Cross-cultural effects on the assumed light source direction: Evidence from English and Hebrew readers

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When judging the 3D shape of a shaded image, observers generally assume that the light source is placed above and to the left. This leftward bias has been attributed to experiential factors shaped by the observers' handedness or hemispheric dominance. Others have found that experiential factors can rapidly modify the direction of the assumed light source, suggesting a role for learning in shaping perceptual expectations. In the current study, instead, we assessed the contribution of cultural factors affecting the way visual scenes are customarily inspected, in determining the assumed light source direction. Left- and right-handed first language English and Hebrew participants, who read and write from left to right and from right to left, respectively, judged the relative depth of the central hexagon surrounded by six shaded hexagons. We found a left bias in first language English participants, but a significantly smaller one in Hebrew participants. In neither group was the light direction affected by participants' handedness. We conclude that the bias in the assumed light source direction is affected by cultural factors, likely related to the habitual scanning direction employed by participants when reading and writing their first language script.

Introduction

Observers use various depth cues in order to recover the three dimensional shape of surfaces from their retinal image. Shading aids the recognition of objects by exploiting the fact that darker surface areas are oriented away from the light source, while lighter areas face it (Horn, 1975). When judging the shape of shaded objects while no information is present about the position of the light source, people tend to assume that the light source is located above, rather than below the object itself (Cavanagh & Lecerc, 1989). Therefore a shaded grey sphere will usually be reported as convex when lighter at the top and concave when lighter at the bottom. This assumption reflects an environmental regularity as sunlight and most artificial lights are placed above the observer (Ramachandran, 1988). Research into the cerebral basis of shape from shading has suggested that the estimation of the light source direction depends on a low level mechanism, within early visual areas (Gerardin, Kourtzi, & Mamassian, 2010; Humphrey et al., 1997; Mamassian, Jentzsch, Bacon, & Schweinberger, 2003). Behavioral data have offered some confirming evidence to this idea, for example, demonstrating that the light source is predominantly represented in retinal or head-centric coordinates (Howard, Bergstrom, & Ohmi, 1989; Kleffner & Ramachandran, 1992; Wenderoth & Hickey, 1993) but gravitational influences on shape judgments have also been found (Adams, 2008; Yonas, Kuskowski, & Sternfels, 1979).

Intriguingly, using a visual search task, Sun and Perona (1998) found that observers were faster at discriminating the shape of convex and concave hemispheres when the shading was consistent with the light source being placed above and left of vertical by as much as 60°. Subsequent reports have confirmed that the assumed light source direction is biased to the left of the observer (Gerardin, de Montalembert, & Mamassian, 2007; Mamassian & Goutcher, 2001; McManus, Buckman, & Woolley, 2004; Thomas,

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Nardini, & Mareschal, 2010). Yet the reason for this bias remains unclear.

Sun and Perona (1998) reported a correlation between handedness and left bias, with left-handed observers demonstrating a weaker leftward bias than right-handed participants. These authors suggested that the habit of positioning light sources on the side opposite to the hand used to write, to avoid casting a shadow with their writing hand, may underlie this correlation. Thus, right-handed individuals would preferentially place a desk lamp on their left, and therefore would have more experience with light originating from the left than from the right. The authors suggested that left-handed individuals have a reduced left bias rather than a mirrored symmetric bias to the above right with the fact that the environment is suited to the predominantly right-handed population, which results in lighting in the environment being placed to benefit right-handed people.

Even though subsequent studies have failed to confirm a handedness difference in the assumed light source direction (e.g., Mamassian & Goutcher, 2001; McManus et al., 2004), the suggestion that biases are influenced by learning and experience has received experimental support. Thomas et al. (2010) investigated the development of shape perception and found that young children, before age 6, assumed the stimulus was convex regardless of lighting direction, but the left bias arises around the time when children achieve literacy. Furthermore, Adams, Graf, and Ernst (2004) modified the shape judgments of shaded spheres by implementing a training phase whereby haptic information about visually presented spheres was incompatible, meaning some spheres which looked convex felt concave or vice versa. This modification of perceived shape generalized to a different task, suggesting that the assumed direction of the light source was updated rather than the shape assigned to specific spherical stimuli. These studies support the assumption that the left bias depends on learned regularities in the environment.

