



Hemispheric differences in spatial relation processing in a scene perception task: A neuropsychological study

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ARTICLE INFO

Article history:

Received 19 July 2010

Received in revised form 20 January 2011

Accepted 12 February 2011

Available online 25 February 2011

Keywords:

Categorical and coordinate spatial relations

Scene perception

Unilateral brain damage

Lateralisation

ABSTRACT

Understanding a complex visual scene depends strongly on our ability to process the spatial relations between objects in that scene. Two classes of spatial relations can be distinguished. Categorical information concerns more abstract relations, like “left of”, while coordinate information is metric and more precise, such as “2 cm apart”. For categorical processing a left hemisphere advantage is typically found, and coordinate processing is linked to a right hemisphere advantage. However, this has scarcely been investigated in more naturalistic settings. The aim of the present study was to explore spatial relation coding in natural scenes as well as to gain more insight in hemispheric differences in processing categorical and coordinate position changes, by testing patients with unilateral stroke. By means of a comparative visual search task using images of rooms, a healthy control group ($N = 28$), patients with left hemisphere stroke (LH) ($N = 16$), and patients with right hemisphere stroke (RH) ($N = 17$) were tested on their ability to detect position changes that were either only coordinately different (coo), or both coordinately and categorically different (coo + cat). The response pattern of the control subjects confirmed previous findings that both coordinate and categorical information contributed to position change detection. Compared to the control group, the RH patient group showed an impairment on both coo and coo + cat position changes. In contrast, the LH patient group was not impaired on the coo condition and showed only a trend of impairment on the coo + cat condition. These response patterns suggest that lateralisation patterns found in previous, more simple and controlled experiments are also present to some degree in a more complex and lifelike setting.

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1. Introduction

During scene perception only very little visual information about the scene is coded (see Henderson & Hollingworth, 1999) as is illustrated by the change blindness phenomenon, in which large differences between scenes can remain undetected (Rensink, O'Regan, & Clark, 2000). However, the mechanisms that have been proposed to underlie this finding appear to lack a clear description of the type of information that is extracted to detect changes in scenes. As an exception, Rosielle, Crabb, and Cooper (2002) investigated the process of location encoding during scene perception. Based on their results, they proposed that position coding can occur in a categorical as well as in a metric, or coordinate, fashion. These two types of encoding relate directly to Kosslyn's (1987) theory on spatial relation processing between and within objects. This the-

ory distinguishes categorical, abstract relations like “left of”, from coordinate, metric relations like “2 cm apart”. It is proposed that these form two separate classes of relations which engage separate underlying mechanisms (for a review see Jager & Postma, 2003).

Rosielle et al. (2002) found that both categorical and coordinate position information is encoded during scene perception. In their change detection experiment participants viewed scenes in which the spatial position of an object was changed. This change could be categorically the same or different with regard to its nearest surroundings. In any position change the coordinate relation would change, as any change in spatial position is coordinate by definition. Therefore, a categorical change can be regarded as the addition of a categorical change of the objects' position with regard to its surroundings, to a coordinate change. Rosielle et al.'s results indicated that a coordinate change was sufficient to detect the change, and that a categorical change enhanced detection performance. This categorical advantage has also been confirmed by Dent (2009), who replicated this effect with stimuli consisting of simple configurations of four small squares.

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Within the field of spatial relation processing, the main focus is directed at the neural underpinnings of the suggested separate processing mechanisms. Along with the first description of this distinction, *Kosslyn (1987)* linked spatial relation processing to differences in hemispheric lateralisation. Categorical processing was thought to show a left hemisphere advantage, whereas the right hemisphere would predominate in processing coordinate information. In many behavioural (e.g. *Hellige & Michimata, 1989; Laeng & Peters, 1995; van der Ham, van Wezel, Oleksiak, & Postma, 2007*) and neurofunctional studies (e.g. *Baciu et al., 1999; Trojano, Conson, Maffei, & Grossi, 2006; van der Ham, Raemaekers, van Wezel, Oleksiak, & Postma, 2009; van der Ham, van Strien, Oleksiak, van Wezel, & Postma, 2010*), this lateralisation pattern has been found for tasks testing categorical and coordinate relation processing. Neuropsychological studies thus far have been sparse but have also found supportive evidence (e.g. *Laeng, 1994; Palermo, Bureca, Matano, & Guariglia, 2008; van Asselen, Kessels, Kappelle, & Postma, 2008*). Yet, to the best of our knowledge, direct evidence that these lateralisation patterns are also present in the processing of spatial relations in natural scenes is lacking. Therefore, in this study we compared patients with unilateral brain damage with respect to their abilities to detect spatial relation changes of objects situated in a daily life setting. Importantly, the outcomes could have clinical relevance by increasing the understanding of the problems these patients may experience in their personal environment.

