Modality-dependent attentional control in human sound localization

Rudolf Andoga[1], Martin Bernát[1], Beáta Tomoriová[1], Norbert Kopčo[1,2]

[1]Perception and Cognition Lab, Technical University, Košice, Slovakia [2]CNS Dept., Boston University & Dept. of Psychological and Brain Sciences, Dartmouth

1. Background

Attention facilitates selection of objects, events, or spatial regions in complex scenes.

Very few studies focused on the effect of auditory attention on sound localization.

Even fewer studies looked at whether the effect is modality-dependent.

2. Experiment

Motivation:

Several previous studies asked whether directing automatic or strategic attention by an auditory cue can improve sound localization. (Spence & Driver, 1994; Sach, 2000; Kopco & Shinn-Cunningham, 2001, 2003)

Results:
Improvements in RTs (Spence&Driver), but small (Sach) or no (Kopco) improvements in performance.

Possible reason: the SOAs too short to orient attention

Current study:

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

Hypotheses:

No effect of automatic attention (previous studies)

Strategic attention will affect performance at long SOAs

Effect modality-independent because the control is top-down and spatial cuing very coarse (only left vs. right)

3. Methods

Experimental Procedure

11 normal hearing subjects

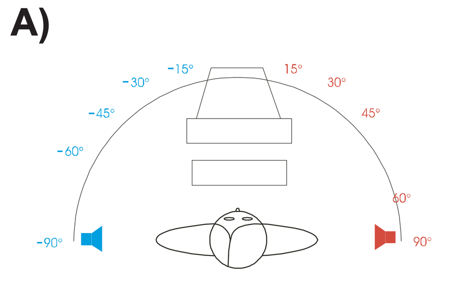
Stimuli
- Target: broadband 2-ms click, simulated at one of 10 locations in virtual anechoic environment (Fig 1A)
- Auditory cue: 100-ms 2-kHz pure tone presented monaurally from L or R side
- Visual cue: left- or right-pointing arrow on a computer screen (Fig 1B)

Experimental conditions
- 7 different types of measurement: 2 (cue modalities) x 3 (cue informativeness) + no cue
- cue modality: auditory or visual
- cue informativeness: cue is valid (i.e., correctly predicts target lateral side) on 100%, 80%, or 50% of trials within a block
- type of measurement fixed within a block
- one block contains 10 (locations) x 3 (SOAs) trials (no-cue block has only 10 trials)
- SOA: 0.4, 0.8, or 1.6 seconds

Experiment
- 10 one-half hour sessions
- each session consists of 7 blocks, each measuring performance in one measurement type

One trial
- subject informed about cue modality, informativeness, and SOA
- presentation of stimulus
- perceived location entered using numeric keypad on computer

A)



B)

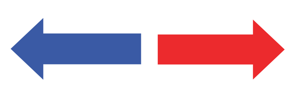


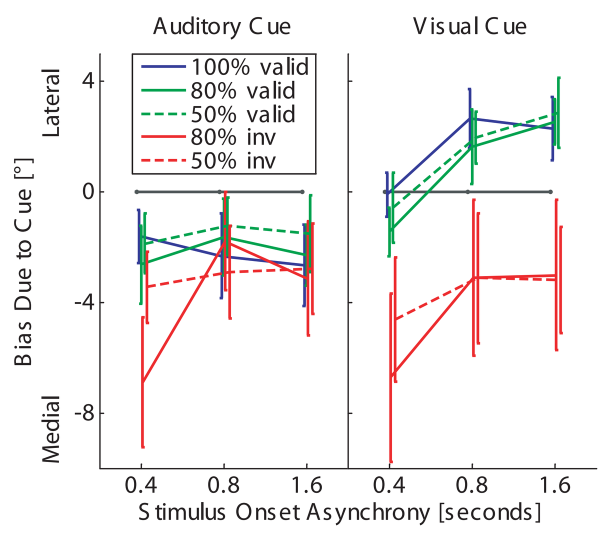
FIGURE 1 Experimental setup. A) Top view of a listener in the simulated environment. Numbers show simulated target locations. B) Sample arrows shown on a computer screen as a visual cue.