Mamassian and Goutcher (2001) suggested instead that biases in the assumed direction of the light source reflect a visual field preference, similar to the left bias found in other visual processes. For example, Beaumont (1985) found that when making aesthetic judgments participants demonstrate a preference for the left side of objects or objects positioned on the left. Similarly there is also a preference to recognize faces using the right side of the face, the side which appears in the left visual field (Campbell, 1978). Finally, line bisection tasks show a tendency for healthy subjects to overestimate the length of the left side (Bowers & Heilman, 1980). These results are thought to reflect a right hemispheric advantage in the processing of visual information. However, several studies have demonstrated that visual biases are influenced by cultural factors: For example Hebrew and Arabic participants, who read from right to left, show a right side preference in tasks using non-verbal stimuli (Chokron & De Agostini, 2000) and a reversal of the line bisection bias (Chokron & Imbert, 1993), suggesting that lifelong learned habits, including scanning direction, affect visual processes.

The current study tested right- and left-handed English and Hebrew participants on a shape from shading task, designed to measure participants' assumed light source direction. If the assumed light source bias is related to the observer's handedness, as proposed by Sun and Perona (1998), then a difference between the left- and right-handed participants would be expected in both groups. On the other hand, if cultural factors influence the assumed light source direction, then the Hebrew participants may demonstrate opposite or smaller biases than the English participants.

Gerardin et al. (2007) suggested that previously used stimuli, including spheres (Sun & Perona, 1998) and undulated stripes, (Mamassian & Goutcher, 2001) may not have contained much salient depth. To address this issue, we generated a novel stimulus, the "honeycomb," which contains depth information both along the inner and outer edges of the figure (see Figure 1).

Experiment 1

In the first experiment we estimated the assumed light source direction in right and left handed first-language English speakers using the honeycomb stimulus. The stimulus consisted of a central hexagon surrounded by six shaded hexagons. Participants reported whether the central hexagon appeared pushed in or out compared to the surrounding hexagons (see Figure 1). The stimulus was presented in different orientations, allowing the assumed light source directions to be estimated.

Participants

Fourteen students at Bangor University (aged 20–42) were recruited and received course credit for their participation. Seven participants were right handed and seven left handed. Handedness was assessed using the Edinburgh Handedness Inventory (Oldfield, 1971). All participants had normal or corrected-to-normal vision. Participants' first language was English. The experiment was approved by Bangor University's ethical

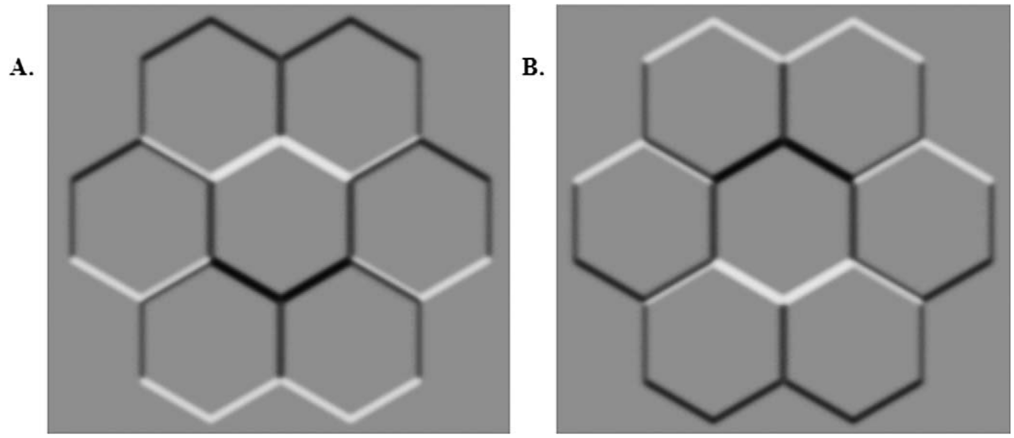

Figure 1. Experimental stimulus, displaying the middle level of blur. (A) stimulus with light and shadow placed as though lit from directly above. (B) stimulus rotated 180°.

committee and complied with the declaration of Helsinki.

