

Processing of global form and motion in migraineurs

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Received 1 December 2004; received in revised form 14 September 2005

Abstract

Previous studies have identified anomalies of cortical visual processing in migraineurs that appear to extend beyond V1. Migraineurs respond differently than controls to transcranial magnetic stimulation of V5, and can demonstrate impairments of global motion processing. This study was designed to assess the integrity of intermediate stages of both motion and form processing in people with migraine. We measured the ability to integrate local orientation information into a global form percept, and to integrate local motion information into a global motion percept. Control subjects performed significantly better than migraineurs on both tasks, suggesting a diffuse visual cortical processing anomaly in migraine.

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Keywords: Migraine; Vision; Visual cortex; Extrastriate cortex; Psychophysics

1. Introduction

A number of studies have identified differences in cortical processing in people with migraine when compared to non-headache controls. A variety of methods have been used including psychophysics (McColl & Wilkinson, 2000; Palmer, Chronicle, Rolan, & Mulleners, 2000; Shepherd, 2001; Wray, Mijovic-Prelec, & Kosslyn, 1995) electrophysiology (for review see Schoenen, 1998; Schoenen, Ambrosini, Sandor, & De Noordhout, 2003) and transcranial magnetic stimulation [TMS] (Batelli, Black, & Wray, 2002; Mulleners, Chronicle, Palmer, Koehler, & Vredeveld, 2001). While there has been some conjecture in the literature regarding the exact nature of the underlying neural cause of these phenomena (Ambrosini, De Noordhout, Sandor, & Schoenen, 2003; Boska, Welch, Barker, Nelson, & Schulz, 2002; Schoenen, 1998) there is general agreement that migraineurs demonstrate differences in cortical processing, and, that an enhanced knowledge of these differ-

ences may assist in our understanding of the migrainous process.

Many previous psychophysical studies measuring visual performance in migraineurs have used measures which presumably measure primary visual cortex (V1) function (for example: McColl & Wilkinson, 2000; Palmer et al., 2000; Shepherd, 2001; Wilkinson & Crotopino, 2000; Wray et al., 1995). Study of V1 function has been motivated because migrainous visual aura is oriented and highly retinotopic (Grusser, 1995). Recent studies using TMS suggest additional differences in neural function in the extrastriate cortical areas of individuals with migraine (Batelli et al., 2002; Fierro et al., 2003).

Several studies have found that migraineurs perform more poorly than controls on global motion perception tasks (McKendrick & Badcock, 2004a; McKendrick, Vingrys, Badcock, & Heywood, 2001). Normal global motion performance is dependent on intact information from early in the motion pathway as well as on normal processing in extrastriate visual cortical area V5. Evidence for the importance of V5 in the processing of global motion arises from neurophysiological studies in primates (Newsome, Britten, & Movshon, 1989; Pack, Berezovskii, & Born, 2001), psychophysical studies where both primates and humans have lesions affecting area V5 (Baker, Hess, & Zihl, 1991; New-

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some & Pare, 1988; Schiller, 1993) and from functional imaging studies investigating human cortical areas active during the perception of motion (Greenlee, 2000; Paradis et al., 2000). Both migraine with aura and migraine without aura groups (McKendrick & Badcock, 2004a) demonstrate an impaired ability to integrate local motion signals into a frontoparallel global motion percept. Given that TMS suggests anomalies in V5 in migraineurs (Batelli et al., 2002), it seems plausible that the functional impairment on global motion tasks may result, at least in part, from abnormalities in V5, rather than purely from reduced or aberrant neural input to V5.

