Effect of Gaze Orientation on Tactilo-Kinesthetic Performance

Sylvie Chokron,*·† Paolo Bartolomeo,‡·§ Pascale Colliot,* and Laurent Auclair*

*LPE, CNRS, Grenoble, France; †Service de Neurologie, Fondation Ophtalmologique Rothschild, Paris, France; ‡Unité Inserm U324, Paris, France; and §Département de Neurosciences, Hôpital Henri Mondor, Créteil, France

Twenty-two normal right-handed subjects indicated with their index finger the midpoint of a horizontal rod that they could not see. Subjects performed this task while directing their gaze either centrally or toward four different locations (5° or 30° to the left or to the right of the midline). Results showed an overall leftward bias in rod bisection, which increased when subjects used their right hand and fixated a right-sided visual target. Thus, orienting of gaze can affect a nonvisual, tactilo-kinesthetic spatial task. The possible mechanisms of this interaction are discussed with respect to activation-orienting theories egocentric hypotheses and directional trends.

INTRODUCTION

Subjects suffering from left unilateral neglect are impaired in responding to stimulation in the hemispace controlateral to the brain lesion. When these patients are asked to bisect a line at its center, they frequently make massive rightward errors (Schenkenberg, Bradford, & Ajax, 1980).

Applied to normal subjects, visual and tactilo-kinesthetic bisection protocols has enabled numerous authors to describe a smaller but systematic leftward deviation of the subjective middle (Bowers & Heilman, 1980; Bradshaw, Nathan, Nettleton, Wilson, & Pierson, 1987; Chokron & Imbert, 1993a; Sampaio & Chokron, 1992; Sampaio & Philip, 1991). This phenomenon was called ''pseudoneglect'' by Bowers and Heilman (1980) to designate the error in the opposite direction to that made by patients suffering from left unilateral neglect.

Pseudoneglect has been explained in terms of hemispheric activation. In a case of a normal right-handed, it has been argued that the spatial nature of the bisection task, which preferentially activates the right hemisphere, would entail an attentional bias to the left hemispace, with resultant enhancement of the left perceptual field, and thereby a leftward deviation of the subjective middle (Bradshaw et al., 1987; Scarisbrick, Tweedy & Kuslansky, 1987). This ''enhancement hypothesis'' is thus a corollary of the ''activation-orienting'' theory (Kinsbourne, 1970a; Kinsbourne, 1970b), which stipulates that distribution of attention in space is biased toward the direction controlateral to the most activated hemisphere.

Rather than linking the position of the subjective middle during bisection to the respective activation of each hemisphere. Jeannerod and Biguer (1989), have proposed that rod bisection and pointing straight ahead protocols are a way to record the position of the egocentric reference (ER). According to these authors egocentric body coordinates such as body midline (or sagittal axis) are represented as a reference (called the egocentric reference) for actions direction to objects within extracorporeal space. In this view, asking the subject to indicate the subjective centre of a tactually explored rod is just an indirect way of recording the position of his egocentric reference, and reciprocally, the position of this reference is seen as determining the position of the subjective middle in bisection.

According to the egocentric hypothesis (Jeannerod & Biguer, 1987; Jeannerod & Biguer, 1989), orienting the subject's gaze to one hemispace a controlateral deviation of the egocentric reference. Moreover, according to these authors (1989), the less the gaze is deviated, the more should be the contralateral deviation, because "when the angle between the eyes and the trunk axis is small (i.e., $\pm 5°$), eye position signals are too weak to be used as an index of the permanent eye deviation. When this angle increases, eye position signals become perceptible and can be used for detecting the deviation of the eyes with respect to the head/trunk axis, so that pointing get closer to the actual straight ahead" (1989).

The aim of the present study was to examine this latter hypothesis by manipulating the gaze direction while tactually bisecting a rod.

The protocol used here was adapted from Jeannerod and Biguer (1989). We imposed five gaze directions (30° left or right, 5° left or right and 0°) to normal subjects while they were bisecting a rod on the basis of tactilo-kinesthetic information.

METHOD

Subjects

Twenty-two right-handed Psychology students (11 women, 11 men), between the ages of 21 and 34 years. The average age was 24,9 years. Their handedness was defined using Delatollas and colleagues' questionnaire (Delatollas et al., 1988), and they all have only left-to-right reading habits.

