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Influence of Age and Sex on Line Bisection: A Study of Normal Performance with Implications for Visuospatial Neglect

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ABSTRACT

Line bisection is an established clinical task used to diagnose visuospatial neglect. To date, few studies have considered the extent to which age and sex as background variables contribute to bisection performance. Both variables affect the neural substrates underlying cognitive processes and hence the behavioural performance of bisection. The purpose of this study was to examine the effects of age and sex on normal bisection performance, using three different line lengths to elucidate the influence of these potential contributing factors. Seventy men and 70 women, divided equally into seven age-cohorts between 14 and 80 years, bisected lines. Results indicated clear age- and sex-related differences both in the magnitude and direction of bisection deviations across the three line lengths. Differences are discussed in terms of neural changes across the adult lifespan including hemispheric differences and hormonally mediated changes.

INTRODUCTION

Rightward deviation on line bisection following right hemisphere damage is one of the characteristic diagnostic markers of unilateral visuospatial neglect (Anderson, 1996; Fink et al., 2002; Halligan, 1995; Michel et al., 2003; Schenkenberg et al., 1980; Zivotofsky, 2004). Research over the last 30 years has shown that bisection performance can vary depending on stimulus or task properties such as line length, number of trials, and task instructions (Fink et al., 2002; Halligan & Marshall, 1988; Halligan et al., 1993). Although comparatively small there is also evidence that differences in non-stimulus properties, such as age and gender, also affect the neural substrates

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and hence the underlying cognitive processes involved in bisection (Bradshaw, 1989; Halpern, 1986; Hellige, 2001; O'Boyle & Hellige, 1989).

Advanced age is a poor prognostic factor for recovery after brain damage, possibly because of the superimposition of neural damage onto a nervous system already coping with the effects of aging (Ringman, Saver et al., 2004). At least three patterns of age-related changes in cognitive behaviour have been suggested: (1) life-long declines (Park et al., 2002; Schaie, 1996); (2) declines occurring late in life (Gregoire & Van der Linden, 1997); and (3) relative stability across life (Fromholt et al., 2003; La Voie & Light, 1994). The differences between these patterns indicate that, although aging can produce global effects, the effect on cognitive function differs (Salthouse & Ferrer-Caja, 2003), suggesting that some cognitive systems are more vulnerable to degradation and loss of neurons associated with age than others. Moreover, some researchers suggest that the two hemispheres decline to the same extent with advancing age but the effects of such aging are different on the two hemispheres (Goldstein & Shelly, 1981; Mittenberg et al., 1989). Others have suggested that the right hemisphere ages more rapidly than the left (Ellis & Oscar-Berman, 1989; Schaie & Schaie, 1977).

Sex is another relevant biological factor that has been shown to contribute to different cognitive performances. For example, females tend to score higher than males on tests of verbal fluency and manual skill whereas males tend to score higher than females on tests of visual perception and spatial ability (Bradshaw, 1989; Halpern, 1986; Hellige, 2001; Voyer, 1996), although these studies did not control for aging effects. While there is substantial overlap in the performance of the two sexes for many tasks, Hellige (2001) suggested that differences occur because the hemispheric asymmetry is not the same for males and females. This is plausible in view of the evidence that sex hormones influence cognition and brain function both at critical stages of ontogenetic development (Geschwind & Galaburda, 1987) and in adulthood as various hormonal levels fluctuate over time (Kimura & Hampson, 1994).

There is also evidence to suggest that the combined factors of age and sex can influence neural functioning and hence cognitive performance. Non-invasive radiological studies of brain atrophy found that the greatest amount of atrophy in elderly men was in the left hemisphere, whereas in women atrophy was more symmetric (Gur et al., 1991). These findings again point to potential sex differences in age-related changes in brain function and highlight the relevance of examining the contribution of both age and sex on line bisection performance.

