Effects of modality-dependent cuing and eye movements on sound localization

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Background

Attention facilitates selection of objects, events, or spatial regions in complex scenes. Here, we investigate how the modality through which strategic spatial auditory attention is directed influences sound localization and whether the effect depends on eye fixation.

Experiment

Motivation

Few previous studies showed that in the task of sound localization directing attention by an auditory cue causes:
- improvements in reaction times (Spence & Driver, 1994),
- small (Sach et al., 2000) or no (Kopco et al., 2001) improvements in performance.

Possible reasons for this lack of strong effects:
- tested SOAs too short to orient attention,
- modality through which attention is directed is important,
- saccadic eye movements (e.g., towards cue) increased variance in responses, making results too noisy.

Current study

Perform behavioral experiment to determine:
- whether attentional effects occur at longer SOAs,
- whether attentional control is modality-dependent (visual vs. auditory cue).

Compare results of current experiment with results of a previous experiment (Experiment 1) in which eyes were not fixated (Kopco *et al.*, 2007) to determine possible effect of eye movements (Werner-Reiss *et al.*, 2003).

Hypotheses
Compared to Exp. 1:
- eye fixation will reduce the effect of visual cue
- there will be no influence on the effect of auditory cue

Methods

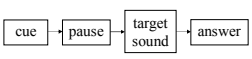
Experiment 1

12 normal hearing subjects

Subject's task to localize a target sound, preceded by either:
- a cue indicating its hemisphere (left or right),
- a cue from the opposite hemisphere,
- no cue (reference trials).

Stimuli
- target: 2-ms broadband click, simulated at one of 10 locations in virtual anechoic environment (Fig 1A),
- auditory cue: 100-ms 2-kHz pure tone presented monaurally from L or R headphone,
- visual cue: left- or right-pointing arrow on a computer screen (Fig 1B).

Procedure
- 10 sessions each consisting of 7 blocks, one per measurement type: 2 modalities (auditory, visual) x 3 informativeness + no cue
- cue informativeness: cue correctly predicts target lateral side on 50%, 80%, or 100% of trials within a block
- one block contains 10 (locations) x 3 (SOAs) trials,
- SOA: 0.4, 0.8, or 1.6 seconds
- one trial consisted of:



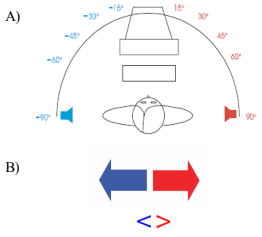


FIGURE 1 Experimental setup. A) Top view of a listener in the simulated environment. Numbers indicate simulated target locations. B) Sample arrows as shown on a computer screen as a visual cue in Exp. 1 (top) and Exp. 2 (bottom).

Setup
- subject seated in front of a computer (Fig 1A), surrounded by a semicircle with pictures of speakers
- perceived location entered using numeric keypad on computer

