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The frequency and severity of extinction after stroke affecting different vascular territories

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ABSTRACT

We examined the frequency and severity of visual versus tactile extinction based on data from a large group of sub-acute patients ($n=454$) with strokes affecting different vascular territories. After right hemisphere damage visual and tactile extinction were equally common. However, after left hemisphere damage tactile extinction was more common than visual. The frequency of extinction was significantly higher in patients with right compared to left hemisphere damage in both visual and tactile modalities but this held only for strokes affecting the MCA and PCA territories and not for strokes affecting other vascular territories. Furthermore, the severity of extinction did not differ as a function of either the stimulus modality (visual versus tactile), the affected hemisphere (left versus right) or the stroke territory (MCA, PCA or other vascular territories). We conclude that the frequency but not severity of extinction in both modalities relates to the side of damage (i.e. left versus right hemisphere) and the vascular territories affected by the stroke, and that left hemisphere dominance for motor control may link to the greater incidence of tactile than visual extinction after left hemisphere stroke. We discuss the implications of our findings for understanding hemispheric lateralization within visuospatial attention networks.

1. Introduction

The ability to attend symmetrically across both sides of space is essential for daily activities, as illustrated by the behavioural problems experienced by patients with attentional problems following stroke (for a review see Kerkhoff, 2001). While such problems have been predominantly investigated in relation to the syndrome of unilateral neglect (when patients ignore the side of space contralateral to lesion; Heilman & Valenstein, 1979), impairments in attention can also be found in patients showing extinction. Extinction is a common spatial disorder diagnosed in patients who can detect a single stimulus on the contralesional side but who fail to detect the same stimulus when presented concurrently with an ipsilesional item (Bender & Teuber, 1946; Critchley, 1953; Wortis, Bender, & Teuber, 1948). The deficit has typically been attributed to differential competition for attention to stimuli on the ipsi- and contralesional sides of space (Duncan, Humphreys, & Ward, 1997), though there may also be contributions from impaired perceptual processing on the contralesional side (Gorea & Sagi, 2000, 2002). Functional imaging studies show that extinction is associated with reduced activation to contralesional stimuli in early visual cortex (primary visual cortex/V1 and early extrastriate cortex including part of V2 and V3), consistent with biased attentional competition modulating perception (e.g., Driver & Vuilleumier, 2001; Rees et al., 2000, 2002).

As for unilateral neglect there are reports that extinction is asymmetrically associated with the damage to the right hemisphere. For example, Becker and Karnath (2007) reported that 24.3% of patients with lesions within the right hemisphere showed visual extinction as compared to only 4.9% of patients with damage to the left hemisphere (although see Ogden, 1985 for a contrary account). The higher incidence of extinction following right hemisphere strokes is consistent with there being an asymmetrical right hemisphere dominance of visuospatial attention (Corbetta & Shulman, 2002; Kinsbourne, 1977, 1987; Weintraub & Mesulam, 1988).

While the frequency of extinction and neglect may be greater after right (RHD) than left hemisphere damage (LHD), there are inconsistent results concerning the severity of the symptoms (e.g., Albert, 1973; Arrigoni & De Renzi, 1964; Chedru, 1976; Costa, Vaughan, Horwitz, & Ritter, 1969; Ringman, Saver, Woolson, Clarke, & Adams, 2004; Stone et al., 1991; Suchan, Rorden, & Karnath, 2012). For example, most studies comparing the severity of neglect have found that the symptoms are more severe after RHD compared to LHD damage (Albert, 1973; Chedru, 1976; Gainotti, Messerli, & Tissot, 1972; Ogden, 1987; Ringman et al., 2004; Stone et al., 1991) – though other reports have found that neglect symptoms can be equally severe in LHD and RHD patients

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(Costa et al., 1969; Suchan et al., 2012). In contrast to neglect symptoms, the severity of extinction after left versus right hemisphere damage has not been examined systematically.

The severity of visuospatial deficits following left versus right strokes has implications for how we view the nature of right hemisphere dominance in these spatial disorders. One account is that the right hemisphere has attentional receptive fields covering both sides of space, while the left hemisphere has attentional receptive fields only for the right side (Kinsbourne, 1987). The consequence of this is that right hemisphere lesions impair attention to both sides of space while left hemisphere lesions have less effect because the right hemisphere can still respond to stimuli in the right field. A somewhat different account is based on the right hemisphere dominance for disengaging attention so that items in unattended areas of field can be detected. It follows from this argument that right hemisphere lesions should lead to a deficit in disengaging attention from right side stimuli to detect those falling on the left and, given right hemisphere dominance for attentional disengagement, this problem should be worse after right than left hemisphere lesions (Corbetta & Shulman, 2002; Posner, Walker, Friedrich, & Rafal, 1984). We examined whether this was the case in a large group of subacute stroke patients with extinction symptoms.

The severity and frequency of spatial disorders such as neglect and extinction has been studied mainly in the visual modality. However extinction occurs also in other sensory modalities (touch, audition, olfaction) and can be considered a multisensory phenomenon (e.g. Bellas, Novelly, Eskenazi, & Wasserstein, 1988a, b; Deouell & Soroker, 2000; De Renzi, Gentilini, & Pattacini, 1984; Hillis et al., 2006; Ladavas, Pavani, & Farne, 2001; Maravita, Spence, Clarke, Husain, & Driver, 2000; Vaishnavi, Calhoun, & Chatterjee, 2001). The asymmetrical association between damage to the right hemisphere and extinction symptoms in different modalities has not been studied thoroughly although De Renzi et al. (1984) demonstrated that, in the auditory modality, the prevalence of extinction symptoms was not significantly different following damage to the two hemispheres. These data suggest that the asymmetrical association between the frequency of spatial deficits and the hemisphere of damage may be either absent or weaker in modalities other than vision.

