Electrophysiological correlates of attentional cueing and auditory spatial discrimination

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INTRODUCTION

Attention facilitates processing of objects, events, or locations in complex scenes. The Line Motion Illusion (LMI) illustrates stimulus-driven attentional modulation in vision (Shimojo et al., 1992).

Very few studies looked at the effect of attention on sound localization, whether the effect is modality-dependent, or whether there is a difference for exogenous vs endogenous attention. Previous studies showed:
- cueing improves reaction times (Spence and Driver, 1994).
- small (Sach et al., 2003) or no (Kopčo et al., 2001) improvements in localization accuracy.
- enhancement of auditory discrimination based on ILD or ITD when the listener’s gaze was directed to the sound, but not when cue was auditory (Mak焐kina et al., 2014).
- lateralized sound elicited an enlarged contralateral positive potential in the interval of 200–450 ms after sound onset localized in visual cortex.

We found main effect of cue position (C).

The ACOP will be predictive of target discrimination accuracy on valid trials (Feng et al., 2014)

RESULTS: Behavioral

PERCENT CORRECT

Overall visual cue performance better than auditory cue performance.

Validity of cue (F(3,4) = 9.508, p = 0.009).

When data divided by target shift direction re FP (Figure 3), for auditory valid cue responses, there is a difference for valid vs invalid auditory cue.

Auditory invalid cue responses strongly away from FP (i.e., from cue to target).

RESULTS: ERPs elicited by cue sounds

N1 results

N1 amplitude was larger over the hemisphere contralateral to the sound location (contralateral vs ipsilateral Fronto-temporal amplitudes over 90–150 ms (F(1,12) = 7.768, p = 0.02); and larger for lateral than for central (F(1,12) = 7.325, p = 0.019) (Figure 4a).

Laterality of cue position interaction was also found to be highly significant (F(1,12) = 9.508, p = 0.009).

Specific comparison showed that this interaction was the result of the N1 difference amplitude between lateral and central cue being larger than ipsilateral localization of fixation (Figure 4b).

CONCLUSIONS AND DISCUSSION

Stimulus-driven automatic spatial attention influences auditory spatial discrimination: Valid auditory cue improves performance (re. invalid cue) by increasing sensitivity and reducing criterion bias. Valid and invalid visual cue results in performance comparable to valid auditory cue. Main effect of cue is the distracting effect of invalid auditory cue, possibly related to the fact that it was identical to the target.

N1 on contralateral vs ipsilateral hemisphere was affected by target location. These asymmetries were not associated with the enhanced discriminability of valid cue targets, not modulated by attentional mechanisms.

In 300–500 ms ACOP time window, peripheral cue resulted in lower amplitude on contralateral hemisphere, with contralateral minus ipsilateral difference associated with better discriminability for valid cues.

CURRENT STUDY

Examine the effect of exogenous attention on spatial discrimination for:
- visual vs auditory central and peripheral cues,
- gaze fixation at a neutral location.

In fully simulated auditory environment. Also measure EEG to examine neural correlates.

Hypothesis and predictions:

Automatic attention attracted by the cue, not only by gaze direction, affects spatial discriminability.
- valid cues will improve in correct vs incorrect trials, valid visual cues will be more helpful than valid auditory cues (even without gaze changes), because of higher visual spatial acuity.

The typical auditory-evoked N1 component peaking at 100–110 ms will be observed in the fronto-temporal neural waves elicited by the lateralized sounds under all conditions.
- we predict N1 amplitude will be larger over the hemisphere contralateral to the sound location
- we predict there will be no contralateral vs ipsilateral difference in N1 amplitudes between correct trials and incorrect trials and invalid and valid trials, (we predict that the N1 will not be associated with better performance of validly cued stimuli)

The ACP will predict of target discrimination accuracy on valid trials.
- there will be significant contralateral vs ipsilateral amplitude difference at occipital sites over the time window 300–400 ms on valid-correct trials, but no difference in valid-incorrect trials (based on Feng et al., 2014)

SUBJECTS, STIMULUS AND SETUP

- 14 subjects (9 male), that
- mean ACOP amplitudes within bias strongly away from FP (i.e., from cue to target).
- auditory invalid cue responses are asymmetrical, dependent on FP. When auditory cue is presented, that asymmetry is suppressed: for valid cue there’s no bias, for invalid cue (identical to target), there’s bias away from cue.

METHODS

RESULTS: ERPs elicited by cue sounds

N1 results

A) ERP waveforms elicited by lateralized and central sounds averaged across five pairs of fronto-temporal electrodes ipsilateral and contralateral to the fixation.

B) Difference between lateral and central cue ERP

ACOP preliminary results

We found main effect of cue position (F(1,12) = 14.37, p = 0.003) with lower amplitude for peripheral cue stimulus, main effect of fixation (F(1,12) = 15.537, p = 0.002) and their interaction (F(1,12) = 14.96, p = 0.002).

-validity x laterality of cue position interaction was also found to be significant (F(1,12) = 6.558, p = 0.025) (Figure 6)

Figure 6 Mean ACOP amplitudes within the time window of 300–500 ms averaged over a cluster of four temporal electrodes, across correct (A) and incorrect (C) trials.

Figure 3 Correct percent responses as a function of cue validity plotted separately for the visual and auditory cues, and for data averaged across target-shift direction (A), or separately for targets moving towards FP (B) and away from FP (C).

Visual cue has very small effect. Invalid auditory cue acts as distractor.

Discrimination responses are asymmetrical, dependent on FP. When auditory cue is presented, that asymmetry is suppressed: for valid cue there’s no bias, for invalid cue (identical to target), there’s bias away from cue.

Figure 5 Correct percent responses as a function of cue validity plotted separately for the visual and auditory cues, and for data averaged across target-shift direction (A), or separately for targets moving towards FP (B) and away from FP (C).

Figure 4 ERP waveforms elicited by lateralized and central sounds averaged across five pairs of fronto-temporal electrodes ipsilateral and contralateral to the fixation.

REFERENCES

- Background.

Figure 2 Experimental setup. A) Temporal structure of a single trial. B) Spatial arrangement of stimuli in different experimental conditions for FP on the right (mirror-flipped setups were used with FP on the left).

DATA ANALYSIS

- statistical significance assessed using repeated-measures ANOVA, only significant effects shown,
- figures plot across subject mean +/- standard error of the mean.

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- there is a contralateral vs ipsilateral amplitude difference between valid correct and valid incorrect for peripheral cue, but no difference between invalid correct and invalid incorrect

- for peripheral cue there is no difference between correct and incorrect responses on contralateral hemisphere

- central cue correct responses have lower amplitude compared to incorrect responses (regardless of validity).

CONCLUSIONS AND DISCUSSION

Stimulus-driven automatic spatial attention influences auditory spatial discrimination: Valid auditory cue improves performance (re. invalid cue) by increasing sensitivity and reducing criterion bias. Valid and invalid visual cue results in performance comparable to valid auditory cue. Main effect of cue is the distracting effect of invalid auditory cue, possibly related to the fact that it was identical to the target.

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