Most studies of non-patient (i.e., control) line bisection performance show a reliable leftward bisection error [i.e., pseudoneglect (Bowers & Heilman, 1980)]. While the magnitude of this error in controls is considerably smaller (i.e., a few millimetres) than clinical cases with neglect, and the direction of deviation is to the left of true centre unlike right, pseudoneglect often depends upon stimulus and task factors. Many of the recent papers reporting pseudoneglect findings have focused on those factors that modulate bisection performance [e.g., scanning direction (Chokron & Imbert, 1993); task instructions (Fink et al., 2002); line length (McCourt & Jewell, 1999); cueing (Milner, Brechmann, & Pagliarini, 1992); or viewing distance (Varnava, McCarthy, & Beaumont, 2002)], rather than explicitly considering or controlling for the basic non-stimulus variables such as age and sex. For example, most studies of pseudoneglect employ young adults (often university students), while most subjects in control groups of clinical studies are age-matched (Jewell & McCourt, 2000). Most stroke patients with visual neglect are older than 50 years, so understanding age-related changes in the brain mechanisms that underlie visuospatial abilities is of both theoretical and practical value. Furthermore, many bisection studies have used mixed sex subject groups or often fail to distinguish the sex of subjects.

To examine the potential influence of age and sex, we used a differential line length bisection task previously employed in bisection studies to establish stimulus-based effects on spatial perception. Line length has a systematic influence on bisection error in most neglect patients (Halligan & Marshall, 1988; Ishiai et al., 1997; Mennemeier et al., 2002; Monaghan & Shillcock, 1998; Ricci & Chatterjee, 2001). Rightward deviation in many patients (but not all: Bisiach et al., 1983) with (left) neglect decreases with line length such that they appear more '*accurate*' on medium lines (e.g. 100 mm), and deviate leftwards on short lines (e.g., 20 mm) (Halligan, 1995; Marshall & Halligan, 1989; Mozer et al., 1997; Tegner & Levander, 1991). In those that show a decrease in the magnitude of deviation across line length, some deviate at a proportional rate; i.e., they deviate from objective centre by a constant percentage of the line's length (Bisiach et al., 1983; Halligan, 1995). Non-patient subjects also show a similar relationship between line length and the magnitude of deviation (Chokron & Imbert, 1993; Halligan et al., 1991; Luh, 1995; Manning et al., 1990; Wolfe, 1923). The finding that patients produce a lawful relationship between line length and magnitude of deviation suggests that in some sense the entire line must have been processed at some early processing stage (Halligan, 1995) and that it is the subsequent (impaired) cognitive or motor task demands that produce gross bisection deviations. However, in these studies, like many studies of pathological and normal bisection performance, age and sex have not been explicitly controlled for. The purpose of this study was to examine the effects of biological factors (age and sex) on normal line bisection using different line lengths. The study was designed to test the hypothesis that age and sex-related differences would influence bisection performance across different line lengths.

METHOD

Subjects

Ethical approval was provided by the Ethics Committee at Cardiff's School of Psychology. One hundred and fifty subjects, with no previous history of head trauma or neurological disease/disorder, consented to participate in the experiment. Subjects were recruited from the Cardiff University Participant Panel: the panel consists of volunteers from the local community who have signed up to the scheme following newspaper advertisements in the local press. They were each paid £3 for their time. All subjects had normal or corrected-to-normal vision. According to the Briggs and Nebes Handedness Questionnaire (Briggs & Nebes, 1975) 140 were deemed right-handed, seven were left-handed and three of mixed-handedness. Handedness has a small effect on line bisection performance, with non-patient dextral subjects erring slightly further to the left than sinistrals (Luh, 1995; Scarisbrick et al., 1987). These differences could have inflated variability and hence the 10 non-right-handers were excluded from the study. The remaining 70 men and 70 women were divided into seven age cohorts: 14–20, 21–30, 31–40, 41–50, 51–60, 61–70, 71–80 years, comprising 10 men and 10 women in each. Age distribution is shown in Table 1.

Stimuli

A total of 15 horizontal black lines were printed individually on white A4 landscape card (297 × 210 mm). Each line measured 1 mm in height and was centred horizontally and vertically on the page. Five lines were 20 mm in length, five were 100 mm and five were 180 mm. The 15 trials were presented in pseudorandom order.

