of eye-of-origin in order to be performed, the results suggest that such conscious identification did not occur. Yet, it has been recently claimed that lack of conscious identification of certain information does not necessarily imply that this information was processed unintentionally, because it is possible that such intentional processing was undetected by the experiments (e.g., Holender, 1986; Jacoby, 1991).

Thus, previous research addressed the question of subjects' awareness of monocular stimulation (i.e., utrocular identification research), or of subjects' ability to use such information to perform a visual search task (i.e., the Wolfe and Franzel, 1988 study). The experiment reported here addressed the question of the possibility of an intentional direction of attention to an eye, using precuing procedure under dichoptic viewing.

An earlier experiment performed in our laboratory suggested that an eye does not serve as an effective cue for selective attention. Subjects performed a simple letter identification task. A central cue indicated the location of the to-be-presented letter and the eye receiving the letter. The cue was valid in 70% of the trials and invalid in 30% of the trials with three kinds of invalidity: eye invalidity, location invalidity, and eye and location invalidity. The results showed that location invalidity had a detrimental effect on performance, whereas eye invalidity had no effect. However, since subjects were given advance knowledge regarding both eye and location of the to-be-presented stimulus on each trial, it is possible that the subjects utilized only the location information, and consequently null effects for eye invalidity were obtained.

The present experiment examined directly the ability of subjects to utilize each type of information. A single letter (H or T) was presented on each trial to one eye, and no distracting information was presented to the other eye. Subjects performed the target detection task under three conditions. In one condition they were given advance knowledge of target location only, in a second condition they were given advance knowledge of the eye receiving the stimulus, and in a third condition they were given advance knowledge of the eye and location. In each condition there were three types of trials: valid trials, neutral (no cue) trials, and invalid trials. This allowed a cost/benefit analysis (Posner, 1980) for each type of cue. If there is any processing bias due to intentional direction of attention to the designated eye, we expect it to be revealed in the present experiment.

2. Method

2.1. Subjects

Three females and nine males from 19 to 26 years old with normal vision were paid for participation in the experiment.

2.2. Apparatus

Two microprocessors (IBM AT) were programmed to operate in synchrony to provide two independent images. A special horizontal T-shaped wooden tunnel was constructed. The two computer monitors were placed facing each other on the two sides of the T head. Images were projected via two reflective mirrors, each positioned at an angle of 45° relative to subjects' eyes and the respected computer monitor (see Fig. 1). The two images were matched for brightness. The subject's head was fixed with a chin rest. Subjects' eyes were at an optical distance of 45 cm from the display. A partition assured the separation between the two eyes so that subjects saw the stimulus with their right eye or with their left eye. The positioning of the images was done subjectively for each subject: a horizontal line was displayed on one screen and a vertical line on the other, and the images were so positioned that viewing them dichoptically gave rise to a perception of a cross. The

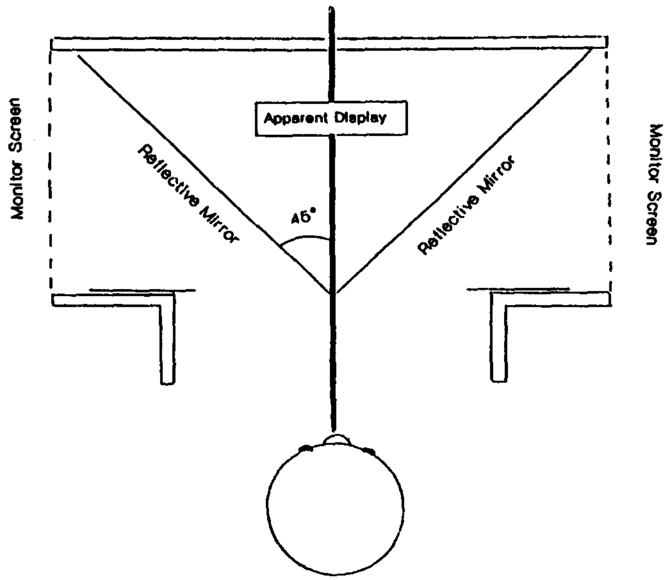

Fig. 1. Schematic top view of the optical arrangement used.

actual optical arrangement was not visible to the subject. Two keys on the IBM keyboard were used as response keys.

2.3. Stimuli

The stimuli were the letters H and T which served as the two target letters. The letters were white on a black background, they subtended 0.25° of visual angle in width and 0.5° in height, and they were presented to the right or left eye, 7.6° of visual angle above or below the fixation point.

