Received: 13 March 2023 | Accepted: 16 April 2023

DOI: 10.1002/pchj.661

SHORT COMMUNICATION

PsyCh Journal

Spatial attention modulates auditory dominance in audiovisual order judgment

Mengtong Cai[1] | **Yan Bao**[1,2,3]

[1]School of Psychological and Cognitive Sciences, Peking University, Beijing, China

[2]Institute of Medical Psychology, Ludwig Maximilian University, Munich, Germany

[3]Beijing Key Laboratory of Behavior and Mental Health, Peking University, Beijing, China

Correspondence
Yan Bao, School of Psychological and Cognitive Sciences, Peking University, 5 Yiheyuan Road, Beijing 100871, China.
Email: baoyan@pku.edu.cn

Funding information
National Natural Science Foundation of China, Grant/Award Number: 31771213

Abstract

Auditory dominance in audiovisual temporal order judgment is shown here to be modulated by exogenous orienting of attention to a spatial cue independent of the cue modality. The visual stimulus has to lead the auditory one further in advance for cued relative to uncued locations in order for the two to be perceived simultaneously, possibly suggesting an inhibitory function of spatial attention on temporal processing.

KEYWORDS
auditory dominance, exogenous attention, spatial attention, temporal order judgment, time perception

One fundamental temporal experience in humans is the perception of the order of two successive stimuli, such as two flashes or two tones. When the two stimuli originate from different modalities, as in the task of audiovisual temporal order judgment, the phenomenon of auditory dominance is typically observed. That is, in order for them to be perceived simultaneously, the visual stimulus has to lead the auditory stimulus by some tens of milliseconds (Hirsh & Sherrick, 1961). This auditory dominance effect has been shown to be influenced by many factors, including spatial information and modality-based attention. When the audio and visual stimuli are presented at the same relative to different locations, a smaller auditory dominance effect is observed (Zampini, Guest, et al., 2005). When attention is directed to a specific modality, attentional modulation on auditory dominance is observable only when attentional orienting to a modality is endogenously or voluntarily initiated (Zampini, Shore, & Spence, 2005) and not when it is exogenously or involuntarily initiated (Frey, 1990).

Previous research on exogenous attention has shown that orienting attention to a spatial location influences the performance of temporal order judgment in the visual domain (Hein et al., 2006; Nicol et al., 2009). However, whether spatial attention also modulates the auditory dominance effect in cross-modal temporal order tasks is unknown. Given that sensory input carries not only spatial but also modality information, it makes sense to address whether auditory dominance in audiovisual temporal order judgment is modulated by exogenous spatial attention as well as by modality-based attention, and whether these two types of attention might interact with each other.

Nineteen students (11 males, 18–27 years old) from Peking University participated in the experiment. Informed consent was obtained from all participants. The study was approved by the Ethical Committee of the School of Psychological and Cognitive Sciences, Peking University, in agreement with the Declaration of Helsinki.

A modified cue–target paradigm was adopted (Figure 1A). Each trial started with a white fixation cross (0.6° x 0.6°) at the center of a black computer screen. After 1000 ms, an exogenous cue lasting 10 ms appeared. The cue was either auditory (a 75-dB white-noise burst from a loudspeaker cone located to the left or right of the screen) or visual (a white-outline box measuring 1° × 1°), appearing at about 21° eccentricity with equal probability on both sides of the fixation. Following an interval that varied randomly from 800 to 1200 ms during which the fixation turned red, signaling the upcoming display of targets, an audiovisual target (the same as the cue in each modality) pair was presented. The first target could be either visual or auditory, with equal probability of the two modalities, appearing at either the cued valid location (Figure 1A, top panel) or the uncued invalid location

