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

Matthew D. Hilchey [a], Mahmoud Hashish [a], Gregory H. MacLean [a], Jason Satel [a], Jason Ivanoff [b], Raymond M. Klein [a,*]

[a] Department of Psychology & Neuroscience, Dalhousie University, Canada
[b] Department of Psychology, Saint Mary's University, Canada

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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 three-fold: (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

* Corresponding author. Address: Department of Psychology & Neuroscience, Dalhousie University, 1355 Oxford St., Halifax, NS B3H 4R2, Canada. Fax: +1 9024946585.
E-mail address: ray.klein@dal.ca (R.M. Klein).

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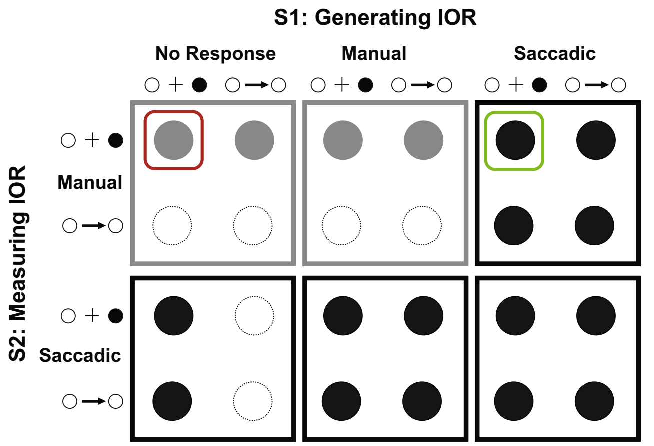

Fig. 1. A schematic illustration of the methods and results from Taylor and Klein (2000). Six experiments differed in terms of the localization task observers were required to perform in response to S1 (none, manual, saccadic) and S2 (manual, saccadic). The rows and columns within each box represent 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

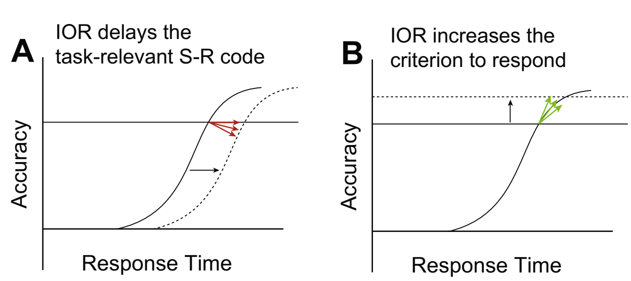

Fig. 2. Two accounts for how IOR might slow response times. The temporal dynamics of information processing is illustrated in both panels by SAT functions with accuracy plotted as a function of RT. The solid function represents the monotonic accumulation of information needed to make a correct response 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).

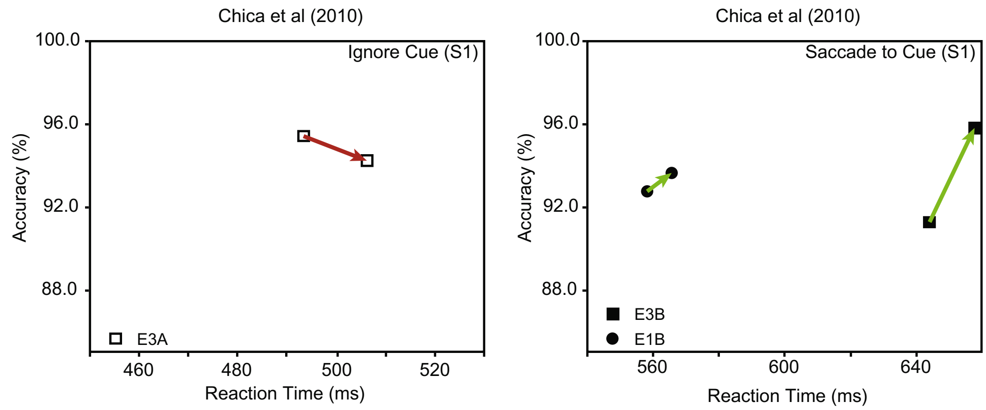

Fig. 3. Results from Chica et al.'s (2010) manual discrimination task plotted in speed–accuracy space (see Fig. 2). Data from the experiment when participants were instructed to ignore the cue are plotted in the left panel; data from the experiments when participants made an eye movement to the cue (and back to fixation) are plotted in the right panel.

