Visual and auditory hemispheric cuing in human sound localization

Norbert Kopčo[1,2], Beáta Tomoriová[2], and Rudolf Andoga[2]

[1]Cognitive and Neural Systems Dept., Boston University and [2]Perception and Cognition Lab, Technical University, Košice, Slovakia

1. Background

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

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

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

2. Experiment

Motivation:

Few previous studies asked whether directing automatic or strategic attention by an auditory cue can improve sound localization (Spence & Driver, 1994; Sach et al., 2000; Kopco et al., 2001)

Results:
- Improvements in reaction times (Spence & Driver, 1994), but
- small (Sach et al., 2000) or no (Kopco et al., 2001) improvements in performance

Possible reasons:
- tested SOAs too short to orient attention
- auditory cue not efficient because audition not primarily a spatial modality

Current study:

Perform behavioral experiment to determine:
- whether attentional effects occur at longer SOAs; Exp. 1
- whether attentional control is modality-dependent (visual vs. auditory cue); Exp. 1
- whether eye movements affect results (Werner-Reiss et al., 2003); Exp 2

Hypotheses:

H1: Attention will affect performance at long SOAs by decreasing bias and variability of responses

H2: Effect of attention will be modality- and eye-position dependent

3. Methods

Experiment 1

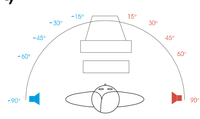
12 normal hearing subjects

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)

Procedure
- 10 one-half hour sessions
- each session consists 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

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

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
- remove responses with errors larger than 40°
- collapse data across median plane
- bin data by location, cue type (modality, valid/invalid), SOA, subject
- compute mean and standard deviation in responses for each bin

Experiment 2

- similar to Exp. 1, except
- 10 subjects (1 excluded, poor performance)
- only visual cue with SOA of 1600 ms
- eyes either moving freely or fixating on center

4. Results: Mean Responses

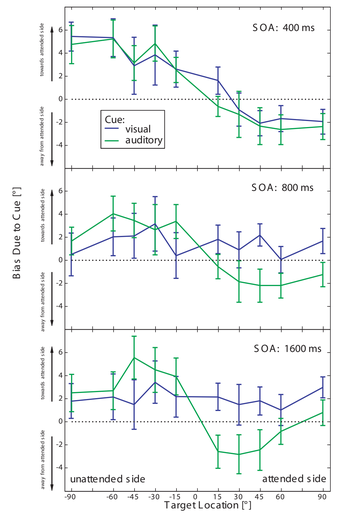
No difference as a function of informativeness - data collapsed.

Experiment 1

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

Auditory Cue
- causes a combination of:
  a) medial bias (3°)
  b) bias towards attended side (rightward shift, 2°)
- independent of SOA

Visual Cue
- at short SOA medial bias similar to auditory cue
- at larger SOAs, bias always towards the cued side (right)



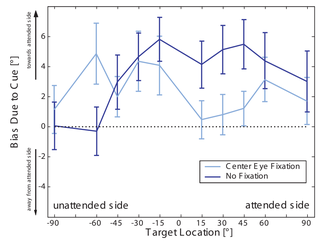
Cue informativeness does not influence performance.
Both cues attract targets presented from the unattended side.
Auditory cue repulses targets from attended side.
Effect of **visual cue** on attended side reverses at larger SOA.

Experiment 2

FIGURE 3 Effect of fixation on the bias in responses induced by a visual cue at SOA 1600 ms. Across-subject mean and standard error in the difference between responses with and without a cue.

Without fixation:
- on attended side bias larger than in Exp 1 (on unattended side, bias decreases)

With fixation:
- bias on attended side reduced



Because fixation reduced the **attended side** bias, it is likely that in Exp 1 the bias was due to eye movement.
Bias on **unattended side** is positive, independent of eye fixation.

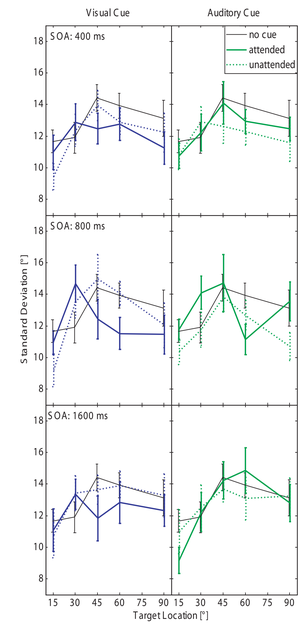
5. Results: Standard Deviations

Only 50%-informativeness data shown because 80%-informativeness data had only 2 measurements per repeat on unattended side - not enough to estimate standard deviation. However, collapsed data are very similar (see Fig. 5).

Experiment 1

FIGURE 4 Standard deviation in responses induced by the 50%-informative cue. Across-subject mean and standard error in the standard deviations observed with vs. without the cue.

Standard deviations in responses on attended and unattended side comparable to no-cue performance



Very small effect of visual or auditory cuing

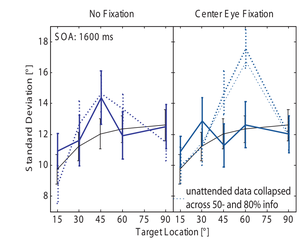
Experiment 2

Effect of eye fixation on performance with visual cue at SOA=1600 ms (Fig. 5)

Without fixation:
- no change in standard deviation, similar to Exp 1

With fixation:
Increase in standard deviations on the unattended side at 45° and 60°:
- interaction in two-way repeated measurement ANOVA with factors of location (5 levels) and side (attended vs. unattended): $F(4,32) = 3.18$, $p < 0.05$

FIGURE 5 Standard deviation in responses induced by the 50%-informative visual cue at SOA 1600 ms with or without fixation. Across-subject mean and standard error in the standard deviations observed with vs. without the cue. Thin dotted line shows data collapsed as in Figs. 2, 3.



Spatial cuing **never reduces** std. dev.
Focusing attention with eyes fixated at the center **increases variability** in responses on the **unattended side**.

6. Summary

H1: Attentional cuing can influence auditory localizbation:
- by inducing biases (not clear whether these biases are improvements)
- by increasing variability in responses on unattended side at cue-to-target stimulus onset asynchronies of up to 1600 ms

H2: The effect of cuing is modality and eye-position dependent:
Auditory cuing
- induces bias and has no consistent effect on variability

Visual cuing
- has effect that has covert and overt components (distinguished by fixation)

7. Discussion

The observed pattern of biases needs further investigation.

Strategic vs. automatic attention
Cue informativeness does not appear to modulate the kind of attention invoked
Given that the effects are observed at the very large SOAs, there are two possibilities:
- effects are due to strategic orienting, or
- automatic orienting has effects for up to 1600 ms

8. References and Acknowledgement

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