Procedure

Each stimulus sheet was presented on an empty table directly in front of the subjects' mid-sagittal plane. The distance between the subjects' eyes and the stimulus was approximately 450 mm, thus subtending visual angles of 2.52° on 20-mm lines, 12.67° on 100-mm lines, and 22.62° on 180-mm

TABLE 1. Age distribution

Age-Cohort	Sex	*n*	Mean Age (SD)	Age Range
14–20 yrs.	Male	10	19 (1)	17–20
	Female	10	18 (3)	14–20
21–30 yrs.	Male	10	24 (2)	21–29
	Female	10	27 (4)	21–30
31–40 yrs.	Male	10	36 (4)	31–40
	Female	10	35 (3)	31–40
41–50 yrs.	Male	10	46 (3)	41–50
	Female	10	46 (3)	41–50
51–60 yrs.	Male	10	56 (3)	52–60
	Female	10	56 (3)	52–60
61–70 yrs.	Male	10	66 (3)	61–69
	Female	10	68 (3)	61–70
71–80 yrs.	Male	10	75 (3)	71–79
	Female	10	73 (2)	71–77

lines. Before beginning the task, subjects were instructed not to move their body position or the stimulus, but were permitted to move their head, whilst carrying out the task. Subjects were not permitted to use the pen or any other object as a guide. Instead they were encouraged to respond quickly with a spontaneous, non-reflective response. Task instructions were read out verbatim to ensure the intention of the study was not distorted. The instructions were 'using your pen I want you to quickly draw a single small vertical mark on the line where you consider the centre to be'. All subjects were provided with a black fine-tip (0.5 mm) pen to make their responses.

Scoring and Analysis

The dependent variable was the deviation from true centre. Magnitude of deviation was established by measuring the distance (to the nearest 0.5 mm) from the objective centre (zero point) to the point where the subjective vertical mark crossed through the stimulus line. Deviations drawn to the right of objective centre were given a positive value and those to the left a negative value. Consequently, the relative (i.e., signed) deviation represents both the *magnitude* and the *direction* of bisection error.

Relative deviations were then transformed into percentage deviations using the following formula:

$$\frac{\text{relative deviations (mm)}}{\text{line length (mm)}} \times 100$$

Percentage deviations allow the different line lengths to be taken into account and represent the *magnitude* of deviation and its *direction* as a percentage of the line's length.

Scoring reliability was established by having 10 subjects' responses scored independently by two scorers. Intraclass correlation coefficients between the two scorers were highly significant for all three line lengths: 0.99 (20 mm line length), 1.00 (100 mm) and 1.00 (180 mm); demonstrating that the scoring of responses was reliable.

RESULTS

Relative Deviation

Relative deviations (see Table 2) made by each cohort of 10 subjects (i.e., 14 cohorts) were subjected to *t*-tests to establish whether or not subjects deviated significantly away from the objective centre (i.e., away from zero). All cohorts bisected significantly away from the centre point on all three line lengths ($p < .05$).

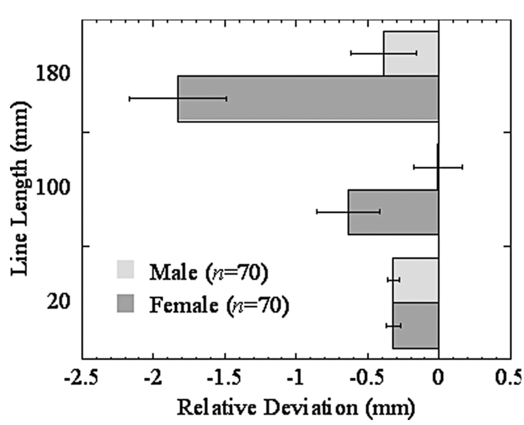
TABLE 2. Mean relative and percentage deviations (SD) as a function of line length, age-cohort and sex

