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Nonverbal auditory agnosia with lesion to Wernicke's area

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ABSTRACT

We report the case of patient M, who suffered unilateral left posterior temporal and parietal damage, brain regions typically associated with language processing. Language function largely recovered since the infarct, with no measurable speech comprehension impairments. However, the patient exhibited a severe impairment in nonverbal auditory comprehension. We carried out extensive audiological and behavioral testing in order to characterize M's unusual neuropsychological profile. We also examined the patient's and controls' neural responses to verbal and nonverbal auditory stimuli using functional magnetic resonance imaging (fMRI). We verified that the patient exhibited persistent and severe auditory agnosia for nonverbal sounds in the absence of verbal comprehension deficits or peripheral hearing problems. Acoustical analyses suggested that his residual processing of a minority of environmental sounds might rely on his speech processing abilities. In the patient's brain, contralateral (right) temporal cortex as well as perilesional (left) anterior temporal cortex were strongly responsive to verbal, but not to nonverbal sounds, a pattern that stands in marked contrast to the controls' data. This substantial reorganization of auditory processing likely supported the recovery of M's speech processing.
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1. Introduction

Auditory agnosia is a rare neuropsychological disorder that is characterized by a relatively isolated deficit in auditory processing, despite normal hearing. The disorder has been associated with bilateral temporal or subcortical lesions; less frequently, unilateral lesions have also been reported (see Clarke, Bellmann, Meuli, Assal, & Steck, 2000; Griffiths, 2002; Saygin, Dick, Wilson, Dronkers, & Bates, 2003; Vignolo, 1982, 2003).

Auditory agnosia restricted to nonverbal sounds is an even rarer phenomenon, previously associated with bilateral (Albert, Sparks, Stockert, & Sax, 1972; Kaga, Shindo, Tanaka, & Haebara, 2000; Kazui, Naritomi, Sawada, Inoue, & Okuda, 1990; Spreen, Benton, & Fincham, 1965) or right hemisphere (Fujii et al., 1990) lesions. Here, our focus is on the processing of sounds for meaning, or on what has sometimes been called associative, as opposed to apperceptive auditory agnosia (Buchtel & Stewart, 1989). When restricted to the nonverbal domain, previous case studies have mainly focused on apperceptive auditory agnosia, and as such, the present case report is unique in the literature.

We report the case of Patient M, who presented with chronic auditory agnosia restricted to nonverbal sounds following a lesion to the language dominant hemisphere. M suffered a left posterior temporoparietal infarct, including Wernicke's area (Fig. 1). We report on the patient's clinical history, audiological tests, and a detailed assessment of his auditory comprehension, accompanied by an acoustical analysis of the sounds he could and could not recognize. We also assessed his neural responses to verbal and nonverbal auditory material using functional magnetic resonance imaging (fMRI).

1.1. Case history

The patient, (here referred to as 'M', not his real initial), was male and was 74 years old at the time of testing. M suffered a cerebrovascular accident at 62 years of age, suddenly developing right-sided numbness and difficulty speaking. Neurologic examination at the time diagnosed acute stroke and revealed decreased sensation and control over the right extremities and language impairment.

After medical stability was achieved, M underwent comprehensive occupational, physical, psychological and speech-language therapy, making substantial gains in all these areas. Specifically, he underwent intensive speech therapy for 12 weeks. His wife reported that after this period, they continued to work at home for

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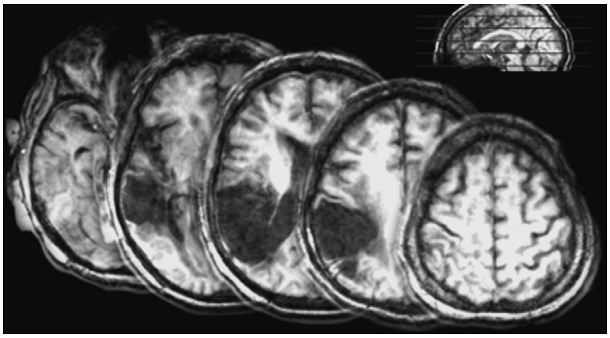

Fig. 1. MRI of the patient's lesion. Five selected axial images are shown to depict the extent of lesion. Neurological convention.

several hours a day every day, with the patient eventually regaining his language abilities.

The patient was not likely to have had atypical language lateralization before his stroke. He was right-handed, never changed handedness, and had no left-handed relatives. Furthermore, had he had right-hemisphere dominance for language, it is less likely that he would have presented with language deficits following his stroke. The patient did not show deficits associated with right hemisphere infarct such as visuospatial neglect following his stroke, nor at the time of testing (Saygin, Wilson, Dronkers, & Bates, 2004; Saygin, 2007). MRI, acquired at the time of present tests, confirmed an extensive lesion covering left temporal and parietal cortex (Fig. 1), with no evidence of subsequent infarct.