Rosielle et al. (2002) employed the “flicker” paradigm, which entails a very fast and intermittent presentation of two scenes; one without and one with a position change. Here we have used the slightly different “comparative visual search” task (*Pomplun et al., 2001*). In this type of task the subject compares two scenes that are simultaneously presented. This design has several advantages over the flicker paradigm. The limited exposure duration of the flicker paradigm influences the scanning rate of the subject’s eye movements and potentially also limits the functional field for information acquisition. Furthermore, the flicker paradigm may violate some of the observer’s assumptions about the visual world (*Galpin & Underwood, 2005; Simons, 2000*). In contrast, the comparative visual search allows for the adoption of a clustering strategy (*Pomplun et al., 2001*), which decreases memory usage and does not hinder the subject’s preferred eye movement patterns (*Galpin & Underwood, 2005*). We implemented the same two conditions as reported by *Rosielle et al. (2002)*: one in which position changes were only coordinately different (“lamp left of chair” would remain “lamp left of chair”, but with a different distance),

and one in which position changes were different coordinately and categorically (“lamp left of chair” would change to “lamp right of chair”).

Here, the lateralisation pattern was not determined based on differences between visual half fields, but between patients with lesions in the left hemisphere (LH) and patients with lesions in the right hemisphere (RH). The more traditional visual half field approach requires very brief presentation durations and consequently limited stimulus complexity. In the comparative visual search task, we could use relatively long and simultaneous presentation of realistic stimuli, which fits well within the neuropsychological setting. We hypothesized that patients with LH or with RH damage are impaired on categorical or coordinate processing, respectively. In terms of our experimental design LH patients should be able to process coordinate information correctly, but would show impairment in categorical processing, in turn leading to impaired performance on categorical change trials, but not on coordinate change trials. In contrast, RH patients were expected to be impaired in determining both types of location changes as they both include coordinate changes, but they might benefit from additional categorical information and show a categorical advantage.

2. Methods

2.1. Participants

Thirty-three patients who suffered from ischemic or haemorrhagic stroke were selected from the Stroke Database of the University Medical Center Utrecht. Inclusion criteria were: (1) age between 18 and 80 years; (2) no history of previous neurological or psychiatric disorder; (3) testing occurred 6–18 months after the onset of the stroke; (4) lesion visible on CT or MRI scan; and (5) no hemispatial neglect or hemianopia. Neurological and neuropsychological reports in hospital records were consulted to exclude patients with neglect or hemianopia. In addition, patients with aphasia were excluded. Informed consent was obtained from each patient. The control group consisted of 28 healthy subjects who were highly comparable to the two patient groups with respect to age ($M = 58.3$, $SD = 6.5$) and level of education ($M = 5.4$, $SD = 1.0$). All controls had normal or corrected to normal vision and had no history of neurological or psychiatric illness.

Level of education was scored using seven categories, one being the lowest and seven the highest level (*Verhage, 1964*). Handedness was assessed with the Dutch version of the Annett Handedness Inventory, with scores ranging between -24 (extremely left-handed) and $+24$ (extremely right-handed) (*Annett, 1970*). Lesions were classified on the basis of the description of the CT or MRI data by an experienced neurologist. Sixteen patients had lesions in the left hemisphere, and 17 in the right hemisphere. In *Appendix A*, a detailed description is given for all patients individually, including detailed lesion information. In *Table 1* characteristics concerning age, gender, education, and handedness are provided for all three groups.

Table 1
The mean scores on the neuropsychological tests for all three groups. Standard deviation in parentheses. Education = category of education level, range 1–7 (low–high). Handedness = raw score of Annett Handedness Questionnaire. NART = National Adult Reading Task (Dutch version). Raven short form = age controlled percentile. Letter number sequencing = age controlled percentile as indicated by WAIS. Corsi block test forward and backward = number of correct trials. TMT B/A = trail making test, time version B/time version A. RAVLT = Rey Auditory Verbal Learning Test, immediate = total number of words recalled, delayed = age controlled decile. Spatial preposition task = number of correctly identified pictures, range 1–16.

	Controls (N = 28)	LH patients (N = 16)	RH patients (N = 17)
Delay event – test (months)		14.0 (3.8)	13.8 (5.5)
Age	58.3 (6.5)	62.4 (11.2)	55.4 (14.3)
Gender	12 M/16 F	12 M/4 F	10 M/7 F
Education	5.4 (1.0)	5.6 (1.2)	5.2 (1.0)
Handedness (Annett)	11.6 (17.7)	16.6 (11.0)	15.9 (13.0)
NART verbal IQ	106.6 (15.8)	108.6 (16.6)	101.8 (18.2)
Raven short form	58.8 (28.1)	62.3 (28.4)	35.0 (32.7)
Letter number sequencing	48.0 (29.5)	44.3 (30.1)	38.1 (32.7)
Corsi Block-Tapping Task forward	7.7 (1.4)	7.4 (1.1)	7.8 (1.7)
Corsi Block-Tapping Task backward	7.8 (1.7)	7.7 (1.7)	6.5 (1.9)
TMT B/A	2.1 (0.8)	2.9 (1.6)*	2.1 (0.3)
RAVLT immediate recall	44.0 (10.7)	30.4 (12.8)**	39.7 (11.4)
RAVLT delayed recall	8.9 (3.5)	5.9 (4.4)*	8.4 (3.0)
Spatial preposition task	15.9 (0.3)	15.8 (0.5)	15.8 (0.6)

* $p < .05$ (compared to control scores).

** $p < .01$ (compared to control scores).

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