Visual field asymmetries in attention and learning

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Abstract—It has been suggested that attentional resolution is greater in the lower than in the upper visual field. As there is no corresponding asymmetry between the areas in the primary visual cortex where the input from upper and lower visual fields is processed, an ‘attentional filter’ has been proposed to act in one or more higher visual cortical areas in order to constrict the availability of visual information to the level of awareness. To investigate this, a visual search array was presented to the entire visual field and reaction times from upper and lower visual fields compared. In a second experiment, subjects were trained in detecting targets in different visual fields.

There was no significant difference between reaction times for targets presented in either upper or lower visual fields when the array was presented to the entire visual field. However, when the array was restricted to either the upper or lower visual fields, reaction times were significantly slower for detection in the upper visual field.

1. INTRODUCTION

There is a long history of studying differences between the perceptual abilities of the upper and lower visual fields (e.g. Previc, 1990; Christman, 1993; Whishaw, 1994; Previc and Murphy, 1997; Niebauer and Christman, 1998). Some attributes, such as colour and orientation, seem to be processed more finely in the lower visual field (Previc, 1990), whereas others, such as apparent size (Ross, 1997), seem to be processed better in the upper visual field. Recently, He et al. (1996) suggested that there may also be attentional differences between the upper and lower visual fields, and that the attentional resolution in the lower visual field may be much finer than that to be found in the upper visual field (He et al., 1996). In the test for attentional resolution for stationary stimuli, He et al. presented

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subjects with elongated columns of stimuli and subjects were required to detect the presence or absence of either a simple feature or a conjunction target. Using a measure of accuracy, they found that subjects were significantly better at detecting the conjunction targets in the lower visual field, and correspondingly impaired in detecting targets in the upper visual field. However, the elongated displays may have encouraged a bottom-to-top scanning strategy, and we were concerned to discover whether He et al.’s claim would extend to arrays covering the entire visual field. We were also interested in seeing whether the attentional differences, if present, extended to differences between the upper and lower visual fields in learning, as has been previously reported for simple gratings by Fiorentini and Berardi (1981). Our results suggest that the attentional asymmetries observed by He et al. are limited to the kinds of stimuli and displays used in their experiments, and do not extend as a general principle to other stimuli or different shaped visual arrays.

2. METHODS

Thirty undergraduate participants (aged between 17–21, 16 female, 11 male) volunteered. Each had normal or corrected-to-normal vision, normal colour vision and were right handed. Stimuli were presented to subjects on an 11.7 deg × 8.4 deg colour monitor divided into a virtual array of 8 × 6 boxes of 1.49 deg × 1.4 deg. Targets and distractors could be presented in any one of these boxes on each given trial; targets were present on 75% of the trials and on every trial there were either eight distractors and one target or nine distractors. Two types of stimuli were used. Feature stimuli were white oblique-oriented bars (0.93 deg long and 0.13 deg thick, 24 cd/m²), distractors being oriented at 45 deg clockwise and targets being oriented at 45 deg anticlockwise. In the conjunction task, the target was a red clockwise oblique (0.93 deg × 0.13 deg, 12 cd/m²), with green clockwise obliques (0.93 deg × 0.13 deg, 24 cd/m²) and red anticlockwise obliques (0.93 deg × 0.13 deg, 12 cd/m²) as distractors. At the beginning of each trial subjects were presented with an alerting tone and a central fixation spot for 500 ms. This was followed by presentation of the search array, which remained onscreen until the subject responded. Subjects responded by depressing one button if the target was present and another button if the target was absent. We used six presentation conditions (see Fig. 1).

Experiment 1 (n = 6): In conditions 1 and 2, a whole-screen condition in which reaction times for the various sections of the display were compared the targets and distractors could occupy any one of the 48 virtual boxes. In the upper and lower visual field comparison, the stimuli could occupy either the upper 16 virtual boxes or any of the lower 16 virtual boxes; and in a centre-periphery comparison, the stimuli could occupy any one of the 12 central boxes or any one of the 22 boxes covering the perimeter of the monitor.

