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Perceptual organization deficits in traumatic brain injury patients

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ABSTRACT

Traumatic brain injury (TBI) is a prevalent condition and there is limited visual perception research with this population. Here, we investigated perceptual organization changes in a rather homogeneous sample of closed head TBI outpatients with diffuse axonal injury only and no other known comorbidities. Patients had normal or corrected visual acuity. Perceptual organization was measured with the Leuven Perceptual Organization Screening Test (L-POST), a coherent motion task (CM) and the Leuven Embedded Figures Test (L-EFT). These tests were chosen to screen for deficits in different aspects of perceptual organization (L-POST), to evaluate local and global processing (L-EFT) and grouping in a dynamic set of stimuli (CM). TBI patients were significantly impaired compared to controls in all measures for both response time and accuracy, except for CM thresholds and object recognition subtests. The TBI group was similarly affected in all aspects of the L-EFT. TBI was also similarly affected in all perceptual factors of the L-POST. No significant correlations were found between scores and time post-injury, except for CM thresholds ($r_s = -0.74$), which might explain the lack of group-level differences. The only score significantly correlated to IQ was L-EFT response time ($r_s = -0.67$). These findings demonstrate that perceptual organization is diffusely affected in TBI and this effect has no substantial correlations with IQ. As many of the neuropsychological tests used to measure different cognitive functions involve some level of visual discrimination and perceptual organization demands, these results must be taken into account in the general neuropsychological evaluation of TBI patients.

1. Introduction

Traumatic brain injury (TBI) is a highly prevalent condition that is responsible for a substantial social and economic impact worldwide. Nevertheless, it is easy to argue that research on the topic is still scarce and this is particularly true in regards to the cognitive aspects of vision. There is growing research on how TBI may be related to changes in the retina, optic nerve, vergence, saccades, and more (see Ventura et al. (2014) for a review), generally with an ophthalmological approach. There is also growing information on how TBI can affect executive functions, attention and personality (e.g. French et al., 2014; Rike et al., 2014; Zaninotto et al., 2014). Notably, we are not aware of any specific investigation of how TBI might affect perceptual organization (broadly defined here as the processes by which one integrates the basic features of visual information into structured wholes, e.g. van der Helm, 2012).

One obstacle for studies on this subject is the variability of severity and behavioral outcomes in TBI patients. According to field standards, TBI may be defined as a traumatically induced structural injury and/or physiological disruption of brain function as a result of an external force that is immediately followed by at least one of the following clinical signs: any period of decreased or lost consciousness, any memory loss for events immediately before or after the injury, any alteration in mental state at the time of the injury, transient or persistent neurological deficits, and/or intracranial lesions (Management of Concussion/mTBI Working Group, 2009).

Although TBI cases may differ in many crucial aspects, one of its most critical and frequent clinical manifestations is diffuse axonal injury (DAI, see Johnson et al. (2013) for a review). DAI is generally characterized as small lesions caused by dynamic deformation of white matter tracts when rapid head rotational movements and inertial forces take place (e.g. Gennarelli, 1992). As DAI seems to be present in most cases of TBI (Johnson et al., 2013), a possible way

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Table 1
Patient information.

Patient	Age	Weeks since trauma	Glasgow coma	Education in years	Medication (daily dose)	Visual acuity logMAR	Perceived change in vision	Comments	IQ
1	25	37	4	14	Amitriptyline 25 mg	0	3		94
2	25	18	7	12	Quetiapine 10 mg Gabapentine 300 mg	0.1	4	Complains about difficulty to read and frequent headaches.	83
3	21	28	6	12	–	−0.1	0		91
4	26	35	3	12	–	−0.1	0		110
5	19	39	8	12	–	−0.1	0		87
6	18	30	7	12	–	−0.1	3		78
7	26	31	3	12	–	−0.2	5	Headaches and some photophobia	94
8	30	38	6	9	-	−0.1	1	Diplopia in the first four months post lesion	83
9	24	24	11	12	–	0.1	0		89
10	18	30	7	9	–	−0.1	0		72
11	44	26	5	12	–	0	0		97
12	21	33	12	12	–	0	0		83
13	20	30	7	12	–	−0.06	10		67
14	18	20	3	12	–	−0.1	0		89

to investigate behavioral changes that might be common to different patients is to assess participants with closed head injuries and diagnosed with DAI only (and no other lesions).

