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Persisting asymmetries of vision after right side lesions

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Abstract

Visual neglect and extinction are well-known effects of lesions in the right hemisphere. This study shows that even with minor or no clinical signs of these deficits, and in the stable phase of recovery, asymmetric visual perception is common after right side lesions. Whole, partial and colour report experiments were used to estimate psychophysical parameters related to visual capacity and attentional weighting in 26 patients with stroke in the right side of the brain. The results were analyzed using Bundesen's Theory of Visual Attention (TVA [Bundesen, C. (1990). A theory of visual attention. *Psychological Review*, *97*, 523–547]) including bootstrap estimation of the measurement error related to each test result [Habekost, T., & Bundesen, C. (2003). Patient assessment based on a theory of visual attention (TVA): Subtle deficits after a right frontal-subcortical lesion. *Neuropsychologia*, *41*, 1171–1188]. Lesions were examined by MR scanning and analyzed statistically. Two main types of deficit were found. The first type was related to perception of unilateral displays, where most patients showed left side reductions of visual processing speed. This visual asymmetry correlated with injury to the putamen and surrounding white matter. The second deficit type occurred with bilateral displays, which increased the visual asymmetry (extinction effect) for most patients with large cortico-subcortical lesions, but rarely for patients with focal lesions. However, in a single case with pulvinar damage, visual asymmetry occurred selectively with bilateral stimulation. Overall, the study provided an overview of the cognitive structure and lesion anatomy of subtle visual asymmetries after right side stroke.

Keywords: Capacity; Extinction; Putamen; Sensory effectiveness; Subclinical; TVA

1. Introduction

Visual extinction is a condition in which a briefly presented contralesional stimulus is perceived normally when shown in isolation, but missed ("extinguished") when accompanied by an ipsilesional stimulus (Bender, 1952). Visual neglect is defined by a similar bias towards the ipsilesional field, but is a more complex syndrome where multiple aspects of space representation and exploration are also disturbed (Karnath, Milner, & Vallar, 2002). Because of impairments in top-down controlled exploration, neglect can be evident even with a single stimulus and unlimited exposure time. Extinction is often considered a mild form of neglect (Heilman, Watson, & Valenstein, 2003) but double dissociations have been reported between the two conditions (Cocchini, Cubelli, Della Sala, & Beschin, 1999), and the lesion anatomy may also differ (Karnath, Himmelbach, & Küker, 2003; Vallar, Rusconi, Bignamini, Germiniani, & Perani, 1994). For these reasons the two syndromes can be regarded as partly independent. However, by an extended definition of extinction, in which ipsilesional stimuli interfere with the processing of contralesional stimuli without making them invisible, extinction-like perception can probably be found in most patients with neglect (Geeraerts, Lafosse, Vandenbussche, & Verfaillie, 2005). Neglect is common in the acute stage, with up to half or more of patients with right hemisphere stroke showing some sign of the condition (depending on the assessment procedure: Azouvi et al., 2002), but it has been argued that neglect rarely persists into the stable phase of recovery (Maguire & Ogden, 2002; Stone, Patel, Greenwood, & Halligan, 1992) especially in the absence of field cuts (Samuelsson, Jensen, Ekholm, Naver, & Blomstrand, 1997). However, this conclusion is based on performance with standard clinical tests such as line bisection and visual cancellation, and attentional biases may still be revealed in the pattern

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of eye movements (Olk, Harvey, & Gilchrist, 2002), judgment of brightness gradients (Mattingley et al., 2004), daily life behaviour (Azouvi et al., 2002) or detection under high attentional demand (Russell, Malhotra, & Husain, 2004). Thus, abnormalities can persist even though most patients eventually recover from or compensate for their initial marked symptoms. Visual extinction is also relatively common in the acute stage (Vallar et al., 1994: 16% of a consecutive series of right side lesions), and clinical experience suggests that the condition tends to be chronic (Heilman et al., 2003). However, systematic investigations of the long-term prevalence of extinction have not been conducted. As with neglect, the prevalence may be underestimated due to low sensitivity of the standard clinical test (detection of unilateral versus bilateral finger movements). Therefore, it is possible that many patients who apparently have recovered from neglect or extinction, or perhaps never been diagnosed with these conditions, in fact continue to have visual asymmetries in some form.