Experiment 2

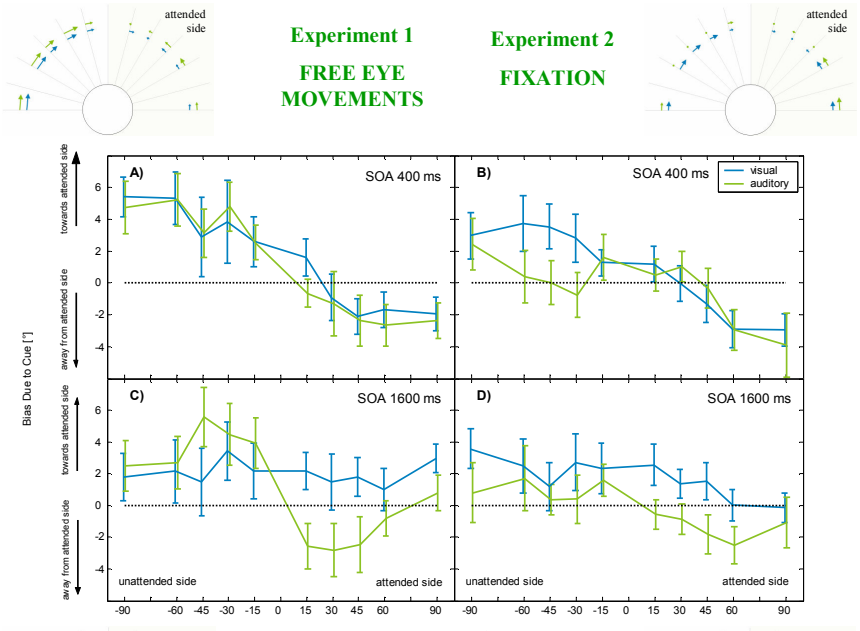
12 normal hearing subjects

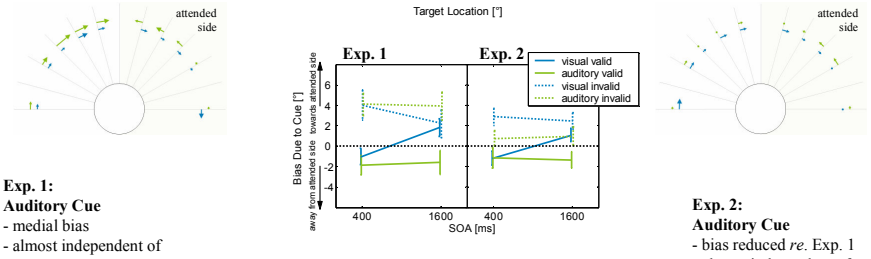
Similar to experiment 1, except
- eyes fixated to the center of the computer screen,
- different (centered) visual cue (bottom of Fig. 1B),
- SOA 0.8 excluded.

Results

FIGURE 2 Bias in responses induced by the cue. Across-subject mean and standard error in the difference between responses with and without cue. The biases are illustrated also on the cartoon by each panel.

Data collapsed across median plane (cue always on right) and informativeness.





Exp. 1:
Auditory Cue
- medial bias
- almost independent of SOA

Visual Cue
- at short SOA medial bias similar to auditory cue
- at large SOA, bias always towards the cued side

FIGURE 3 Bias in responses induced by the cue in Exp. 1 (left panel) and Exp. 2 (right panel). Across-subject mean and standard error in the difference between responses with and without cue, averaged across location.

Exp. 2:
Auditory Cue
- bias reduced *re*. Exp. 1
- almost independent of SOA (as in Exp. 1)

Visual Cue
- results similar to Exp. 1

Auditory and visual cueing shifts perceived locations of auditory targets.

Experiment. 1: Free eye movements (panels A and C)

Both cues attract targets presented from the unattended side.

Effects of auditory and visual cueing are similar at short SOA but not at long SOA.

Experiment 2: Eyes fixated (panels B and D)

Eye fixation changed the visual cue bias minimally (blue lines in panels A vs. B and C vs. D). However, it affected the auditory-cue bias (green lines).

Conclusion & Discussion

Attentional cuing induced shifts in sound localization responses:
- towards the cue when target is on unattended side,
- slightly away from cue when target is on attended side, except for 1600-ms visual cue which had the opposite effect.

Cue modality is important, especially at longer SOA.

Eye fixation reduced the effect of auditory, but not visual, cue → the visual-cue biases not related to eye saccades.

Why eye fixation affected auditory and not visual cue?
Alternative 1. Keeping the eyes fixated requires concentration, reducing the resources available for processing and using a cue from different modality (i.e., auditory).

Alternative 2. Processing of auditory cue might have been more difficult because it was presented from a location (-90° or 90°) that differed from the fixation point (0°). Visual cues and fixation point were aligned at 0°.

References & Acknowledgment

1. Kopco, N, A Ler, and B Shinn-Cunningham (2001). "Effect of auditory cuing on azimuthal localization accuracy," JASA 109, 2377
2. Kopco, N , Tomoriova, B, Andoga, R. (2007) "Visual and auditory hemispheric cuing in horizontal sound localization (A)" J. Acoust. Soc. Am., 121, 3094
3. Sach, AJ, Hill, NI, and Bailey PJ. (2000) Auditory spatial attention using interaural time differences. JEP:HPP. 26(2):717-729
4. Spence, CJ and Driver J (1994) Covert spatial orienting in audition: Exogenous and endogenous mechanisms. JEP:HPP. 20(3): 555-574.
5. Werner-Reiss, U, Kelly, KA, Trause, AS, Underhill, AM and Groh, JM. (2003). Eye position affects activity in primary auditory cortex of primates. Current Biology, 13:554-562.

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