cortex 49 (2013) 827–836

Available online at www.sciencedirect.com

SciVerse ScienceDirect

Journal homepage: www.elsevier.com/locate/cortex

Research report

Stimulus- and state-dependence of systematic bias in spatial attention: Additive effects of stimulus-size and time-on-task

Christopher S.Y. Benwell [a,b,*], *Monika Harvey* [b], *Stephanie Gardner* [b] and *Gregor Thut* [a]

[a] *Centre for Cognitive Neuroimaging, Institute of Neuroscience and Psychology, University of Glasgow, Glasgow, United Kingdom*
[b] *School of Psychology, University of Glasgow, Glasgow, United Kingdom*

ARTICLE INFO

Article history:
Received 18 October 2011
Reviewed 15 November 2011
Revised 20 December 2011
Accepted 23 December 2011
Action editor Carlo Umilta
Published online 3 January 2012

Keywords:
Pseudoneglect
Cross-over
Landmark task
Alertness
Orienting

ABSTRACT

Systematic biases in spatial attention are a common finding. In the general population, a systematic leftward bias is typically observed (pseudoneglect), possibly as a consequence of right hemisphere dominance for visuospatial attention. However, this leftward bias can cross-over to a systematic rightward bias with changes in stimulus and state factors (such as line length and arousal). The processes governing these changes are still unknown. Here we tested models of spatial attention as to their ability to account for these effects. To this end, we experimentally manipulated both stimulus and state factors, while healthy participants performed a computerized version of a landmark task. State was manipulated by time-on-task (>1 h) leading to increased fatigue and a reliable left- to rightward shift in spatial bias. Stimulus was manipulated by presenting either long or short lines which was associated with a shift of subjective midpoint from a reliable leftward bias for long to a more rightward bias for short lines. Importantly, we found time-on-task and line length effects to be additive suggesting a common denominator for line bisection across all conditions, which is in disagreement with models that assume that bisection decisions in long and short lines are governed by distinct processes (Magnitude estimation *vs* Global/local distinction). Our findings emphasize the dynamic rather than static nature of spatial biases in midline judgement. They are best captured by theories of spatial attention positing that spatial bias is flexibly modulated, and subject to inter-hemispheric balance which can change over time or conditions to accommodate task demands or reflect fatigue.

1. Introduction

'Pseudoneglect' represents the tendency for neurologically normal participants to misbisect horizontal lines when asked to judge their midpoint during line bisection tasks (Bowers and Heilman, 1980). The direction of bias has usually been found to be to the left of veridical centre and of a much smaller magnitude than the rightward bias typically exhibited by patients with visuospatial neglect after right hemisphere (RH) stroke (Schenkenberg et al., 1980; Harvey et al., 1995; Vallar, 1998). However, the direction and magnitude of bias varies systematically within participants as a function of a number of stimulus and context factors (Jewell and McCourt, 2000; McCourt, 2001; Failla et al., 2003; Pérez et al., 2009; Heber et al., 2010; Schmitz and Peigneux, 2011).

* *Corresponding author*. School of Psychology, 58 Hillhead Street, Glasgow G12 8QB, United Kingdom.
E-mail address: chrisb@psy.gla.ac.uk (C.S.Y. Benwell).
0010-9452/$ – see front matter
doi:10.1016/j.cortex.2011.12.007

The magnitude of the leftward bias in line bisection tends to decrease as a function of decreasing line length and has been reported to 'cross-over' to become a bias in the opposite, rightward direction in very short lines (<2 cm) (McCourt and Jewell, 1999; Rueckert et al., 2002). Previous studies investigating the robustness of this line length effect in normal participants display mixed findings, though differing bisection tasks and experimental designs have been employed (Manning et al., 1990; Luh, 1995; Laeng et al., 1996; McCourt and Jewell, 1999; Jewell and McCourt, 2000; Mennemeier et al., 2001, 2002; Rueckert et al., 2002; Varnava et al., 2002; Heber et al., 2010). The most commonly employed tasks include the landmark task, a perceptual line bisection judgement task designed to dissociate the contribution of perceptual and motor factors (Milner et al., 1992; Harvey et al., 2000; Olk and Harvey, 2002), and manual line bisection, of which the former shows more reliable cross-over with short lines (Rueckert et al., 2002) suggesting perceptual bisection tasks to be optimal for detection of the line length effect in healthy participants.

