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Failure to integrate visual information from successive fixations

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After a 200-msec exposure to 12 dots from a 5 × 5 array, subjects made 4-deg saccades during a 37-msec blank interval, and then saw another 12 dots from the array for 17 msec. Subjects failed to identify the location of the missing dot, contradicting the conclusions of Jonides, Irwin, and Yantis (1982). Performance was also at chance levels with a 2.25-deg saccade, eliminating the possible effect of saccadic suppression of displacement. Screen brightness (2 log units above threshold) eliminated the phosphor persistence that probably accounts for the success of Jonides et al.'s subjects.

One of the unsolved and largely unstudied problems in perception is how we put together a stable and consistent sensory world from successive samples of it. In vision, this problem is defined as the integration of information from successive fixations punctuated by saccadic eye movements. Jonides, Irwin, and Yantis (1982) seemed to provide a powerful method for studying this question. Their task was an extension of one by Di Lollo (1977, 1980), who had subjects integrate samples of a 5 x 5 dot matrix. Subjects first saw 12 dots of the matrix, then saw another 12, and determined the position of the missing dot. Jonides et al. interposed a saccade between the first and second frames, while leaving the matrix in the same position in space. To succeed at this task, subjects must integrate frames at different positions on the retina but in the same spatial locations, thus performing the interfixational synthesis necessary for the perception of a stable world. According to Jonides et al., subjects were successful at performing this integration in about three-fifths of their experimental trials. Control trials in which frames appeared at two different spatial positions during visual fixation, but at the same retinal locations as in the experimental condition, resulted in near-random performance.

Success at the Jonides et al. (1982) task, however, seems inconsistent with other experiments showing high thresholds for the detection of displacement of a large target during a saccadic eye movement. Displacement of a continuously visible target by 25% of saccade magnitude results in no perception of the displacement of the target (Bridgeman, Hendry, & Stark, 1975; Bridgeman & Stark, 1979; Mack, 1970). This displacement is equivalent to displacing the two 5 x 5 Jonides et al. matrices by one interdot distance. If a displacement by one interdot distance is below perceptual threshold, how can subjects integrate the two patterns with precision?

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To resolve this issue and to investigate the nature of interfixational integration, we performed a series of experiments attempting to replicate the Jonides et al. (1982) result and to extend the method to other questions.

METHODS

At a distance of 76.5 cm, subjects viewed an oscilloscope screen 7.8 deg high x 9.9 deg wide illuminated with room fluorescent lighting, resulting in a screen luminance of 21.8 cd/m². In the center of this screen was permanently mounted a black frame 3.75 deg square and 2.25 min wide. Fixation points 2.25 min square were mounted in the frame's center and 4 deg to the left. Dots were separated by 43 min horizontally and vertically, and the matrix appeared symmetrically within the reference frame. We used a P-4 phosphor screen, which has a fast initial decay (microseconds) and a slower secondary decay that begins at a brightness of about 0.1% of the original exposure. To eliminate effects from this secondary emission, we ran all subjects at 2 log units above brightness threshold. A neutral-density filter with 1% transmittance was mounted over the display area of the screen, and dot luminance was adjusted during 200-msec exposures until the dot matrix was barely visible at the viewing distance. Thus, even with the neutral density filter removed for testing, the secondary emission remained below threshold.

RESULTS AND DISCUSSION

We first replicated the Di Lollo (1977) experiment by placing a fixation point 2.25 deg from the center of the matrix and exposing the first pattern for 200 msec and the second for 10 msec, with a 10-msec blank interval. As did Di Lollo (1977), we found that the subjects could perform this task, but that they did better with a 50-msec first interval. We repeated the Di Lollo (1977) task with intervals replicating those which Jonides et al. (1982) used (150-msec first frame, 37-msec blank, and 17-msec second frame). Again, two male subjects performed wll above chance.

In attempting to replicate the Jonides et al. (1982) saccade condition, we monitored eye movements using a photoelectric instrument with a time constant of 2 msec. Eye movements were monitored with two photocells aimed at the iris-sclera border, which was illuminated by an infrared LED (Bahill, Clark, & Stark, 1975). Using the same two subjects who had successfully performed the Di Lollo tasks, we measured eye movement latency to appearance of the dot matrix on the screen at the experimental brightness. For both subjects, the latency averaged 200 msec; this was the duration of the first frame in subsequent experiments. To replicate the Jonides et al. timing conditions as closely as possible, we used a blank time of 37 msec and a second exposure of 17 msec. Eye movement and one axis of the computer-generated display were recorded on two channels of a storage oscilloscope, and the eye movement record was inspected after each trial to assure that the saccade had begun after the end of the first interval and had ended before the beginning of the second. Trials in which this was not the case, about two-thirds of the total, were discarded; the results below refer to the remaining trials. Each subject received 100 practice trials with feedback before experimental trials without feedback began.

The first subject was correct in 2.2% of 89 successful trials. Chance performance with no information from either matrix frame should give about 4% success. If information from one matrix is used, chance performance should improve to 1/13, or 7.7%. Therefore, this subject's success was less than expected by chance with no information from either frame, but not significantly less when analyzed statistically ($\chi^2_1 = 1.37$, $p > .1$). The performance of the second subject was virtually identical to that of Jonides et al.'s (1982) first control subject, with 8.2% correct in 220 trials. This is significantly above the chance value of 4% with no information ($\chi^2_1 = 19.2$, $p \leqslant .001$) but does not differ significantly from 7.7%. This suggests that both this subject and Jonides et al.'s first control subject were using dot positions in one of the frames to make their decisions. The very low success rate of both of our subjects, however, makes us suspect that they were not integrating pre- and postsaccadic aspects of the visual scene.

An analysis of errors by frame shows that like Jonides et al.'s (1982) control subjects, our subjects made most of their errors by guessing that the missing dot was in a position where a dot occurred in the first frame. The first frame generated 61% of the errors for our first subject, and 81% for the other. Most of the correct trials occurred on the left 40% of the screen, the part closest to the fovea before the start of the saccade. Of the 20 correct trials gathered during 309 attempts in the two subjects, 60% were in the left two columns and all of the remaining successes were in the center column or the bottom row. The greater success in the left two columns was marginally significant ($\chi^2_1 = 4.0$, $.05 > p > .025$).

To avoid the saccadic-suppression-of-displacement problem, we repeated the experiment using a smaller saccade of 2.25 deg. The other parameters were identical. The results were similar, with a 7.5% overall success rate on correctly timed trials. Thus, saccadic suppression of displacement was not responsible for the inability of the subjects to integrate the two dot matrices.

In agreement with Jonides (Note 1), we feel that phosphor persistence probably accounts for the success of Jonides et al.'s (1982) subjects. When precautions are taken to eliminate secondary persistence, the effect disappears.

REFERENCE NOTE

1. Jonides, J. Personal communication, November 12, 1982.

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