Simultaneous dual-fMRI, sparse temporal scanning of human duetters at 1.5 and 3 Tesla

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Introduction. Recent studies of singing by individual humans implicate a distributed network of brain areas (Brown, Martinez, & Parsons, 2004, 2006). A key feature of human duetting as with other music and dance performances, is close interactive and coordinated entrainment amongst participants. Such fine online, socially organized cognitive, sensory-motor, and emotional behavior is highly representative of humans, but has not been studied with current neuroscientific methods. To begin such investigations, we conducted a simultaneous dual fMRI study, using sparse temporal sampling, of pairs of musicians sight-reading and singing complex and simple folksongs. Each member of the duetting pair performed under three conditions: solo singing, singing in unison with their human partner, and singing in unison with a computerized piano performance. Trials were blocked by conditions in 6-minute periods. During the duetting with their human partner, each singer heard the other singer and themselves. The singing performances were recorded for analyses.

Methods. Musicians sight-read and sang each song for 45 s as follows: singing 11.5 s (in silence), then singing a single note during the 3.5 s functional acquisition; continuing the song for another 11.5 s (in silence), then singing a single note for a 3.5 s functional acquisition; and continuing the song again for 11.5 s (in silence), and then holding a single note for a 3.5 s functional scan. Each song performance was followed by a 15 s period of rest. Each pair of duetters performed all conditions twice, once in the 1.5 scanner (Eclipse, Philips) and once in the 3T scanner (Achieva, Philips). During each functional block, 24 time-points were sampled. At both field strengths, fMRI data were acquired using T2*-weighted, single-shot, gradient recalled, EPI sequences, using a Sparse temporal sampling technique. In each field, equivalent sequence parameters were employed: TR=3000 ms; TA=15s; FOV=240mm, 32 contiguous slices of thickness 4mm; and at 1.5T a TE of 40ms (no SENSE) and at 3T a TE of 35ms with a SENSE factor of 1.5 along the phase direction). Analyses were performed using FSL 4.0 (FMRIB Software Library, Oxford University).

Results. Briefly, the contrast of human+human duetting minus solo singing revealed significant foci in bilateral precuneus, bilateral anterior cingulate (BA24), right motor-sensory mouth cortex (BA 2,3,4), bilateral dorsal premotor cortex (BA6), right primary auditory cortex (BA 41), and right inferior frontal cortex (BA 9). To compare interpersonal synchronization to synchronization with a computerized prerecorded unchangeable melody, we used a direct contrast of human+human duetting minus human+piano duetting. This analysis uncovered activations in left thalamus, left caudate body, right hippocampus, right inferior and middle temporal cortex (BA 20, 21), left precuneus, primary visual cortex (BA17, 18), bilateral cingulate (BA 31, 32), left middle frontal (BA 11), left superior frontal gyrus (BA 10), and right medial frontal gyrus (BA 10). The opposite contrast human+piano duetting minus human+human duetting isolates activity in right fusiform (BA 37), right middle frontal (BA 6), and right primary motor cortex (BA 4). The more general mechanisms for duetting per se are assessed by subtracting the solo condition from the combination of human+human and human+piano conditions. This analysis reveals foci in left precuneus, bilateral medial and superior frontal cortex (BA 8), bilateral posterior cingulate (BA 29/30), parahippocampal (BA 30), left anterior cingulate (BA 24), and right pulvinar,

Conclusions. These findings suggest that complexity in music performance recruits left inferior frontal (BA 45), an area associated with the production of sequential and structural patterning of musical phrasing. In addition, lingual, fusiform gyri in occipital lobe is activated selectively for complex songs, presumably in order support mid-level visual representations for music score reading. Moreover, there is a more intricate and cognitive network engaged for the dynamic human duetting than for duetting with a pre-recorded computerized melody. Finally, duetting in general recruits areas implicated in auditory, motor-sensory, premotor, attentional, executive, and serial sequential information processing. This study provides the basis for a much wider use of dual-scanning paradigms (either in simultaneous or successive formats).