Stimuli

Two rods of 5 mm in diameter, fixed to a wooden support and placed on a table bearing a mark corresponding to the sagittal middle of the subject. This is an adaptation of an apparatus used in previous studies (Bowers & Heilman, 1980; Chokron & Imbert, 1993a; Sampaio & Chokron, 1992; Sampaio & Philip, 1991). The rods were 12 and 24 cm in length.

Procedure

The experiment took place in a quiet dark room. At the start of each trial, the subjects were asked to look at an illuminated light emitting diode (LED) at 5° or 30° to the left or right, or at 0°. The LEDs used as visual targets were displayed on a screen at 57 cm from the subject. Zero degrees corresponded to the subject's sagittal middle. The to-be-bisected rod was presented in the horizontal plane and was covered to prevent the subject looking at his/her hands. The rod was centered with respect to the subject's sagittal middle. The subject's head position was ensured by a chin-rest and the trunk was maintained in a straight position by the way of a belt fixated aroud the chair. The test began when the experimenter placed the subject's index finger at one extremity of the rod. The subject was not limited in the number of movements back and forth along the rod. The exploration stopped at a point estimated by the subject as being the middle. Each subject performed 80 trials, 40 with the right hand and 40 with the left hand, the order of hand used was counterbalanced. Each block was divided into 20 trials starting from the right end and 20 starting from the left end of the rod. Each rod was explored with the five different positions of gaze: 5° to the left, 30° to the left, 0°, 5° to the right and 30° to the right. For each block the order of presentation of the two rods (different lengths), the hand used, the starting position (left or right extremity), and the position of the visual target (5° and 30°, left and right or 0°), were drawn at random. Each rod was therefore presented to the subject 40 times: once starting from the left, once from the right for each hand and for each of the five eye positions. All the conditions occured at random and differ from one subject to another. Thereby, data were collected for each condition according to the hand used, the length of rod, the starting point and the gaze direction.

The error was determined by measuring (in cm) the distance between the subjective middle and the objective middle of the rod (corresponding to the sagittal middle of the subject and to 0°). A thin plastic arrow (0.5 mm) was pasted on the index tip in orde to measure the error to the nearest millimeter. Leftward deviations carried a minus sign, whereas rightward deviations carried a plus sign.

RESULTS

The overall bisection was significantly deviated to the left of the objective middle ($m = -0.21$ cm, $t(21) = 3.03$, $p < .05$).

A repeated measures analysis of variance (ANOVA) was conducted with hand, gaze direction, and length as between subjects factors. The ANOVA revealed a significant effect of the hand used [$F(1, 21) = 15, 60$, $p < .005$], and of gaze direction [$F(4, 84) = 6, 01$, $p < .005$], on the position of the subjective middle.

The use of the right hand induced a significant leftward deviation of the subjective middle ($m = -0.39$ cm, $t(21) = 5.21$, $p < .05$), while the use of the left hand produced a nonsignificant leftward deviation ($m = -0.03$ cm, $t(21) = 0.34$ ns).

Concerning the effect of gaze direction on rod bisection, the more the visual target was deviated on the right, the more noticeable was the leftward deviation of the bisection (Fig. 1). In fact the only significant deviations of the subjective middle occured for 5° right ($m = -0.319$ cm $t(21) = 4.14$ $p < .05$) and 30° right gaze direction ($m = -0.491$ cm t21 $= 5.03$, $p < .05$) (Table 1).

Planned comparisons revealed that gaze directions differed significantly regarding the hemispace of visual fixation: the fixation 5° to the left differed significantly from