In the current study we examined the frequency and severity of extinction in the visual and tactile modalities in right versus left hemisphere strokes based on data from a large group of sub-acute patients ($n=454$). We also evaluated how these factors vary depending on the vascular territory affected by the stroke. Visual and tactile extinction were measured using matched procedures, minimizing the chances that non-specific task effects confounded the results.

Our results point to (i) the greater frequency of extinction after right relative to left hemisphere lesions for both the visual and tactile modalities, but no differences in the severity of the symptoms when they occur, (ii) a shift in the prevalence of tactile vs. visual extinction after left and right hemisphere damage, and that (iii) the frequency but not the severity of the extinction deficit depends on the vascular territory affected by the stroke.

2. Material and methods

2.1. Participants

Patients were recruited as a part of the BCoS project (Birmingham Cognitive Screen, http://www.bcos.bham.ac.uk), a large clinical study with several participating stroke units across the West Midlands area, UK. After excluding patients with incomplete behavioural data, we sampled data from a total of 454 sub-acute stroke patients (240 males and 214 females; average age of 69.9 years, range 30–93 years; see Table 1 for full demographic and clinical data) were included in the study. Within this group 215 patients had middle cerebral artery (MCA) stroke and 47 posterior cerebral artery (PCA) stroke. The remaining 192 patients had either strokes not visible on CT scans (131 patients; lesions may not be apparent on CT if the scan was conducted very early after the stroke, or if there was only a minor neurological change) or affecting other vascular territories (61 patients) such as anterior cerebral artery (ACA) stroke, basal ganglia and thalamus (LSA/lenticulostriate arteries and AChA/anterior choroideal artery territories strokes) as well as the cerebellum (PICA/posterior inferior cerebellar artery and SCA/superior cerebellar artery territories stroke). Clinical and demographic data for all patients were obtained from the clinical files. This included computed tomography (CT) scans acquired as part of routine clinical assessment following stroke and hospital admission. Clinical notes and CT scans (screened for visible presence of a lesion) were used to determine the type of stroke (ischemic or hemorrhagic/bleed or no clear abnormality/no visible lesion), vascular territory affected by stroke and the affected hemisphere. Specifically, for each patient the vascular territory affected by stroke was first defined based on clinical notes and further confirmed by examining CT scans by one of the experienced members of the research team. In the case of any uncertainty about stroke location further advice was sought from an experienced neuroradiologist. Patients were only included in the statistical analyses if they had well-defined unilateral lesions.

All study participants provided written informed consent in agreement with ethics protocols approved by the National NHS ethic committee and local NHS trusts.

2.2. Behavioural measures

Behavioural data were only collected from patients who were physically stable, willing to perform the task and had a concentration span of at least 60 min (judged clinically). The neuropsychological testing took place in the sub-acute phase

Table 1
Patient's details: clinical and demographic data ($n=454$, all recruited stroke patients).

	All patients ($n=454$) Mean (SD) or number	**MCA ($n=215$)** Mean (SD) or number	**PCA ($n-47$)** Mean (SD) or number	**Other[a] ($n=61$)** Mean (SD) or number	**NVL[a] ($n=131$)** Mean (SD) or number
Age in years	69.9 (13.7)	71.2 (13.1)	72.8 (10.7)	68.1 (14.2)	68.0 (15.0)
Sex: male/female	240/214	112/103	23/24	35/26	70/61
Aetiology: ISCH/BL	417/37	194/21	44/3	48/13	131/0
Affected hemisphere: right/left/NVL	161/162/131	103/112/0	21/26/0	37/24/0	0/0/131
Handedness: right/left	404/50	196/19	44/3	54/7	110/21
Stroke-BCoS in days[b]	23.0 (20.7)	24.6 (22.2)	24.7 (17.2)	24.2 (23.0)	18.8 (17.3)
Left VE index[c]	3.2 (2.5)	3.2 (2.5)	2.7 (2.7)	3 (1.4)	3.6 (2.9)
Right VE index[c]	2.3 (1.6)	2.7 (1.7)	N/A	2 (0)	1.3 (0.8)
Left TE index[c]	3.3 (2.3)	3.7 (2.3)	2.6 (2.1)	2.7 (2.7)	2.7 (1.8)
Right TE index[c]	2.6 (1.9)	3.0 (2.2)	2.5 (1.7)	1.5 (0.6)	2.2 (1.5)

[a] Patients with strokes affecting vascular territories other than MCA and PCA (only patients with lesions visible on CT scans) and NVL, patients with strokes not detected on CT scans.

[b] Interval between stroke onset and BCoS cognitive assessment.

[c] Mean extinction index score calculated based on data from patients with both contralesional and ipsilesional extinction deficits (not relevant for NVL patients; we have not calculated these separately due to very small number of patients with ipislesional deficits), please note that by contrast results section and Fig. 3 only present data for contralesional deficits; BL, bleed (hemorrhagic stroke); ISCH, ischemic stroke; MCA, patients with strokes affecting middle cerebral artery; N/A, not applicable, no patients with this type of deficits; PCA, patients with stroke affecting posterior cerebral artery; SD, standard deviation; TE and VE index; tactile and visual extinction index, both tests consists of 4 unilateral left, 4 unilateral right and 8 bilateral trials, extinction index was calculated to assess extinction severity by measuring selective drop in response to two stimuli relative to the response to one stimulus.