Besides stimulus factors, arousal level also seems to influence spatial bias, with leftward bias associated with states of relatively high alertness and rightward bias associated with states of low alertness or fatigue [Bellgrove et al., 2004; Manly et al., 2005; Fimm et al., 2006; Matthias et al., 2009; though see Schmitz et al. (2011) for conflicting results with the landmark task]. In addition, left- to rightward shifts in line bisection judgement have been observed over the course of prolonged performance of the landmark task. This has been labelled the 'Time-on-task' effect (Manly et al., 2005; Dufour et al., 2007). These intra-individual variations indicate that visuospatial bias is a dynamic phenomenon fluctuating over time and depending on context. Accounting for fluctuations in attentional asymmetry may represent an important step in fully understanding how the visuospatial attention system is organized. The aim of the present study was to probe models of spatial attention as to their ability to explain the cross-over effect using time-on-task as an experimental manipulation, detailed below.

All influential models of spatial attention assume contribution of both the RH and left hemisphere (LH) to orienting towards the contralateral visual fields, although to different extent (e.g., Kinsbourne, 1970; Heilman and Van Den Abell, 1980; Mesulam, 1981). In line with these models, predominant RH-activation during line bisection tasks (Fink et al., 2000; Foxe et al., 2003; Waberski et al., 2008) may induce an attentional bias towards the left side of the line, thereby increasing its perceived length relative to the right side and shifting the perceived midpoint to the left of veridical centre (Bultitude and Aimola-Davies, 2006). How can the left- to right cross-over from long to short lines then be explained? One model suggests that cross-over results from the leftward attentional asymmetry coupled with a previously reported, general tendency to underestimate the absolute length of long lines and to overestimate the absolute length of short lines (Werth and Poppel, 1988; Tegner and Levander, 1991). This orientation/estimation hypothesis (Mennemeier et al., 2005) posits that once attention is preferentially oriented to one end of a line (typically the left), underestimating the absolute length of long lines leads to the bisection mark being placed short of veridical centre (i.e., to the left), whereas overestimating the absolute length of short lines leads to the bisection mark being placed beyond veridical centre (i.e., to the right). An alternative model suggests that task specific hemispheric dominance for line bisection may switch from the RH in long lines to the LH in short lines. A potential mechanism for this may be RH-dominance for lower spatial frequencies and/or global perception, in contrast to LH-dominance for higher spatial frequencies and/or local perception (Sergent, 1982; Ivry and Robertson, 1998; Monaghan and Shillcock, 2004; Flevaris et al., 2011). Behavioural dissociations have been found in bisection tasks when participants were directed to focus on either the local or global elements of the stimulus respectively, and these differences have been suggested as a possible explanation for the line length effect (Hughes et al., 2005; Gallace et al., 2008). We call this the "Local/Global" hemispheric specialization hypothesis. Importantly, these models lead to different predictions as to the outcome of time-on-task on bisection judgement performance in long versus short lines.

The time-on-task modulation of attentional bias by arousal level has been interpreted to represent an interaction between orienting and arousal networks in the RH, which biases attention towards the left visual field in states of high alertness but results in a reduction or even reversal of this bias as RH-activation decreases with reduced alertness/increasing fatigue (Corbetta et al., 2005; Manly et al., 2005; Fimm et al., 2006; Dufour et al., 2007). To date, the time-on-task effect in the landmark task has only been investigated using relatively long lines (Manly et al., 2005; Dufour et al., 2007). We investigated for the first time the influence of time-on-task on midpoint judgements in short (1 cm) as well as long lines (29 cm). The models above would predict the following outcomes. Under both the orientation/estimation hypothesis and the "local/global" hemispheric specialization hypothesis, long and short lines should differ in directional bisection errors, with more leftward bias in long than short lines (line length effect) at the beginning of the experiment (high alertness). Under the orientation/estimation hypothesis, a rightward shift in spatial bias over the course of the experimental session should lead to a reversal of the direction of cross-over. Once attention is shifted rightwards (time-on-task effect), underestimating the length of long lines should lead to the bisection mark being placed short (i.e., to the right) of veridical centre. In contrast, overestimation of short lines should lead to the bisection mark being placed beyond (i.e., to the left of) veridical centre. Under the "local/global" hemispheric specialization hypothesis, one would expect decreasing alertness and thus RH-depletion to primarily affect the bisection of long but not short lines (due to RH-dominance for long line but LH-dominance for short line processing), therefore leading to a rightward shift primarily in long but not short lines. We tested these predictions by assessing line bisection biases for short and long lines in the landmark task at the beginning and end of the experimental session, before and after an extended practice period (about 1 h time-on-task) in which participants performed the task either exclusively on long lines or on short lines (group design).