ARTICLE IN PRESS

Neuropsychologia xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Neuropsychologia

journal homepage: www.elsevier.com/locate/neuropsychologia

Action blindsight and antipointing in a hemianopic patient

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ARTICLE INFO

Keywords:
Action blindsight
Hemianopia
Residual vision
Pointing
Spatial localisation

ABSTRACT

Blindsight refers to the observation of residual visual abilities in the hemianopic field of patients without a functional V1. Given the within- and between-subject variability in the preserved abilities and the phenomenal experience of blindsight patients, the fine-grained description of the phenomenon is still debated. Here we tested a patient with established “perceptual” and “attentional” blindsight (c.f. Danckert and Rossetti, 2005). Using a pointing paradigm patient MS, who suffers from a complete left homonymous hemianopia, showed clear above chance manual localisation of ‘unseen’ targets. In addition, target presentations in his blind field led MS, on occasion, to spontaneous responses towards his sighted field. Structural and functional magnetic resonance imaging was conducted to evaluate the magnitude of V1 damage. Results revealed the presence of a calcarine sulcus in both hemispheres, yet his right V1 is reduced, structurally disconnected and shows no fMRI response to visual stimuli. Thus, visual stimulation of his blind field can lead to “action blindsight” and spontaneous anti-pointing, in absence of a functional right V1. With respect to the antipointing, we suggest that MS may have registered the stimulation and subsequently presumes it must have been in his intact half field.

1. Introduction

The paradoxical term *blindsight* refers to the ability of patients, who suffer from visual field defects due to damage to the primary visual cortex, to respond above chance level to visual stimuli in the blind areas of their visual field. The first scientific description of blindsight was published by Pöppel et al. (1973) who demonstrated that hemianopic patients made accurate saccades to light flashes presented in their blind half-field. Weiskrantz and co-workers (e.g. Sanders et al., 1974; Weiskrantz et al., 1974; Weiskrantz, 2009) took this initial observation one step further and showed that the effects could also be demonstrated using manual pointing and verbal forced-choice responses. Perenin and Jeannerod (1975) extended the evidence for residual manual localisation after cortical lesions, while the effect was not found for pattern discrimination in the impaired field of their patients.

Not surprisingly, this phenomenon attracted widespread attention, as it has major implications for theories of mental processing in general and consciousness in particular (e.g. Cowey, 2010), and blindsight is now one of the hallmarks of the cognitive neurosciences, not unlike the split-brain phenomenon (e.g. Gazzaniga, 2005). However, as is the case with split-brain research (e.g. Pinto et al., 2017), the fine-grained description of blindsight has remained controversial. Earlier criticism (e.g. Campion et al., 1983) focused on alternative explanations such as scattered light and/or rudimentary near-threshold vision. Although subsequent studies refuted most of these criticisms (see Cowey, 2010 for a review), there is still a need for a better description of the blindsight phenomenon in different, individual patients. Apart from blindsight for location, it has since been argued that blindsight patients may respond to flicker, contrast sensitivity, motion and wavelength (e.g. Weiskrantz, 2009; Stoerig and Cowey, 1992). In addition, above chance processing of higher-order properties has been proposed (e.g. Tamietto and Morrone, 2016). For instance, Trevethan et al. (2007) argued for preserved categorical perception and Solcà et al. (2015) for recognition of familiar faces presented in the blind field.

Over the years, it has become apparent that different patients may show differences in the nature of the phenomenon. In response to differences in the phenomenal experience of patients, two forms of it have been proposed by Weiskrantz et al. (1995). In type 1 blindsight, the patients experience no awareness of any kind, while patients with type 2 blindsight experience a non-visual experience that, and even where, something occurred. In addition, Danckert and Rossetti (2005) suggested three different types of blindsight. First, patients who are able to act upon stimuli in the blind field (e.g. by pointing or saccades) are classified as having “action-blindsight”. Second, patients who respond

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https://doi.org/10.1016/j.neuropsychologia.2018.03.029
Received 8 September 2017; Received in revised form 14 March 2018; Accepted 22 March 2018

on the basis of attentional processing of blind field stimuli are thought to have "attention-blindsight", and third, patients who demonstrate above-chance perceptual judgements for different stimulus characteristics presented in the blind field are classified as having "perceptual blindsight".

Thus, there are good reasons for in-depth, experimentally sound, studies of individual patients who demonstrate a form of preserved processing in their blind field, in order to formulate a reliable taxonomy of different forms of the blindsight phenomenon. In this paper, we sought to explore further the characteristics of the preserved processing in the patient MS, who has been studied in detail by Cowey and co-workers. MS suffers from a complete left homonymous hemianopia but can respond to visual stimulation in his blind field, notably to motion (e.g. Alexander and Cowey, 2010; Pavan et al., 2011). Alexander and Cowey (2009) used Transcranial Magnetic Stimulation (TMS) over the middle temporal visual area (MT+ or V5) in the right hemisphere to show that the detection of motion in the blind field was dependent on cortical processing. The aim of the current study is to investigate the possibility of "action blindsight" in a case of well established "perceptual and attentional blindsight", employing a pointing paradigm. Also, we perform structural and functional magnetic resonance imaging (MRI) to evaluate the magnitude of V1 damage and the possibility of rudimentary V1 activation in both hemispheres, since the absence of a functional V1 is central to the definition of blindsight.

