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Simultanagnosia does not affect processes of auditory Gestalt perception

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ABSTRACT

Simultanagnosia is a neuropsychological deficit of higher visual processes caused by temporo-parietal brain damage. It is characterized by a specific failure of recognition of a global visual Gestalt, like a visual scene or complex objects, consisting of local elements. In this study we investigated to what extend this deficit should be understood as a deficit related to specifically the visual domain or whether it should be seen as defective Gestalt processing per se. To examine if simultanagnosia occurs across sensory domains, we designed several auditory experiments sharing typical characteristics of visual tasks that are known to be particularly demanding for patients suffering from simultanagnosia. We also included control tasks for auditory working memory deficits and for auditory extinction. We tested four simultanagnosia patients who suffered from severe symptoms in the visual domain. Two of them indeed showed significant impairments in recognition of simultaneously presented sounds. However, the same two patients also suffered from severe auditory working memory deficits and from symptoms comparable to auditory extinction, both sufficiently explaining the impairments in simultaneous auditory perception. We thus conclude that deficits in auditory Gestalt perception do not appear to be characteristic for simultanagnosia and that the human brain obviously uses independent mechanisms for visual and for auditory Gestalt perception.

1. Introduction

A holistic perception of complex visual scenes is a crucial aspect of human 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 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 but fail in the recognition of the *Gestalt* or visual scene that these elements contribute to.

Simultanagnosia is mainly considered to be an impairment of attentional processes in the visual modality (Balslev et al., 2014; Dalrymple et al., 2013; Robertson et al., 1988). However, deficits in other sensory domains, such as audition, in patients suffering from this syndrome are widely unexplored. Typical mechanisms of visual Gestalt perception, like global precedence (Navon, 1977), have been identified in the auditory domain (Bouvet et al., 2011; Justus and List, 2005). In particular, it has been demonstrated that healthy subjects were significantly primed by global features of tone sequences in a sequence recognition task (Justus and List, 2005) and that the global direction of a tone sequence (ascending or descending over several tones) influenced the perception of the direction of local sequences within the global sequence (Bouvet et al., 2011). Thus, it is interesting to investigate whether or not such auditory deficits of Gestalt perception exist in simultanagnosia. If so, this would indicate that simultanagnosia is a non-domain specific deficit, like e.g. spatial neglect or extinction that can affect multiple domains within the same subject (Bellmann et al., 2001; Clarke and Thiran, 2004; De Renzi et al., 1989; Karnath et al., 2002; Tanaka et al., 1999). More specifically, this study aims to answer if the human brain uses same or different mechanisms for visual and for auditory Gestalt perception.

While previous studies investigating mechanisms of auditory Gestalt perception in healthy subjects (Bouvet et al., 2011; Justus and List, 2005) as well as studies that identified deficits in complex auditory perception in patients with PCA and Alzheimer's disease (Golden et al., 2015a, 2015b; Goll et al., 2012) focused on rather abstract stimulus material, like tone sequences or rhythmic patterns, we applied real life sounds and created auditory tasks matching typical visual tasks that are particularly demanding for simultanagnosia patients. We know that

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integration of local parts into a global structure is disturbed in simultanagnosia in the visual domain (Navon, 1977; Cooper and Humphreys, 2000; Robertson et al., 1997; Riddoch and Humphreys, 2004). We thus presented single sounds interrupted with Gaussian noise to test if such deficits of integration can also be evoked in the auditory domain. Luria (1959) and Poppelreuther (1917); see also Balslev et al., 2014; Rennig and Karnath, 2016) reported that simultanagnosia patients are impaired perceiving visual objects presented side-by-side or are overlapping. To match this visual task we presented two natural sounds simultaneously to simultanagnosia patients. Finally, we tested if the known deficit of grasping the overall gist of visual scenes, like in the Broken Window picture (Roid, 2003), also exists for auditory scene perception in simultanagnosia patients.

2. Material and methods

2.1. Participants

We tested complex auditory perception in four simultanagnosia patients diagnosed with PCA (Crutch et al., 2012; Tang-Wai et al., 2004). Fig. 1a shows neuroimaging data from these patients; they all demonstrated marked temporo-parietal atrophy. We further tested 15 chronic control patients with uni- or bilateral stroke lesions (L/R/bilateral: 6/4/5) as well as 14 age-matched healthy control subjects; Fig. 1b demonstrates a simple overlap of the stroke lesions. Table 1 gives 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 gave their informed consent.