Experiment 2 (n = 24): In the learning experiment, subjects carried out 500 trials per day. In both the feature and conjunction task, three participants trained
3. RESULTS

In each condition, accuracy was above 90%. In condition 1, the entire visual field experiment, there were no significant differences between upper and lower visual fields for either feature or conjunction tasks. Feature tasks, as expected, were reliably quicker than the conjunction tasks (500 ms vs. 750 ms) (see Fig. 2a).

In conditions 3 and 4, in which stimuli appeared either in the upper or the lower fields, detection in the lower visual field was slightly faster than detection in the upper visual field for conjunction targets ($p = 0.0499; t = 2.1457, df = 14$) (see Fig. 2b). In the feature tasks, detection in the lower visual field was slightly, but not significantly, slower than the upper visual field ($p = 0.152; t = 1.123, df = 14$). In conditions 5 and 6 in which stimuli appeared either in
the central or peripheral regions of the display, there was a marked difference in the detection of the conjunction targets. Also, as one would expect, the central visual field detections were much quicker than the peripheral visual field detections ($p = 0.0043; t = 3.0511, df = 14$). Indeed, when centre-only conditions were used conjunction detection was almost as fast as for feature detection (Fig. 2d). However, when the entire visual field is stimulated, the differences between centre and periphery detection of conjunction targets disappear (see Fig. 2c).

In the learning experiment (see Fig. 3), the shapes of the learning curves were virtually identical for both the upper and lower visual fields in the feature task and in the conjunction task. The slight advantage of the lower visual field was maintained in the learning of the conjunction task but not in the feature task. In a comparison of learning between the centre and peripheral visual fields, the central visual field showed a much shallower learning curve than the peripheral visual field for both feature and conjunction searches. Indeed, in the feature search, detection in the
Figure 3. a and b: training curves in upper and lower visual fields for feature and conjunction tasks. c and d: training curves in upper and lower visual fields for feature and conjunction tasks.
peripheral visual field, after five days of training, was as quick as the detection in the central visual field. This was also true for the conjunction task.

4. DISCUSSION

Our results do not provide unequivocal support for He et al.’s notion that the attentional resolution of the lower visual field is markedly higher than that of the upper visual field. In our comparison of upper and lower visual fields when the stimuli were presented in one or the other visual field, we did find that detection in the lower visual field was slightly faster than in the upper visual field. However, this advantage disappeared when the stimuli were presented in both the upper and lower visual fields simultaneously. This suggests that the lower visual field advantage is limited to when the lower visual field is stimulated in isolation or in very simple visual scenes such as those used by He et al. However, this is an unlikely scenario in any natural visual scene, when salient objects may appear in any part of the visual field. A much more robust difference between regions of the visual field was seen between the centre and the periphery; indeed, the differences between the centre and the periphery are much more marked than those between the upper and lower visual fields. One possible explanation for this is that the processing capacities of the central visual field benefits from the greater density of pattern sensitive P cells relative to the periphery. The P and M asymmetries are less marked between upper and lower fields. The same trend of differences is evident when the entire visual field is stimulated. As has been reported elsewhere (Ahissar and Hochstein, 1993), learning proceeds only when stimuli need to be attended to. One possible explanation for this is that if there is a pattern sensitive attentional bias in one or other of the two hemifields, one would see this bias reflected in learning performance. As Fig. 3 shows, there is no evidence to support a different mechanism of learning in the lower or upper visual field. Rather, the forms of the learning curves in the two visual fields are basically identical irrespective of type of stimulus. The implication of this is that in spite of the higher pattern sensitivities of the central visual field, the capacity for plasticity may be similar across all regions of visual space.

In conclusion, it seems that there is no robust attentional asymmetry between the upper and lower visual fields, whereas there are robust differences between the central and peripheral visual fields. Correspondingly, there are no marked differences in the form of the learning curve between the upper and lower visual fields, whereas there are marked and robust differences in the learning curves between the central and peripheral visual fields. Of course, this does not preclude the possibility that there are specific asymmetries for specific shapes of visual arrays or specific types of stimuli, but what it does preclude is any notion that there may be a generalizable asymmetry in attention function between the upper and lower visual fields.
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REFERENCES


