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The relative capabilities of the upper and lower visual hemifields

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Abstract

Visual performance is better in the lower visual hemifield than in the upper field for many classes of stimuli. The origin of this difference is unclear. One theory associates it with finer-grained attention in the lower field, an idea consistent with a change in relative efficacy with task difficulty. The first experiment in this study confirmed a lower hemifield advantage for discriminating a range of stimuli, including those that differ in contrast, hue, and motion. An identical paradigm revealed an upper field advantage when stimuli differed in their apparent distances from the observer. Presentations of stimuli in the upper or lower hemifield were interlaced to reduce the likelihood of possible artifacts or biases. A second experiment varied the difficulty of these discriminations, showing that difficulty does not determine field preference. Thus, an attentional mechanism is not a likely explanation for these preferences.

Keywords: Visual fields; Detection; Task difficulty

1. Introduction

Visual capabilities are not uniform throughout the visual field. Acuity is highest in the central field, and worsens toward the periphery. There are also clear nasal-temporal differences (Curcio & Allen, 1990). A difference that has not been explored as thoroughly is that between the upper and lower visual hemifields.

As a general rule, subjects perform somewhat better when stimuli are in the lower visual hemifield than in the upper visual field. This may not seem surprising, since ganglion cell densities are somewhat higher in the superior retina (Curcio & Allen, 1990; Croner & Kaplan, 1995). However, there are differences that do not follow directly from simple retinal cell density. For example, Rubin, Nakayama, and Shapley (1996; see also Shapley, Rubin, and Ringach, 2004) found that the illusion of subjective contours is more pronounced in the lower visual field than the upper. This indicates a contribution from areas beyond the retina.

Other indications that higher-level processing areas enhance performance in the lower visual field come from various experiments showing lower field preferences; these are extensively reviewed by Danckert and Goodale (2003). Some of these preferences seem more pronounced when the "difficulty" of the task or complexity of the stimuli is increased, implying that attentional demands may account for the differences. A common interpretation is that the "spotlight of attention" is more finely focused in the lower visual hemifield, so performance is better in the lower field when fine discriminations must be made (He, Cavanagh, & Intriligator, 1996).

While performance for stimuli in the lower visual hemifield seems generally better than for those in the upper, a few experiments have demonstrated conditions in which the reverse is the case (see Previc, 1990; Danckert & Goodale, 2003). Some of these exceptions involve serial searches in which the distracters are present in both the upper and lower fields; since we tend to

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scan left-to-right and top-to-bottom (as we read), the upper field preference could be attributable to the search strategy. There also have been studies in which no preference was shown for the upper or lower hemifields (e.g., McColgin, 1960).

In previous work on a visual illusion called "blanking," it was noticed that thresholds for a small disk rendered less visible by surrounding squares were higher in the upper visual hemifield than in the lower (McAnany & Levine, 2004). Moreover, this discrepancy was greater when thresholds were high than in control conditions when thresholds were low. This could be due to a greater blanking effect in the upper field, but alternatively might be due to improved relative performance in the lower field as a result of the greater complexity and difficulty of the task.

The present studies were designed to answer several questions about the different visual capabilities within the upper and lower hemifields. In order to test for the effects of difficulty, it was necessary to find stimuli such that the upper field would show better performance than the lower in an experimental paradigm comparable to those in which other stimuli facilitated lower field performance. Experiment 1 was designed to establish stimuli with robust preferences for each of the fields.

Experiment 2 was a series of tests of the effects of difficulty upon each type of stimulus. Would more difficult tasks enhance performance disproportionately in the lower visual hemifield, and thus reverse the upper field preference for those stimuli favored in the upper field while increasing the performance gap for those favored in the lower field? Or might difficulty simply increase the discrepancy, regardless of the preference? Or is task difficulty irrelevant for the relative performance of the upper and lower visual hemifields in a specific task?

2. Methods

2.1. Subjects

The same subjects who served in a previous publication (McAnany & Levine, 2005) served in this study. Subjects 1, 2, and 3, respectively, were the authors (males, 25 and 61 years old) and a naïve observer (female, 25 years old). All had normal or corrected-to-normal acuity, normal stereopsis, and no known color anomalies. The experimental protocol and process of consent were approved by a UIC Institutional Review Board.

2.2. Apparatus and calibrations

The apparatus and calibrations have previously been described in detail (McAnany & Levine, 2005). Briefly, the subject sat with his or her chin in a chin rest, facing an EIZO 19 in. FlexScan FX · D7 monitor in a dark room. A first-surface mirror stereoscope provided fusion of separate images on the left and right halves of the screen to provide a three-dimensional display. Relative positions of points on the two images were corrected for each subject's horopter, which was first ascertained by the Nonius method.

Display luminance was calibrated with a Minolta LS-110 luminance meter. The RGB units (the binary numbers controlling the guns) were converted to luminance by a quadratic function. In all experiments, the background was neutral gray with a luminance of 23.6 Cd/m^2 (red = 5.0, green = 16.3, blue = 2.3 Cd/m^2).

2.3. Time-course and display

Each block of trials began with a 30 s period during which the subject fixated at the center of a uniform field of the background gray (in each eye). The fixation pattern consisted of a black dot and two concentric circles, with small disparities such that, when properly fused, one circle appeared in slightly in front of the gray field and one appeared slightly behind it. This pattern was available to the subject to ensure proper fixation before and during each stimulus presentation trial. It vanished during the response period, and reappeared to signal readiness for the next trial.

The subject initiated each trial ad libitum by pressing an arrow key on a computer keyboard. The stimulus was presented 500 ms after this initiation signal. Static stimuli were presented for 280 ms, after which they were replaced by a uniform gray screen until the subject indicated a response choice with the numeric keypad. Dynamic stimuli consisted of two consecutive frames of equal duration; each frame could be 56 or 112 ms.

The stimulus pattern consisted of an array of disks placed randomly on a field of the background gray; the field was 18° wide and 13° high. The number and diameters of disks could be set as a parameter. In most cases, there were 125 disks with diameters of 29 min. Thus, the disks typically covered about 13% of the stimulus area. An example is shown in Fig. 1.

A block of trials typically consisted of 144–250 trials, a number of trials the subjects found comfortable in a single sequence. Within each trial, the stimulus pattern appeared randomly either above or below fixation. The target cluster of disks (3.5° in diameter) could appear in one of three regions within the field: directly centered over or under fixation, or centered 4.4° to the left or right of that position. It was always 12° above or below fixation. The subject's task was to indicate whether the target was left, center, or right (3 AFC).

There were typically seven disks clustered within the target region; these could differ from disks in the balance of the field in luminance, color, motion in depth, relative disparity, or lateral motion. When luminance was under