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Vertical biases in scene memory

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Abstract—In a recent theoretical paper (*Behavioral and Brain Sciences*, 1990, **13**, 519–542), Previc argued that vertical asymmetries in perception may largely result from the biases of the lower and upper visual fields toward proximal and distal space, respectively. The present study examined whether this same relationship may exist for visual scene memory, by re-analyzing data from Intraub and Richardson (*Journal of Experimental Psychology: Learning, Memory, and Cognition*, 1989, **15**, 179–187). In that study, subjects remembered photographs of scenes as being farther away than was actually the case and extended the boundaries of the scenes accordingly; in some cases, the remembered scenes were also shifted vertically. This study formally examined whether prominent landmarks in Intraub and Richardson's close-up and wide-angle photographs were displaced vertically in subjects' reproductions of them from memory. A total of 475 measurements in 210 drawings by 41 subjects were made. The results were that 64% of the original landmark points were shifted downward in the drawings made from memory, whereas only 36% were shifted upward. Although most of the original points were located in the upper-field and would have been expected to be shifted downward as the original image contracted in memory, a chi-square analysis showed that more upper-field points were shifted downward than were lower-field points shifted upward in the remembered scenes. The downward shift could reflect an expansion of the upper-field in memory, consistent with the scene being placed farther away, or it could reflect an elevation of the assumed viewing (head) position in memory. Published by Elsevier Science Ltd.

Key Words: visual; scene; memory; vertical; asymmetries; distance.

Introduction

Vertical asymmetries occur in a wide variety of perceptual-motor behaviors, including visual search, motion perception and eye movements (see [11, 12] for reviews). Recent studies have also provided evidence of vertical biases in various *memory* tasks [1, 2, 9, 14]. Previc [11] interpreted vertical perceptual-motor asymmetries in the context of the ecological linkage of lower-field processing to near space and upper-field processing to distant space, as manifested in the slope of the ground plane up and away from the observer and the confinement of most reaching activity to the lower visual field. Previc [11] also argued that specialized neural systems exist that mediate our operations in near and far space and are biased toward the lower and upper visual fields, respectively.

Whether Previc's interpretation is also valid for vertical biases in memory processes is unclear. Intraub and Richardson [7] found that memory for visual scenes contained in photographs is distorted such that the original scene is compressed (as if it were receded in distance) and its boundaries extended accordingly (as in a 'wide-angle' view). 'Boundary extension' has been replicated under a variety of stimulus durations and attention instructions [5, 6, 10]. Intraub and colleagues have proposed that this memory distortion is primarily due to the activation of a 'perceptual schema' during viewing that results in the incorporation of elements of the scene that were not visible in the picture, but that were likely to have existed just beyond the picture's boundaries. However, the remembered drawings illustrated in Fig. 1 of Intraub and Richardson [7] and Figs 1 and 2 of Intraub [4] also exhibit *vertical asymmetries* in their boundary extension—specifically, an expansion of the *upper-field* portion of the scene (see Fig. 1). Such a tendency would be consistent with Previc's proposed ecological linkages, given that Intraub and Richardson's scenes were also remembered as lying at a greater distance from the subject.

The purpose of the present study was to formally test whether a vertical bias exists in the boundary extension phenomenon, by re-analyzing Intraub and Richardson's original data.

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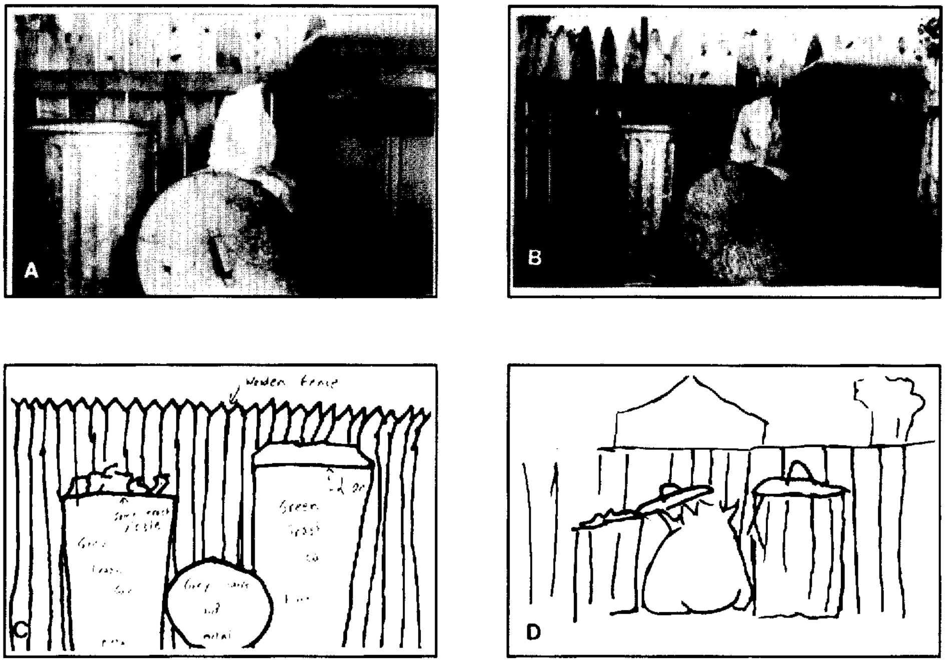