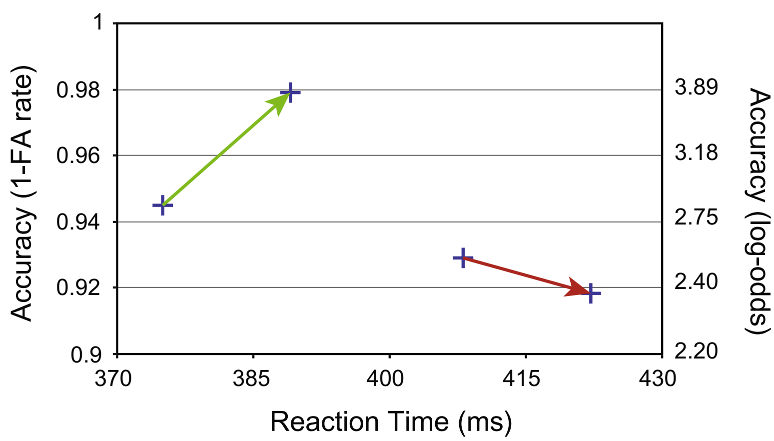

Fig. 4. The results from peripheral targets in Ivanoff and Klein (2001; green/dotted arrows in this illustration) and the present experiment (red/dashed arrows) represented in speed–accuracy space (see Fig. 2). The data from both experiments have been collapsed across CTOA, T-R correspondence, and in the case of Ivanoff and Klein, position of the non-responding effector). In both experiments the faster data point is from peripheral targets preceded by a peripheral cue at the opposite location; the slower data point is from peripheral targets preceded by a cue at the same location as the target; in both cases the IOR effect in RT was 14 ms. The dramatic difference is in accuracy with a speed–accuracy tradeoff in Ivanoff and Klein and a genuine change in the quality of performance in the present study.

the experiments by Taylor and Klein (2000) and Chica et al. (2010). We thought this difference might be critical (cf Klein & Hilchey, 2011) and, when reviewing the literature to identify all studies exploring IOR using a go/no-go task, we found one that supported our conjecture. Using a go/no-go task, Cheal, Chastain, and Lyon (1998, Experiment 3) monitored eye position and provided feedback to their observers whenever eye movements were detected.[2] As would be expected from the theoretical integration presented in the previous section, a robust IOR effect was obtained in RT (26 ms) while there was no evidence for an SAT: the FA rates did not differ between conditions (15.6% for uncued trials; 15.4% for cued trials). Miss rates were substantial enough in this experiment to permit the computation of d' which was also nearly identical for the cued (2.109) and uncued (2.114) conditions.

If our conjecture were correct, then when – in conditions akin to those used by Ivanoff and Klein (2001) – the eye movements of observers are actively discouraged, the effect of IOR ought to be of the input form. To test this conjecture we replicate the methods of Ivanoff and Klein (2001) while: (1) adding eye movement monitoring, (2) providing explicit error feedback when untoward gaze shifts were detected, and (3) excluding any such eye movement trials from analysis. If the active discouragement of reflexive saccadic eye movements to peripheral visual events is the critical factor responsible for an input-based IOR effect, we should observe IOR in RT but, in contrast to Ivanoff and Klein (2001), we should *not* find an accuracy advantage at the cued location.

Although we no longer have the raw data from Ivanoff and Klein we do have the mean RTs and error rates for each participant. This will allow us to make a direct statistical comparison of the pattern of results with (the present study) and without (Ivanoff and Klein) active discouragement of eye movements. The critical results (identical cuing effects on RTs accompanied by significantly different in cuing effects on FA rates) are foreshadowed in Fig. 4.

4. Methods

4.1. Participants

Fourteen students (10 females and 4 males) from Dalhousie University volunteered for participation and were compensated with course credit. All participants were naïve to the purposes of the experiment and reported normal or corrected-to-normal vision.