Apparatus and stimuli

Participants were tested in a dimly lit room. A Dell LCD monitor was used to present the stimuli. A chin rest was used to ensure that participants maintained a constant distance of 60 cm from the screen.

The stimuli were drawn using proprietary software (Inkscape, Software Freedom Conservancy, Inc. Brooklyn, NY) and presented on E-Prime (Psychology Software Tools, Pittsburgh, PA). The stimuli consisted of seven hexagons on a grey background; each edge was either brighter or darker than the background, giving the impression that the hexagons were lit from one side (see Figure 1). The stimulus size was 17.6° diameter. This stimulus orientation was varied over 24 levels, 15° apart.

Procedure

Each participant's handedness was tested using the Edinburgh Handedness Inventory. Participants completed a practice block of 24 trials followed by four testing blocks consisting of 240 trials. Each stimulus orientation was presented 40 times in a random sequence.

Each trial began with a fixation cross presented for 1000 ms followed by the stimulus, presented for 500 ms (1000 ms in the practice trials). Immediately after the stimulus presentation, a prompt appeared on screen containing the following written question "is it in (left) or out (right)?" This prompted the participants' response. Participants pressed one of two keys indicating whether they perceived the center hexagon to be pushed in or out.

Results and discussion

The relation between the proportion of convex judgments ("out" response) and the stimulus orientation was estimated for each participant using a multivariate logistic regression:

$$p(\mathrm{C}|\theta) = \frac{1}{1 + e^{-f(\theta)}}$$

The independent variables included a constant term and a series of sine and cosine functions of the stimulus orientation, θ, in the image plane:

$$f(\theta) = \alpha_0 + \alpha_1 \cdot \cos(\theta) + \beta_1 \cdot \sin(\theta)$$

The assumed light source direction was then computed using the following formula:

$$O_{light\_source} = \tan^{-1}\left(\frac{\beta_1}{\alpha_1}\right)$$

Negative values for the assumed light source direction indicate biases to the left of vertical.

Figure 2 shows the proportion of trials in which a typical participant reported the central hexagon to be pushed out as a function of the orientation of the stimulus.

In order to establish whether a participant's reports were significantly modulated by the orientation of the stimulus, we computed the ratio of the log-likelihoods of two models. The first one included only the constant term among the independent variables; the second included the first sinusoid and cosinusoid term of the harmonic series. The ratio of the log-likelihood has an approximately chi-square distribution with two degrees of freedom. Participants whose log-likelihood ratio had a p value greater than 0.01 were not included in the group level analysis. None of the participants in the English group met this criterion.

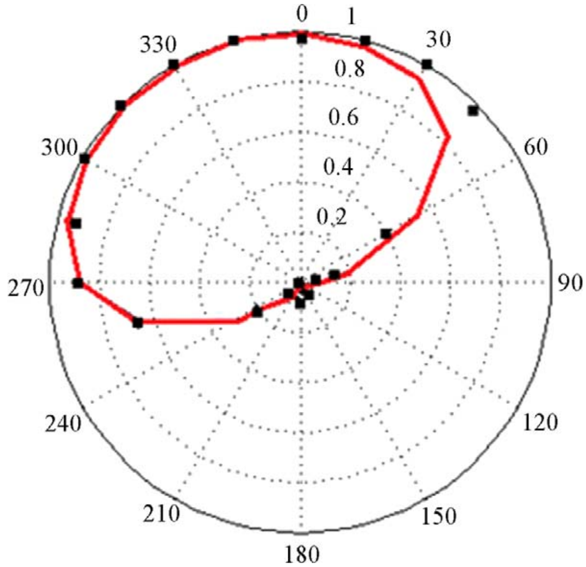

Figure 2. Data for one representative participant whose assumed light source was estimated to be 22.5° to the left of the vertical. The filled circles show the proportion of "out" responses for each stimulus orientation. The red line shows the model fit. The 0° orientation corresponds to stimuli where the central hexagon was brightest at the top.