Data Analysis

- collapse data across median plane
- bin data by location, cue type (modality, Informativeness, valid/invalid), SOA, subject
- compute mean and standard deviation in responses for each bin
- compute across-subject mean and standard error of the mean

4. Results: Mean Responses

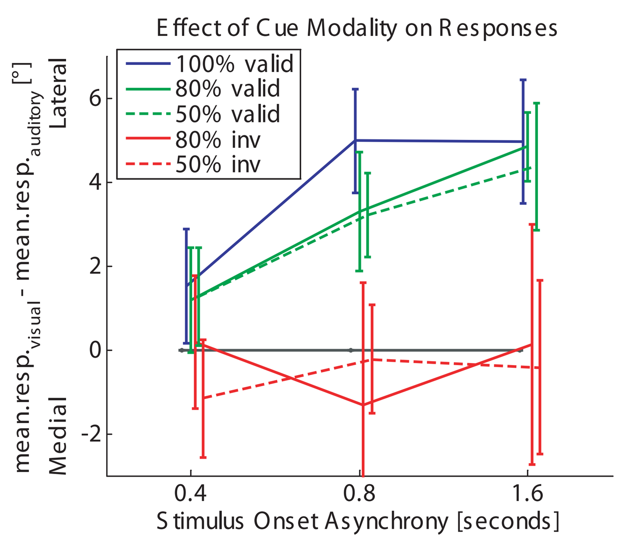
FIGURE 2 Bias in responses induced by the cue. Across-subject mean and standard error in the difference between responses with and without cue, averaged across location.



Auditory Cue
- on 50%-inv. trials (- -), medial bias 3 - 4°, independent of SOA
- on valid trials (–,–,- -), similar medial bias 2 to 3°, independent of information value or SOA
- on 80%-inv. trials (–), results less consistent

Visual Cue
- on invalid trials (–,- -) effects identical to auditory cue
- on valid trials (–,–,- -)
  - consistent lateral bias (2 to 3°)
  - independent of information value
  - growing with increasing SOA

FIGURE 3 Difference in biases induced by visual vs. auditory cue. Across-subject mean and standard error in the difference between responses with a visual vs. auditory cue, averaged across location.

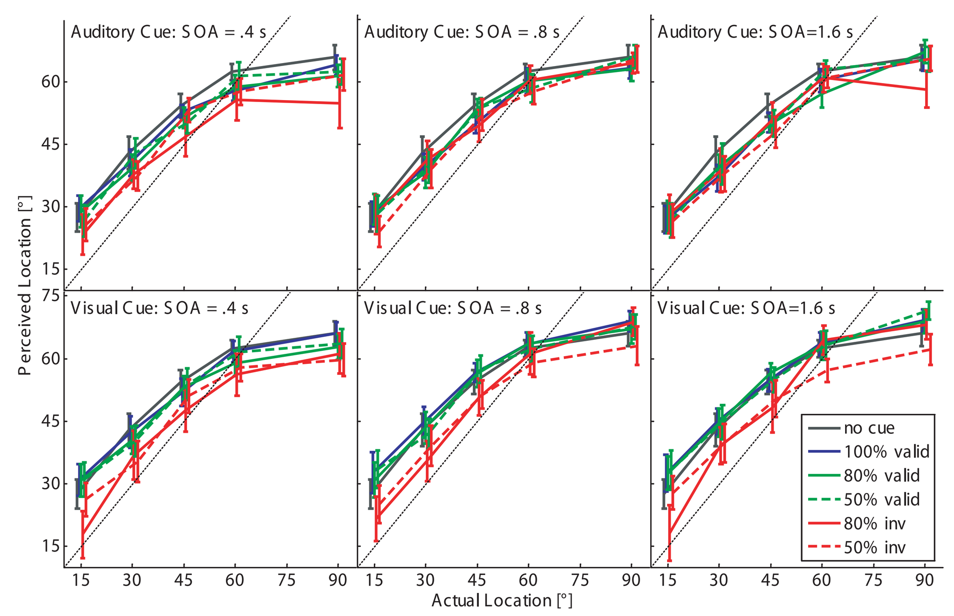


Invalid Trials (–,- -)
- no effect of cue modality or SOA
- larger across-subject variation in 80% invalid trials (–)