[2] From this experiment's methods section: "If an eye movement occurred immediately before, during or immediately after the trial, the subject was admonished by the experimenter."

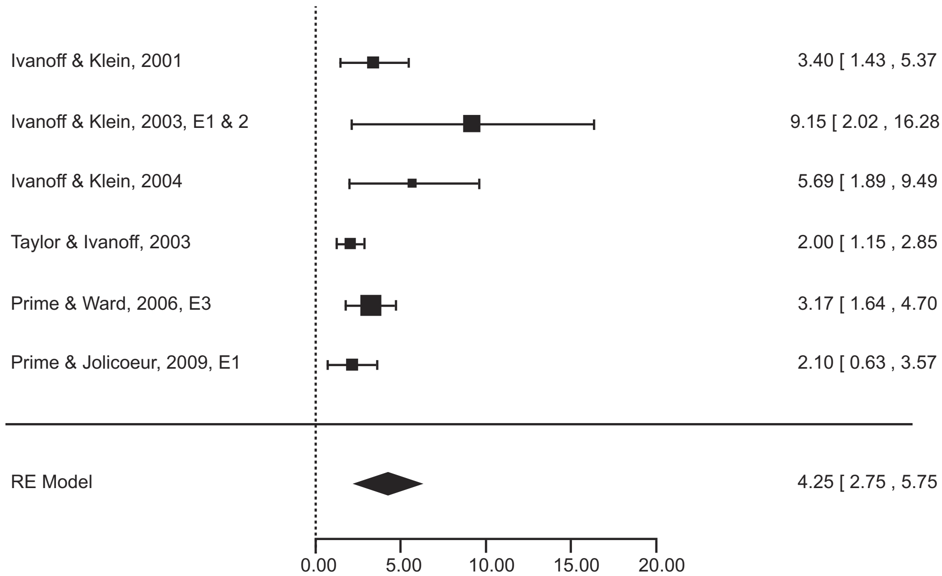

Fig. 5. This forest plot was generated using the metafor package (Viechtbauer, 2010) within R version 2.12.1 (R Development Core Team, 2011). Each symbol in the upper panel of the figure represents the data from one of the 6 studies in the literature that explored IOR using a go/no-go task, reported separately the FA rates for cued and uncued no-go targets, and did not provide trial-by-trial feedback on eye movements. The *X*-axis projections of the symbols in the upper panel of the figure represent the mean FA rate difference: Uncued FA minus Cued FA. The sizes of these symbols are positively related to the number of participants in each study. Studies were weighted equally to generate an estimate of the overall effect of cuing upon FA rates which is illustrated by the diamond (whose width represents the 95% confidence interval) in the bottom portion of the figure. Mean cuing effects and 95% confidence intervals for each of the six studies and for this literature as a whole are presented in the right side of the figure.

4.2. Apparatus and stimuli

Participants were tested under dim lighting conditions with stimuli presented at a viewing distance of 57 cm. Stimuli were presented in black against a white background on a 19″ CRT monitor connected to an Intel Core Duo processor. An Eyelink II head-based eye monitoring system was used to monitor eye position.

The stimuli used in this experiment were as similar as possible to those administered by Ivanoff and Klein (2001). Three landmark squares (black outline with white fill), each measuring 1.5 × 1.5 degrees visual angle, formed an imaginary horizontal plane at the midpoint of the monitor. The observer's midline was approximately in line with the center of the middle placeholder. The distance between the lateral side of the middle landmark square and the inner lateral side of the peripheral landmark squares was 6.2 degrees visual angle. The fixation point was a small filled dot (0.3 degrees visual angle in diameter) centered in the middle landmark square. The cue was a "+" or "×" symbol embedded in and encompassing the entirety of a circle (1.5 degrees visual angle in diameter). The go and no-go signals measured 1.5 × 1.5 degrees visual angle and were solid black, and checkered black and white squares, respectively.