Fig. 1. Examples of the 'boundary extension' phenomenon, from Fig. 1 of Intraub and Richardson [7]. 'Close-up' and 'wide-angle' versions of one of the original scenes presented to subjects are shown in A and B, respectively, whereas representative drawings of those same scenes from memory are shown in C and D, respectively.

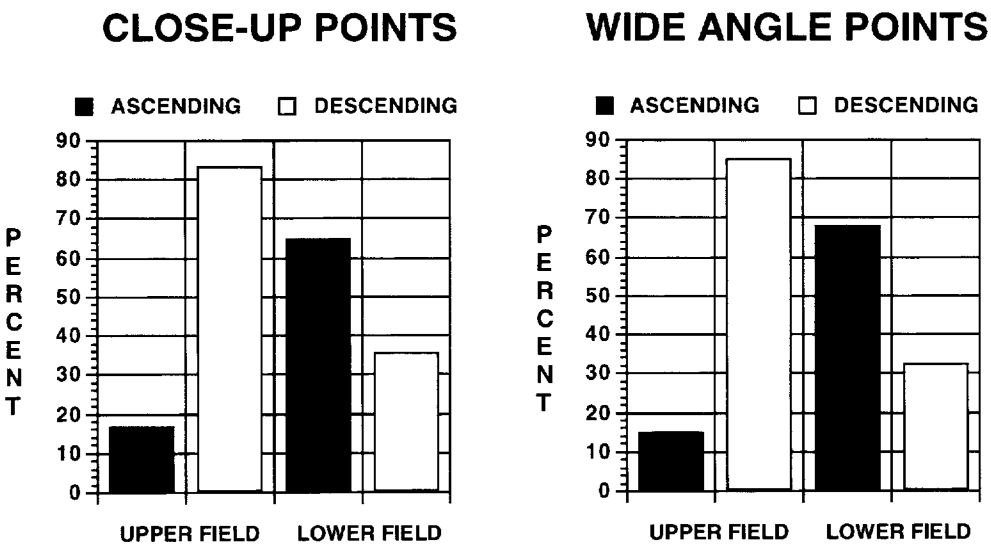

Fig. 2. The percentage of upper-field and lower-field points that were shifted in the opposite direction (either ascending or descending) from the original photographs to the remembered drawings. The data for the close-up scenes are shown in the left panel, whereas the data for the wide-angle scenes are shown in the right panel.

Methods

The analysis used in the present study was performed on the data from Experiment 2 of Intraub and Richardson [7]. In that experiment, 20 common scenes were photographed using two different settings on a zoom lens, to create a relatively 'close-up' view and a relatively 'wide-angle' view of each scene. Forty-one subjects (all undergraduates at the University of Delaware) were presented with the 20 scenes, in a slide format; half of the slide scenes were shown in the close-up version and the other half were shown in the wide-angle version. The slides were presented to subjects in a large auditorium, for 15 sec each; depending on where subjects were seated, the size of the projected images ranged from $14^\circ \times 22^\circ$ to $30^\circ \times 44^\circ$. Subjects were told to "focus their full attention on each picture and to remember it in as much detail as possible" [7] (p. 183) and were required approximately 48 hr later to draw the six pictures that they remembered best in a rectangle that had the same horizontal-to-vertical aspect ratio (1.5:1) as the original slide. (Subjects actually drew an average of 5.4 pictures, for a total of 222 remembered drawings.)*

In attempting to determine whether vertical shifts occurred in the remembered scenes, the following procedures were used. First, the 40 slides originally used by Intraub and Richardson

* See Intraub and Richardson [7] for further methodological details concerning the task and stimuli.

were printed and copied, with the aspect ratio remaining approximately the same (1.43:1). The original scene and all drawings of it were then reviewed, and a set of landmarks that were clearly visible in both the original image and the majority of drawings at recall were identified (e.g., the top of the fence and the top of the trashcans in Fig. 1B). A total of 138 landmark points from 84 drawings of the close-up photographs and 337 points from 128 drawings of the wide-angle photographs were selected for analysis. The total number of drawings analyzed in this study (210) was slightly less than that analyzed by Intraub and Richardson [7], because 12 drawings had no points that could be legitimately matched with the original photograph (e.g., a drawing of a pizza lying upside down on a table relative to its position in the original photograph was excluded from the present study's analysis). The reason that more points per drawing were selected in the wide-angle set (2.63) than in the close-up set (1.64) is that many major elements of the scene were partly obscured in the original close-up photograph (e.g., the top of the fence is not fully present in the close-up photograph shown in Fig. 1A).