The patient came to our attention 10 years after his stroke. His aphasia had resolved into effective verbal communication and fluent speech, with occasional word-finding difficulties (usually with long or infrequent words, e.g., "rehabilitation", "bronchitis", "jacuzzi"). On the Western Aphasia Battery (Kertesz, 1979), his aphasia quotient (AQ) was 91/100 and he was classified as an Anomic aphasic. His language comprehension was found to be unimpaired. In particular, he scored 60/60 in auditory word recognition. This performance pattern clearly rules out the word deafness and verbal comprehension deficits that are commonly associated with posterior lesions of the left hemisphere.

1.2. Speech and environmental sound comprehension

Despite his high-functioning neuropsychological profile and mild (and solely productive) aphasia, M showed a severe impairment in recognizing environmental sounds. This was first observed when M participated in an experiment exploring verbal and nonverbal auditory comprehension in aphasic patients (Saygin et al., 2003). In this study, a group of left hemisphere-injured patients ($N = 29$) and age-matched controls were asked to match environmental sounds and corresponding verbal phrases to visually presented pictures of objects (e.g., picture of a cat for the phrase "cat meowing" or the sound of a meow). The same stimuli and paradigm have since been successfully used to contrast comprehension of verbal and nonverbal comprehension of auditory material in a number of populations, details of which have been provided in previous publications (Cummings, Saygin, Bates, & Dick, 2009; Dick et al., 2004, 2007; Saygin, Dick, & Bates, 2005; Saygin et al., 2003).

Deficits in the comprehension of speech sounds and environmental sounds went hand in hand for the left-hemisphere injured patients, with strong correlations between performance in verbal and nonverbal sound comprehension for both accuracy ($p < 0.0001$; $r^2 = 0.75$) and for reaction time ($p < 0.0001$; $r^2 = 0.96$). However, whereas Patient M showed a significant deficit in environmental sound comprehension (in comparison to controls, $z = -6.09$, $p < 0.0001$), he was well within the normal range for speech comprehension ($z = 0.7$, $p > 0.1$). There were three other left hemisphere-lesioned patients who performed worse than M on the nonverbal material, but importantly they did not show a selective deficit, presenting with correspondingly poor performance in speech comprehension. Fig. 2 shows M's accuracy and reaction time for speech (verbal) and environmental (nonverbal) sounds, along with the rest of the left hemisphere-injured patients (Saygin et al., 2003). M was the only participant to demonstrate a quantifiable dissociation between verbal and nonverbal sound processing in this experiment (Bates, Appelbaum, Salcedo, Saygin, & Pizzamiglio, 2003).

2. Methods

2.1. Audiology

A clinical audiologist conducted standard tests and otoscopic examination, as well as Auditory Brainstem Response (ABR) measurements at 60 dB, 80 dB, and 90 dB, 100–3000 Hz. Sound localization and music recognition were assessed using non-standard tests.

2.2. Behavioral testing

We further tested M's environmental sound comprehension using a large, extensively normed sample of environmental sounds. This was a sound naming experiment that had previously been administered to neurologically healthy subjects, and published in Saygin et al. (2005).

M was asked to listen to a set of environmental sounds and to provide a verbal description for each sound. The test was conducted at the patient's home and

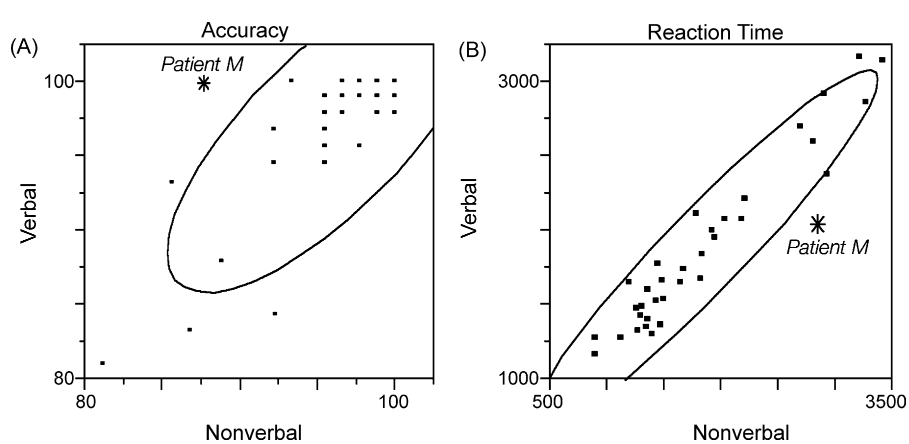

Fig. 2. M's accuracy (A) and reaction time (B) plotted along with all left hemisphere injured patients in a previously published study of speech and environmental sounds comprehension (as measured in a sound to picture matching task, Saygin et al., 2003). For both measures, the 90% confidence ellipse is shown. M's performance, marked with '*', was the only quantifiable dissociation in the sample (Bates et al., 2003).

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