2.4. Design

A simple target detection task was used. Subjects performed the task under three cue conditions that differed in terms of the advance knowledge given to the subject: (1) Eye cue – a horizontal arrow indicated the eye (right or left) receiving the target; (2) Location cue – a vertical arrow indicated the target location (up or down); (3) Eye and location cue – an oblique arrow indicated the eye (right or left) and the location (up or down) of the to-be-presented target letter. The arrow cue was presented centrally with the fixation cross and subtended 1.9°. The arrow cues for each condition are presented in Fig. 2. The order of the three cue conditions was counterbalanced across subjects. For each cue condition, a cue was presented in 50% of the trials. In 50% of the trials no cue, only a fixation cross sign, was presented (neutral trials). If a cue was presented, it was valid with a probability of

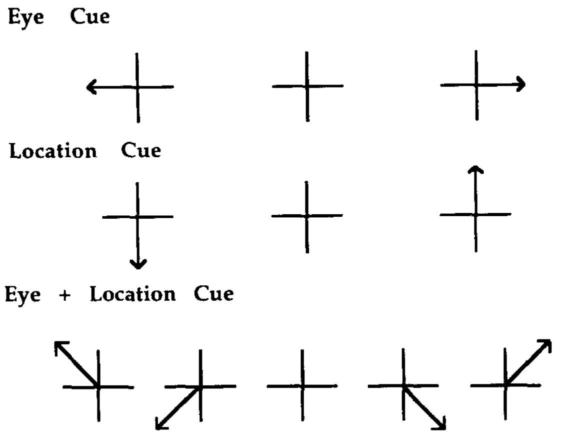

Fig. 2. The arrow cues used in each of the three cuing conditions.

0.8 (valid-cue trials), and invalid with a probability of 0.2 (invalid-cue trials). On the valid-cue trials of the location cue condition the target occurred on the cued location. On the invalid-cue trials it occurred on the uncued location, and on the neutral trials the target could occur equally likely on each of the two possible locations. In the eye cue condition the target was presented to the cued eye on the valid-cue trials, and to the uncued eye on the invalid-cue trials. On the neutral trials each eye was equally likely to receive the target. On the valid-cue trials of the eye and location cue condition the target occurred on the cued location and was presented to the cued eye. On the invalid-cue trials the target occurred on the uncued location and presented to the uncued eye, and on the neutral trials the target could occur equally likely on each of the four combinations of eye and location.

For each cue condition there were 320 experimental trials in 4 blocks of 80 trials each. 40 trials in each block were neutral trials, 32 were valid-cue trials, and 8 were invalid-cue trials. These 3 type of trials were randomized within each block. For each type of trials the 8 combinations of target letter × eye × location appeared equally often and in a random order. At the beginning of each cue condition subjects received 40 practice trials. In addition there were 2 warm-up trials in the beginning of each block and they were not included in the analyses.

2.5. *Procedure*

Subjects participated individually. At the beginning of the experimental session the subjects were instructed as to the designated task. They were told that the stimulus would appear in one of two possible locations (above or below fixation), and would be presented to the right or left eye. For each cue condition they were instructed about the specific cue employed. In the location cue condition they were told that an up/down arrow indicates the likely location of the target letter, in the eye cue condition they were told that a left/right arrow indicates the likely eye receiving the target, and in the eye and location cue condition they were instructed about the four possible arrows indicating the likely location and eye. The subjects were directed to make their responses with the index fingers of their left and right hands as quickly as possible while making as few errors as possible. Half of the subjects were instructed to press the leftmost key for the letter H, and the rightmost key for the letter T, and half of the subjects were given the opposite instruction. The instructions requested the subject to look directly at the fixation and not to move their eyes during a trial.

The sequence of events for each trial was as follows. First a central fixation cross with an arrow (the cue) appeared for 150 ms. The target appeared 100 ms later and was presented for 150 ms. A feedback, indicating a correct ("Y") or incorrect ("N") response, was presented at the fixation for 300 ms upon subject's response. A 3000 ms interval was allowed for a response, and there was a 1200 ms intertrial interval. The experiment lasted about one hour.

