Auditory capture in an auditory and visual spatial cueing task

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Introduction

Previous cueing studies show that a sound coming from a particular location in space can capture auditory and visual attention [1, 2]. In other words, when hearing a sound we have the tendency to direct our attention to the location of the auditory event. This allows for more accurate and quicker responses to succeeding auditory or visual events occurring at that same location [3]. Bottom-up or exogenous capture of attention can occur in a covert [4] manner so this can occur without eye movements. This exogenous capture of covert attention is most often studied by means of a cueing task in which a localizable onset is presented at a valid or invalid target location prior to the presentation of the target. People respond faster and more accurately to validly cued targets than to invalidly cued targets. Importantly, this cueing effect occurs when the cue is valid at chance level, which indicates that it is an automatic process [e.g. 5, 6].

Automatic processes should be unaffected by top-down influences. In other words any prior knowledge about target location should have no effect on attentional capture by sound. In the two studies reported here we test how top-down focusing of attention affects auditory attentional capture during an auditory or visual task. In both studies target location was known prior to the presentation of both cue and target.

In most spatial cueing studies, only the total cueing effect – the difference between response times for valid and invalid cues – is determined. However, valid and invalid cues are associated with 'benefits' and 'costs' which can be determined when a neutral condition is included as reference [7]. In neutral conditions a cue provides only temporal and no spatial information. Visual cuing studies show that an irrelevant visual cue near the target location results in performance benefits relative to a neutral condition. In contrast, when the irrelevant visual cue comes from a non-target location there are performance costs relative to a neutral condition. To test whether the auditory cueing effect can also be defined in terms of cost and benefits we introduced a neutral condition in which the auditory cue was spatially diffuse and therefore did not seem to emanate from a specific direction. To do this we presented two uncorrelated noise bursts through two separate speakers [8]. Both studies that are discussed below use this neutral cue in order dissociate between attentional costs and benefits.

Study 1

It is known that effects of covert orienting in audition can occur when a spatially relevant task is performed [2]. In the first study we apply a novel paradigm that allows us to study how spatial cue-target differences influence the inhibitory and facilitatory effects of covert orienting in audition. In addition, we can determine how an auditory non-informative cue influences target localization. It was shown recently that the perceived position of a target can be shifted away from a preceding distracter coming from a different location [9]. However, during this experiment distractor locations were fixed and always deviated from the possible target location. This made these distractor locations informative in the sense that participants could inhibit these locations prior to the presentation of the distractor. We were interested to see whether similar effects occurred when participants did not know the location of the distractor cue in advance. Therefore, Study 1 examined how an auditory non-informative spatial cue influences detection and localization of auditory targets.

Materials and Methods

Twelve participants took part in Experiment 1 which took place in an anechoic chamber at the TNO Human Factors institute in Soesterberg, The Netherlands. For this experiment loudspeakers were placed at 0° (frontal), ±3°, ± 7° and ± 12° at a distance of 3 m (see Fig. 1a). In each trial a cue (a 50-ms

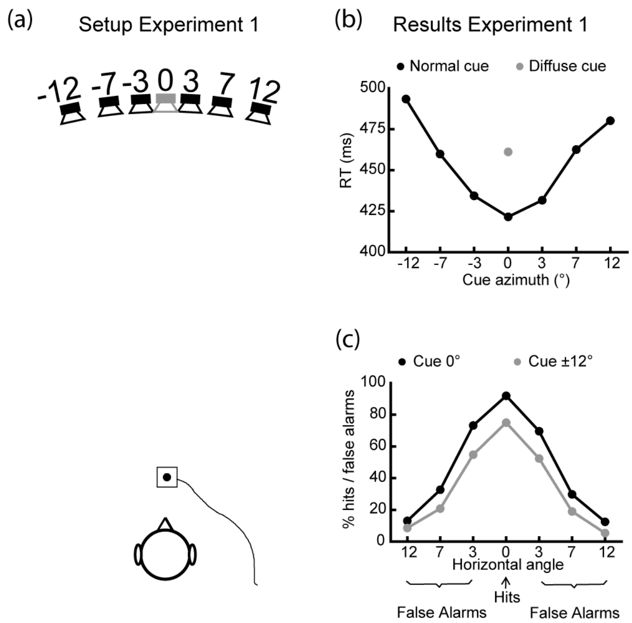

Figure 1: (a) Loudspeaker Set-up of Experiment 1. (b) The RT's measured in Experiment 1. (c) The percentage hits and false alarms obtained in Experiment 1.

pulse train) and a target (a 50-ms white noise burst) were presented with an SOA of 100 ms. The stimuli had cosine-shaped on- and offsets. A baseline condition was included with a spatially diffuse cue, using out-of-phase presentation. Participants were instructed to only press the response button when the target was heard from the centre loudspeaker. They had 1000ms to respond before receiving a feedback tone indicating a correct or incorrect response.

