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Reduced Inhibition of Return for Self-relevant Stimuli

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Abstract

Self-relevant stimuli (e.g. own-name) have been known to enjoy cognitive priority, known as the self-prioritization effect (SPE). Attentional bias towards any event consists of two components: how quickly attention is captured and how long attention dwells on that event. Although faster attentional capture by self-relevant stimuli has been consistently established in the literature, it is unclear whether captured attention is held by self-relevant stimuli for longer, delaying attentional disengagement from self. Thus, the current study aims to provide a more comprehensive picture of the attentional mechanisms underlying SPE by employing the Posner cueing paradigm to investigate both facilitation (capture) and inhibition of return (disengagement), to test the commonly touted yet not investigated delayed disengagement hypothesis. The results found a self-specific facilitation at shorter CTOA, in line with literature, as well as a reduced IOR for self, indicating a slower attentional disengagement from self. The findings and implications are discussed in detail.

Keywords: Self-prioritization effect; inhibition of return; attentional dwell

Introduction

Literature has robustly established that any event or stimulus relevant to the self enjoys a bias in processing, which is referred to as the self-prioritization effect (SPE) in attention and perception (Sui et al., 2012; Humphreys & Sui, 2015; Schäfer et al., 2016; Scheller & Sui, 2022; Keil et al., 2023). Though the cognitive priority enjoyed by self-relevant information has been demonstrated across processing stages, outcome measures, and modalities, the mechanisms underlying the manifestation of the self-bias remain rather elusive. Humphreys and Sui (2015) proposed the Self Attention Network (SAN) as a broader framework for reconciling behavioral and physiological manifestations of the attentional prioritization enjoyed by the self. According to SAN, a self-representation is seated in the ventro-medial prefrontal cortex (vmPFC) which gets instantly triggered at the presence of self-referential information, which subsequently triggers the excitatory pathway between vmPFC and the posterior superior temporal sulcus (pSTS), which is involved in bottom-up orienting of attention, thus modulating the self-driven attentional orienting that is manifested as self-prioritization.

The instant, automatic capture of attention by self-relevant information has long since been explored and demonstrated using spatial cueing paradigms. Though significant and consistent cueing benefits have been observed for events occurring at a self-referentially cued (vis-à-vis a non-self-referentially cued) location have been robustly established (Alexopoulos et al., 2012; Orellana-Corrales et al., 2020; Li et al., 2022), the attentional capture alone does not explain why the cued location is prioritized even after the stimuli that captured the attention are no longer present to elicit the cognitive priority. Attentional bias towards any event could be understood as being constituted of two component mechanisms: attentional capture, i.e., how quickly attention is captured by the event, and attentional dwell, i.e., how long the event can hold on to the captured attention. Therefore, it naturally follows that the most commonly touted explanation for the self-referential cueing benefits is that attention is dwelling or being held longer at the self-referentially cued location, thus lengthening the priority enjoyed by the space, which is manifested as the benefits enjoyed by any subsequent event occurring at the self-referentially cued spatial location (Devue et al., 2009; Alexopoulos et al., 2012; Wójcik et al., 2018). In other words, attentional disengagement from the self-referentially cued location has been proposed to be delayed as compared to a non-self-referentially cued location. However, as commonly as this hypothesis has been touted in the discussion sections of previous studies, it has remained largely unexplored, rendering drawing inferences about the attentional prioritization of self-referential information obscure.

Conventionally, the disengagement of attention from a previously cued location is measured in terms of the inhibition of return (IOR) to the particular location. IOR is considered as a search strategy that evolved to ensure optimal sampling of one's surroundings and manifests at a later stage of processing (Posner & Cohen, 1984; Lupiáñez et al., 1997; Klein, 2000; Lupiáñez et al., 2007). Typically, events occurring at a validly cued location enjoy prioritized processing immediately after the cue is presented, i.e. at shorter temporal intervals between cue and target onsets, known as Cue Target Onset Asynchronies (CTOA), which is reflected as cueing benefits or facilitation. As time passes and the likelihood of the target occurring at the cued location decreases, attention shifts to the uncued location, and to avoid the redundancy of scanning the non-useful location repeatedly, the return of attention to the previously cued location becomes inhibited, which gets manifested as a cost or negative cueing effect at the validly cued location,

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at longer CTOAs, thus making IOR an indication of the disengagement of attention from the previously validly cued location. Therefore, if the cueing benefits for self-cued locations arise from attention dwelling longer at the cued location, it could be expected that the time course of IOR would be delayed for targets appearing at the self-referentially cued (vis-à-vis non-self-referentially cued) location.