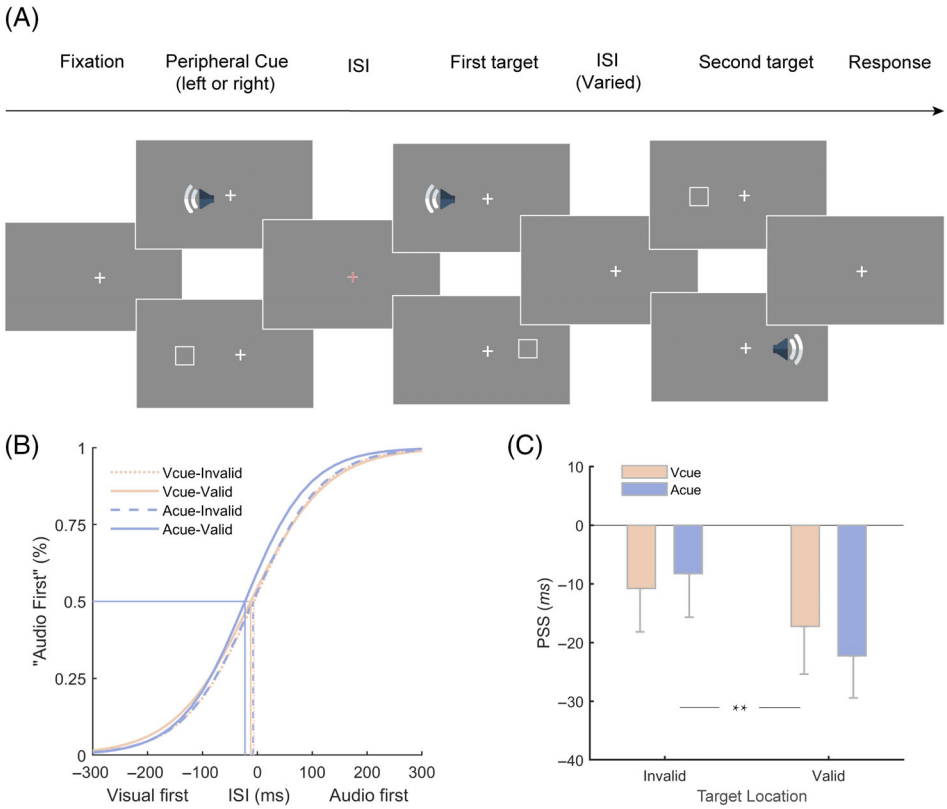

FIGURE 1 Experimental procedure and results. (A) Sample trial sequence. The top panel shows a sample cued valid trial with a peripheral auditory cue followed by an auditory–visual target pair. The bottom panel shows a sample uncued invalid trial with a peripheral visual cue followed by a visual–auditory target pair. (B) Psychometric curves with the percentage of "audio-first" responses calculated as a function of the interstimulus interval (ISI) between the two target pairs for each of the four experimental cueing conditions ("Vcue" represents a visual cue; "Acue" represents an auditory cue). (C) Mean values of the point of subjective simultaneity (PSS) for the four experimental conditions. The error bars represent the standard errors.

(Figure 1A, bottom panel) with equal probability. The second target was always presented on the same side but with a different modality, thus forming a cross-modal stimulus pair. The interstimulus interval (ISI) between the two targets varied as follows: ±300, ±180, ±90, ±50, ±20 ms (positive value indicates audio-first; negative value indicates visual-first). The participants were instructed to report which target appeared first (visual or auditory) by pressing the "Z" or "M" key. There were 800 trials in total, separated into four blocks. Each block contained an equal number of randomly presented trials from 40 conditions (2 modalities x 2 locations x 10 ISIs). Two practice blocks of 20 trials were conducted before the main experiment.

The proportion of "audio-first" responses was calculated as a function of the ISI between the audiovisual target pairs for each of the four cueing conditions (visual-valid, visual-invalid, auditory-valid, auditory-invalid). Psychophysics curves were plotted with the logit psychometric function using the Psycho toolbox for MATLAB, version 3.0.15. In order to examine the auditory dominance effect, the mean point of subjective simultaneity (PSS), or 50% point of the psychometric functions, was calculated and analyzed using a repeated-measure analysis of variance (ANOVA) with *cue modality* (visual or auditory) and *target location* (valid or invalid) as two within-subjects factors. All the PSS values for the four conditions were negative (Figure 1B), confirming auditory dominance in the audiovisual temporal judgment task. Importantly, the ANOVA results revealed a main effect of spatial attention ($F_{(1,18)} = 13.44$, $p < .01$); the PSS values for valid trials were more negative than those for invalid trials (−19.82 ms vs. −9.4 ms), showing a larger effect of auditory dominance at the spatially cued relative to the uncued location (Figure 1C). No significant main effect of cue modality ($F_{(1,18)} = 0.02$, $p > .05$) and the two-way interaction ($F_{(1,18)} = 0.95$, $p > .05$) were observed.

