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Stimulus size mediates Gestalt processes in object perception - evidence from simultanagnosia

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ABSTRACT

Simultanagnosia caused by posterior temporo-parietal brain damage is characterized through an inability to recognize a global Gestalt from an arrangement of single objects while perception of single objects appears widely intact. We asked whether recognition of single objects in simultanagnosia is still intact if objects are really large, i.e. if they exceed the size of a usual computer screen. Single objects were presented in three different sizes: 'regular', 'medium', and 'large'. Simultanagnosia patients demonstrated a decrease of recognition performance with increasing object size; recognition of 'large' objects was significantly impaired while perception of 'regular' sized objects was unaffected. The results argue against the traditional view of preserved recognition of single objects in simultanagnosia. They provide evidence for a more general perceptual impairment that emerges irrespective of presenting single or multiple objects, but whenever the visual system has to assemble information over larger spatial distances or other demanding viewing conditions. It appears that perception of large single objects requires intact abilities of dorsal Gestalt processing, in addition to regular functions of ventral object recognition.

1. Introduction

A holistic perception of object arrangements, like visual scenes, is a crucial aspect of human visual perception. Usually, recognizing an object arrangement, or grasping its so-called Gestalt, precedes the perception of local details (Navon, 1977). The importance of Gestalt perception is emphasized through a neuropsychological disorder called simultanagnosia (Bálint, 1909; Wolpert, 1924). In this condition, patients suffering from bilateral temporo-parietal stroke lesions or neurodegenerative diseases, like posterior cortical atrophy (PCA; Tang-Wai et al., 2004; Crutch et al., 2012), have widely preserved abilities of perceiving local elements or single objects but fail in the recognition of meaningful arrangements of multiple objects or visual scenes. It has been demonstrated that Gestalt perception in simultanagnosia can be manipulated by several aspects of a global stimulus. In particular, it was shown that in simultanagnosia perception of hierarchical Navon letters decreased with an increasing overall size of the global stimulus and wider spacing of local elements (Huberle and Karnath, 2006; Huberle et al., 2010). Also in healthy subjects, Gestalt perception can be negatively affected by the overall size of the stimulus and the distance between local parts (Kojo et al., 1993; Liinasuo et al., 1997; Rennig et al., 2013b).

In contrast to Gestalt perception, the perception of single objects appears widely unimpaired in simultanagnosia (Coslett et al., 1995; Thomas et al., 2012). Early reports of simultanagnosia have emphasized that the characteristic deficit of this syndrome is the inability to perceive two or more objects simultaneously while single object perception is not impaired. For example, from two overlapping or side by side presented stimuli simultanagnosia patients only identified one of these objects (Luria, 1959). Several studies replicated this finding, demonstrating that only the perception of multiple objects was impaired in simultanagnosia while single object recognition was widely preserved (Coslett and Saffran, 1991; Pavese et al., 2002). Only if recognition required higher perceptual effort due to alienation or unusual viewing conditions, impairments for single object perception were observed in simultanagnosia patients (Cooper and Humphreys, 2000; Riddoch and Humphreys, 2004; Robertson et al., 1997). Also, a study investigating mechanisms of feature processing in single objects reported a deficit in simultaneous perception of different object attributes in a patient with simultanagnosia (Coslett and Lie, 2008).

In previous studies where simultanagnosia patients succeeded in the recognition of single objects (Cooper and Humphreys, 2000;

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Riddoch and Humphreys, 2004; Robertson et al., 1997), these objects were of regular size, i.e. did not exceed the size of a usual computer screen or a sheet of paper. This was also the case in a study by Coslett et al. (1995) in which they compared the perception of line drawings of large size to those of a smaller size in two patients suffering from Alzheimer's disease with pronounced parieto-occipital atrophy and deficits in perceiving global Navon letters. The authors observed no significant difference in the two patients' perception of the large versus the smaller line drawings. In the present study, we asked whether recognition of single objects in simultanagnosia is still intact if objects are really large, i.e. if they exceed the size of a usual computer screen or a sheet of paper. Intact object recognition independent from object size would indicate that single object processing is widely independent from Gestalt perception. In particular, it would argue for separate systems of object and of Gestalt perception. Alternatively, it is possible that the perception of large single objects also require Gestalt perception processes because different object parts are situated far away from each other and may require visual integration. In the latter case, a large single object should elicit perceptual impairments in patients suffering from simultanagnosia.

2. Material and methods

2.1. Participants

We tested single object recognition in four simultanagnosia patients, presenting objects of 'regular', enlarged, and of very large size. One of these patients (JB) already participated in a previous study (Balslev et al., 2014), the other three were consecutively admitted to the Center of Neurology of the University Hospital Tübingen during a one year period. All of these patients suffered from neurodegenerative diseases: three of these patients were diagnosed with PCA (Crutch et al., 2012; Tang-Wai et al., 2004), one patient suffered from corticobasal degeneration (CBD) (Mahapatra et al., 2004). Fig. 1a shows neuroimaging data of the four simultanagnosia patients; they all demonstrated marked temporo-parietal atrophy. We further tested 10 chronic control patients with uni- or bilateral stroke lesions (L/R/bilateral: 1/5/4) and 12 age-matched healthy control subjects. Fig. 1b demonstrates a simple overlap of the stroke lesions. Table 1 gives the demographic and clinical data of all subjects. The study was performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki; participants or their relatives gave their informed consent.