Though Liu et al. (2021) asserts that the effect of SPE on IOR in the 2D space is both well-established as well as that the effect is such that self-referential stimuli enjoys priority in terms of capturing attention in the early stages of processing and facilitates voluntary shifts of attention at the later stages, suggesting an overall reduced IOR for self-referentially cued locations, the assertions, in addition to being counterintuitive, also stems from spurious studies such as Liu et al. (2012) and Wang et al. (2013), as well as a misguided interpretation of Sui et al. (2009).

Sui et al.'s observation that self-referential cues facilitate attentional reorientation and thereby reduce IOR, is inferred from an endogenous cueing task across two SOAs (Stimulus Onset Asynchrony) — 250ms and 350 ms. The conclusions drawn seem to reflect a larger cueing effect at the latter SOA for self, rather than a reduced inhibition. Additionally, SOAs used are still short enough to fall within the facilitatory range (around 400 ms) for discriminatory tasks, as established by Lupiáñez et al. (1997). Lupiáñez et al. have established that IOR occurs later and disappears sooner in discrimination tasks as compared to detection tasks. The endogenous nature of the cue and the overall facilitatory nature of the temporal window of processing involved could be the reasons why Sui et al. found self-referential cues facilitating disengagement of attention from the cued to the uncued location by supporting the voluntary shifts of attention and thereby, task performance.

Orellana-Corrales et al. (2020), on the other hand, found that participants responded more slowly to targets at self-referentially cued locations as compared to non-self-referentially cued locations, at longer SOAs, suggesting that IOR is more pronounced for self-referential cues. However, the inference is drawn across three experiments, one with the short SOA (100 ms) and the other with the long SOA (1000 ms), rendering the indirect comparison insufficient in understanding the time course of facilitation and inhibition for self and non-self conditions, in the absence of a systematic variation of CTOAs as the two anchor SOAs could not reflect the dynamic and transient nature of IORs in discrimination tasks. Furthermore, the inhibition as observed in the study has been suggested by the authors themselves to be cautionary, since the dot-probe task presented both self and non-self spatial cues simultaneously, letting them compete for the attentional resources and examined the cueing effects in terms of where the target was presented in the particular trial rather than which location was spatially cued. Simultaneous spatial cueing of both possible target locations in all trials, therefore, makes it difficult to tease apart the differences in disengagement from self-cues (vis-à-vis non-self-cues), suggesting that the slower RTs (and lack of a negative cueing effect) could be stemming from other factors affecting the attentional spotlight.

Therefore, the current study aimed to directly test the delayed attentional disengagement hypothesis by systematically varying the CTOAs for self and stranger cues, within a classic spatial cueing paradigm (Posner cueing paradigm) designed to elicit facilitation at shorter CTOAs and inhibition at longer CTOAs. It is expected that the IOR would be delayed for the targets occurring at self-referentially cued locations.

Method

Participants

A G*Power analysis (Faul et al., 2007) conducted for a 2 x 2x 4 repeated-measures within factors design with an estimated medium effect size (f = 0.25) according to Cohen's (1988) conventions yielded a minimum sample size of 16 to detect a self-specific effect at a power of 0.80 (α = .95). Final sample consisted of twenty-nine participants (11 females, 18 males; mean age = 28.13 years, SD = 4.3) with no current or past diagnosed psychological or neurological conditions, normal or corrected-to-normal vision, and no colour blindness, and naïve to the purposes of the experiment, recruited from the student pool at the institute (masked for anonymity) campus, after providing informed consent. The study was approved and adhered to all the norms prescribed by the Institute Human Ethics Committee.

Stimuli, Apparatus, Design, and Procedure

The experiment was run on a 24-in. LCD monitor (1920 × 1080 resolution; refresh rate: 60 Hz), controlled by a Dell PC running MATLAB R2023b along with Psychtoolbox-3. All responses were made using keypresses, differentially assigned for each phase of the study. All the visual stimuli, unless stated otherwise, were presented in white colour against a black background. The study consisted of two phases in total —the Association phase and the Experimental phase.

