Exogenous cueing and visual latency: attention, response bias or sensory facilitation?

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Introduction

The idea that attention accelerates sensory processing, reducing perceptual latency, has become well entrenched in the literature. The purpose of this series of ongoing experiments is to determine the magnitude of this attentional effect relative to other factors, response bias and sensory facilitation, that can also affect latency measures.

Background

Titchener (1908) developed his Law of Prior Entry, that attended stimuli enter consciousness more rapidly that unattended stimuli, based on multimodal experiments which seemed to show that stimuli presented to an attended modality were perceived prior to simultaneous stimuli presented to an unattended modality. More recently, Hikosaka, Miyauchi et al. (1993) and Stelmach & Herdman (1991) have shown that, within the visual modality, exogenous visual cues bias temporal order judgments in favor of the cued target, such that the cued target must be delayed relative to the uncued target in order for participants to be maximally uncertain about the order of the two targets. Jaskowski (1993) showed that the existence of the effect for endogenous cueing depends on the response options, and in any case, both Stelmach & Herdman (1991) and Shore, Spence et al. (2001) agree that the effect of endogenous cueing is smaller than for exogenous cueing. Frey (1990) and Shore, Spence et al. (2001) have shown that instructions can affect the size of the attentional effect on order judgments. From this literature it is clear that temporal order judgments can be affected by non-attentional factors. The reduction or elimination of the effect with the endogenous cues suggests that the exogenous cues may have effects on order judgments beyond simple attentional effects.

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- Hikosaka, O., S. Miyauchi, et al. (1993). Focal visual attention produces illusory temporal order and motion sensation. *Vision Research* **33:** 1219-40.
- Jaskowski, P. (1993). Selective attention and temporal-order judgment. *Perception* **22:** 681-9.
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- Stelmach, L. B. and C. M. Herdman (1991). Directed attention and perception of temporal order. *Journal of Experimental Psychology: Human Perception and Performance* **17:** 539-50.
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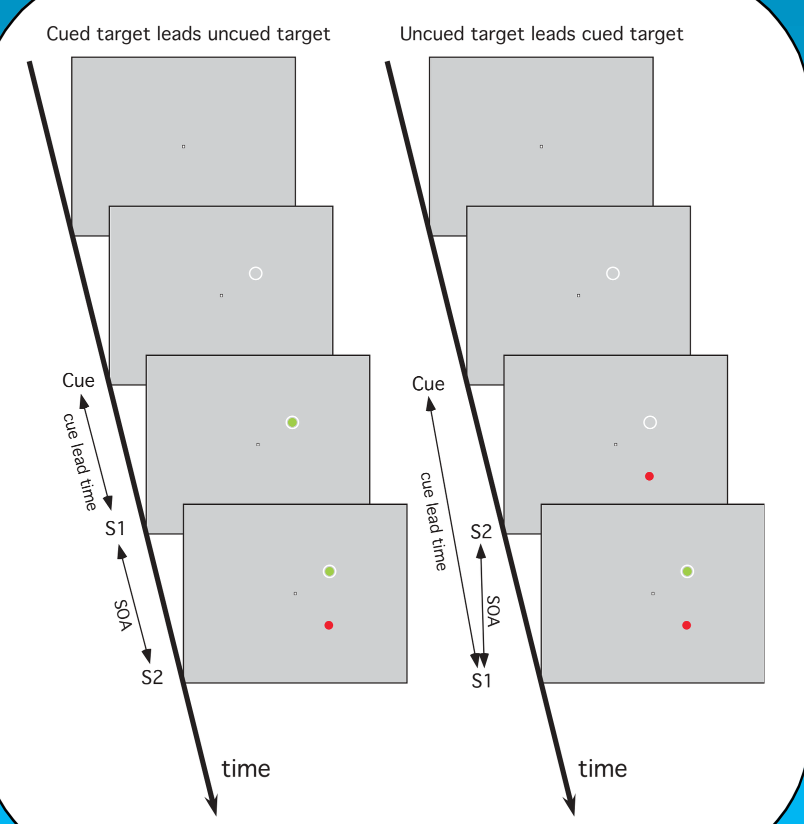
Method Details