Valid Trials (–,–,- -)
- responses with visual cue more lateral
- difference grows with increasing SOA

When visual cue (but not auditory cue) correctly predicts target side, it induces lateral response bias

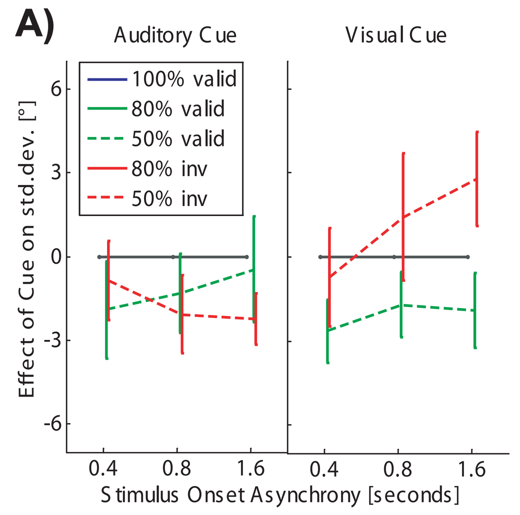
FIGURE 4 Raw mean responses collapsed across median plane. Across-subject mean and standard error in the mean response as a function of actual target location.



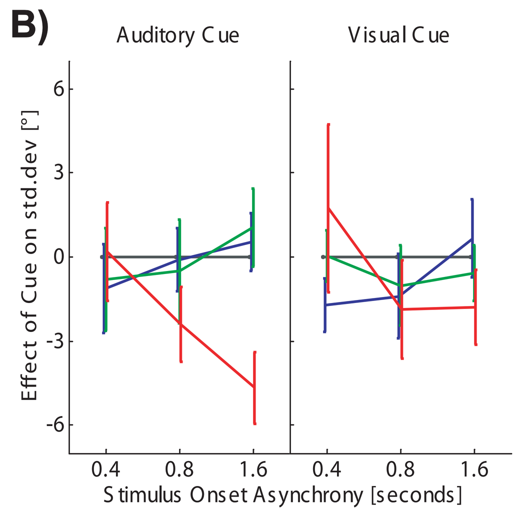
5. Results: Standard Deviations

FIGURE 5 Standard deviation in responses induced by the cue. Across-subject mean and standard error in the difference between standard deviations observed with vs. without the cue, averaged across location.

A)



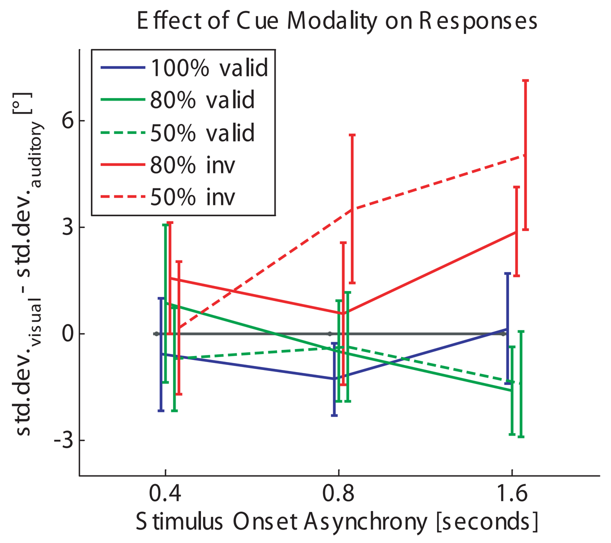
B)



50% informative data (Fig. 5A)
- auditory cue has no influence
- visual cue causes
  - slight decrease in s.d. on valid trials (- -)
  - increased s.d. on invalid trials at long SOA (- -)

80% and 100% informative data (Fig. 5B)
- no effect on valid trials (–,–)
- on invalid trials (–) not enough measurement repetitions

FIGURE 6 Mean difference between standard deviations with visual vs. auditory cue. Across-subject mean and standard error in the difference between standard deviations with a visual vs. auditory cue, averaged across location.