The cortical visual neural pathways are comprised of two major processing streams, often referred to as the dorsal and ventral pathways (for review see Croner & Albright, 1999; Ungerleider & Haxby, 1994). These pathways have been traditionally considered to be anatomically and functionally separate (Croner & Albright, 1999). The dorsal stream receives most of its projections from the magnocellular precortical visual pathway. After V1, neurons within the dorsal stream either project directly to the intermediate processing extrastriate area V5 (Movshon & Newsome, 1996) or project to V5 indirectly through V2 and V3 (Rosa, 2002). This dorsal pathway is considered chiefly responsible for the processing of information about visual motion (for review see: Croner & Albright, 1999; Ungerleider & Haxby, 1994). In contrast, the ventral stream receives most of its projections from the parvocellular precortical visual pathways, and, after V1, has substantial projections to V4, again through V2 and V3. The ventral stream is considered chiefly responsible for the processing of visual colour and form information (Croner & Albright, 1999; Ungerleider & Haxby, 1994). The hierarchical organisation of the human visual system results in V1 processing predominantly local attributes of a visual stimulus, whereas neurons in extrastriate areas V5 and V4 are able to integrate local motion and form information, respectively, into more complex percepts (Gallant, Shoup, & Mazer, 2000; Newsome et al., 1989; Pack et al., 2001; Wilkinson et al., 2000). The traditional view of total separation between motion and form processing has been shown to be overly simplistic (Tolias, Keliris, Smirnakis, & Logothetis, 2005) as stimulus pattern structure can significantly influence perceived motion (Badcock, McKendrick, & Ma-Wyatt, 2003; Ross, Badcock, & Hayes, 2000), and conversely, motion information can affect perceived form (Regan, 2000). Nevertheless, the predominant processing of motion and form information appears to occur in the dorsal and ventral streams, respectively (Tootell, Tsao, & Vanduffel, 2003).

Given that both TMS and psychophysical studies suggest anomalies of neural processing at the level of V5 in the dorsal pathway, we were interested in exploring whether similar differences could be identified at an analogous level of the ventral cortical visual pathway (V4). To address this question we measured the ability of people with migraine to integrate local orientation information

into a global form percept, an ability that is likely to be mediated by neurons in area V4 (Wilson & Wilkinson, 1998; Wilkinson et al., 2000; Wilson, Wilkinson, & Asaad, 1997). In the same subjects, we also measured the ability to integrate local motion signals into a coherent motion percept. A generalised cortical hyperexcitability, such as has been proposed to exist in people with migraine, may result in an increase in neuronal noise. As the ability to integrate global motion yields a signal:noise ratio that is constant at threshold in the density range used here (Edwards & Badcock, 1994), if hyperexcitability results in increased neuronal noise, we may predict that performance on global motion tasks may be impaired in migraineurs. Detection of coherence in Glass patterns (an analogous global form task used in our experiments) by normal observers also depends on the signal:noise ratio but in this case the threshold rises more slowly with increases in noise than in the global motion case (Badcock, Clifford, & Khuu, 2005). We endeavoured to determine whether visual processing abnormalities in people with migraine exist for both global motion and global form tasks, implying a generalised anomaly of intermediate level cortical visual processing.

2. Methods

2.1. Subjects

Nineteen subjects with migraine participated in the study, including 10 migraine without aura (aged 24–42 years); and 9 migraine with aura (aged 21–36 years). A group of 16 non-headache controls was also recruited (aged 18–46 years). Control subjects were required to have never experienced a migraine and to be free from regular headaches. The mean ages of the groups were not significantly different (mean age: controls = 29.8 years; migraine without aura = 28.6 years; migraine with aura = 29.7 years: one-way ANOVA $F(32, 1) = 0.10$; $p = 0.90$). Psychophysical observation experience was approximately equivalent between the two groups. Four subjects in each of the migraine and control groups had previously participated in psychophysical experiments in our laboratory.

Subjects were required to meet the following visual and ocular health criteria: best corrected visual acuity of 6/7.5 or better, refractive errors less than ± 5.00 diopters sphere and ± 2.00 diopters astigmatism, normal anterior eye and ophthalmoscopic examination, intra-ocular pressures of less than 21 mmHg, no evidence of glaucoma, no history of diabetes or other systemic disease known to affect ocular function with the exception of migraine, and were not taking any medications known to affect visual field sensitivity or contrast sensitivity.

Migraine subjects were required to have migraine symptoms meeting the International Headache Society criteria (Headache Classification Committee of the International Headache Society, 1988) for either Migraine with Aura (MA) or Migraine without Aura (MO). Headache severity was assessed using the Migraine Disability Assessment

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