All measurements were expressed as a percentage of the distance from the midline to the upper or lower boundary of the photograph or drawing. The percentage distance of each point in the drawings was then subtracted from the percentage distance of each corresponding point in the original, to obtain a 'vertical shift' score.

Results

All but one of the points in the remembered drawings exhibited a vertical shift relative to its counterpart in the original photograph. The average vertical shift was downward in both the close-up (−15.0%) and wide-angle (−9.5%) drawings. The downward shift of the average point reflected the fact that a majority of points overall shifted downward in both sets of drawings (66.6% in the close-ups, 62.5% in the wide-angles). Because some drawings had many more measured points than others, the overall downward-shift bias could conceivably have been caused by substantial shifting in only a few drawings. In fact, however, the percentage of drawings that showed a mean overall downward shift (67.9% and 63.5% for the close-ups and wide-angles, respectively) closely matched the downward-shifting prevalence when the points were examined individually. When all points were averaged together across all remembered drawings of a particular photograph, a similar trend was evident: 10 of the close-up scenes were associated with greater downward shifting, five with greater upward shifting and two exhibited no vertical shifting,* whereas 12 wide-angle scenes were associated with greater downward shifting, seven with greater upward shifting and one showed no vertical change. Only three of the original 20 pictures—a horn on a wall, a fruit plate as viewed from directly above and a television set shown at eye level—were associated with upward shifting in both the close-up and wide-angle views.

* Three of the close-up scenes (the laundry basket, the vase and the typewriter) had no drawings made of them.

One factor that could have caused a greater downward shifting in the drawings from memory was the predominant upper-field location of the original close-up and wide-angle landmark points (65.2% and 57.4%, respectively, were located in the upper-field). Because a general contraction of the image would be expected to lower the vertical position of the upper field points and raise the height of those points originally located in the lower field, an overall downward shift could have occurred secondarily to the overall contraction tendency (i.e. distance shift). However, fewer lower-field points were shifted upward in both the close-up and wide-angle drawings (64.6% and 67.8%, respectively) than were upper-field points shifted downward (83.3% and 85.0%, respectively) (see Fig. 2). Chi-square analyses performed on the upper- and lower-field shifts showed significantly more opposite shifting for the upper-field points than for the lower-field ones [$\chi^2(1\ \text{d.f.})=6.18$, $P<0.05$ for the close-ups; $\chi^2(1\ \text{d.f.})=13.92$, $P<0.001$ for the wide-angles).

Greater downward shifting could also have resulted from an overall contraction of the scene in memory had the lower-field points resided closer to the horizontal meridian than the upper-field points in the original photographs, because an equivalent contraction would have produced a smaller percentage change *relative to the size of the overall scene* for points lying closer to the center of the image. However, the lower-field points in the original image were actually located *farther away* vertically from the center of the image ($x=-45.9\%$ and -31.1% for the close-ups and wide-angles, respectively) than were the upper-field points ($x=+22.8\%$ and $+24.6\%$, respectively). Moreover, despite their more eccentric original position, the lower-field points shifted less on average than their upper-field counterparts in both the recalled close-up drawings (Δ +12.4% versus Δ −29.6%) and wide-angle ones (Δ +19.6% versus Δ −31.2%).

Discussion

This study's re-analysis of the data from Intraub and Richardson's study [7] revealed that remembered scenes are associated with both an overall contraction and a downward shift of the original image, resulting in an expansion of the boundaries of the original scene that is most pronounced in the upper visual field. Two alternative hypotheses will be put forth as to why vertical shifting in scene memory occurs, along with speculation concerning the neural substrate of this phenomenon.