			Line Length (mm)					
			20		100		180	
Age-Cohort	Sex	*n*	Relative	*Percentage*	Relative	*Percentage*	Relative	*Percentage*
14–20 yrs.	Male	10	–.43 (.38)	*–2.15 (1.89)*	–1.00 (1.28)	*–1.00 (1.28)*	–.14 (1.20)	*–.08 (.67)*
	Female	10	–.27 (.33)	*–1.35 (1.63)*	–.23 (1.66)	*–.23 (1.66)*	–.01 (2.72)	*–.01 (1.51)*
21–30 yrs.	Male	10	–.10 (.27)	*–.50 (1.37)*	.19 (1.40)	*.19 (1.40)*	.48 (2.96)	*.27 (1.64)*
	Female	10	–.26 (.42)	*–1.30 (2.12)*	–.69 (1.98)	*–.69 (1.98)*	–.99 (2.08)	*–.55 (1.15)*
31–40 yrs.	Male	10	–.22 (.24)	*–1.10 (1.20)*	–.23 (2.11)	*–.23 (2.11)*	–.95 (2.45)	*–.53 (1.36)*
	Female	10	–.28 (.39)	*–1.40 (1.93)*	–.85 (1.86)	*–.85 (1.86)*	–2.43 (2.78)	*–1.35 (1.54)*
41–50 yrs.	Male	10	–.35 (.39)	*–1.75 (1.93)*	–.59 (1.54)	*–.59 (1.54)*	–1.00 (2.39)	*–.56 (1.33)*
	Female	10	–.35 (.28)	*–1.75 (1.38)*	–.91 (1.19)	*–.91 (1.19)*	–1.69 (2.02)	*–.94 (1.12)*
51–60 yrs.	Male	10	–.32 (.62)	*–1.60 (3.12)*	.10 (3.25)	*.10 (3.25)*	–.93 (3.05)	*–5.17 (1.70)*
	Female	10	–.38 (.65)	*–1.90 (3.26)*	–1.20 (2.15)	*–1.20 (2.15)*	–2.79 (3.33)	*–1.55 (1.85)*
61–70 yrs.	Male	10	–.54 (.37)	*–2.70 (1.83)*	1.03 (2.02)	*1.03 (2.02)*	.23 (2.82)	*.13 (1.57)*
	Female	10	–.30 (.51)	*–1.50 (2.56)*	–.25 (1.61)	*–.25 (1.61)*	–2.36 (2.57)	*–1.31 (1.43)*
71–80 yrs.	Male	10	–.27 (.45)	*–1.35 (2.25)*	.43 (2.19)	*.43 (2.19)*	–.42 (1.72)	*–.23 (.96)*
	Female	10	–.37 (.45)	*–1.85 (2.25)*	–.36 (2.55)	*–.36 (2.55)*	–2.57 (3.55)	*–1.43 (1.97)*
All Cohorts	Male	70	–.32 (.41)	*–1.59 (2.05)*	–.01 (2.07)	*–.01 (2.07)*	–.39 (2.41)	*–.22 (1.34)*
	Female	70	–.32 (.43)	*–1.58 (2.15)*	–.64 (1.85)	*–.64 (1.85)*	–1.83 (2.81)	*–1.02 (1.56)*
All Cohorts	Male & Female	140	–.32 (.42)	*–1.59 (2.09)*	–.33 (1.98)	*–.33 (1.98)*	–1.11 (2.71)	*–.62 (1.50)*

Relative deviations were subjected to a line length (3) by age cohort (7) by sex (2) mixed ANOVA and pairwise comparisons (with Bonferroni adjustment), with line length as the repeated measure, to establish whether or not subjects bisected differently (in terms of relative magnitude and direction) on different line lengths, according to their age and/or sex. Effect sizes (*r*) were also calculated. There was no significant interaction between line length, sex and age-cohort [$F(10.11, 212.21) = 0.55$, $p > .05$; $r = .161$]; however, there were main effects for line length [$F(1.68, 212.21) = 13.38$, $p < .001$; $r = .310$] and sex [$F(1, 126) = 7.59$, $p < .01$; $r = .239$]. The overall direction of deviations was left for all line lengths with the magnitude of deviations on 180-mm lines being greater than that on the other two (shorter) lines (i.e., 20 and 100 mm) ($p < .001$ for both comparisons; $r = .200$ and $.162$, respectively). Deviations did not differ between the two shorter lines ($p > .05$; $r = .003$). A line length × sex interaction [$F(1.68, 212.21) = 8.45$, $p < .01$; $r = .251$] revealed that this pattern was evident in women, while men appeared to perform similarly for all three different line lengths (see Figure 1). The difference between the sexes was, however, only significant on the longest (180 mm) line ($p < .01$; $r = .265$); although it approached significance on the 100-mm line ($p = .06$; $r = .158$). There was no difference between men and women on the shortest (20 mm) line ($p > .05$; $r = 0$).

