Functional Specificity in the Right Human Auditory Cortex for Perceiving Pitch Direction

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Abstract

Previous lesion and functional imaging studies in humans suggest a greater involvement of right rather than left auditory cortical areas in certain aspects of pitch processing. In the present study, adaptive psychophysical procedures were used to determine auditory perceptual thresholds in 14 neurologically normal subjects, and in 31 patients who had undergone surgical resection from either the right or left temporal lobe for the relief of intractable epilepsy. In a subset of the patients, the lesion encroached significantly upon the gyrus of Heschl or its underlying white matter as determined from MRI analysis. Subjects were asked to perform two different perceptual tasks on the same set of stimuli. In a pitch discrimination task, the subject had to decide whether two elements of a pure tone pair were the same or different. In a task requiring the judgement of direction of pitch change, subjects decided whether pitch rose or fell from the first tone to the second. Thresholds were determined by measuring the minimum pitch difference required for correct task performance. Mean thresholds in the pitch discrimination task did not differ between patient groups and control subjects. In contrast, patients with temporal lobe excisions that encroached upon the gyrus of Heschl in the right hemisphere (but not in the left) showed significantly elevated thresholds when judging the direction of pitch change. These findings support a specialization of function linked to right auditory cortical areas for the processing of pitch direction, and specifically suggest a dissociation between simple sensory discrimination and higher order perception.

auditory cortex; hearing; hemispheric specialization; music; pitch
Introduction

A considerable amount of neuropsychological evidence and functional imaging data support the idea that structures within the human right hemisphere are specialized for at least some aspects of pitch processing (Milner, 1962; Divenyi and Robinson, 1989; Peretz, 1990; Zatorre and Samson, 1991; Zatorre et al., 1992, 1994). In particular, studies requiring various types of spectral pattern analysis yield consistent evidence supporting a right hemisphere prepotency. For example, Zatorre found that patients with surgical excisions of the right, but not the left, auditory cortex are impaired at perceiving the pitch of complex tones with a missing fundamental (Zatorre, 1988). Similarly, patients with right but not left hemisphere vascular lesions were impaired on tasks requiring processing of complex spectral structure (Sidtis and Volpe, 1988; Robin et al., 1990). Timbre discrimination tasks, in which discrimination must be based on harmonic structure, have also yielded similar evidence (Milner, 1962; Samson and Zatorre, 1994; Paquette and Peretz, 1997).

Discrimination of melodic pitch patterns is also generally more affected by damage to the right than to the left superior temporal area (Milner, 1962; Zatorre, 1985; Samson and Zatorre, 1988; Liégeois-Chauvel et al., 1998), although much more severe deficits are observed after bilateral damage (Peretz et al., 1994). Simple frequency discrimination, on the other hand, does not appear to involve right hemisphere cortical mechanisms preferentially. Unilateral excisions from primary and anterior secondary auditory cortex appear to affect such discrimination minimally or not at all (Milner, 1962; Berlin et al., 1965; Zatorre, 1988; Zatorre and Samson, 1991), and this is consistent with studies showing that even large bilateral lesions of auditory cortex do not generally result in a permanent impairment on tests of simple frequency discrimination in humans (Peretz et al., 1994) or other mammals (Meyer and Woolsey, 1952; Butler et al., 1957; Wegener, 1964; Cranford et al., 1976; Whitfield, 1980).

Thus, the current evidence suggests that the right auditory cortex is most important for specific types of pitch processing: either when the acoustic stimuli are complex (as in the missing fundamental task) or when the task itself is complex, or both (as in melodic discrimination tasks). If this generalization is correct, then certain specific cortical lesions might result in a dissociation between simple frequency discrimination and discrimination under more complex conditions, i.e. when the stimuli are acoustically simple, but the task requires some cognitive computation. The purpose of the present study was to test this prediction. In particular, we compared a simple frequency discrimination task with a task requiring the judgement of pitch direction, using an adaptive psychophysical procedure (Levitt, 1971) that should be optimally sensitive to impairment. Unlike simple frequency discrimination, pitch direction judgement requires sequential analysis and the perception of relative pitch, which we assume are higher order perceptual phenomena. An additional important goal of this study was to determine to what degree the primary auditory cortex or closely adjacent regions are implicated in the
performance of these tasks. For this purpose, we tested patients with unilateral excisions extending into or sparing the lateral portion of the gyrus of Heschl, as determined from detailed quantitative lesion analysis using MRI (Penhune et al., 1999).

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