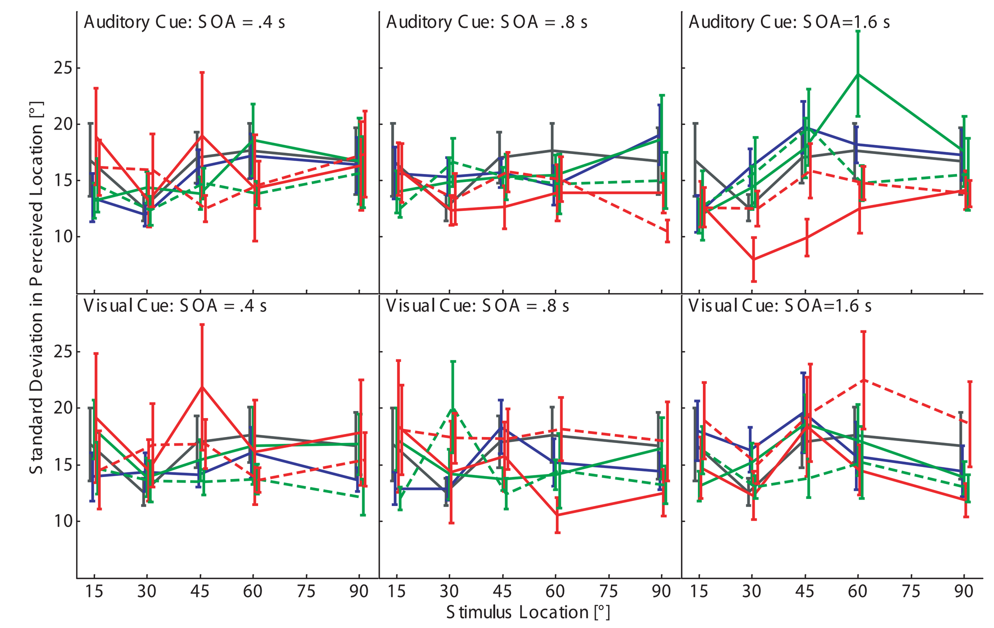


Invalid Trials (–,- -)
- visual cue increases std.dev. at long SOA

Valid Trials (–,–,- -)
- no effect of modality

When visual cue (but not auditory) incorrectly predicts target side, it increases response variability

FIGURE 7 Raw standard deviations in responses collapsed across median plane. Across-subject mean and standard error in the s.d. in responses as a function of actual target location.



6. Summary

Visual cues influence perception at the long SOAs:
- valid cues induce lateral bias
- invalid cues increase standard deviation in responses

No consistent effect of auditory cue (slight medial bias and decrease in s.d.)

No consistent effect of cue informativeness (note: too few measurements to analyze 80% invalid cues)

7. Discussion

Visually induced bias might be related to attentional processing, but also to eye position (arrows were at different location on screen).

Visually induced increases in s.d. are probably due to attentional processing. But, is it strategic or automatic? And is it due to covert or overt orienting?

Spatial auditory attention can be controlled visually, but not by auditory spatial cues. The reason for this difference is not clear.

8. References and Acknowledgement

Kopco, N, A Ler, and B Shinn-Cunningham (2001). "Effect of auditory cuing on azimuthal localization accuracy," JASA 109, 2377

Kopco, N and B Shinn-Cunningham (2002). "Effect of Cuing on Sound Localization Accuracy in a Room," Presented at the MidWinter meeting of the ARO.

Sach, AJ, Hill, NI, and Bailey PJ. (2000) Auditory spatial attention using interaural time differences. JEP:HPP. 26(2):717-729

Spence, CJ and Driver J (1994) Covert spatial orienting in audition: Exogenous and endogenous mechanisms. JEP:HPP. 20(3): 555-574.

Support: Slovak Science Grant Agency grants #1/3134/06, 1/2183/05