The Association phase was designed to make the participants form the self and non-self (Stranger) associations that would serve as the basis for the actual experiment. The phase consisted of two stages- the Exposure stage and the Testing stage (Sui et al., 2012; Li et al., 2022). In the Exposure stage, the labels 'YOU' and 'STRANGER' were randomly assigned to two (out of the four) primary-colored box outlines (red, RGB- 255, 0, 0; blue, RGB- 0, 0, 255; green, RGB- 0, 255, 0; yellow, RGB- 255, 255, 0), and the participants were instructed to proceed only once they were clear of these associations. In the Testing stage, the strength of the formed associations was tested to ensure that the participants had indeed formed the associations correctly. A typical trial in the Testing stage goes as depicted in Fig. 1. Each trial starts with a central fixation cross (0.55 cm x 0.55 cm; 0.52° x 0.52° visual angle) for 500 ms, followed by a display of two boxes flanking the fixation cross — one white and the other either in the self-associated or the non-self-associated colour— along with the text 'You' or 'Stranger', subtending a visual angle of 0.79° at a distance of 5.26° from the center which remains on the screen till the participant responds whether the colour of the box and the label beneath matches or not with the colour-label association they have learnt previously. The response is made using the 'b' and 'n' keys for 'match' and 'mismatch' (counterbalanced) using their non-dominant hand, followed by feedback displayed for 500 ms, with an intertrial interval of 1000 ms. Each coloured box was displayed an equal number of times to the left and right of the fixation cross, maintaining consistency with the cueing in the Experimental phase. Across a total of 180 trials (90 trials per identity), match and mismatch trials for each identity were distributed equally and presented in a random order. A break was offered after every 30 trials. Only the data from those participants whose accuracy in the Association phase is greater than 90% were included in the final analysis. In the current study, all 29 participants had accuracy rates well above 90%, and thus, no dataset had to be eliminated.

The Association phase was followed by the Experimental phase, where the effect of self-referential and non-self-referential cues on attentional disengagement was tested by using an adapted version of Posner's cueing task (Posner & Cohen, 1984; Lupiáñez et al., 2007). A typical trial is as depicted in Fig. 2, and starts with a central fixation cross along with the two white boxes, one on either side of the cross (the fixation display), for 1000 ms, followed by the cue for 50 ms, followed by the fixation display for 50/350/650/950 ms depending on the CTOA for the trial, followed by the target displayed in either of the two white boxes for 100 ms, which is further followed by the fixation display again for a maximum response window of 2000 ms. The cue consisted of the brief change in colour of one of the boxes to either the self- or stranger-referential colour, with the change in luminance giving the impression of a flicker, and was uninformative in nature (50% validity), while the target was either the letter 'X' or 'O' displayed inside one of the boxes flanking the fixation cross. The participants were supposed to indicate the identity of the alphabet using their dominant hand with the left and right arrow keys for 'X' and 'O' (counterbalanced). Unlike the Association phase, participants received feedback only if their response was incorrect or if they failed to respond within the response window. The feedback was displayed for 1000 ms, and the intertrial interval was also 1000 ms.

The experiment thus followed a 2 (Identity: Self, Stranger) × 2 (Validity: Valid, Invalid) × 4 (CTOA: 100, 400, 700, 1000 ms) design, with 20 trials per condition, resulting in a total of 320 trials. The presentation order was randomized for each participant, and a break was offered after every 40 trials. The Experimental phase was preceded by a Practice session of 16 trials, with the same trial structure, to familiarize the participants with the task.