4.3. Procedure

The procedure for this experiment was identical to that in Ivanoff and Klein (2001) except: (1) the location of the non-responding hand relative to target events was not manipulated (this is in conformity with the remaining studies represented in Fig. 5); (2) a trial abruptly terminated if an eye movement was detected (Eyelink default settings: velocity threshold = 35°/s and acceleration threshold = $9500°/s^2$); and (3) such termination was followed immediately by visually presented feedback: "Eye movement detected. Please refrain from making any eye movements." A keypress response was required to acknowledge the feedback and to re-initiate the trial sequences. The sequence of events (on non-terminated trials) was as follows: At the outset of each trial, three landmark squares and the fixation point appeared for 750 ms when the fixation point was extinguished and a cue occurred randomly in one of the three landmark squares for 375 ms. Ninety or 675 ms after the cue's disappearance [cue-target onset asynchronies (CTOAs) of 465 or 1050 ms, respectively], a go or no-go signal appeared randomly in one of the three landmark squares. Observers were instructed to withhold or make single keypress responses (either the "/" or "z" key with the left or right index finger, respectively) on no-go or go trials, respectively. The go and no-go signals appeared onscreen for a maximum of 1 s or until a response was detected. A failure to respond was recorded as a miss; a FA was recorded if a response occurred during the no-go target. Following termination of the trial a blank white screen appeared for 750 ms (the inter-trial interval). The next trial was initiated following the inter-trial interval.

4.4. Design

The ratio of go to no-go trials was 2:1. Each observer participated in one practice block containing 54 trials followed by 4 experimental blocks, each containing 108 trials. Half of the observers were randomly selected to respond to go signals with the left index finger ("/" key) whereas the other half responded with the right index finger ("z" key). Observers were correctly informed that there was no spatial relationship between the location or identity of the cue the subsequent go or no-go signal. Speed and task-appropriate responding were emphasized and eye movements were explicitly discouraged.

4.5. Methods of analysis

One observer was excluded from analysis for making almost 50% FAs on no-go trials (the next highest rate was 12.5%). All practice trials were excluded from analysis. All trials with a failure to maintain fixation at any point during the trial were excluded from analysis. Less than 1% of the trials were excluded because the observer either made a keypress response before target onset or

Table 1
LMM analyses of error rates across cue conditions in two studies.

	Probability of error			
	B	SE	*z*	Pr(>|*z*|)
Model 1				
Intercept	−3.42886	0.23078	−14.858	
Study (Ivanoff and Klein vs. Hashish et al.)	−0.41638	0.22943	−1.815	0.0695
Cueing (Cued vs. Uncued)	0.39599	0.07453	5.313	1.08E−07
Model 2				
Intercept	−3.42572	0.23122	−14.816	
Study (Ivanoff and Klein vs. Hashish et al.)	0.47057	0.23122	2.035	0.04184
Cueing (Cued vs. Uncued)	0.21680	0.09254	2.343	0.01914
Interaction (Cueing * Study)	0.30396	0.09254	3.285	0.00102

failed to make a response to a go signal. Two correct RTs less than 200 ms were excluded from analysis. Because we are not interested in the same questions that Ivanoff and Klein (2001) were pursuing, our analyses will be constrained to the critical question for present purposes which is about the effect of peripheral cuing upon RT and FA rates[3] and a comparison of these results against those of Ivanoff and Klein. That comparison will be made using logistic regression. A more complete presentation of the results can be found in Supplementary material.

5. Results

A failure to maintain fixation at any point during a trial (see Section 4) resulted in the termination of 19.7% of the trials. Comparison with some of our other studies using similar feedback about unwanted eye movements reveals that this relatively high rate of unwanted eye movements was likely due to our low threshold for detecting them.[4]

RTs following peripheral cues were significantly slower [$t_{12} = 2.99$, $p = .011$] for cued (422 ms) than uncued peripheral targets (408 ms). FA rates did not differ between these two conditions [$t_{12} = .51$, ns].[5] In point of fact, there were approximately 1% **more** FAs for cued (8.4%) as compared to uncued (7.4%) targets.

Because the IOR effect in RT observed in the present study was almost identical to that reported by Ivanoff and Klein (2001; 14.02 ms vs. 13.74 ms, respectively) no statistical comparison was performed on these effects.