There was no main effect of age-cohort [$F(6, 126) = 0.69$, $p > .05$; $r = .179$] and no interaction between age-cohort and sex [$F(6, 126) = 0.67$, $p > .05$; $r = .176$]. Age-cohort, however, did interact with line length [$F(10.11, 212.21) = 1.98$, $p < .05$; $r = .293$]. Most age-cohorts produced a leftward directional deviation on all line lengths. Older age-cohorts (31–40, 51–60, 61–70 and 71–80) deviated with greater magnitude on lines measuring 180 mm than on the two shorter lines (i.e., 20 and 100 mm) ($p < .05$ for all comparisons; *r* values ranged from .153 to .355). Younger age-cohorts (14–20

FIGURE 1. Relative deviations as a function of line length and sex.



and 21–30) deviated to a similar magnitude across all three line lengths ($p >$ .05 for all comparisons; r values ranged from .002 to .149).

Interestingly, most women (see Figure 2a) produced a leftward directional deviation on all line lengths, while as a group men failed to show any consistent pattern of lateral deviation (see Figure 2b) – bisecting to the left on short lines (20 mm) similar to women and either to the left or right on the two longer lines (100 and 180 mm). Pairwise comparisons revealed that women over 30 deviated to a greater extent on lines measuring 180 mm than that on the two shorter lines ($p < .05$ for all comparisons; r values ranged from 0.273 to 0.486). Younger women (<30 years) and all men bisected to a similar magnitude on all three line lengths.

Percentage Deviation

Relative deviations were divided by line length to produce percentage deviations that represent the magnitude and direction of deviation irrespective of line length. Percentage deviations (see Table 2) made by each cohort

FIGURE 2. Relative deviations as a function of line length, age-cohort and sex: (a) n = 70 female; (b) n = 70 male.

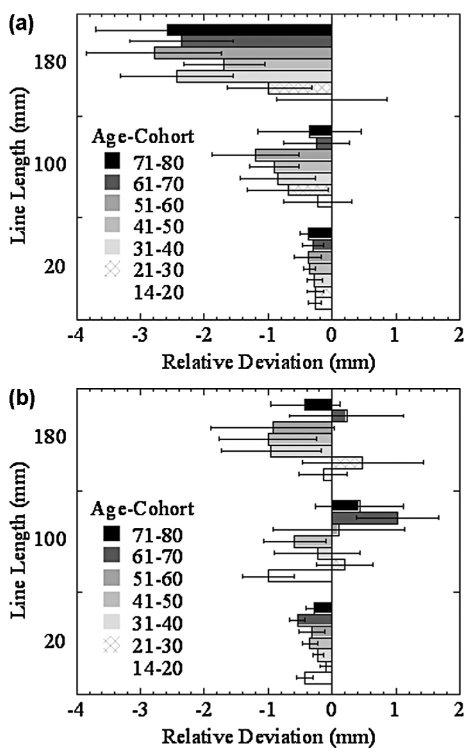
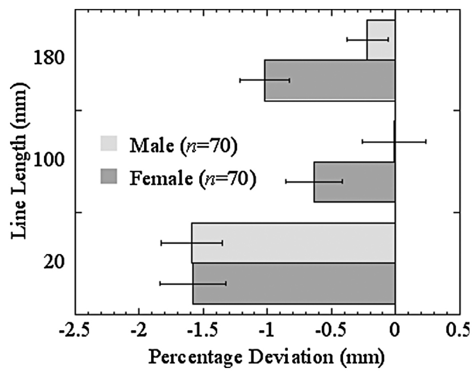


FIGURE 3. Percentage deviations as a function of line length and sex.



were subjected to a similar (3 × 7 × 2) mixed ANOVA procedure to establish whether or not subjects bisected at a constant percentage of the line's length according to their age and/or sex. There was no interaction between line length, age-cohort and sex [F(9.60, 201.50) = 0.68, p > .05; r = .176]. There was no main effect of sex [F(1, 126) = 3.48, p > .05; r = .164], although it approached significance (p = .07), or age-cohort [F(6, 126) = 0.46, p > .05; r = .148] and no interaction between the two [F(6, 126) = 0.57, p > .05; r = .161].