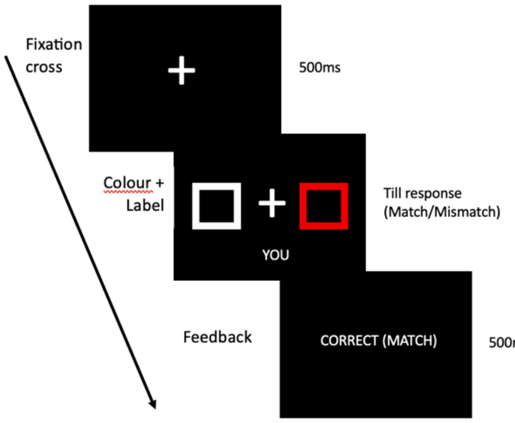

Figure 1: Sample Trial Structure in the Association Phase

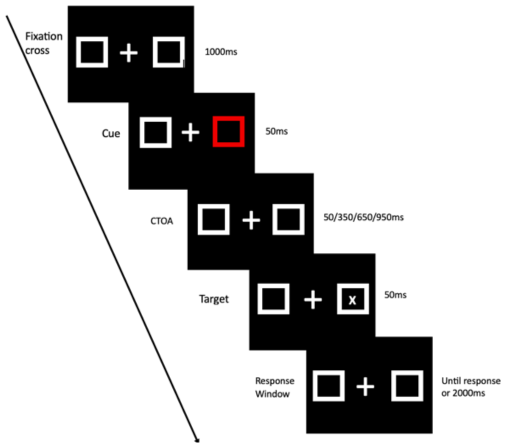

Figure 2: Sample Trial Structure in the Experimental Phase

Results

A 2 (Identity: Self, Stranger) × 2 (Validity: Valid, Invalid) × 4 (CTOA: 100, 400, 700, 1000 ms) repeated measures ANOVA was conducted on error rates, and only the main effect of Validity emerged significant[$F(1,28)=4.76$, $p=.038$, $\eta p^2=.145$), with overall error rates lower in Valid($M = 1.46$, $SD = .262$) than Invalid ($M = 2.04$, $SD = .357$) trials. No differences in error rates between self and stranger were observed at the larger CTOAs, ruling out the possibility of a speed-accuracy trade-off (Table 1).

A 2 (Identity: Self, Stranger) × 2 (Validity: Valid, Invalid) × 4 (CTOA: 100, 400, 700, 1000 ms) repeated measures ANOVA on RT showed a significant main effect of CTOA [$F(3,84)=43.195$, $p <.001$, $\eta p^2=.607$]. Significant effects were also obtained for Identity × Validity interaction [$F(1,28)=4.917$, $p =.035$, $\eta p^2=.149$] as well as Validity × CTOA interaction [$F(3,84)=7.482$, $p <.001$, $\eta p^2=.211$]. No other main or interaction effects emerged as significant[1]. The results asserted the observation of a basic IOR effect, while suggesting self-specific differences in cueing effect.

Post hoc comparisons on cueing effect ascertained the faster attentional capture by self-relevant stimuli; paired samples t-test found that self-cued locations enjoyed significantly greater facilitation (M = 35.84, SD = 35.36) than stranger-cued locations (M = 10.13, SD = 39.36), $t(28) = 2.48$, $p = .019$ at 100ms CTOA. On the other hand, at larger CTOA, self-relevant stimuli were found to elicit a reduced inhibition of return (IOR); paired samples t-test observed that self-cued locations enjoyed significantly lesser inhibition (M = -1.25, SD = 45.75) than stranger-cued locations (M = -18.61, SD = 39.28), $t(28) = 2.08$, p = .047 at 700ms CTOA. The self-specific differences disappeared at 1000ms CTOA.