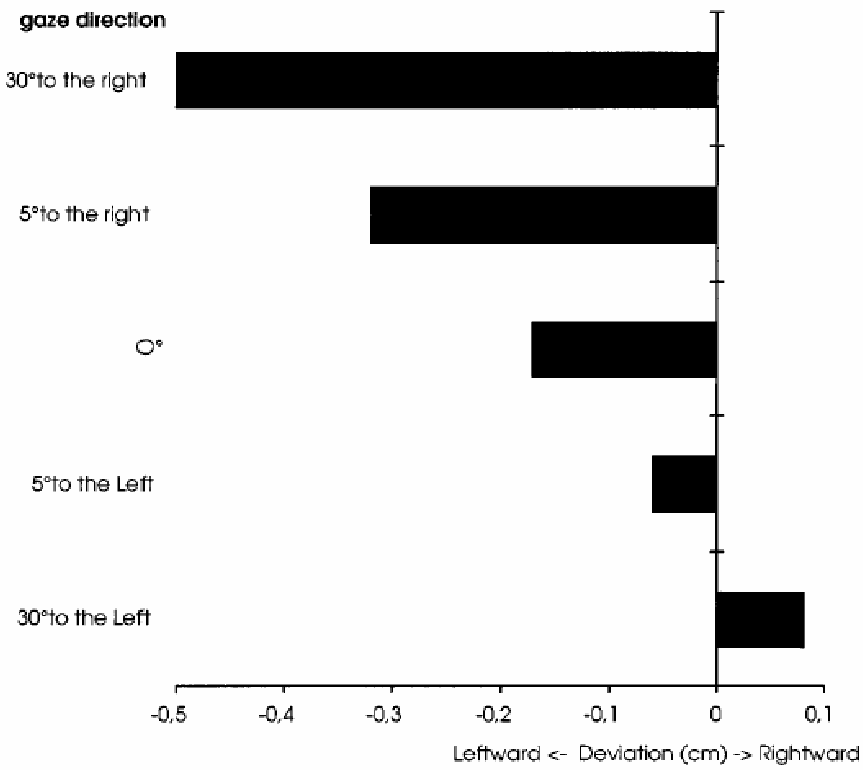

FIG. 1. Effect of gaze direction (in degrees) on the rod bisection.

TABLE 1
Effect of the Gaze Direction (30° to the Left, 5° to the Left, 0°, 5° to the Right, 30° to the Right) on the Deviation (in cm)

Gaze direction				
−30°	−5°	0°	+5°	+30°
+0.08 (0.45)	−0.06 (0.52)	−0.17 (0.50)	−0.32 (0.36)	−0.50 (0.46)

Note. (−) leftward deviations; (+) rightward deviations.

5° to the right [$F(1, 21) = 6, 55, p < .005$], and the fixation 30° to the left differed significantly from 30° to the right [$F(1, 21) = 11, 27, p < .005$]. Rightward visual fixations entailed significant leftward bisection, while leftward visual fixations induced a nonsignificant deviation of the subjective middle to the left for the 5° visual target, and to the right for more remote visual targets.

DISCUSSION

Normal dextrals were found here to bisect tactually a rod significantly to the left of the objective middle, in agreement with previous results (Bowers & Heilman, 1980; Bradshaw et al., 1987; Chokron & Imbert, 1993a; Sampaio & Chokron, 1992; Sampaio & Philip, 1991). We were also able to confirm here that leftward bias is magnified by the use of the right hand and by right-sided eye deviation (Chokron & Imbert, 1993a).

These effects of the hand used and of the gaze direction rule out any attempt to explain the leftward bias in bisection of normal subjects only in terms of hemispheric activation (Bradshaw et al., 1987; Kinsbourne, 1970a; Kinsbourne, 1987). Activation hypotheses would have in fact predicted exactly the opposite pattern, that is a maximal amount of leftward bias when the subjects use their left hand, and fixate a target in the left hemispace, because of the overactivation of the right hemisphere by the spatial nature of the task, the use of the left hand, and the deviation of the eyes to the left. On the other hand our results confirm some recent findings of Brodie and Pettigrew (1996) who found a systematic deviation of the subjective middle in line bisection, toward the side opposite to the hand used, thus again challenging the activation hypotheses.

As we have mentioned in the Introduction, egocentric hypotheses predict a deviation of the egocentric reference (here of the position of the subjective middle) contralateral to the eye deviation that may decrease as the gaze deviation increases (Jeannerod & Biguer, 1989). Our results confirm only partially this hypothesis in showing a bias contralateral to the eye position. However, we found that the more peripheral to the right the visual target is, the strongest is the leftward deviation tendency. Even if the most leftward visual target is able to induce a slight rightward deviation, our results indicate a gradient of leftward deviation that increases from gaze deviated 5° to the left to more rightward eyes deviation, including the baseline condition (0°) (Fig. 1). The fact that a lateralized visual fixation has not the same effect on straight ahead pointing and tactile bisection provides evidence against an interpretation of the leftward bias in bisection in normal subjects related only to the position of egocentric reference.

