

The Effects of Cue Validity and Cue-Target Delay on Reflexive Attention

ELENA CHRISTEEN ADITYA PUTRI & ATIKA DIAN ARIANA

Faculty of Psychology, Universitas Airlangga, Surabaya, Indonesia

ABSTRAK

Atensi refleksif memungkinkan orientasi perhatian yang cepat dan otomatis terhadap perubahan visual yang menonjol. Penelitian ini menguji apakah respons lebih cepat pada trial valid daripada trial invalid serta apakah efek isyarat lebih besar pada jeda isyarat-target yang singkat. Sebanyak 343 mahasiswa mengikuti eksperimen dalam-partisipan menggunakan PsyToolKit. Isyarat berupa perubahan warna kotak selama 75 ms; 75% trial bersifat valid dan 25% invalid. Jeda isyarat-target ditetapkan pada 150 dan 575 ms. Efek isyarat dihitung sebagai waktu reaksi trial invalid dikurangi trial valid. Efek tersebut positif pada kedua jeda dan lebih besar pada 150 ms ($M = 68,96$; $SD = 43,02$) daripada 575 ms ($M = 22,27$; $SD = 41,39$), $t(342) = -15,43$; $p < 0,001$; $d_z = 0,83$. Temuan ini menunjukkan bahwa orientasi refleksif paling kuat segera setelah isyarat muncul dan melemah ketika interval bertambah panjang.

Kata kunci: *atensi refleksif; efek isyarat; jeda isyarat-target; waktu reaksi*

ABSTRACT

Reflexive attention enables rapid, automatic orienting toward salient visual changes. This study examined whether responses were faster on valid than invalid trials and whether the cueing effect was greater at a short cue-target delay. In a within-participants experiment, 343 undergraduate students completed a visual cueing task programmed in PsyToolKit. A 75-ms color change served as a peripheral cue; 75% of trials were valid and 25% were invalid. Cue-target delays were 150 and 575 ms. The cueing effect was calculated as reaction time on invalid trials minus reaction time on valid trials. It was positive at both delays and substantially larger at 150 ms ($M = 68.96$, $SD = 43.02$) than at 575 ms ($M = 22.27$, $SD = 41.39$), $t(342) = -15.43$, $p < .001$, $d_z = 0.83$. These findings show that reflexive orienting is strongest shortly after cue onset and declines as the cue-target interval increases.

Keywords: *attentional cueing; cue-target delay; reaction time; reflexive attention*

INTRODUCTION

Attention is a limited-capacity cognitive system that allows people to prioritize relevant information while suppressing distraction. Without this selection mechanism, the perceptual system would be overwhelmed by the volume of sensory input available at any moment. Directing attention toward a particular location or object generally improves the efficiency with which information at that location or object is processed (Stevens & Bavelier, 2012; Goddard et al., 2022). Because attention supports perception, decision-making, and adaptive responses to environmental change, it remains a central topic in cognitive psychology and neuroscience (Lindsay, 2020).

One important form of attention is reflexive attention, which is rapidly and automatically elicited by a salient stimulus. It differs from voluntary attention, which is goal-directed and relies on top-down control. Reflexive attention allows the visual system to prioritize sudden changes before a person deliberately shifts focus or makes an eye movement (Corbetta & Shulman, 2002; Hopfinger & Mangun, 1998). In everyday life, this mechanism supports rapid responses to warning lights, moving objects, and other potentially important visual events.

Reflexive attention is commonly investigated with spatial cueing tasks. In these tasks, a cue appears before a target and draws attention to one of several possible locations. A cue is valid when the target subsequently appears at the cued location and invalid when the target appears elsewhere. Responses are typically faster on valid trials because the target location has already been prioritized. On invalid trials, attention must be disengaged from the cued location and redirected to the target, producing a reaction-time cost (Posner, 1980; Bowman et al., 1993). The difference between reaction times on invalid and valid trials is known as the cueing effect; a positive value indicates a processing advantage at the cued location.

The magnitude of the cueing effect also depends on the interval between cue and target onset. Reflexive orienting emerges quickly but is short-lived. Facilitation is generally strongest at brief intervals, often around 100-300 ms, and declines as the interval lengthens (Müller & Rabbitt, 1989; Nakayama & Mackeben, 1989). At longer intervals, the initial advantage may disappear or reverse into inhibition of return, a tendency to respond more slowly to stimuli presented at a previously attended location. This temporal pattern suggests that reflexive orienting is not a stable attentional state but a transient response that changes over time.

Previous studies have established both the reaction-time advantage associated with valid cues and the changing time course of reflexive orienting. However, cue validity and cue-target delay have often been examined in separate lines of research. Manipulating both factors within the same design makes it possible to determine whether the advantage of a valid cue is especially strong when the target follows the cue quickly. Such a comparison can clarify the temporal dynamics of reflexive attention and distinguish early facilitation from the later decline in attentional benefit.