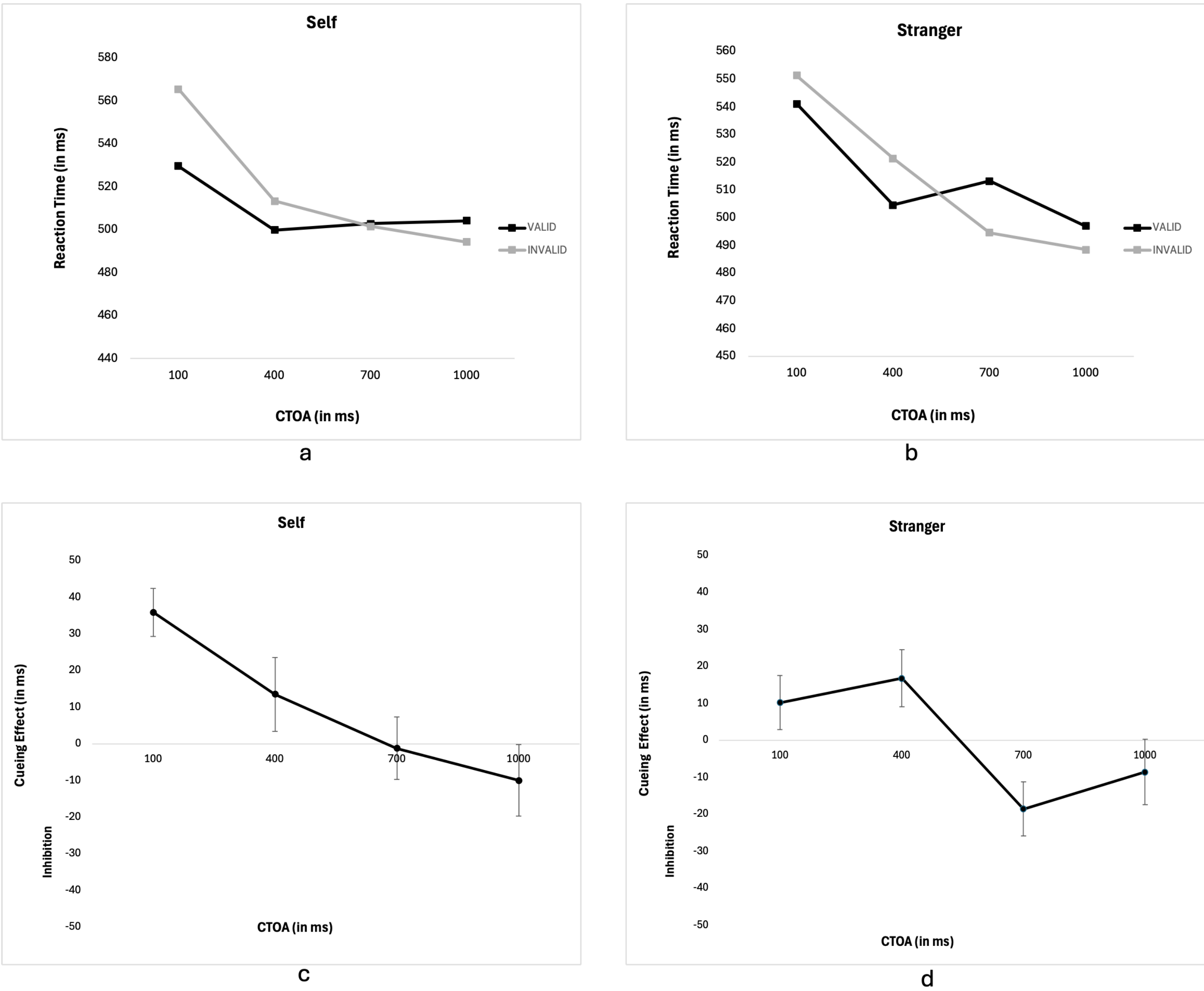

Figure 3: Reaction times (figures a & b) and cueing effects (figures c & d) for Self and Stranger conditions across CTOA

[1] As remarked by reviewer 1 and Klein et al. (2006), though the three-way interaction between Identity, Validity and CTOA was not significant (p =), since the observance of RT (valid) > RT (invalid) at the longer CTOAs is enough to establish IOR, and the cross-over point between RT (invalid) > RT (valid) and RT (valid) > RT (invalid) appears earlier for Stranger-cues than Self-cues, the findings support rather than challenge the primary hypothesis.

Table 1: Mean correct RTs and error rates (ER) for Self and Stranger conditions across CTOA

CTOA	Self				Stranger			
	Valid		Invalid		Valid		Invalid	
	RT (SE)	ER (in %)	RT (SE)	ER (in %)	RT (SE)	ER (in %)	RT (SE)	ER (in %)
100 ms	529.6(13.66)	1.72	565.44(13.76)	2.24	541.12(13.63)	0.86	551.25(14.21)	2.24
400 ms	499.77(15.1)	1.37	513.28(16.29)	1.55	504.56(16.44)	1.03	521.33(16.34)	3.44
700 ms	502.76(15.82)	2.41	501.51(14.43)	1.72	513.23(15.58)	1.03	494.62(15.85)	1.72
1000 ms	504.23(15.82)	1.55	494.26(17.16)	1.37	496.99(15.77)	1.72	488.43(16.79)	2.06

Discussion

The study aimed to investigate attentional mechanisms underlying the prioritization enjoyed by self-relevant events. Though faster attentional capture, as reflected in facilitation observed for events occurring at a self-referentially cued (vis-à-vis a non-self-referentially cued) location has been robustly established (Alexopoulos et al., 2012; Orellana-Corrales et al., 2020; Li et al., 2022), the mechanism of attention dwelling longer on the same has so far only been touted as a possible explanation and remained underexplored. Thus, the current study systematically varied the CTOAs to investigate whether attentional disengagement is delayed at a self-referentially cued location. The study results indicate a reduced IOR for self at larger CTOA, suggesting a slower disengagement of attention from self-referentially cued locations, in addition to confirming the self-specific facilitation at the shorter CTOA.