3. Results

Reaction times for correct responses and percentage of errors were analyzed by a five-factor repeated measures analysis of variance (ANOVA). The five factors were cue condition (eye cue, location cue, eye and location cue), cue validity (valid, neutral, invalid), target (H, T), eye (right, left), and location (upper, lower). The analysis indicated a significant effect of cue validity ($F(2,22) = 27.91$, $p < 0.0001$, for reaction times, $F(2,22) = 12.83$, $p < .0002$, for percentage errors), and a significant interaction between cue condition and cue validity ($F(4,44) = 6.48$, $p < 0.0003$, for reaction times, $F(4,44) = 3.17$, $p < 0.02$, for percentage errors). Reaction times and percentage errors as a function of cue validity for each of the cue conditions are presented in Fig. 3. A breakdown of this interaction revealed that cue validity had a significant effect in the location cue condition ($F(2,22) = 17.05$, $p < 0.0001$, for reaction times, $F(2,22) = 8.84$, $p < 0.002$, for percentage errors), and in the eye and location cue condition ($F(2,22) = 23.21$, $p < 0.0001$, for reaction times, $F(2,22) = 6.48$, $p < 0.006$, for percentage errors). No significant effect of cue validity was obtained in the eye cue condition, $F < 1$. Mean reaction times for this condition were virtually the same for the three types of trials: 778 ms, 777ms, and 778 ms, for neutral, valid, and invalid cue trials, respectively. The respective percentage errors were 23%, 22%, and 22%.

Mean reaction times for the location cue condition were 744 ms, 696 ms, and 811 ms, for the neutral, valid, and invalid cue trials, respectively. The respective percentage errors were 20%, 15%, and 24%. Pairwise comparisons using the Duncan procedure revealed significant differences in reaction times between the three types of trials, and a significant difference in percentage errors between the valid cue trials and the two other types of trials. Mean reaction times for the eye and location cue condition were 765 ms, 737 ms, and 842 ms for the neutral, valid and invalid cue trials, respectively. The respective percentage errors were 20%,

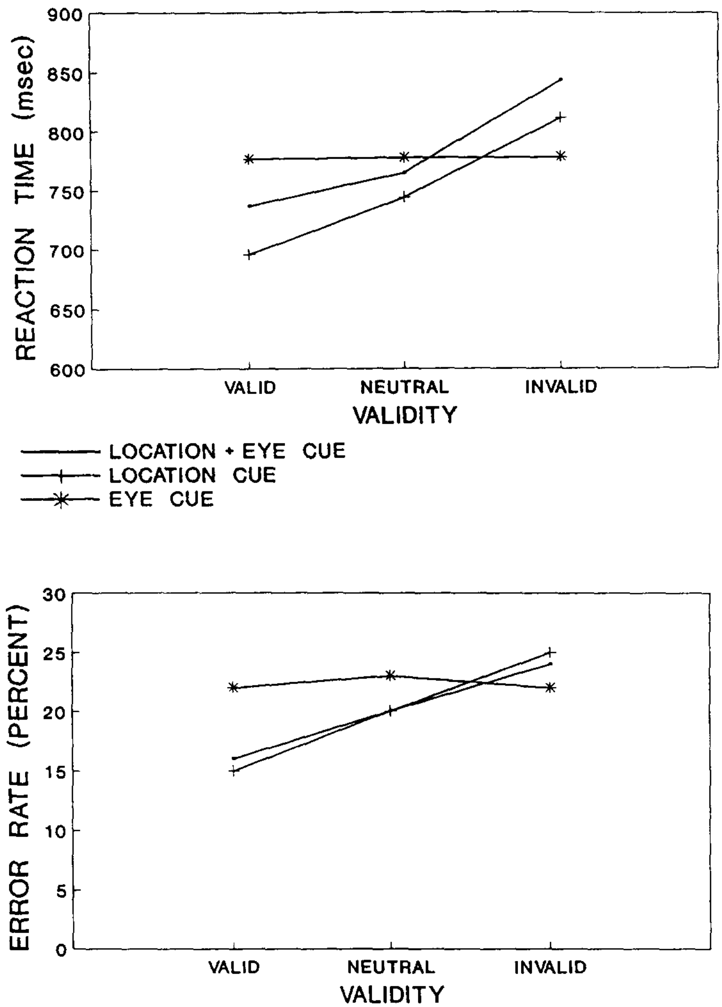

Fig. 3. Reaction times and percentage errors as a function of cue validity for each of the cue conditions.

16%, and 24%. Pairwise comparisons revealed a significant difference in reaction time between invalid cue trials and the two other types of trials, and a significant difference in percentage errors between valid and invalid cue trials.

