Assessing relative sound localisation abilities of human listeners in noise

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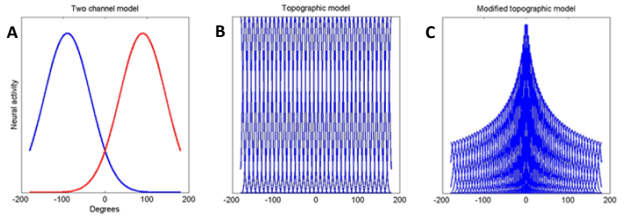
Introduction

- Recent brain imaging studies have suggested that auditory space might be represented in human auditory cortex by a 'hemifield code' (e.g. Salminen et al., 2010) Fig A.
- In contrast, the topographic model proposes that neurons exist tuned throughout auditory space (Fig B, or Fig C, where central auditory space is over represented).
- Brain imaging methods have attempted to disambiguate these two models by testing the neural response elicited by a change in location of a sound.
- We performed a human psychophysics experiment using broadband free-field stimuli with three aims:
  - to map how the accuracy of relative sound localisation varies throughout auditory space
  - to determine how signal-to-noise ratio (SNR) affected subjects' performance
  - to probe whether there is a behavioural correlate of the enhanced neural signal observed for sounds that shift in location away from, as opposed to towards, the midline and test opposing models of the neural representation of auditory space.



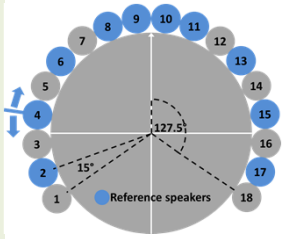
Methods

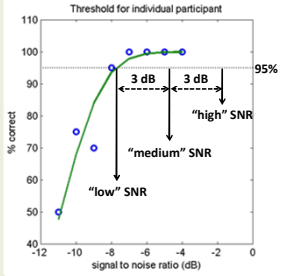
Set-up
- 8 subjects
- Anechoic chamber
- 18 speakers separated by 15° intervals from -127.5° to 127.5°

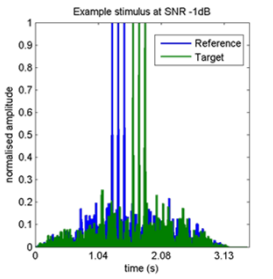
Stimuli and task
- 6 white-noise pulses (15 ms duration, presented at 10 Hz) embedded in noisy background. Pulses 1-3 were presented from one speaker (the 'reference') and the 4th-6th from an adjacent speaker (the 'target'). The subject's task was to report (by button press) whether the target pulses were to the left or to the right of the reference pulses at 3 different SNRs (see 'Threshold' below)
- Noisy background - amplitude-varying 15 ms noise bursts generated independently from each speaker
- Adaptation paradigm
  - 8-13 white-noise pulses from the reference speaker, followed by 3 pulses at the target location
- ITD paradigm
  - Low pass filtered pulses (<1 kHz)

Threshold
- A threshold test was performed by each participant to determine detection thresholds
  - Stimuli presented at 10 different SNRs
  - fixed level of background noise at 59 dB SPL
  - signal attenuation varied from 48 to 57 dB SPL
  - Reference location was 0° and the targets were ± 90°
- Such stimuli were well above the subjects' localisation threshold therefore we used a correct response to measure detection threshold
- The lowest SNR tested was taken as the 95% correct SNR from the threshold with the medium and high SNRs being this plus 3 and 6 dB respectively

Analysis
- Overall performance was assessed by calculating d-prime statistics for subjects' ability to discriminate whether a target sound moved left or right at each reference speaker location
- We then divided trials into those where the target sound moved towards the midline, and those where it moved away from the midline and calculated % correct performance for each SNR either with respect to each reference sound location ("Reference Analysis"), or to each target sound location ("Target Analysis").
- We examined subjects accuracy for such subsets of trials in order to compare relative-localisation abilities with those predicted by the different models of neural encoding of auditory space

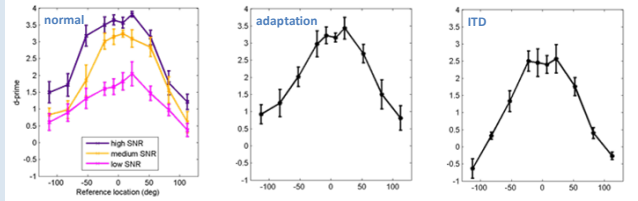


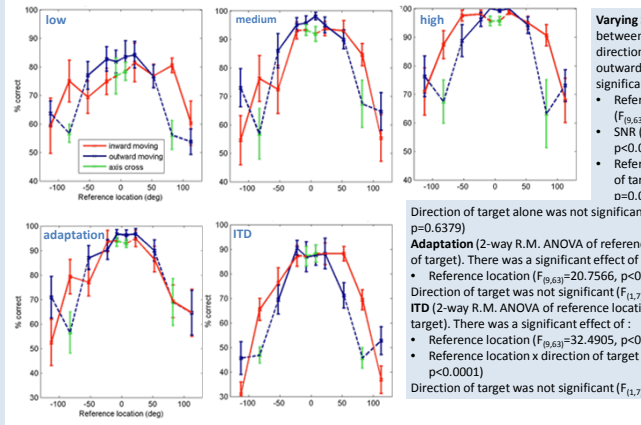




Results

Reference analysis





Varying SNR (3-way R.M. ANOVA between reference location, direction of target (inward vs. outward) and SNR). There was a significant effect of :
- Reference location ($F_{(9,63)}$=24.556, p<0.0001)
- SNR ($F_{(2,479)}$=48.487, p<0.0001)
- Reference location x direction of target ($F_{(9,479)}$=3.186, p=0.0031)