However, there was a main effect of line length [F(1.60, 201.50) = 31.71, p < .001; r = .448] which interacted with sex [F(1.60, 201.50) = 3.38, p < .05; r = .161] but not with age-cohort [F(9.60, 201.50) = 1.64, p > .05; r = .270]. Percentage deviations were greater on the shortest line (20 mm) than on the two longer lines (100 and 180 mm) (p < .001 for both comparisons; r = .296 and .258, respectively). Deviations did not differ between the two longer lines (p > .05; r = .082). This pattern was evident in men (see Figure 3). However, women (Figure 3) deviated by a similar percentage on the shortest (20 mm) and longest (180 mm) line (p > .05; r = .147) but differently on the shortest and medium line (p < .01; r = .228). The difference between the sexes was only significant on the longest (180 mm) line (p < .01; r = .265), although it approached significance on the medium (100 mm) line (p = .06; r = .158).

DISCUSSION

The results demonstrate an age and sex-related difference in bisecting different line lengths. Most women over 30 showed a linear relationship between line length and bisection performance by deviating to the left by a greater extent as line length increased. Women under 30 years bisected to the left but to a similar extent on all line lengths. Men displayed no trend, and as a group deviated left on short lines (similar to women) but either left or right to a similar extent on longer lines. The magnitude of deviation on the longer lines increased at a constant percentage of the line's length in both men and women. However, percentage deviations were greatest on the short line. The fact that subjects deviate at a proportional rate on longer lines suggests that the entire length of the line was processed (Halligan, 1995) and that it was subsequent cognitive or motor performance demands that probably produced the systematic '*misperception*' of linear extent.

The combined effect of age and sex has not (so far as we are aware) been systematically examined in control bisection performance. Indeed, only a few studies have examined the separate effects of either age or sex. Four studies that examined the effects of age all report variable results (De Agostini et al., 1999; Failla et al., 2003; Fujii et al., 1995; Hausmann et al., 2003). One reason for such discrepancies in reported findings is the distribution of age and sex grouping involved. One study did not distinguish the sex of their subjects (Hausmann et al., 2003), another reported results but only as a function of sex (De Agostini et al., 1999), while another collapsed results across the sexes (Fujii et al., 1995). All four compared uneven age-cohorts and failed to test subjects across different age groups. These weaknesses and inconsistencies make it difficult to elucidate the changes that might have occurred across the lifespan from changes that occur at one particular time of life.

Twelve studies have examined sex alone as a modulating factor in line bisection performance. Nine failed to find significant effects (Bradshaw et al., 1985; Brodie & Pettigrew, 1996; Chokron & Imbert, 1993; Fukatsu et al., 1990; Luh, 1995; Mefferd et al., 1969; Milner et al., 1992; Scarisbrick et al., 1987; Shuren et al., 1994). All, however, differ with respect to subjects' age, handedness, sample size, stimuli and task instructions, making it difficult to draw firm conclusions about the influence (or not) of sex on bisection performance. Three studies report sex-related differences (Hausmann et al., 2002; Roig & Cicero, 1994; Wolfe, 1923). These studies, however, vary in terms of sample size and age-grouping. None controlled for age effects and grouped young adults with subjects almost 30 years older. Moreover, none of them tested subjects from the age ranges commonly seen with visuospatial neglect (i.e., 50 years or above) making it difficult to reconcile healthy and pathological bisection performance.