The present study therefore examined the effects of cue validity and cue-target delay on reaction time in a visual cueing task. The first hypothesis was that participants would respond faster to targets preceded by valid cues than to targets preceded by invalid cues. The second hypothesis was that the cueing effect would be larger at a 150-ms delay than at a 575-ms delay. Comparing these two intervals was expected to provide evidence for the rapid but transient nature of reflexive attention.

METHOD

Research Design

This study used a quantitative, within-participants experimental design. Every participant completed all cue-validity and cue-target-delay conditions, thereby controlling for individual differences in baseline response speed. The independent variables were cue validity (valid vs. invalid) and cue-target delay (150 vs. 575 ms). The dependent variable was reaction time in milliseconds, measured from target onset to the participant's keypress. This design was appropriate because it allowed stimulus location and timing to be manipulated under controlled conditions while directly assessing the temporal dynamics of reflexive orienting.

Participants

Participants were 343 undergraduate students enrolled in the PYB204 Perception and Cognition course at Queensland University of Technology. Of the sample, 267 identified as women, 66 as men, five as nonbinary, and five did not disclose their gender. Participant age was not available in the dataset. No participant-level exclusion criteria were applied; all students who attended the Week 5 practical session were included in the analysis. Participation occurred as part of the scheduled practical class, and the documentation available for this article did not describe a separate informed-consent procedure.

Apparatus and Procedure

Stimuli were presented on laboratory computers using PsyToolKit, which also recorded responses. Each trial began with a central fixation marker and two gray boxes positioned to the left and right of fixation for 425 ms. One box then changed color for 75 ms, creating a peripheral cue. After the cue ended, a black target dot appeared following either a 150-ms or 575-ms delay. On 75% of trials, the target appeared in the cued box (valid trials); on the remaining 25%, it appeared in the opposite box (invalid trials). Participants were instructed to maintain fixation and press the left or right response key as quickly and accurately as possible according to the target's location. A trial ended when a response was made or after 1.5 s.

Each block began with eight practice trials. PsyToolKit recorded reaction time automatically for every experimental trial. Trials with no response within 1.5 s were excluded, and the first 10 trials of each block were omitted so that the analyzed data more closely represented stable task performance. Because the primary outcome was reaction time rather than a multi-item psychological scale, an internal-consistency reliability coefficient was not applicable.

Data Analysis

Data was analyzed in Jamovi. For each participant, the cueing effect was calculated separately at the 150-ms and 575-ms delays by subtracting mean reaction time on valid trials from mean reaction time on invalid trials. Positive values therefore indicated faster responses on valid trials. Means, medians, standard deviations, and standard errors were used to summarize the cueing effect in each condition. A paired-samples *t* test compared cueing effects across the two delays, with statistical significance evaluated at $p < .05$. Because both scores were obtained from the same participants, this test directly assessed whether the benefit of cue validity changed as a function of cue-target delay.

RESULTS

All 343 participants contributed data to both delay conditions after trials without a response were removed. The mean cueing effect was positive at both delays, indicating that responses were faster on valid than on invalid trials. Descriptively, the cueing effect was substantially larger at the 150-ms delay than at the 575-ms delay (Table 1).

Table 1. Descriptive Statistics for the Cueing Effect at Each Cue-Target Delay

Cue-target delay	N	M (ms)	Median	SD	SE
575 ms	343	22.27	15	41.39	2.23
150 ms	343	68.96	65	43.02	2.32

A paired-samples *t* test showed that the cueing effect was significantly larger at the 150-ms delay than at the 575-ms delay, $t(342) = -15.43$, $p < .001$. The mean cueing effect was 46.69 ms greater in the 150-ms condition, 95% CI [40.74, 52.64], and the standardized difference was large, $d_z = 0.83$. The data therefore supported the hypothesis that cueing would be stronger at the shorter delay.