Here we propose to investigate perceptual organization in a group of TBI outpatients with DAI alone and no other known comorbidities. As visual perception is crucial for the adaptation in everyday life and has a structuring role in cognition as a whole, better understanding the effects of TBI on perceptual organization is critical for a more encompassing understanding of TBI and its behavioral outcomes. Also, as many of the neuropsychological tests used to measure different cognitive functions involve some level of visual discrimination and perceptual organization, it is important to evaluate if these functions are affected in these patients and take this into account when analyzing the results of vision-based neuropsychological tests.

But why focus on perceptual organization in particular? Visual perception is a hierarchical process that might be divided in three levels: a lower level (involving the hardwired extraction of primitive stimulus properties such as contrast, orientation and spatial frequency), mid-level vision (mostly involving the integration of basic stimulus features into more structured wholes) and higher-order processes involved in the recognition of specific elements (see Wagemans et al. (2005, 2012) for a review). Mid-level vision encompasses perceptual organization and we have focused on this process for three reasons: (i) higher-order visual processes generally involve some level of semantic knowledge, memory and other such processes that might become confounding factors in a clinical population like TBI; (ii) lower-level vision investigations offer significant insight on the functional status of the early visual system (and if it is disrupted or preserved) but might offer limited information on the difficulties found in everyday life (e.g. Costa et al., 2012); (iii) a large portion of our brain is devoted to vision and mid-level vision is at the core of this process; as many alterations in brain function are reflected in visual processing changes, evaluating mid-level vision could provide substantial insight into these changes.

As we did not have information on how TBI might affect perceptual organization before performing this study, we have used a new perceptual organization screening test (Leuven Perceptual Organization Screening Test, L-POST) in order to see how different grouping processes and figure-ground organization were affected. As the L-POST is a screening tool (with a limited number of trials in each of its subtests), we decided to test also a few aspects of perceptual organization in more detail. As the ability to integrate local features in global wholes and separate figure from ground is crucial aspects of perceptual organization, we decided to use an embedded figures task in these patients. The Leuven Embedded Figures Test (L-EFT) is a version of the classic embedded figures task by Witkin et al. (1962) and intends to measure the ability to identify a figure that is embedded in a background, giving a glimpse on the status of the patient's figure-ground organization and their ability to integrate local parts in global wholes. We have also used a coherent motion task to assess the ability to extract a globally defined motion direction signal from locally randomly moving noise elements. As DAI is characterized by diffuse and multiple lesions in the white matter, we expected to observe general perceptual organization deficits.

2. Methods

This was a case-control study where we intended to test as many aspects of perceptual organization as possible, given the limited availability of patients and time. This study followed international ethical standards and was approved by the Institutional Ethics Committee and registered with the number 0097/11.

2.1. Participants

Fifteen closed head TBI outpatients (23.9 ± 6.6 years old) were tested. One of the patients was excluded given the presence of ocular injury. Participants had sustained TBI for at least 4 and no more than 9 months at the time of the evaluation. All subjects suffered TBI after traffic accidents. Participants were not included in the study if they had more than one episode of TBI, showed evidence of abnormalities other than DAI in structural MRI scans (e.g. contusions, epidural hematoma, subdural hematoma, etc.) were diagnosed with neurologic or psychiatric conditions (e.g. epilepsy, stroke, tumors). All patients had sustained one single episode of moderate to severe DAI, defined here as a Glasgow Coma Scale score below 13. Patients with scores above the cut-off point for anxiety or depression in the Hospital Anxiety and Depression Scale (Zigmond and Snaith, 1983) were also not included. Patients who claimed to have a recent history of alcohol or substance abuse were not included. More detailed patient information can be found in Table 1. An age-matched control group with 15 participants (22.3 ± 4.7 years old) with no history of TBI or other neuropsychiatric conditions was tested too. Patients and controls did not differ in years of education ($P=0.12$) or visual acuity ($P=0.23$).