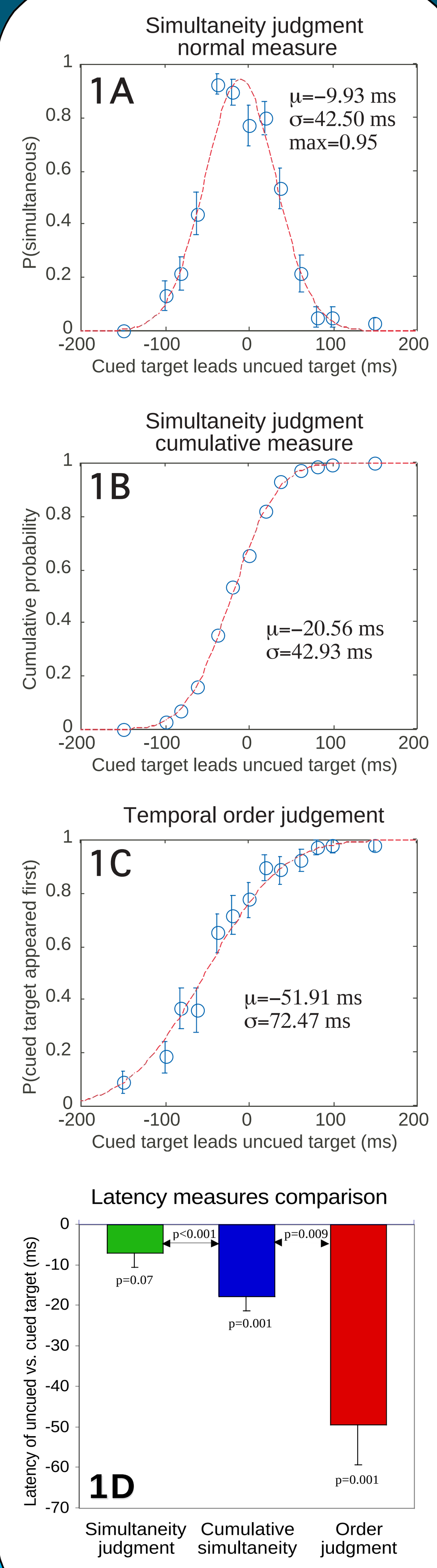
In each experiment, the cue(s) preceded target S1 by an interval (250 ms for Exp. 1, variable for Exp. 2, and 150 ms for Exp. 3), and the onset time (SOA) of the uncued target S2 relative to S1 were varied. Both cues and targets remained visible until a response was made. Each of the SOAs was repeated 50 (Exp. 1) or 20 (Exps. 2 & 3) times, with all conditions randomly interleaved. Participants reported with key presses the order (which target appeared first) or simultaneity (yes/no) of the two targets in separate blocks (Exp. 1) or separate days (Exps. 2 & 3). Presented on a gray background, the targets were red or green 0.3° circles, brightness matched by flicker photometry, and the cues were white 0.5° rings. Fixation was instructed throughout the experiment. The stimuli were located randomly at 5±1° (Exp. 1) or 7±1° (Exps. 2 & 3) from the fixation point, and were separated by at least 3°. Cues and cued targets were concentric. Excluded from subsequent analysis were trials in which the targets were separated by less than 5° (Exp. 1) or 7° (Exps. 2 & 3), to prevent apparent motion contamination, or in which the response time exceeded 2 standard deviations from the mean.

Experiment 1

The purpose of the first experiment is to compare two methods of measuring the effect of attention on perceptual latency: temporal order judgment (TOJ) and simultaneity judgment (SJ). TOJs, in which the observer indicates which stimulus occurred first, are susceptible to response biases. The observer may be biased to respond, especially when the actual order is unclear, that the cued stimulus occurs first. A response bias in the TOJ affects the mean of the response distribution. A response bias in a yes/no SJ affects the height of the response distribution but not the mean.

In this experiment, two targets appeared, one preceded by a spatial cue, and one uncued. In separate blocks, the participants judged either the order or simultaneity of the targets