Direction of target alone was not significant ($F_{(1,479)}$=0.6379, p=0.6379)

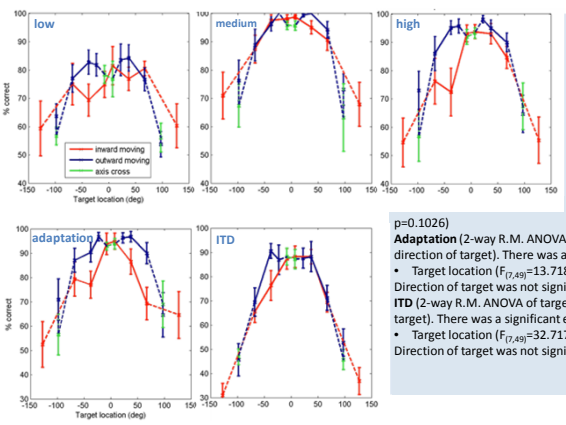
Adaptation (2-way R.M. ANOVA of reference location and direction of target). There was a significant effect of :
- Reference location ($F_{(9,63)}$=20.7566, p<0.0001)

Direction of target was not significant ($F_{(1,7)}$=0.7219, p=0.4236)

ITD (2-way R.M. ANOVA of reference location and direction of target). There was a significant effect of :
- Reference location ($F_{(9,63)}$=32.4905, p<0.0001)
- Reference location x direction of target ($F_{(9,63)}$=4.9807, p<0.0001)

Direction of target was not significant ($F_{(1,7)}$=5.0128, p=0.0602)

Target analysis



Varying SNR (3-way R.M. ANOVA between reference location, direction of target (inward vs. outward) and SNR). There was a significant effect of :
- Target location ($F_{(7,49)}$=17.547, p<0.0001)
- SNR ($F_{(2,14)}$=46.476, p<0.0001)

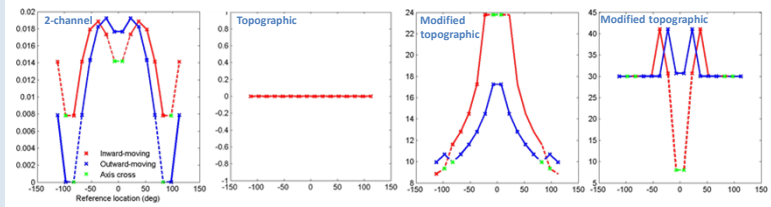
Direction of target was not significant ($F_{(1,7)}$=3.523, p=0.1026)

Adaptation (2-way R.M. ANOVA of target location and direction of target). There was a significant effect of :
- Target location ($F_{(7,49)}$=13.7187, p<0.0001)

Direction of target was not significant ($F_{(1,7)}$=4.7727, p=0.0652)

ITD (2-way R.M. ANOVA of target location and direction of target). There was a significant effect of :
- Target location ($F_{(7,49)}$=32.7174, p<0.0001)

Direction of target was not significant ($F_{(1,7)}$=3.5232, p=0.1026)

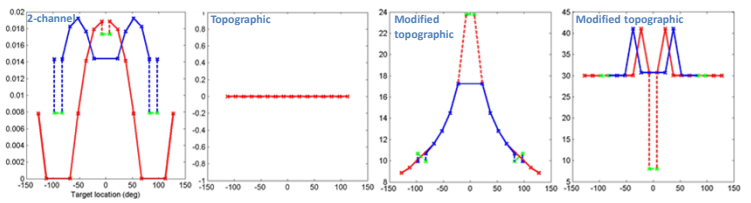


Ratio of area under the activity curves induced in the two channels (Fig A)

Difference between the peaks in activity for the reference and target sounds

Peak height induced by inward and outward-moving target sounds

Euclidean distance between the peaks induced by the reference and the inward or outward-moving target sounds



Summary

- The accuracy of relative sound localisation varies throughout auditory space relative sound localisation abilities are worse in the periphery compared to frontal space
- The accuracy of relative sound localisation also varies with SNR, with a lower SNRs decreasing accuracy

References

- Magezi D.A. & Krumbholz K. 2010. *Journal of Neurophysiology*
- Salminen N.H., May P.J.C., Alku P., & Tiitinen H. 2009. *Plos One*
- Salminen N.H., Tiitinen H., Yrttiaho S. & May P.J.C. 2010. *JASA*

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