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On the role of eye movement monitoring and discouragement on inhibition of return in a go/no-go task

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ABSTRACT

Inhibition of return (IOR) most often describes the finding of increased response times to cued as compared to uncued targets in the standard covert orienting paradigm. A perennial question in the IOR literature centers on whether the *effect* of IOR is on motoric/decision-making processes (output-based IOR), attentional/perceptual processes (input-based IOR), or both. Recent data converge on the idea that IOR is an output-based *effect* when eye movements are required or permitted whereas IOR is an input-based *effect* when eye movements are monitored and actively discouraged. The notion that the *effects* of IOR may be fundamentally different depending on the activation state of the oculomotor system has been challenged by several studies demonstrating that IOR exists as an output-, or output- plus input-based effect in simple keypress tasks not requiring oculomotor responses. Problematically, experiments in which keypress responses are required to visual events rarely use eye movement monitoring let alone the active discouragement of eye movement errors. Here, we return to an experimental method implemented by Ivanoff and Klein (2001) whose results demonstrated that IOR affected output-based processes when, ostensibly, only keypress responses occurred. Unlike Ivanoff and Klein, however, we assiduously monitor and discourage eye movements. We demonstrate that actively discouraging eye movements in keypress tasks changes the form of IOR from output- to input-based and, as such, we strongly encourage superior experimental control over or consideration of the contribution of eye movement activity in simple keypress tasks exploring IOR.

1. Introduction

As explored in a typical covert orienting paradigm, inhibition of return (IOR) refers to the phenomenon of slower response times (RTs) to previously cued locations (for reviews, see Klein, 2000; Lupiañez, Klein, & Bartolomeo, 2006). The effect of IOR can be separated into two broad classifications or forms: those affecting *output* (motoric or decision-making), and *input* (attentional or perceptual) pathways (e.g., Klein & Hilchey, 2011; Taylor, 1999; Taylor & Klein, 2000). Two completely dissociable mechanisms underly these forms (e.g., Bourgeois et al., 2012; Kingstone & Pratt, 1999; Sumner et al., 2004). Efforts (Chica et al., 2010; Klein, Hilchey, & Satel, 2012) to integrate ideas about when (*cause*; Taylor & Klein, 2000) and how (*mechanism*; Ivanoff, Klein, & Lupianez, 2002) these two forms are generated have been made difficult by robustly observed output-based effects in variants of the go/no-go task in which input-based effects are predicted. Our purpose here is threefold: (1) to assert a particular relation between the activation state of the oculomotor system and the form of IOR, (2) to illustrate a range of data that seems to conflict with this assertion, and (3) to resolve the discrepancy.

2. On the underlying mechanisms for the effects associated with the two forms of IOR

Taylor and Klein (2000) manipulated the nature (peripheral events; central arrows) of the stimuli that might cause (the first signal; S1) and measure (the second signal; S2) IOR. The 4 possible pairings of S1/S2 were randomly intermixed within each of 6 combinations of response modality for S1 (no response, manual or saccadic localization responses) and S2 (manual or saccadic localization responses). Their methods and findings are illustrated in Fig. 1. Whenever an eye movement response was required and IOR caused, the effect was observed whether S2 was a peripheral onset or central arrow. Simply, responses to S2s were slower when the direction indicated by the S1 was compatible with the response required by S2. This pattern implies that the effect of IOR in these

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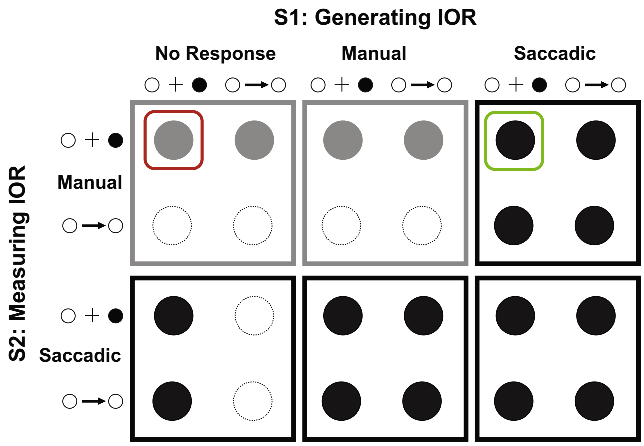

Fig. 1. A schematic illustration of the methods and results from Taylor and Klein (2000). Six experiments differed in terms of the localization task observers were required to perform in response to S1 (none, manual, saccadic) and S2 (manual, saccadic). The rows and columns within each box represent the nature of the stimuli (peripheral luminance changes and central arrows) that were randomly intermixed in each block of trials. Solid circles represent conditions in which significant IOR was obtained. IOR was not observed in the remaining (dotted) circles. The gray region illustrates the conditions for which Taylor and Klein inferred an "input" form of IOR that was characterized by a delay in attending peripheral inputs or linking them with their correct responses. The black region represents the conditions for which Taylor and Klein inferred a "motoric" form of IOR that was characterized by a bias against responding in the originally cued direction. The conditions highlighted by red and green boxes (in the on-line version and which are rendered using dashed and dotted lines, respectively, in the print version) are discussed in the text.

conditions is more closely related to delayed responding (i.e., a decision or output-based effect). In contrast, when eye movements were forbidden and withheld during a trial (made neither to S1 nor S2), IOR was only observed in response to peripheral S2s. Because IOR only delayed responding when S2 was a peripheral event (occurring at the *location* indicated by S1), the pattern implies that the effect is closer to the input end of the processing continuum. Taylor and Klein (2000) suggested that the requirement to withhold eye movements altered the activation state of the oculomotor system, fundamentally changing the form of IOR.