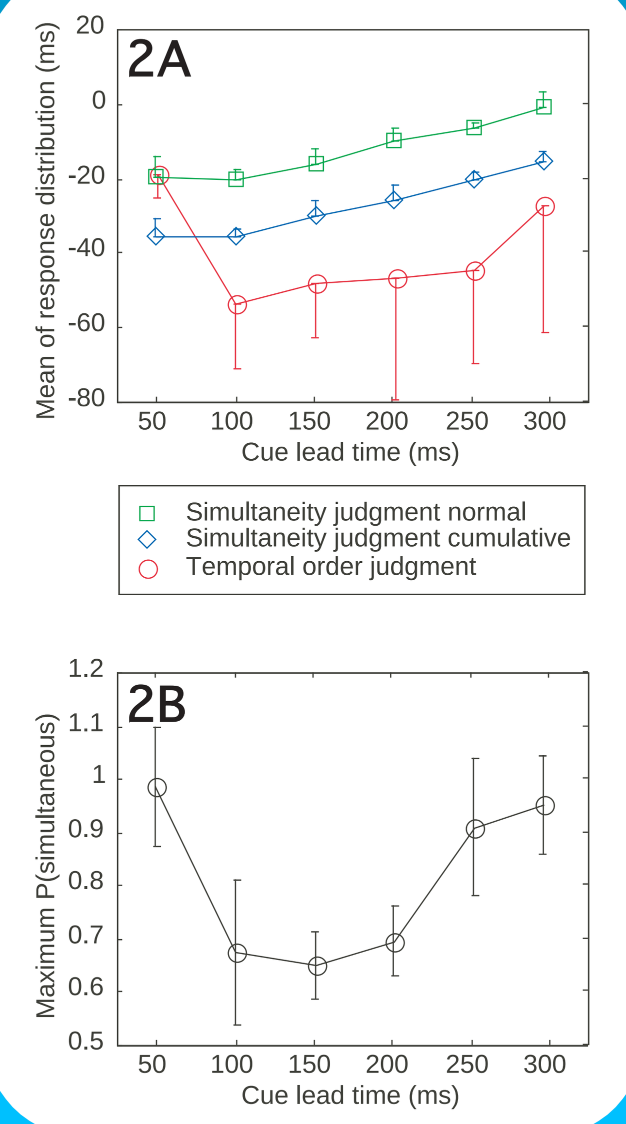




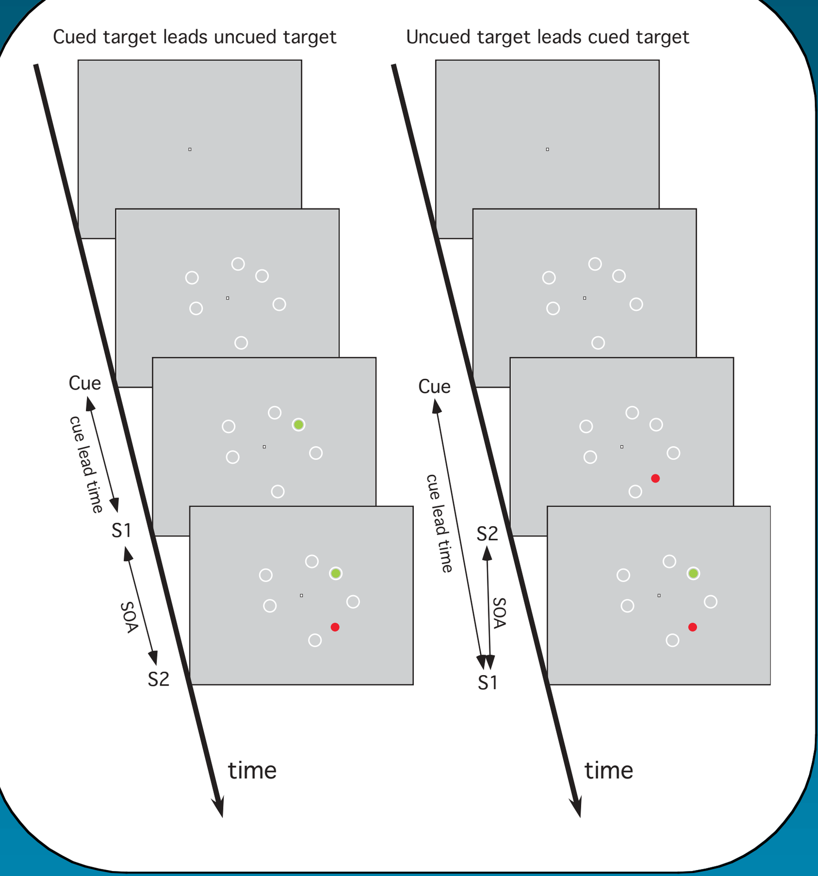
Figures 1A-C show data for a single subject. Figure 1A shows a simultaneity judgment fit to a normal distribution. The response distribution is skewed, having an unequal mean and median. Figure 1B shows a normalized cumulative sum of the responses in Figure 1A, fit to a cumulative normal distribution to estimate the median. Figure 1C shows a temporal order judgment fit to a cumulative normal distribution. Figure 1D shows the means of each distribution for 10 participants. The measures differ significantly—latency effects depend on the measurement method. The difference between the methods may be due to response biases or to different decision processes.