2. Materials and methods

2.1. Case history

MS is a former police cadet who contracted a febrile illness in 1970, at the age of 23. A full case description has been given by Newcombe and Ratcliffe (1975) and Ratcliff and Newcombe (1982), so we will only summarize the essential details here. The presumptive diagnosis was herpes encephalitis, but this was never confirmed by viral antibody studies. Radiology showed that most of the ventral temporal cortex of both hemispheres was destroyed extending to occipital cortex on the right, leaving him with a complete left homonymous hemianopia. However, his visual acuity in the seeing field is normal (6/6; N5 for near vision). He suffers from achromatopsia and his colour perception impairment has been studied extensively (Mollon et al., 1980; Heywood et al., 1991, 1994, 1996). He also has a severe object agnosia (successfully identifying only 8/36-line drawings) and prosopagnosia (e.g. Newcombe et al., 1989) but remains able to read accurately. His comprehension of what he reads is, however, affected by an impairment of semantic memory which can also be seen in the fact that he could only successfully name 20/36 objects from verbal descriptions of their functions. This semantic memory impairment is more marked for living than for non-living things (Young et al., 1989). More recently, Cowey and co-workers have provided convincing evidence for perceptual blindsight (e.g. Alexander and Cowey, 2009; Cowey, 2010; Pavan et al., 2011).

2.2. Experimental set-up

This experiment was set up to evaluate immediate pointing and reach-to-grasp movements to targets in the visual periphery. Target positions were arranged in an arc of 55 cm radius around MS's body. The centre of the arc was marked by a black cross and aligned with the subject's midsagittal axis. Throughout the trials, the subject was asked to fixate this cross. The first peripheral target position was approximately 5° from fixation with subsequent target positions at 5° intervals. The locations were indicated by black dots printed on a large plasticised white paper (841 mm x 297 mm) placed flat on the table. In addition, the fixation cross itself was used as a target location. A blue circle placed 5.5 cm from the table edge indicated the starting position for the index finger, in front of the central target location. The starting position was 27 cm apart from the fixation cross. A schematic representation of the experimental set-up is shown in Fig. 1.

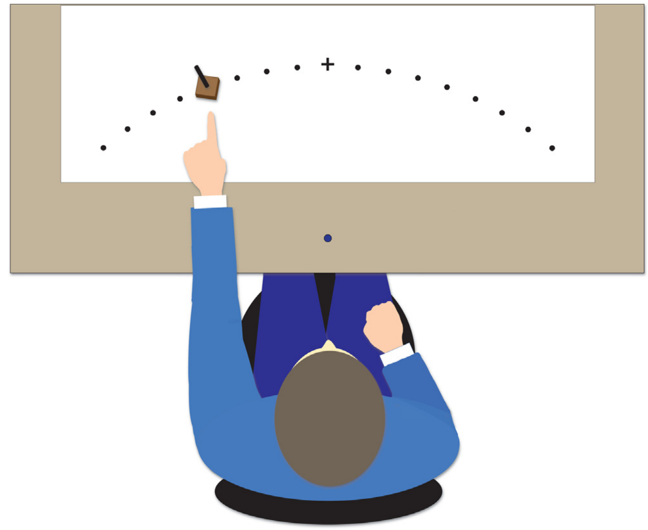

Fig. 1. Experimental set-up. The target position is depicted at 20° in the left visual field.

In a practice run performed the day before, MS was familiarised with the set-up. There were 23 practice trials performed with his right hand (9 left visual field, 9 right visual field, 5 central) and 24 practice trials with his left hand (3 left visual field, 13 right visual field, 8 central). During the practice trials, the target object was a light wooden cylinder (diameter: 9 mm, height: 161 mm), attached to a small square footing ($w \times h$: 34 mm × 5 mm). To enhance the target's discriminating features, it was replaced by a black cylinder during experimental trials.

Data were collected in two separate sessions. In the first session, the target object was the experimenter's finger, that moved up and down at one of the predefined target positions. In the second session, the target object was a black cylinder (diameter: 9 mm, height: 161 mm), attached to a wooden square board ($w \times h$: 34 mm × 5 mm). Performance was monitored through two video cameras placed in front and above the table.

2.3. Procedure

The procedure for both test sessions was identical. MS sat comfortably behind a table and rested his index finger on the starting position. Each trial started with MS fixating the central cross. After a variable delay, the investigator moved the target object in pseudo-random order to one of the locations along the arc. A verbal "go" signal, instructed MS to start a movement. In both sessions, performance in the sighted field was explored first to familiarise him with the task. MS was instructed to make fast pointing movements to the target whilst maintaining fixation on the central cross. For trials in the blind visual field, MS was encouraged to point to where he thought the target was located even when he could not perceive it. MS responded with his left dominant hand. Eye-fixation was monitored visually on all trials by a second investigator who sat opposite MS and confirmed using the front view camera footage.

2.4. Movement recording

Movements were recorded using a video camera mounted on the ceiling above the table, providing an overhead view. To be able to make measurements from the video images, perspective distortions were corrected using Final Cut Pro (version X) video editing software. Further video analysis was performed on a frame-by-frame basis in