Figure 3. Graph displaying the mean light bias in degrees for the left- and right-handed participants in the English and Hebrew speaking groups. Negative bias scores indicate scores left of vertical. Error bars indicate two standard errors.

Effect of handedness

The light source bias in the right- and left-handed groups is shown in Figure 3. The light bias was similar for the left-handed ($M = -30.14°$, $SE = 6.44$) and the right-handed ($M = -29.44°$, $SE = 5.69$) participants. An independent sample t test showed no significant difference between left- and right-handed participants, $t(12) = -0.08$, $p = 0.94$. Similarly, the Spearman's correlation between strength of handedness, as assessed using the Edinburgh Handedness Inventory (Oldfield, 1971), and assumed light source direction was not significant, $r = 0.04$, $p = 0.89$.

The data, obtained with the honeycomb stimulus, demonstrated a consistent left lighting bias in English readers. Our findings confirm there is no effect of handedness on assumed light source direction, in agreement with previous reports (Mamassian & Goutcher, 2001; McManus et al., 2004).

Experiment 2

We then estimated the assumed light source in first-language Hebrew participants. If cultural factors influencing habitual scanning direction also affect the processing of shaded stimuli, then the Hebrew participants may show a smaller left bias, or a right bias. To test further the effect of handedness, we tested right- and left-handed participants.

Participants

Seventeen participants (nine right handed) from Ben-Gurion University of the Negev in Israel, aged 20–25, took part in the experiment for course credit. All were first-language Hebrew and had normal or corrected-to-normal vision. Participant's handedness was established by self-report. The experimental protocol was approved by Ben-Gurion University.

Apparatus and stimuli

The apparatus was identical to the apparatus used in Experiment 1 and stimuli were viewed at the same visual angle, ensuring that any differences between groups were not due to differences in the physical appearance of the stimuli.

Procedure

The procedure was identical to the procedure used in Experiment 1.

Results

Two right-handed participants showed log-likelihood ratios of $p = 0.56$ and $p = 0.49$, suggesting that their responses were not modulated by the stimulus' orientation, so their results were excluded from the study. A left-handed participant was also excluded as their results were consistent with the assumption that the light was coming from below rather than above. Therefore 14 (seven right-handed) Hebrew speakers remained in the analysis.

The assumed light source direction did not differ significantly between right-handed ($M = -8.23°$, $SE =$ 5.7) and left-handed ($M = -8.09°$, $SE = 5.34$) Hebrew participants, $t(13) = 0.018, p = 0.99$.

Next, we compared estimates of the assumed light source direction in the Hebrew and the English participants. The average bias for the Hebrew readers was –8.16° ($SE = 3.75$; range = –31.02°–18.32°), while the average bias for the English readers was –29.79° ($SE = 4.13$; range = –58.19—9.74; see Figure 3). A factorial ANOVA with handedness (right and left) and group (English and Hebrew) as factors showed a significant effect of group, $F(1, 24) = 13.9$, $p = 0.001$, $\eta^2_p = 0.37$. The main effect of handedness was not significant. $F(1, 24) = 0.002$, $p = 0.96$, $\eta^2_p < 0.001$, nor was the interaction of handedness and group, $F(1, 24) = 0.01$, $p = 0.94$, $\eta^2_p < 0.001$.