Experiment 2

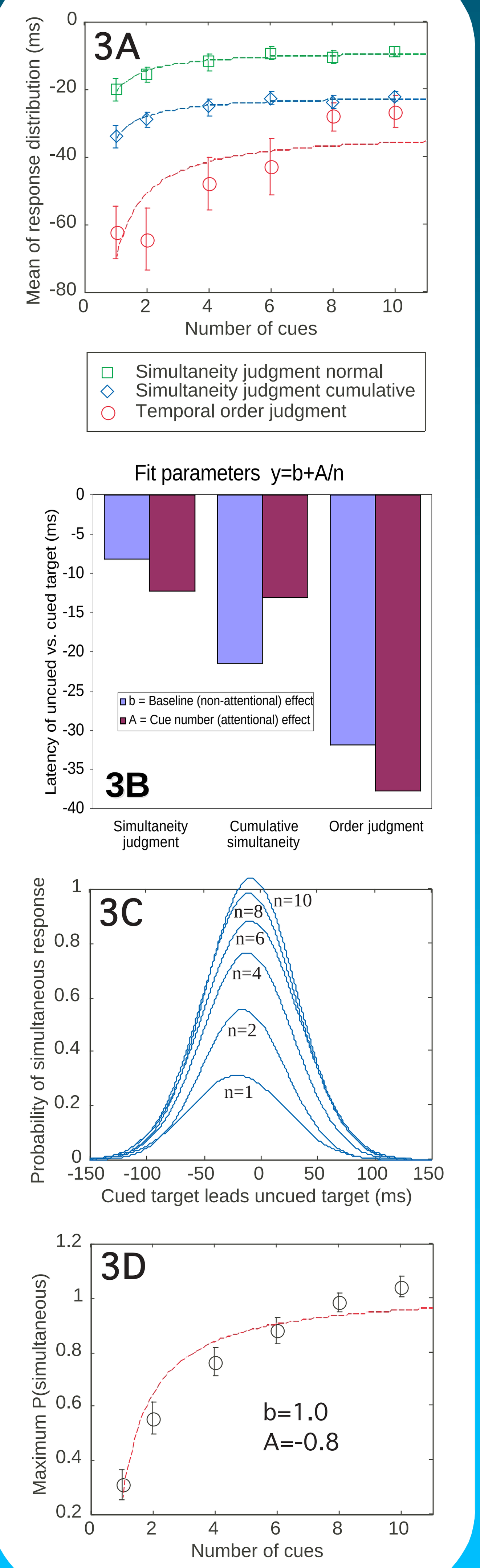
Exogenous attention has a well-established temporal profile that should causally extend to any latency effects it produces. In this experiment, the lead time was varied between the cue and its target. Five participants judged on separate days either the order or simultaneity of the cued and uncued targets. The effects on each latency measure shown in Figure 2A, are only weakly suggestive of the timecourse exogenous attention. In contrast, Figure 2B shows that the effect on the maximum probability of a simultaneous response (height of the response distribution in Figure 1A) strongly resembles the dynamics of exogenous attention. Observers are least likely to judge two targets simultaneous when attentional effects are maximum, possibly indicating that exogenous attention affects the response bias of the simultaneity judgment. Overall, this experiment does not suggest that the latency measures are tightly influenced by exogenous attention.



Experiment 3



To examine the size of the attentional effect on latency relative to other effects, the number of cues was varied. With a large number of cues, the attention allocated to each should be minimal. The cued target appeared in one of the cues, and the uncued target appeared elsewhere. The effect of the number of cues is shown in Figure 3A for 12 participants. Increasing the number of cues reduces but does not eliminate the latency effect. The data is fit to a simple model y=b+A/n were b is the residual baseline (non-attentional), and A is dependence on n, the number of cues (attentional). Figure 3B shows the relative contributions of these effects for each latency measure. It is apparent that non-attentional factors, possibly perceptual facilitation, contribute to the observed latency effects. Figure 3C stacks the mean simultaneity response distributions for the different numbers of cues, and Figure 3D plots their maxima.



Conclusions

Exogenous cues affect measurements of perceptual latency, but the effects are not limited to the attention that such cues draw. The different latency measurements given by order and simultaneity judgments may be due to response biases affecting only the order judgment, but the difference might also be due to different decision processes. Experiment 3 manipulates the contribution of attention, and reveals that exogenous cues produce non-attentional facilitation effects on measured latency. Pending a more detailed model, it seems that the effects of attention on perceptual latency are rather small.