Results and Discussion

The results of Experiment 1 show both costs and benefits due to cueing. Cues shortened reaction times (RTs) at small cue-target angles (up to ± 7º) and increased them at larger angles (see Fig. 1b). The reaction time difference was up to 80 ms. No indications of speed-accuracy tradeoffs were found. Furthermore, the cueing effects did not occur at the expense of target localization accuracy. We derived this from plots displayed in Figure 1c that show how the percentages of false alarms (responses for targets at nonzero azimuths) are distributed around the hits. Both valid cues (coming from 0° azimuth) and the most lateral invalid cues (coming from 12° azimuth) resulted in symmetrical distributions. These findings show that our auditory system is aided by cues preceding nearby targets but impeded by cues further away from the focus of attention. Because such stimuli apparently cannot be suppressed even when attention is in a focused state this provides evidence for capture of auditory attention.

Study 2

It is known that a sound coming from a particular location can capture visual attention, as previously shown in crossmodal cueing studies [e.g. 1]. In Study 2 we tested whether it is possible to suppress such auditory capture by endogenously focusing visual attention to a restricted area in space. Some previous studies have shown that endogenously focusing attention can eliminate capture by visual stimuli [10, 11]. However crossmodal studies show opposite results [12, 13]. Therefore in Study 2 [14] we presented a visual endogenous cue prior to the presentation of the auditory exogenous cue. In addition we used a spatially neutral cue to investigate the distribution of attentional costs and benefits during unfocused (Experiment 2) and focused (Experiment 3) attention.

Materials and Methods

The paradigm used in this study was similar to the orthogonal cueing task used by Spence and Driver [1]. In Experiment 2 a target in the form of a dot appeared on the left or right side of a computer screen slightly above or below the vertical meridian. Participants made an above or below judgment independent of side. Prior to the onset of the target a white noise burst was briefly presented at the left or to the right side of the screen indicating the target side at chance level. We defined the neutral cue by presenting out-of-phase noise through both loudspeakers. This cue was not localizable but still conveyed the same temporal information as the localizable auditory cues. In Experiment 3 we presented a central arrowhead that was 100% valid to allow subjects to endogenously focus their visual attention at a predefined target location indicated by placeholders. Both designs are shown in Figure 2a.

Results and Discussion

The results of Experiment 2 show that when performing a visual discrimination task, there are performance benefits when an irrelevant auditory cue is presented near the target location and performance costs when the cue comes from a non-target location (Fig. 2b). The results of Experiment 3 show that even when attention is highly visually focused, auditory stimuli still capture visual attention (Fig. 2c).

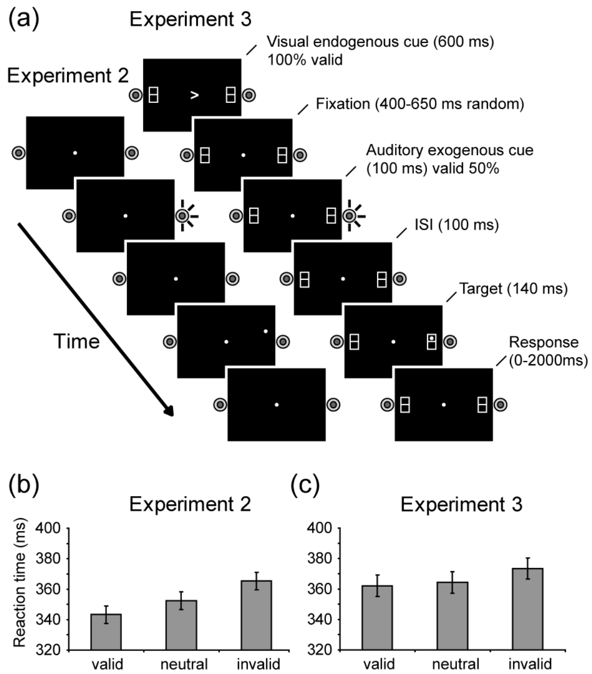

Figure 2: (a) A schematic representation of the paradigms used in Experiment 2 and 3 [14]. (b) The results of Experiment 2 showing both costs and benefits. (c) The results of Experiment 3 showing only costs.

General Conclusion

The results of Study 1 and 2 show the effects of auditory capture on both auditory and visual task performance. They show that the cueing effect can be described in terms of costs and benefits. Therefore, these results indicate that the typical costs and benefits of crossmodal cueing can be attributed to shifts of spatial attention just as is the case in unimodal studies of visual cueing [7]. Drawing attentional resources toward a valid target location by means of sound allows for easier processing of both visual and auditory targets compared to a neutral condition. Drawing attentional resources toward an invalid location results in less resources for target processing at the valid location and therefore worse performance compared to a neutral condition. The results indicate that auditory signals capture attention. This is beneficial when these signals are meaningful (e.g. warning signals) but detrimental in that irrelevant sounds will disrupt task performance even when attention is in a focused state.

Acknowledgements

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