To control better for ceiling effects in performance, a number of recent studies have tested neglect and extinction patients using computer based experiments that enable individualized, near-threshold stimulation. A main result of these investigations is that contralesional stimuli are often perceived abnormally even when presented alone (i.e. without competing stimuli in the ipsilesional field) suggesting that sensory effectiveness is compromised unilaterally. Especially, in case of extinction this runs counter to traditional notions. Both extinction and neglect can occur without damage in the primary visual pathways, and by definition cannot be attributed to sensory or motor defects (Heilman et al., 2003). It is often assumed that unilateral displays are processed normally and that bilateral stimulation (or in case of neglect: tasks involving space exploration) is necessary to bring out the right side advantage (Karnath, 1988). Both behavioural and electrophysiological evidence now makes this assumption untenable. In a group of patients with right side lesions, Smania et al. (1998) found that both reaction time (RT) and detection rates were impaired for single brief flashes of light in the contralesional compared to the ipsilesional hemifield. The interfield difference was greatly pronounced for patients with neglect; extinction patients showed a smaller effect. Marzi et al. (1996) also found slowing of RT to contralesional flashes and Angelelli, de Luca, and Spinelli (1998) reported decreased contrast sensitivity contralesionally in neglect patients, but normal performance in other patients with right side lesions. In addition to these behavioural demonstrations, evoked response potential studies have revealed abnormalities in the neural response to single contralesional stimuli in patients with neglect (Angelelli, de Luca, & Spinelli, 1996; Spinelli, Angelelli, de Luca, & Burr 1996; Spinelli, Burr, & Morrone, 1994) and extinction (Marzi, Girelli, Natale, & Miniussi, 2001). In summary, there is now solid evidence that processing of single contralesional stimuli is abnormal in neglect and, probably to a lesser extent, extinction patients. However, it has not been demonstrated that the asymmetry extends to right damaged patients with minor or no clinical signs of attentional deficit.

We aimed to test the hypothesis that impaired sensory effectiveness in the contralesional field is common after right side brain damage, even for patients in the stable phase of recovery with no clear symptoms of neglect or extinction. We also wanted to explore the prevalence of rightward attentional biases (extinction-like effects) in this group. To obtain a comprehensive picture of the patients, we included measures of attentional control and general capacity, as well as detailed lesion analysis. As in the above mentioned studies, we used stimulation near perception threshold for sensitive testing. However, the previous investigations were extended in a number of ways. First, we selected patients by a broad anatomical criterion (damage in the right side of the brain) and not by clinical symptoms of attention deficit. As patients were also in the stable phase of recovery ($\geq$6 months post-injury), most showed only minor or no clinical signs of neglect or extinction. This in effect focused the study on sub-clinical deficits. Second, to minimize motor involvement and biases in space exploration, we studied perception within the time frame of a single fixation, arguably the basic element of vision. Unlike the RT experiments described above our tasks involved no significant motor component, but only required unspeeded report of perceived items. This should make findings specific to the visual system and not confounded by asymmetrical motor biases or general slowing of response. Third, we based the analysis of the experimental data on the Theory of Visual Attention (TVA) developed by Bundesen (1990). This enabled us to analyze performance into a number of parameters related to sensory effectiveness, perception thresholds, attentional weighting and visual short-term memory capacity, and thus to identify specific components in the visual asymmetries. By measuring this range of visual parameters in each patient, we were able to address hypotheses on the relation between extinction and general attentional capacity (Husain, Shapiro, Martin, & Kennard, 1997; Karnath, 1988; Mattingley, 2002) and the relation between sensory effectiveness and extinction (Marzi et al., 2001). Another strength of TVA analysis is that it can be coupled with statistical bootstrap methods to estimate the measurement error related to each test result (Habekost & Bundesen, 2003), which is very useful for investigating minor abnormalities. As a final feature, the study included high-resolution MR scans of each patient, which were used for statistical lesion analysis.

1.1. Theory of Visual Attention

The TVA theory forms a basic analytic frame for our study. The theory was presented by Bundesen (1990) and accounts for findings from a wide range of experimental paradigms such as single-stimulus recognition, whole report, partial report, detection and visual search (for a recent review of TVA and the attention literature, see Bundesen & Habekost, 2005). The model has also been integrated with theories of memory, categorization and executive function (Logan, 2002; Logan & Gordon, 2001). Whereas the original TVA model was framed at a cognitive description level, its principles have recently been shown to have a strong analogy at the single cell level (Bundesen, Habekost, & Kyllingsbæk, 2005). The principles of TVA were introduced in a neuropsychological context by Duncan et al. (1999), who studied a group of neglect patients. Since then the method has