ICSC 2006
Dynamics in Spatial Interactions

ORAL PAPER

Processing of binaural sound coherence in the human brain

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Keywords Binaural coherence · Audition · fMRI

Background

In everyday life we are presented with complex sound signals that often originate from different sources and convey competing information. In order to select relevant information for further processing and to guide behaviour, the brain must group together signals relating to specific events, segregating signals that are unrelated (Cherry 1953). The localisation of the signal sources may act as a powerful cue for selection (Woldorff et al. 1993). Sound localisation on the horizontal plane strongly rely on timing differences between the two ears. However, timing differences can be used to localise sounds in space only when the inputs to the two ears have similar spectro-temporal profiles (high binaural coherence, e.g. Chernyak and Dubrovsky 1968; Blauert et al. 1986). Psychophysical data of humans and owls indicate that decreasing binaural coherence leads to decreasing spatial localisation (Chernyak and Dubrovsky 1968; Saberi et al. 1998). At the neuronal level, localisation of sounds with full binaural coherence takes place in auditory regions posterior to Heschl's Gyrus (e.g. Rauschecker and Tian 2000; Weeks et al. 1999).

Methods

We used fMRI to investigate whether the level of binaural sound coherence, and thus the ability to localise sounds in space, modifies activity in the human's auditory cortex. In two different studies we varied the degree of binaural coherence either during passive stimulation or during active sound localisation. Spatial sound directions were produced using variable interaural timing differences.

Results

We found that activity in Heschl's Gyrus increased with increasing coherence, irrespective of active localisation or passive stimulation. Posterior auditory regions also showed increased activity for high coherence, primarily when sound localisation was required and subjects successfully localised sounds.

Conclusion

We conclude that binaural coherence cues are processed throughout the auditory cortex, and that these cues are used in posterior regions for successful auditory localisation (Zimmer and Macaluso, 2005).

Follow-up

Evans (1998) suggested that sound-movement processing relates to the localisation of sound-positions in space. This would imply that changes of binaural coherence should also affect sound-movement processing. Using fMRI, we want to verify this prediction by presenting moving versus stationary sounds at different levels of coherence. Decreasing binaural coherence should result in poorer perception of sound-movement. Correspondingly, we expect that activity in inferior parietal regions that were previously implicated in sound-movement perception (Griffith et al. 1998) should decrease. This would demonstrate that binaural coherence can affect activity not only within temporal auditory cortex, but also in higher-order parietal regions.

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References

Blauert J, Lindemann W (1986) J Acoust Soc Am 79:806–813
Cherry EC (1953) J Acoust Soc Am 25:975–979
Chernyak RI, Dubrovsky NA (1968) Acoustics, Tokyo A-3-12
Evans MJ (1998) Proceedings of ICAD'98, pp 1–10
Griffith TD et al (1998) Nat Neurosci 1:74–79
Rauschecker JP, Tian B (2000) Proc Natl Acad Sci USA 97:11800–11806
Saberi K et al (1998) Neuron 21:789–798
Weeks RA et al (1999) Neurosci Lett 26:155–158
Woldorff MG et al (1993) Proc Natl Acad Sci USA 90:8722–8726
Zimmer U, Macaluso E (2005) Neuron 47:893–905