To compare the cued and uncued FA rates from the two experiments these rates were subject to logistic regression analysis. The LMER package with R Environment for Statistical Computing was used to compute two LMMs (M1 and M2; see Table 1), with participant as a random effect and study and cue condition as fixed effects (R Development Core Team, 2011). The only difference between the two models was that M1 did not include the interaction as a fixed effect whereas M2 did. If eye tracking does not affect error rates in the IOR task the interaction should be unimportant and the simpler M1 should yield a lower or comparable AIC score. M2 (AIC = 1683.3) fit the dataset much better than M1 (AIC = 1674.5, with an AIC score reduction of 8.8. Thus, M1 falls somewhere between having considerably less support than M2 and having essentially no support given M2 (Burnham & Anderson, 2004). Within M2, the interaction between study and cue condition was highly significant ($Z = 3.285$, $p < .00102$; See also Fig. 6).[6] Given that the crucial difference between Ivanoff and Klein's (2001) experiment and the present one concerns whether eye movement activity was monitored and controlled we believe that observers in the present study were suppressing the natural tendency to make eye movements to peripheral stimuli while, in the absence of feedback, participants in the Ivanoff and Klein experiment were not.

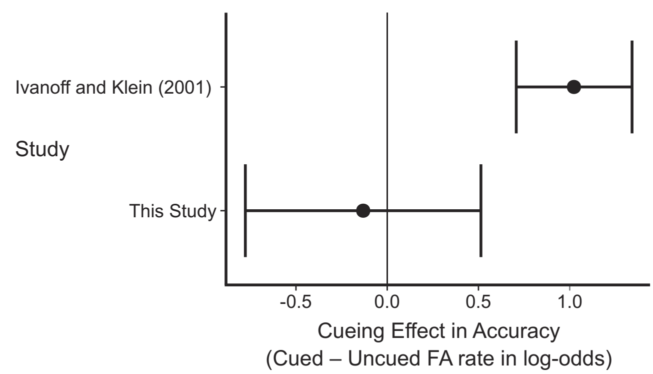

Fig. 6. The effect of cues on FA rates in the present experiment (left) and in Ivanoff and Klein's (2001) previous investigation (right) computed from the predicted values of linear mixed model "M2". The ezPreds function from the ez package within the R Environment for Statistical Computing (R Development Core Team, 2011) was used to compute the predicted values (Lawrence, 2012). Ivanoff and Klein's participants produced significantly fewer FAs when targets appeared at the cued location than when they appeared at the uncued location. This effect differed significantly from the present study, wherein cues did not influence FA rates. Error bars represent 95% confidence intervals.

6. Discussion

Consistent with the hypothesis that the effect of IOR is on input pathways when oculomotor responses to peripheral visual stimuli are actively discouraged (Chica et al., 2010; Taylor & Klein, 2000), FA rates observed here were similar if not greater for peripherally cued as compared to uncued no-go signals in the presence of delayed responding for cued relative to uncued go-signals. This pattern of results (represented by the red/dashed arrow in Fig. 4) is qualitatively different from the output-based IOR effects re-

[3] For consistency with the literature our primary analyses will be of the untransformed percentages. However, following the recommendations of Dixon (2008), we also analyzed the FA data after conversion to log odds using the formula:

$$\text{log odds} = \ln(pc/(1 - pc)); \text{where } pc = (1 \text{ minus the proportion of FAs})$$

To avoid any divisions by zero, in any cells for which there were no FAs, following convention, it was assumed that rate of FAs was 1/64 (or 1/2 way between zero and the minimum number possible).

[4] Many fewer unwanted eye movements were detected in the manual-response experiments of Chica et al. (2010) whose threshold was much higher (to be detected an eye movement had to exceed 2 degrees of visual angle) than used here and a similar rate of unwanted eye movements were detected in Hilchey, Klein, and Satel (in preparation, Experiment 2) who used the same threshold as we did here.

[5] This finding was replicated when we analyzed log odds of the FA rates.