Apart from its role on hemispheric activation or on egocentric reference construction, gaze direction can be seen as behavioural correlate of automatically orienting of attention in space (Shepherd, Findlay, & Hockey, 1986). Regarding this hypothesis, the results of the present experiment and of those dealing with the effect of scanning direction in line bisection (Chokron, Bartolomeo, Perenin, Helft, & Imbert, 1998; Chokron & De Agostini, 1995; Chokron & Imbert, 1993b; Chokron, Perenin, & Imbert, 1993) suggest that directing attention to one side of space by staring at (or scanning toward as in previous experiments) a lateralized visual target leads to a contralateral spatial bias in both tactile and visual bisection in normal subjects. These findings confirm several studies concerning both normal and brain-damaged patients, showing that eye movements may orient the subject's attention toward the appropriate part of space not only during visual tasks but also in the tactile or auditory modality (Belin, Perrier, Cambier, & Larmande, 1988; Gopher, 1973; Honoré, 1982; Larmande, Blanchard, Sintes, Belin, & Autret, 1984; Larmande, Elghozi, Sintes, Bigot, & Autret, 1983) [see (Gainotti, 1993) for a review].

From a neurophysiological point of view, Heilman and his colleagues have been claiming for a long time that the left hemisphere mediates attention primarily for stimuli in right hemispace while the right hemisphere appears to attend to stimuli in both hemispaces (Heilman & Van Den Abell, 1980). Recently, they have collected more evidence for this hypothesis. Using infrared pupillography Kim, Barett, and Heilman (1999) have recorded changes in the pupillary diameter while subjects were looking and attending to the stimuli on the right and left sides of space. Their findings revealed more pupil dilatation when looking to a stimulus on the right than when looking toward the left. Looking (and therefore attending) rightward may induce a greater attentional arousal response than looking leftward because, when one looks rightward, both hemispheres activate the mesencephalic reticular formation (MRF) whereas when one looks leftward, only the right hemisphere activates the MRF.

According to these psychological and neurophysiological hypotheses, the asymmetry we observed here between left and rightwad gaze deviations could come both from the natural tendency of left-to-right readers to orient their attention to the right and from a greater neuronal activation when directing the gaze to the right rather than to the left hemispace.

In conclusion, the present experiment confirms the presence of a spatial bias in normal subjects, adds evidence for an effect of gaze direction on spatial attention and raise the question of an attentional rightward bias in normal subjects linked perhaps to reading habits. Further studies are needed to establish to what extent eyes signals and directional trends play a role on the orientation of attention in space in normals as well as in brain-damaged patients in the different sensory modalities.

ACKNOWLEDGMENT

This research was supported by a grant from the Rhône-Alpes Regional Council (Arrash and Thematiques contracts).

REFERENCES

Belin, C., Perrier, D., Cambier, J., & Larmande, P. (1988). Influence de la déviation pathologique du regard par lésion du tronc cérébral sur l'équilibre inter-hémisphérique. *Neuropsychologia,* **19,** 753–758.

Bowers, D., & Heilman, K. M. (1980). Pseudoneglect: Effects of hemispace on a tactile line bisection task. *Neuropsychologia,* **18,** 491–498.

Bradshaw, J. L., Nathan, G., Nettleton, N. C., Wilson, L. E., & Pierson, J. M. (1987). Why is there a left side underestimation in rod bisection? *Neuropsychologia,* **25,** 735–738.

Brodie, E. E., & Pettigrew, L. E. L. (1996). Is left always right? Directional deviations in visual line bisection as a function of hand and initial scanning. *Neuropsychologia,* **19**(4), 571–581.

Chokron, S., Bartolomeo, P., Perenin, M. T., Helft, G., & Imbert, M. (1998). Scanning direction and line bisection: A study of normal subjects and unilateral neglect patients with opposite reading habits. *Cognitive Brain Research,* **7,** 174–178.