2.2. Stimuli & procedure

2.2.1. Neuropsychological Screening

All simultanagnosia and control patients were clinically tested for simultanagnosia, spatial neglect, visual extinction, optic ataxia, and verbal working memory. 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 Stanford Binet Intelligence scale (Roid, 2003). Data are presented in Table 1. The simultanagnosia patients showed severe impairments of visual Gestalt perception. Pathological

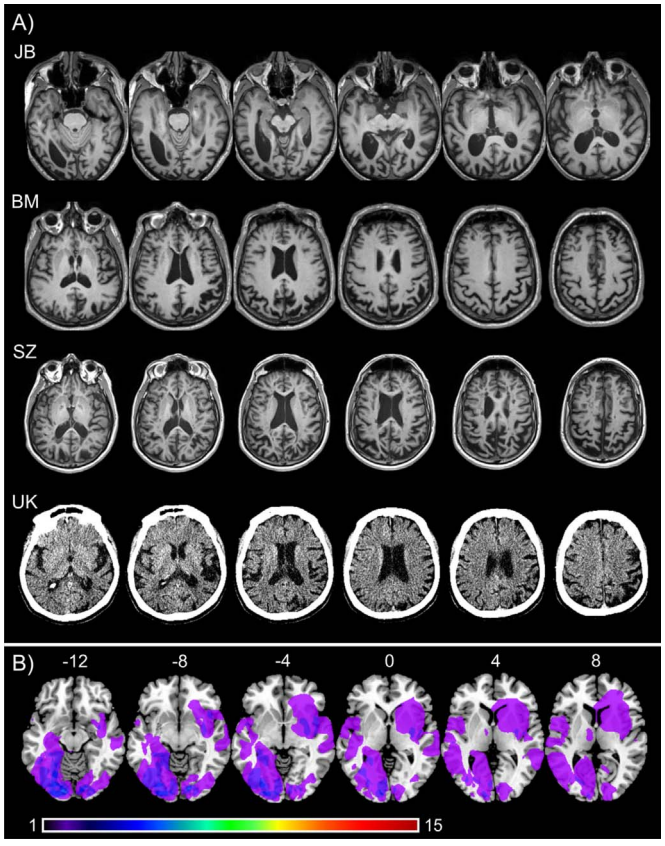

Fig. 1. Neuroimaging data from the four simultanagnosia and the control stroke patients. **(A)** High resolution T1 images demonstrate posterior temporo-parietal tissue loss in all four simultanagnosia patients. **(B)** Lesion overlap for the control patients. In each patient, lesion boundary was delineated directly on the individual scan for every single transverse slice using MRIcron software (http://www.mccauslandcenter.sc.edu/mricro/mricron). Both the MRI/CT scan and the lesion shape were then mapped into stereotaxic space using the normalization algorithm provided by the "Clinical toolbox" (Rorden et al., 2012) based on SPM8 (http://fil.ion.ucl.ac.uk/spm). The lesion maps of all control patients were superimposed on the single-subject T1 MNI152 template. The figure shows the vertical z coordinate for each slice of standardized MNI space. For each voxel, the number of patients with a lesion at that location is color coded. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article).

Table 1
Demographic and clinical data of all simultanagnosia patients, control patients and healthy control subjects. The correct performance for global/local recognition of the 20 Navon stimuli and for perception of elements from the Poppelreuther figure are given in percent correct; for the Broken Window Picture dichotomous results are reported. The results of the WMS-R are given in age-corrected percentile ranks. For the two control groups mean, standard deviation (SD) and range are given. Beyond, all subjects included into the study had normal or corrected to normal visual acuity and did not show relevant impairments in a pure-tone audiometry screening. None of the simultanagnosia or control patients demonstrated symptoms of spatial neglect, biased line bisection or visual extinction. All four simultanagnosia patients showed clinical symptoms of optic ataxia.

Patient	Sex	Age	Etiology	Global Recognition	Local Recognition	Poppelreuther	Broken Window	WMS-R (forwards)	WMS-R (backwards)
JB	M	58	PCA	0%	100%	20%	abnormal	98	5
BM	M	62	PCA	40%	100%	80%	abnormal	98	7
SZ	M	57	PCA	0%	100%	20%	abnormal	20	2
UK	F	61	PCA	20%	100%	20%	abnormal	6	2
	M/F	Mean (SD)							
Control Patients	8/7	60.7 (12.2)	12 infarct, 3 hemorrhage	100%	100%	100%	normal	Mean: 8 SD: 2 range: 3–11	Mean: 6 SD: 3 range: 2–10
Healthy controls	3/11	60.4 (6.4)	–	–	–	–	–	Mean: 74 SD: 27 range: 2–98	Mean: 60 SD: 34 range: 2–97