[6] When we compared the cueing effects from these two studies (uncued minus cued FA rates) using a 2-sample *t*-test, the difference remained significant ($t_{30} = -2.06$, $p < .05$).

ported by Ivanoff and Klein (2001, represented by the green/dotted arrow in Fig. 4) as well as from the studies we have found on this topic, that, like Ivanoff and Klein, failed to actively discourage eye movements. Our results are consistent with the only published study we were able to find using a go/no-go task in which eye movements were actively discouraged (Cheal, Chastain, & Lyon, 1998) and with the Chica et al. (2010) investigation dedicated to evaluating the effect of saccadic eye movements on the form of IOR in a non-spatial two-alternative forced choice task.

The reader might wonder[7] whether the genuine improvement that we and Cheal, Chastain, and Lyon (1998) observed while discouraging eye movements and, conversely, the SAT that is generally observed when eye movements are not discouraged (see Fig. 5) are due to the actual eye movements made in these two conditions or to the mental set that eye movements are forbidden or permitted. There are several reasons why we are confident that mental set explains the dissociation. First, consider that the maximum possible rate of trials with unwanted eye movements in Prime and Jolicoeur (2009, Experiment 1) was about 19% (total % of trials excluded for eye movement artifacts or for responses being too fast, too slow or erroneous). Yet the SAT that they observed was similar to, if not larger than, that reported by Chica et al. (2010) when participants were instructed to make eye movements on every trial. Second, the behavioral data in the two EEG studies by David Prime that we have reported in Fig. 5 were generated after excluding trials with obvious eye movement artifacts (Prime, personal communication). This provides direct evidence that the SAT is not dependent on trials with eye movements. Finally, we know it is not the occurrence of eye movements *per se* that is responsible for the SAT form of IOR because an input form of IOR is generated by anti-saccades (e.g., Abegg, Sharma, & Barton, 2012; Fecteau et al., 2004; Khatoon, Braind, & Sereno, 2002; Rafal, Egly, & Rhodes, 1994). As we explain elsewhere (Klein & Hilchey, 2011; Klein, Hilchey, & Satel, 2012), the form of IOR that is generated does not depend on the occurrence of eye movements *per se* but rather on whether the system responsible for reflexive saccades is inhibited (as it needs to be to perform accurately in an anti-saccade task; Forbes & Klein, 1996) or not inhibited during the trial when IOR is being measured. The neurophysiological data from anti-saccade experiments requiring controlled eye movements directed to locations opposite the source of stimulation are clear in demonstrating suppression over the primitive midbrain structures responsible for reflexively-generated saccades at the cellular level (Everling et al., 1999; Ignashchenkova et al., 2004).

As demonstrated here and elsewhere, the effects of IOR are dissociable on the basis of whether or not the oculomotor circuits responsible for reflexively-generated saccades are actively suppressed (for review see Klein & Hilchey, 2011). This dissociation poses challenges when it comes to integrating the extant data on IOR into a unified and coherent theoretical framework primarily because the activation state of the oculomotor system is so often unknown in simple keypress RT tasks. More specifically, little effort is made in experimental designs to discourage untoward oculomotor response activation in covert spatial orienting paradigms. For example, Zhao et al. (2011) provided some evidence that IOR affects both input- *and* output-processing in a discrimination task requiring only keypress responses, a result that seemed to challenge the notion that output- vs. input-based effects are determined by the activation state of the oculomotor system. Yet, in that study, the presence of eye movements was not monitored let alone discouraged. This failure to discourage oculomotor responding raised the specter that the oculomotor system was shifting in and out of activation states throughout the task. Such phasic activation would yield data consistent with a two-component theory. On any given trial, however, only one form of IOR may have been in effect. It is precisely this ambiguity, rooted in the fact that the effects of IOR in keypress tasks are distinct depending on the activation state of the oculomotor system, that compels us to urge investigators of IOR to ensure adequate control over, and measurement of the activation state of, the oculomotor system. Simply, and more to the point, it is clear that research objectives dedicated to evaluating the nature of covert orienting should actively discourage oculomotor responding.

[7] We thank an anonymous reviewer for raising this concern. The same reviewer also suggested that "it is essential to replicate the current methods without providing feedback on eye movements". We disagree. All studies illustrated in Fig. 5 demonstrated output-based forms of IOR in the absence of express feedback discouraging oculomotor responding, including Ivanoff and Klein (2001) whose methods we have closely replicated while adding eye movement feedback.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.visres.2013.11.008.

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