2.2. Stimuli and procedure

2.2.1. Neuropsychological screening

All simultanagnosia and control patients were clinically tested for simultanagnosia, visual object identification, spatial neglect, visual extinction and visual field defects. Simultanagnosia was examined by three different tests: perception of 20 hierarchically organized Navon letters (Navon, 1977) where a global letter was constructed from several local letters (only incongruent versions were applied; for example, a global E composed of local Ks, etc.), recognition of elements from the Poppelreuther figure (Poppelreuter, 1917) where five overlapping objects are presented, and recognition of the gist of the Broken Window Picture, a complex visual scene from the Stanfrod Binet Intelligence scale (Roid, 2003). General abilities of visual perception were examined with the VOSP test battery (Warrington and James, 1991) and the Boston Naming Test (Kaplan et al., 1983). Data are presented in Table 1. The simultanagnosia patients showed severe impairments of global gestalt perception. Advanced object recognition functions as tested in the VOSP test revealed deficits in two patients, comparable to demanding recognition tasks in previous studies of simultanagnosia patients (Cooper and Humphreys, 2000; Riddoch and Humphreys, 2004; Robertson et al., 1997). BM showed deficits in the 'Incomplete Letter' test, while JB failed in all object recognition sub-tests of the VOSP. No abnormalities were observed in the Boston Naming test.

Spatial neglect was investigated by the Letter Cancellation Test (Weintraub and Mesulam, 1985), the Bells Test (Gauthier et al., 1989), and a Copying Task (Johannsen and Karnath, 2004). In addition, we applied a Line Bisection Task (Ferber and Karnath, 2001). For the two cancellation and the copying tasks cut-off criteria were used as applied in previous studies (Karnath et al., 2011; Rorden and Karnath, 2010); a deviation of more than 14% from the true midpoint was considered abnormal for the bisection task (Ferber and Karnath, 2001). Visual extinction was assessed with the typical neurological confrontation technique (Becker and Karnath, 2007). Ten bilateral and 10 unilateral left- or right-sided visual stimuli were presented in random order. Patients were classified as showing visual extinction when they reported at least 90% of the left or right stimuli on each side correctly but failed to indicate the contralesional stimulus during bilateral stimulation in 50% of trails. Beyond the confrontation method primary visual field deficits were assessed by a perimetry screening test. We applied the same experimental setup used to run the object identification tests of the main experiment described below. Visual stimuli (black dots; diameter: 1.6°) were projected onto a plane white wall at 16 possible locations, covering the same area where the object stimuli were planned to be presented in the main experiment (see below). Subjects had to fixate a central grey fixation cross. The examiner pressed a button to start the trial: as a cue for the upcoming stimulus presentation the cross turned black and after a randomized interval (1–2 s) a single dot was visible for 50 ms. Thirty-two test trials and 4 'catch trials' (where no dot presentation followed the cue) were conducted. Subjects had to indicate verbally if they detected a dot.

All subjects included into the study had normal or corrected to normal visual acuity. None of the control or simultanagnosia patients demonstrated symptoms of spatial neglect, biased line bisection or visual extinction. None of the simultanagnosia patients showed visual field defects; two control patients with bilateral lesions demonstrated quadrantopia. However, in all experimental object recognition tests of the main experiment (see below), the recognition performance of these two control patients were not impaired compared to the healthy control group and the other control patients. Further, all four simultanagnosia patients showed clinical symptoms of optic ataxia (Borchers et al., 2013).

2.2.2. Object identification

All patients and healthy control subjects were tested in a quiet room with dimmed light. Stimulus presentation was running under the Matlab programming environment (MathWorks, Natick, MA) and the Psychophysics Toolbox (Brainard, 1997). Stimuli were shown on a plane white wall using a projector (Hitachi CP-S21, resolution 1020 × 768 px, 60 Hz). For the object recognition tests (see below) and the perimetry screening test (see above) a distance of 114 cm between the subject and the screen was kept constant, allowing a projection area of 40° left and right as well as 30° above and below individual eye level (0°/0°). Subjects had to fixate a centrally presented (0°/0°) grey fixation cross before each presentation; fixation was visually controlled by the examiner. The examiner pressed a button to start the trial: as a cue for the upcoming stimulus the cross turned black and after a randomized interval (1–2 s) a visual stimulus appeared. With the onset of the stimulus fixation was abrogated and natural viewing behavior allowed. Presentation time ensuring stable object perception (e.g. Grill-Spector et al., 1998; Baeck and Op de Baeck, 2010) for the