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Music and language side by side in the brain: a PET study of the generation of melodies and sentences

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Abstract

Parallel generational tasks for music and language were compared using positron emission tomography. Amateur musicians vocally improvised melodic or linguistic phrases in response to unfamiliar, auditorily presented melodies or phrases. Core areas for generating melodic phrases appeared to be in left Brodmann area (BA) 45, right BA 44, bilateral temporal planum poles, lateral BA 6, and pre-SMA. Core areas for generating sentences seemed to be in bilateral posterior superior and middle temporal cortex (BA 22, 21), left BA 39, bilateral superior frontal (BA 8, 9), left inferior frontal (BA 44, 45), anterior cingulate, and pre-SMA. Direct comparisons of the two tasks revealed activations in nearly identical functional brain areas, including the primary motor cortex, supplementary motor area, Broca's area, anterior insula, primary and secondary auditory cortices, temporal pole, basal ganglia, ventral thalamus, and posterior cerebellum. Most of the differences between melodic and verbal generation were seen in lateralization tendencies, with the language task favouring the left hemisphere. However, many of the activations for each modality were bilateral, and so there was significant overlap. While clarification of this overlapping activity awaits higher-resolution measurements and interventional assessments, plausible accounts for it include component sharing, interleaved representations, and adaptive coding. With these and related findings, we outline a comparative model of shared, parallel, and distinctive features of the neural systems supporting music and language. The model assumes that music and language show parallel combinatorial generativity for complex sound structures (phonology) but distinctly different informational content (semantics).

Introduction

Observations during the preceding two centuries by neurologists such as Broca, Wernicke, Penfield, Lurje, and Geschwind established language as a paradigm of specialization, localization, and lateralization of higher cognitive function in the human brain (Price, 2000). Less influential were the discoveries of early neurologists showing that brain lesions could have similarly specific effects on musical functioning (Johnson & Grainger, 2003), implying the existence of cognitive and neurobiological specificity for music, similar to that for language (Pavani, 2002; Pavani & Zatorre, 2005). However, the analogy of music, like that of language, has been plagued by ambiguity, as the underlying lesions are usually neither focal nor are they replicated across patients showing similar clinical symptoms. In addition, the picture of independent specializations for language and music is clouded by the fact that most amusia are accompanied by aphasia (Marin & Perry, 1999), although the reverse is not generally the case (but see Paul, 2000, 2005).

In terms of function, music and language appear to show strong divergences at the level of the meaning (or semantics) but significant parallels with respect to grammar (or syntax) and intonation (Drovin, 1997; Hanson & Schla, 2000; Paul, 2000). Language conveys

semantic meaning in a manner that appears to have few parallels in music (but see Koelsch *et al.*, 2004), yet both music and speech are generative phrasing systems, in which phrases have larger meanings than the sum of their elements, unlike most animal vocal communication systems (Hauser, Chensky, & Fitch, 2002). Both music and speech are combinatorial systems in which larger structures are generated hierarchically from a pool of smaller, more arbitrary components. Moreover, musical and linguistic phrases can undergo changes in conveyed emotion through variation in pitch, amplitude, tempo, rhythm, etc. To the extent that music and speech share the use of structured pitch and rhythmic patterns to express their meanings, they may be expected to have common or similar brain mechanisms (Paul *et al.*, 1999).

In the last decade, a view has emerged that music and language have reciprocal cerebral hemispheric dominance, with music and language localized predominantly to homologous regions of opposite hemispheres (reviewed in e.g. Price, 2000; Pavani & Zatorre, 2005). For instance, functional neuroimaging studies of nonmusicians often show activity in right hemispheric areas homologous to classical language areas; i.e. the auditory association cortex of the posterior superior temporal gyrus and regions of the inferior frontal gyrus (Zatorre *et al.*, 1994; Halpern & Zatorre, 1999; Zatorre & Binder, 2000; Jeffries *et al.*, 2003; Brown *et al.*, 2004a; Koelsch, 2005; reviewed in Pavani & Zatorre, 2005). Interestingly, two pilot functional neuroimaging studies using within-subject comparisons of music and language processes in nonmusicians observed that speech and singing tasks elicited similar activity patterns but with tendencies

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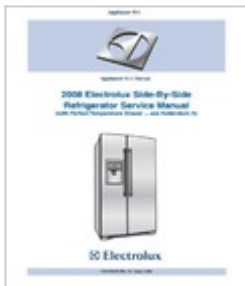
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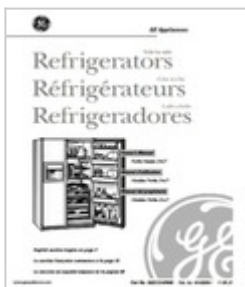
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