Chokron, S., & De Agostini, M. (1995). Reading habits and line bisection: a developmental approach. *Cognitive Brain Research,* **3**(1), 51–58.

Chokron, S., & Imbert, M. (1993a). Egocentric reference and asymmetric perception of space. *Neuropsychologia,* **31,** 775–782.

Chokron, S., & Imbert, M. (1993b). Influence of reading habits on line bisection. *Cognitive Brain Research,* **1,** 219–222.

Chokron, S., Perenin, M. T., & Imbert, M. (1993). Scanning direction and line bisection. *Perception,* **22,** 120.

Delatollas, G., De Agostini, M., Jallon, P., Poncet, M., Rey, M., & Lellouch, J. (1988). Mesure de la préférence manuelle par auto-questionnaire dans la population française adulte. *Revue de Psychologie Appliquée,* **38,** 117–136.

Gainotti, G. (1993). The role of spontaneous eye movements in orienting attention and in unilateral neglect. In I. H. Robertson & J. C. Marshall (Eds.), *Unilateral neglect: Clinical and experimental studies.* Hove, UK: Erlbaum.

Gopher, D. (1973). Eye movements patterns in selective listening tasks of focused attention. *Perceptual Psychophysics,* **14,** 259–264.

Heilman, K. M., & Van Den Abell, T. (1980). Right hemisphere dominance for attention: The mechanisms underlying hemispheric asymmetries of inattention (neglect). *Neurology,* **30,** 326–330.

Honoré, J. (1982). Posture oculaire et attention sélective à des stimuli cutanés. *Neuropsychologia,* **20,** 727–730.

Jeannerod, M., & Biguer, B. (1987). The directional coding of reaching movements. A visuomotor conception of visuospatial neglect. In M. Jeannerod (Ed.), *Neurophysiological and neuropsychological aspects of spatial neglect.* Amsterdam: Elsevier.

Jeannerod, M., & Biguer, B. (1989). Référence égocentrique et espace représenté. *Revue Neurologique,* **145,** 365–369.

Kim, M., Barett, A. M., & Heilman, K. M. (1999). Lateral asymmetries of pupillary responses. *Cortex,* **34,** 753–762.

Kinsbourne, M. (1970a). The cerebral basis of lateral asymmetries in attention. *Acta Psychologica,* **33,** 193–201.

Kinsbourne, M. (1970b). A model for the mechanism of unilateral neglect of space. *Transactions of the American Neurological Association,* **95,** 143–146.

Kinsbourne, M. (1987). Mechanisms of unilateral neglect. In M. Jeannerod (Ed.), *Neurophysiological and neuropsychological aspects of spatial neglect.* Amsterdam: Elsevier.

Larmande, P., Blanchard, F., Sintes, J., Belin, C., & Autret, A. (1984). Test d'ecoute dichotique verbal et non verbal chez le sujet normal: influence de l'état d'activation hémisphérique chez les sujets normaux musiciens et non-musiciens. *Revue Neurologique,* **140,** 49–54.

Larmande, P., Elghozi, D., Sintes, J., Bigot, T., & Autret, A. (1983). Test d'ecoute dichotique verbal et non verbal chez le sujet normal: influence de l'état d'activation hémisphérique. *Revue Neurologique,* **139,** 65–69.

Sampaio, E., & Chokron, S. (1992). Pseudoneglect and reversed pseudoneglect among left-handers and right-handers. *Neuropsychologia,* **30,** 797–805.

Sampaio, E., & Philip, J. (1991). Sensory and motor aspects of pseudoneglect, hemifield and hemiespace in the tactile modality. *Brain and Cognition,* **16,** 74–82.

Scarisbrick, D., Tweedy, J. R., & Kuslansky, G. (1987). Hand preference and performance effects on line bisection. *Neuropsychologia,* **25,** 695–699.

Schenkenberg, T., Bradford, D. C., & Ajax, E. T. (1980). Line bisection and unilateral visual neglect in patients with neurologic impairment. *Neurology,* **30,** 509–517.

Shepherd, M., Findlay, J. M., & Hockey, R. J. (1986). The relationship between eye movements and spatial attention. *The Quarterly Journal of Experimental Psychology,* **38A,** 475–791.

This is doi:10.1006/brcg.2001.1368.