It can be concluded that auditory dominance in audiovisual order judgment is modulated by the exogenous orienting of spatial attention to a peripheral cue, independent of the cue modality. The spatial cue, no matter whether it was a visual or an auditory one, produced a larger audiovisual bias; that is, the visual target had to lead more further in advance over the auditory target so that the two could be perceived at the same time.

Why did the PSS value at the spatially cued location shift to the left (become more negative) compared with the uncued location? We propose that this left shift might suggest an inhibitory influence of spatial attention on temporal processing. It is well documented that exogenous spatial attention typically shows a biphasic effect: an early facilitation (Carrasco, 2011) followed by a later inhibition when the cue–target asynchrony (SOA) exceeds about 300 ms (Posner & Cohen, 1984). Because the present study adopted a much

longer SOA between the peripheral cue and the first target, it makes sense that at the attended location, a greater temporal gap between the two targets is needed in order for the subject to initiate a subjective feeling of non-simultaneity. This larger auditory dominance effect seems to be an indicator of less competence in simultaneity perception due to the inhibitory influence of exogenous cueing with a longer cue–target interval.

The present study is the first to examine both location-based and modality-based attentional effects on audiovisual temporal order judgment at the same time. The findings suggest that spatial attention plays a fundamental role in modulating the auditory dominance effect, no matter whether this spatial orienting of attention is initiated by a visual or an auditory cue.

ACKNOWLEDGMENTS

This work was supported by the National Natural Science Foundation of China (31771213).

CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

ORCID

Yan Bao https://orcid.org/0000-0002-5907-3955

REFERENCES

Carrasco, M. (2011). Visual attention: The past 25 years. *Vision Research*, *51*(13), 1484–1525. https://doi.org/10.1016/j.visres.2011.04.012

Frey, R. D. (1990). Selective attention, event perception and the criterion of acceptability principle: Evidence supporting and rejecting the doctrine of prior entry. *Human Movement Science*, *9*(3–5), 481–530. https://doi.org/10.1016/0167-9457(90)90012-3

Hein, E., Rolke, B., & Ulrich, R. (2006). Visual attention and temporal discrimination: Differential effects of automatic and voluntary cueing. *Visual Cognition*, *13*(1), 29–50. https://doi.org/10.1080/13506280500143524

Hirsh, I. J., & Sherrick, C. E. (1961). Perceived order in different sense modalities. *Journal of Experimental Psychology*, *62*(5), 423–432. https://doi.org/10.1037/h0045283

Nicol, J. R., Watter, S., Gray, K., & Shore, D. I. (2009). Object-based perception mediates the effect of exogenous attention on temporal resolution. *Visual Cognition*, *17*(4), 555–573. https://doi.org/10.1080/13506280802113860

Posner, M. I., & Cohen, Y. (1984). Components of visual orienting. In H. Bouma & D. G. Bouwhuis (Eds.), *Attention and performance X* (pp. 531–556). Erlbaum.

Zampini, M., Guest, S., Shore, D. I., & Spence, C. (2005). Audio-visual simultaneity judgments. *Perception & Psychophysics*, *67*(3), 531–544. https://doi.org/10.3758/BF03193329

Zampini, M., Shore, D. I., & Spence, C. (2005). Audiovisual prior entry. *Neuroscience Letters*, *381*(3), 217–222. https://doi.org/10.1016/j.neulet.2005.01.085

How to cite this article: Cai, M., & Bao, Y. (2023). Spatial attention modulates auditory dominance in audiovisual order judgment. *PsyCh Journal*, *12*(4), 537–539. https://doi.org/10.1002/pchj.661