General discussion

Three conclusions can be drawn from this study: First, the light-source bias is not influenced by the observer's handedness. Second, cultural factors may affect the assumed direction of the light source. Finally, regardless of handedness and experience, there appears to be a default bias to place the light source left of vertical. We discuss each point in some detail.

Sun and Perona (1998) found that the bias in the assumed light source direction was related to handedness. In agreement with subsequent studies (Mamassian & Goutcher, 2001; McManus et al., 2004), we did not find any difference between left- and right-handed participants, suggesting that handedness is not a crucial determinant of the light source bias.

We did, however, find a difference in the direction of the assumed light source between first language English and Hebrew participants. Although the participants in both language groups displayed a left bias, the bias was significantly smaller in the Hebrew than in the English participant group. This group difference cannot be attributed to experimenter induced effects. Participants in both groups were instructed only to indicate the perceived shape of the honeycomb stimulus and were naïve to the concept of light source biases. Furthermore, the procedure and the physical appearance of the stimuli were identical in both groups. Similar results have been found in visual processing of objects and faces. Right-to-left readers do not show the same left visual processing bias as left-to-right readers, demonstrating instead a preference for the right side of objects (Chokron & De Agostini, 2000; Chokron & Imbert, 1993) and a reduced left visual field bias in face processing (Gilbert & Bakan, 1973). Chokron and DeAgostini (2000) state that reading direction can affect the way attention is directed, resulting in observers directing attention toward the side on which they begin reading. Therefore, Hebrew readers may direct their attention toward the right of stimuli and place higher perceptual value on the right side of objects. This preference would result in different object and light manipulations within their environment and subsequently affect their lighting preferences.

While processing faces and objects depends on the direction of scanning the stimulus, performing a shape from shading task requires recalling the light source direction from internal representations. Our results imply that habitual scanning direction affects the internal layout of these representations. Independent support for this interpretation comes from a study with hemispatial neglect patients. Neglect occurs after a lesion to the right hemisphere, which results in patients ignoring the left side of space (Heilman, Watson, & Valenstein, 1979). The bias towards the right occurs not only for external stimuli but also for mental representations of the environment (Bisiach & Luzzatti, 1978; Vuilleumier, Ortigue, & Brugger, 2004). A recent study found in some patients with neglect a diminished left bias for the assumed light source direction (de Montalembert, Auclair, & Mamassian, 2010).

Hebrew participants did not show the opposite bias, but rather a smaller left bias than the English participants. There are two possible explanations for this finding. First, it is possible that the default assumed direction of light is left but is being modified by habits related to the customary reading direction. Adams et al. (2004) found that individual's light source assumptions are quickly modified by new information, and predicted that the bias will return to the above left when this new information is no longer relevant. Therefore, Hebrew observers could have a reduced left bias because of reading direction and experience in their environment, but the bias remains left because this is the default bias caused by some unrelated factor. This suggestion implies that the left bias is due to a default factor such as hemispheric dominance.

An alternative explanation may be based on the fact that Hebrew readers are not pure right to left readers. For example, although letters are written from right to left in Hebrew, numbers are written from left to right. In addition, children in Israel generally learn English starting from fourth grade. All our Hebrew participants were university students, with some exposure to English. Maas and Russo (2003) tested the directional preference in the mental representation of spatial events in three groups of students at an Italian University:

Italian students, Arab students tested in Italian, Arab students tested in Arabic, and a fourth group of Arab students attending university in their home country. Opposite directional biases were found in Italian and Arab students studying in their home countries; however, the Arab students studying in Italy, whether responding in Italian or Arabic, did not show a significant bias in either direction. This result shows that not only can the reading direction you are exposed to from an early age affect the visual processing bias, but also that exposure to more than one reading direction can modify processing biases.

In summary, handedness does not contribute to the lighting bias. Instead, it appears to be cultural habits that affect the bias, particularly the exposure to the direction in which a language is read. So far, there is no conclusive explanation for why people show a left lighting bias.

Keywords: light source assumptions, shape from shading, scanning direction

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