Reaction times and percentage errors were somewhat higher for the target letter H than for T, but the difference was not statistically significant. the interaction between cue validity and cue condition was significant for both letters, but the effect of cue validity under the location cue and the location and eye cue conditions was somewhat larger for the letter H than for T, as indicated by the significant interaction between target, cue validity, and cue condition ($F(4,44) = 5.78$, $p < 0.001$, for reaction times, $F(4,44) = 2.77$, $p < 0.04$, for percentage errors).

A main effect of location was found for percentage errors only ($F(2,22) = 7.23$, $p < 0.002$). Mean percentage errors for targets that appeared in the upper visual field was 24.3%, and for those that appeared in the lower visual field was 16.7%. The effect of cue validity under the location cue and the location and eye cue conditions was larger for targets that appeared in upper than in lower location, as indicated by the significant interaction between target location, cue validity, and cue condition ($F(4,44) = 3.08$, $p < 0.03$).

4. Discussion

The results of the present experiment clearly show that the three types of cues differed in their effect on subjects' performance. The location cue produced a significant benefit, averaged 48 ms, when the target occurred on the cued location, and a significant cost, averaged 67 ms, when the target occurred on the uncued location. This finding converges with previous findings reported in the literature suggesting that prior knowledge of target location in the visual field can facilitate response time to the target, and occurrence of the target in an uncued location may result in an inhibitory effect (e.g., Eriksen and St. James, 1986; Eriksen and Yeh, 1985; Posner, 1980; Posner et al., 1980; Tsal, 1983). Cuing both the eye and location produced an average benefit of 28 ms, and an average cost of 77 ms, indicating that cuing both eye and location had no effect beyond that of cuing only location. [1] On the other hand, the eye cue indicating which eye is more likely to yield the target produced no cost or benefit.

Granted that findings obtained in a precuing procedure like the one used in the present experiment are seen to suggest the presence or absence of an attentional process (e.g., Posner, 1980; Kinchla, 1992) the present results suggest that whereas location is an effective cue for selective attention, there is no evidence of an attentional process involved in eye cuing. Further support to the presence of attentional process in precuing target location is provided by the finding that the effect of cue validity was somewhat larger for the detection task which tended to be more difficult (i.e., the detection of H vs. the detection of T, and the detection in the upper location vs. the detection in the lower location).

Studies on utrocular identification suggest that information about the eye-of-origin is not available to consciousness (e.g., Ono and Barbeito, 1985), and Wolfe and Franzel (1988) showed that visual searches which depend on such knowledge cannot be performed. In principle, these findings do not necessarily rule out the possibility of an intentional direction of attention to an eye, resulting in a processing bias of the information presented to this eye. However, the present study clearly demonstrates that subjects are unable to voluntarily direct attention

[1] The cost and benefit effects in the location cue and the eye and location cue conditions were replicated with monitoring of eye movements (Trainin, 1993). Thus, an eye movements account of the present effects is ruled out.

to the eye which is more likely to yield the relevant information, even under the simple condition of no rivalry between the eyes.

Subjects do show an ability to selectively attend to information presented to one eye or the other when the information presented to each eye is uniquely defined on some dimensions. For example, Kimchi et al. (1993) showed that subjects, under simultaneous monocular presentation, were able to follow instructions to focus attention on one eye and ignore competing information presented simultaneously to the irrelevant eye when the information presented to each eye appeared in different spatial locations in the visual field, and their performance was identical to that under normal binocular viewing. Similarly, Neisser and Becklen (1975) showed that subjects, under dichoptic viewing, were able to focus their attention on information presented to one eye while ignoring the information presented to the other eye when one eye was presented with an episode of a ballgame and the other eye with an episode of a handgame, and their performance was the same as when both eyes viewed the two episodes superimposed.

Studies on auditory attention using the dichotic listening task showed that subjects were able to selectively attend to a message presented to one ear and ignore the message presented to the other ear (e.g., Cherry, 1953). But clearly the selection in this case was by spatial location, not by the sensory organ as such (e.g., Kahneman, 1973). In general, spatial location is an effective cue for both auditory and visual selective attention (e.g., Johnston and Dark, 1986; Kahneman, 1973).

In summary, the results of the present experiment suggest that an eye does not constitute an information channel for attention. This may not be at all surprising if we consider the goal of the perceptual system. The goal of perception is to provide information about objects and events in the world. Consequently, the nature and the location of these objects are relevant, not which receptors were stimulated by these stimuli (see also Neisser and Becklen, 1975; Ono and Barbeito, 1985). From this point of view, the sense organs are at the service of attention; they are not the objects for attention.

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