Ivanoff, Klein, and Lupianez (2002) described two distinct mechanisms (illustrated in Fig. 2) that might lead to IOR effects

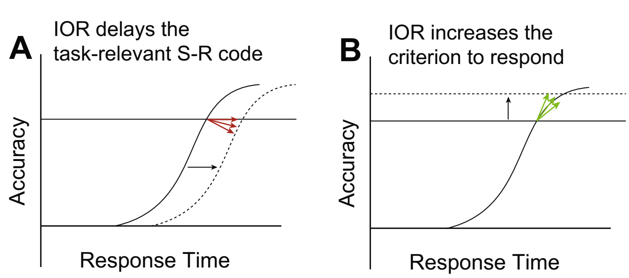

Fig. 2. Two accounts for how IOR might slow response times. The temporal dynamics of information processing is illustrated in both panels by SAT functions with accuracy plotted as a function of RT. The solid function represents the monotonic accumulation of information needed to make a correct response to the target, and the solid horizontal line represents the average criterion amount of evidence the observer requires to initiate a response. According to the input-based account (panel A) IOR delays the accumulation of task-relevant information (cf Hilchey et al., 2011) as represented by the dotted SAT function. The typical effect of input-IOR on performance (a genuine improvement in speed, or accuracy, or both) is represented by the red/dashed arrows. According to the output-based account (panel B) IOR increases the amount of evidence required to initiate a response (dotted horizontal line). The typical effect of output-IOR (slower and more accurate responding; viz a speed–accuracy tradeoff) is represented by the green/dotted arrows.

on RT. An input-based mechanism delays the accumulation of information linking cued targets with their corresponding responses (Fig. 2A). This IOR effect would result in a genuine reduction in performance for cued relative to uncued targets (e.g., Hilchey et al., 2011; Ivanoff & Klein, 2006). In contrast, an output-based mechanism operates as a bias against responses in the direction indicated by the earlier cue (e.g., Ivanoff & Klein, 2001; Klein & Taylor, 1994; Posner et al., 1985; Prime & Jolicoeur, 2009; Tassinari et al., 1987). This IOR effect would have no effect on the accumulation of information about the target (Fig. 1B); instead, it increases RT by raising the criterion for responding (Ivanoff & Klein, 2001; Klein & Taylor, 1994; Prinzmetal et al., 2011). When such a criterion shift is in effect, delayed responding is accompanied by increased accuracy (Posner, 1975). Simply, the output effect is characterized by a speed–accuracy tradeoff (SAT).

These ideas about the conditions necessary to elicit the two forms of IOR and the two different mechanisms that could slow RT to cued targets were empirically linked by Chica et al. (2010). IOR was generated by a peripheral cue and measured by manual responses in a non-spatial two-alternative forced choice task. When participants were instructed to ignore the peripheral cue and, importantly, given feedback whenever an incorrect eye movement occurred (the condition highlighted by the red/dashed box in Fig. 1), there was a genuine decline in performance at the cued location (see the red/dashed arrow in Fig. 3). In contrast, when participants made a saccade to the peripheral cue (and back to the original fixation before target onset, the condition highlighted by the green/dotted box in Fig. 1), the delay in RT at the cued location was accompanied by an improvement in accuracy (viz., an SAT as represented by the green/dotted arrows in Fig. 3).

3. The puzzle: An "output" form in a condition where the "input" form of IOR should exist

Ivanoff and Klein (2001)'s participants performed a go/no-go task wherein a simple keypress response was required for "go" stimuli whereas no response was required for "no-go" stimuli. Providing the first direct evidence for the suggestion that IOR could manifest as a bias against responding to the cued location (Klein & Taylor, 1994), they found that false alarms (FAs; i.e., responses to no-go targets) were rarer on cued than uncued trials in the presence of an IOR effect on RT (green/dotted arrow in Fig. 4). In the context of our effort to integrate the two mechanisms of IOR with the two forms of IOR, this finding (IOR = an SAT) is problematic because the condition tested by Ivanoff and Klein corresponds to that highlighted by the red/dashed box in Fig. 1, where an input-based effect ought to have been observed.

This anomalous finding cannot be dismissed as a fluke. We found five, post 2001 papers[1] using a go/no-go task in which cuing effects on FA rates could be examined using methods similar to those of Ivanoff and Klein (2001). In each of these studies, IOR was expressed as an SAT. The consistency of this SAT is illustrated in Fig. 5. As would be expected given that each of the false alarm effects were significant, the 95% confidence intervals for each study excludes zero. The overall effect is illustrated at the bottom of the figure.

Typical of most studies measuring IOR with keypress responses, Ivanoff and Klein (2001) did not monitor eye movements. Importantly, in none of the studies represented in Fig. 5 did participants receive trial-by-trial feedback on their oculomotor behavior. This is in sharp contrast to the assiduous feedback that was provided in

[1] These are: Ivanoff and Klein (2003, E1 and E2, no mask data only), Ivanoff and Klein (2004, E1), Prime and Ward (2006, E3), Prime and Jolicoeur (2009, E1 Hi probability of go target), Taylor and Ivanoff (2003).