Age and sex are clearly biological factors that have the potential, either separately or collectively, to affect the cognitive mechanisms involved in simple cognitive tasks such as bisection. The possibility of age or sex affecting bisection performance has previously been discussed, respectively, in terms of asymmetric changes or differences across hemispheres (De Agostini et al., 1999; Failla et al., 2003; Fujii et al., 1995; Hausmann et al., 2002, 2003; Roig & Cicero, 1994). The age-related differences on line bisection found in the current study suggest that cognitive processes in older subjects (>30 years) during a manual (visually mediated) task are qualitatively different to younger subjects. Complex brain changes are known to underlie the decline of motor, perceptual and cognitive skills associated with advancing age (Calautti et al., 2001; D'Esposito et al., 1999; Esposito et al., 1999; Grady, 2000). For example, slowing of motor movements and fine motor skills are thought to reflect underlying age-related 'degeneration' in brain areas sub-serving motor function (Smith et al., 1999). However, many studies on the aging brain have shown that elderly subjects demonstrate *greater* activity in the same brain areas (D'Esposito et al., 1999) but use *different* brain areas when compared with young subjects on perceptual (visual) or cognitive (mnemonic) tasks (Cabeza et al., 1997; Esposito et al., 1999; Grady, 2000) or for motor functions (Mattay et al., 2002). This has been interpreted as a *compensatory* mechanism by the aging brain to compensate for brain areas that are not working with efficiency. That is, additional cortical and/or sub-cortical regions can be recruited as a compensatory response to increased functional demands.

Alternatively, the results described in the current study could represent functional *reorganization* and *redistribution* that take place in brain circuitry in response to neurotransmitter imbalances and cytoarchitectural changes that are known to occur with aging (Pradhan, 1980). For example, studies have shown that the aging brain is not only associated with dendritic *atrophy* and a *decline* in the number of synapses in the cerebral cortex, but also with *growth* of dendrites and synapses as a compensatory response to cell loss (Ivy et al., 1992). It is possible that changes in bisection performance (i.e., an increase in leftward deviations) as a function of age could similarly reflect (either selectively or in combination) compensatory mechanisms and/or the reorganization and redistribution of the cognitive mechanisms involved in the manual line bisection task. Moreover, according to the activation orientation theory of Kinsbourne (1970a, 1970b, 1977), enhanced right hemispheric activation will increase the magnitude of attention applied to contralateral (left) hemispace and the salience of objects within it. These changes appeared to occur in the right hemisphere resulting in the greater leftward orientation of spatial bias.

However, on their own, such interpretations do not explain why significant changes in bisection performance only occurred in women. Men bisected lines more symmetrically (i.e., to the left and right) while women (beyond 30 years) were more lateralised – deviating to the left with greater magnitude as they increased in age – reflecting the fact that men score higher than women on visuospatial tasks (Bradshaw, 1989; Broverman et al., 1986; Halpern, 1986; Hellige, 2001; McGlone, 1980). In terms of age effects, behavioural research on the aging brain has found that although aging has global effects, it influences certain cognitive functions disproportionately (Salthouse & Ferrer-Caja, 2003). The age-related changes seen here in women may be a result of specific changes to cognitive functions specific to line bisection [e.g., representation of linear extent, computation of midpoint and/or pre-motor planning to respond (Halligan, 1995)]. The same functions for bisecting a line in men, appear to be unaffected by aging. Why such distinct lateralization in women should occur after the age of 30 could be explained in terms of specific hormonally mediated changes in women approaching (and beyond) menopause. Indeed, some studies have shown that hormonal changes in females can change cerebral function during some visuospatial tasks (Chiarello et al., 1989; McCourt et al., 1997), although the literature appears equivocal.

Alternatively, it is conceivable that differences in male and female bisection performance reflect differences in strategy choice. Even when sex-related differences are found in performance that is thought to reflect differences in brain and/or chemical activation, it does not necessarily mean that men and women differ in relatively permanent aspects. For example, it may be the case that they use different cognitive strategies to complete the same task. In terms of the bisection performance described in this study, it is possible that men have the ability to adopt strategies that result in a relatively stable (symmetrical) bisection performance, while women do not adapt accordingly and perform asymmetrically. Indeed, it has already been shown that the pattern of bisection performance can be determined by the processing strategies adopted more than by the nature of the stimuli (Fink et al., 2002). Consequently, explanations in terms of preferred strategy must be considered in addition to explanations in terms of brain structure *per se*. Age and sex-related differences in strategy choice in the manual line bisection task are currently being examined in our lab.

The age- and sex-related differences described here highlight the importance of controlling for age, sex and line length in studies of healthy and pathological bisection performance and provide a robust starting point from which to consider some of the theoretical constructs underlying visuospatial neglect.

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