The significantly greater facilitation enjoyed by self at the shortest CTOA (100ms) is in line with the previous literature that has consistently demonstrated attentional capture by self-relevant stimuli (Alexopoulos et al., 2012; Orellana-Corrales et al., 2020; Li et al., 2022). As the Self Attention Network (SAN) explains, the existence of a self-representation ready to be triggered by the presence of self-relevant information guides the rapid attentional orienting towards the self. The current study, therefore, validated the facilitation enjoyed by self-referential stimuli.

On the other hand, the current study is the first to systematically investigate and find a reduced IOR for self at larger CTOA. The findings suggest that attention is not just captured faster by the self-relevant stimuli, but it also dwells longer at the self-relevant information. While attention has already been reoriented from the stranger-cued location, reflecting a higher cost for responding to the previously attended location, the absence of such a cost for self indicates that attention continued to be held at the self-cued location, negating the need for attention to return since attention has not yet been reoriented from the self-cued location. Thus, the evidence for a delay in the disengagement of attention from self-relevant information provides a more comprehensive picture of the mechanisms underlying the attentional bias enjoyed by self-relevant information, suggesting that both attentional capture and attentional dwell are modulated by the self-relevant properties of an event, leading to the prioritized processing enjoyed by the self.

It could be argued that the self-specific differences at the 700ms CTOA might reflect a prolonged facilitation rather than a qualitatively distinct disengagement mechanism. However, the cost in attending to the previously attended self-cued location, albeit of minuscule magnitude, suggests that, the inhibition is not offset by a facilitation, rather the dwelling of attention at the self-cued location makes it easier and thus less costly to return to the validly cued location even after a delay.

Though Orellana-Corrales et al. (2020) suggested a pronounced IOR for self-cues, the suggestion had been drawn indirectly across three experiments, one with the short SOA (100 ms) and the other two with the long SOA (1000 ms), using a dot-probe task, rendering the comparison insufficient in understanding the manifestation of facilitation and inhibition for self and non-self conditions. The simultaneous spatial cueing of both possible target locations in all trials in their study, and the resulting competition for attentional resources, therefore, makes it difficult to tease apart differences in disengagement from self-cues vis-à-vis non-self-cues, suggesting that the slower RTs (and lack of a negative cueing effect) need not necessarily reflect an efficient disengagement mechanism.

It is also important to note that Sui et al.'s observation (2009) that self-referential cues facilitate attentional reorientation and thereby reduce IOR reflects a larger cueing effect at the longer of the two SOAs for endogenous self-cues, rather than a reduced inhibition, with both SOAs still falling under the temporal window for facilitatory effects. The current study, on the other hand, focused on exogenous cueing, trying to understand how attention involuntarily captured by self-referential information affects the further processing of events in the same spatial location. We have also lengthened the temporal window to include both facilitatory and inhibitory processes for a comprehensive investigation, as is evidenced by the manifestation of both facilitation and inhibition of return.

The current study thus deviates from the findings of the previous studies in this domain. The current study investigated IOR within a classic spatial cueing paradigm designed for eliciting IOR, finding evidence for both early attentional capture as well as delayed attentional disengagement, potentially complementing the Self Attentional Network (Humphreys & Sui, 2015), and providing a more comprehensive understanding of the different attentional mechanisms that contribute to the attentional prioritization enjoyed by self-referential stimuli.

Conclusions

The current study aimed to investigate the attentional capture as well as attentional dwell at the self-relevant event, as the two components driving the attentional bias towards self, as observed in the self-prioritization effect (SPE), by systematically varying the CTOAs. Self-relevant stimuli elicited faster attentional capture as evidenced by a self-specific facilitation at the shorter CTOA. It was also observed that attention disengages more slowly from self-relevant stimuli as evidenced by the reduced IOR for self (vis-à-vis stranger)-cued locations, at the larger CTOA. Together, the results provide a more comprehensive picture of the attentional mechanisms underlying SPE.

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