The first hypothesis is based on the natural slope of the ground plane upward and away from the observer and the consequent ecologically derived relationships between near space and the lower visual field and far space and the upper field [11]. This 'ecological' hypothesis, which essentially represents an extension of Previc's theory [11] into the area of memory, predicts that the upper field will be more greatly represented whenever a scene is remembered at a greater distance (as is the case during 'boundary extension'). This 'ecological' hypothesis is consistent with the critical role of the medial occipital–temporal cortex (which receives inputs predominantly from the peripheral upper visual field) in topographical memory [3, 8].* Two findings argue against this hypothesis, however: (1) downward shifting was almost equally prevalent in the close-up and wide-angle remembered drawings (see Fig. 2), even though Intraub and Richardson [7] showed that wide-angle pictures are subject to less of a 'distance shift' in memory; and (2) consistent *upward shifting* occurred for the close-up and wide-angle versions of three scenes (the horn, fruit plate and television).

An alternative hypothesis is that the downward shift results from the recreation, during the memory process, of *an elevated head-view* of the original scene. Whereas Intraub and Richardson's photographs were typically taken with the camera at or near eye-level, most of their images were of objects lying along the ground or on tables, *which would normally be viewed with the head above them*. By elevating the assumed head position during scene recall, the images would necessarily be remembered as having moved downward in the visual field. In support of the 'prototypical head position' hypothesis, only when the camera mimicked a head position that would normally be close to level with the scene (as in the 'horn on the wall' and 'television' slides) or when the camera was placed at a higher angle than normal (as in the 'god's eye' view of the fruit plate) did a consistent *upward shift* occur. Moreover, in certain photographs wherein a well-defined perspective was present (e.g., the six-pack of bottled beer sitting on a table), the majority of drawings from memory displayed a perspectival splay that clearly indicated a downward view of the scene (see also Fig. 1 of Nystrom [10]). The fact that downward shifting primarily occurred for those pictures normally seen from above indicates that the assumption of an elevated viewing angle in memory was probably not related to the head position relative to the paper during the actual *drawing* of the remembered scene; indeed, 'boundary extension' is also obtained when memory is tested using a recognition procedure in which the original and test pictures are both oriented vertically on the presentation screen [7]. Rather, assumption of a 'protypical head position' may represent an intrinsic aspect of the memory representational process and thereby be linked to the recent discovery of 'head direction' cells in the parahippocampal gyrus, anterior thalamus, cingulate cortex and other brain areas believed to play an important role in scene memory [13].

Given that the elevated head position in erect primates has allowed us to see a larger expanse of the higher, distant natural world (i.e. the distant ground plane and neighboring sky) than is typically visible to most mammals, the 'ecological' and 'prototypical head position' hypotheses are clearly related. However, the assumption of a prototypical head position on visual scene memory is dissociable from the imposition of an 'ecologically appropriate' (i.e. greater) radial distance, given that 'boundary extension' can occur even for upward-shifted scenes.

Of course, it is not entirely clear whether the vertical biases observed in the remembered drawings in the study of Intraub and Richardson [7] are entirely due to memory processes *per se*. 'Boundary extension' has been shown to occur even at a 1-sec delay interval [6, 7], so that it is conceivable that perceptual biases may also contribute to the downward shifting. Preliminary evidence suggests that vertical shifting even occurs while subjects directly copy a scene from a slide that is available for continuous inspection.*

In summary, a re-analysis of the data from Intraub and Richardson [7] further documents the spatial distortions inherent in our visual scene memories. It is highly likely that, in addition to any cognitive schemas that may be employed, a prototypical visuospatial framework consistent with the ecological features of our natural three-dimensional world and our normal location within it is used in remembering scenes. A task for neuropsychologists is to identify the neural systems that, when damaged, prevent the generation of spatially and cognitively biased visual scene memory representations in humans.

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* A similar downward shift of a visuospatial array in memory reportedly occurs even in a temporal-lobectomized population, however [9].

* We recently conducted a brief comparison of vertical biases in drawing from immediate memory versus directly copying three of the scenes that were associated with downward shifting in the Intraub and Richardson study: the fence and trashcans shown in Fig. 1, a pizza slice surrounded by a carton on a table, and a six-pack of beer sitting on a table. Ten subjects were asked to draw each scene after immediately turning their backs on the slide, while a second group of 10 subjects was allowed to view the scenes while at the same time drawing them. Significant downward shifting was observed in both situations, although the mean downward shift was greater in the immediate-recall condition (14.5%) than in the direct-copy condition (9.8%). Nine of the 10 subjects in the immediate-recall group exhibited a downward shift in their drawings (the remaining one showed no shift), whereas eight of 10 subjects showed a downward shift in the direct-copy condition. The significant downward shifting found in the direct-copy condition is not necessarily indicative of a vertical bias in perception *per se*, however, given that subjects had to switch from the slide to the paper even in this condition, thereby presumably resulting in their drawing the scenes from an immediate memory representation. By contrast, one of us (H.I.) has informally observed that the 'boundary extension' phenomenon does not occur when subjects verbally describe a scene that they remain visually fixated on.

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