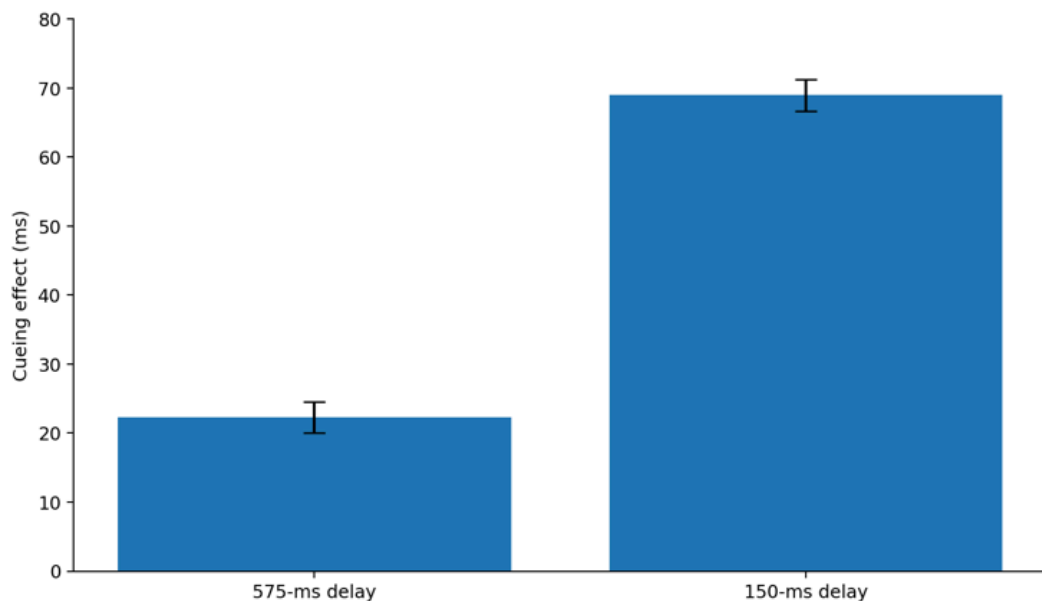


Figure 1. Mean Cueing Effect at the 575-ms and 150-ms Delays

Note. Error bars represent standard errors.

DISCUSSION

The findings revealed two main patterns. First, the mean cueing effect was positive at both delays, indicating faster responses to validly cued targets than to invalidly cued targets. This pattern is consistent with the logic of spatial cueing: when the target appears where attention has already been drawn, processing begins

from a prioritized state. When the cue is invalid, attention must instead be disengaged from the cued location and redirected to the target, adding a reactiontime cost (Posner, 1980; Bowman et al., 1993). The results therefore supported the first hypothesis at the descriptive level.

Second, the cueing effect at 150 ms was approximately three times as large as the effect at 575 ms. The statistically significant difference and large effect size indicate that the benefit of the cued location was greatest when the target followed the cue quickly. This result is consistent with the view that reflexive orienting develops rapidly and then declines. Müller and Rabbitt (1989) and Nakayama and Mackeben (1989) found that reflexive facilitation is strongest at short intervals and weakens as the interval increases. Similarly, Langley et al. (2011) reported clearer visuospatial facilitation at short stimulus-onset asynchronies than at longer ones.

Although the cueing effect was smaller at 575 ms, it remained positive. The present findings therefore demonstrate reduced facilitation rather than direct evidence of inhibition of return. Evidence for inhibition of return would require responses at the cued location to become slower than responses at the uncued location, producing a negative cueing effect. The absence of this reversal may reflect the specific timing used in the task, the characteristics of the stimuli, or the high probability of a valid cue. This distinction is important because a declining attentional benefit is not equivalent to the emergence of an inhibitory effect.

The 75% proportion of valid trials also warrants consideration. Peripheral cues can attract attention automatically, but a highly predictive cue may also allow participants to learn that the cued location is usually the correct one. Strategic expectation may therefore have contributed to the validity advantage, even though the task was intended to measure reflexive orienting. Future studies could use nonpredictive cues with 50% validity, compare multiple validity levels, or include a neutral-cue condition. These modifications would help separate automatic attentional capture from expectation-based orienting.

The generalizability of the findings is limited by the use of students from a single course and by the predominantly female sample. Participant age was unavailable, preventing analysis of developmental differences in the time course of reflexive attention. In addition, only two cue-target delays were tested, so the full temporal function could not be mapped. Future research should examine several intervals ranging from very brief delays to more than 1,000 ms, counterbalance the order of delay blocks, and analyze accuracy alongside reaction time to assess possible speed/accuracy trade-offs.

From an applied perspective the results suggest that a salient visual signal provides the greatest processing advantage when relevant information follows soon afterward. This principle may be useful in the design of vehicle warnings, digital interfaces, sports training, and emergency response systems. Nevertheless, the 150-ms interval should not be treated as a universal optimum, because cue effectiveness depends on task complexity, stimulus properties, and user context. Realworld applications therefore require direct testing to ensure that a signal not only captures attention but also directs it toward the correct information at the appropriate time.

CONCLUSION

Cue validity was associated with a clear reaction-time advantage in the visual cueing task: positive cueing effects indicated that participants responded faster to targets at validly cued locations than to targets at invalidly cued locations. This advantage was strongly influenced by cue target timing. The cueing effect was significantly larger at 150 ms than at 575 ms, supporting the conclusion that reflexive orienting develops rapidly and then weakens as the interval increases.

Future research should employ a wider range of cue-target delays, nonpredictive cues, counterbalanced block orders, and samples with documented age characteristics. These improvements would allow a more precise account of the temporal limits of reflexive attention and a clearer distinction between automatic attentional capture and strategic expectation.

ACKNOWLEDGMENTS

The authors thank the Faculty of Psychology at Universitas Airlangga, Queensland University of Technology, the teaching team for PYB204 Perception and Cognition, and all participants who contributed to the study.

DECLARATION OF POTENTIAL CONFLICTS OF INTEREST

“Elena Christeen Aditya Putri and Atika Dian Ariana declare that they do not work for, consult for, own shares in, or receive funding from any company or organization that could benefit from the publication of this article.”

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