Long-term inhibition of return for spatial locations: Evidence for a memory retrieval account

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It has generally been accepted that attention is inhibited from returning to previously attended locations, and that this inhibition of return (IOR) lasts just two or three seconds. Recently, Tipper, Grison, and Kessler (2003) showed that IOR can occur over much longer periods of time provided the inhibition is encoded with a context-rich event. Here we examine standard (i.e., typical time range) and long-term IOR within the same experimental paradigm as a means to compare their properties. Experiment 1 used the simple displays typical of cueing paradigms and revealed that both standard and long-term IOR can be obtained under such conditions. Experiment 2 showed that both standard and long-term IOR occurred when there was incongruence between the required response on the current trial and that stored in memory. Furthermore, IOR was not produced when there was incongruence between a target feature (colour) of the current trial and that stored in memory. These results are consistent with a memory retrieval account of IOR and suggest that the same inhibitory mechanism may underlie both standard and long-term IOR.

When an observer searches a complex visual display for an item of interest, several shifts of attention are required. Visual search efficiency would be maximized if the observer could avoid reinspecting locations that have been previously searched. There is, in fact, strong evidence that targets at previously attended peripheral locations are responded to slower than targets at unattended (novel) locations (e.g., Kingstone & Pratt, 1999; Maylor, 1985; Posner & Cohen, 1984; Taylor &

Klein, 2000). This effect has been termed inhibition of return (IOR), reflecting the notion that attention is inhibited to return to previously attended locations (Posner, Rafal, Choate, & Vaughan, 1985).

In the two decades since Posner and Cohen's (1984) original work, a good deal of research has been conducted, much of it with the goal of identifying the general properties of IOR. Studies of the temporal properties of IOR have suggested

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that there is some minimum amount of time that must follow the onset of a peripheral cue for IOR to be observed (e.g., Posner & Cohen), although this time varies with the duration of the cue (e.g., McAuliffe & Pratt, 2005), type of response (e.g., Briand, Larrison, & Sereno, 2000), type of task (e.g., Lupiáñez, Milán, Tornay, Madrid, & Tudela, 1997), and working memory load (Klein, Castel, & Pratt, in press). Furthermore, while there is little information on IOR beyond stimulus onset asynchronies (SOAs) of 3 seconds, the standard conclusion has been that IOR has a limited duration with the inhibitory effect persisting for only about 3 seconds from the onset of the cue with detection tasks (Castel, Chasteen, Scialfa, & Pratt, 2003; Samuel & Kat, 2003) and slightly shorter for discrimination tasks (e.g., Lupiáñez et al.). It is worth noting that these temporal properties are based on studies that used variations of the "traditional" IOR paradigm (originating from Posner & Cohen): (a) relatively simple stimuli for cues and targets (often dots or circles or squares); (b) uninformative cues that are not responded to; and (c) the basic trial sequence of peripheral cue, then delay (with or without a fixation cue), then peripheral target.

Recently, using a very different procedure from the traditional IOR paradigm, Tipper et al. (2003) found evidence that the inhibitory effect can be reinstated several minutes after its initial occurrence. They propose that the presentation of a cue leads to transient inhibition at the cued location lasting only for a few seconds—the same explanation for IOR as originally put forth by Posner and Cohen (1984). However, they extend the Posner and Cohen account by asserting that this transient inhibitory state is encoded into memory along with the associated event. Later, even several minutes later, given appropriate retrieval cues, the event may be automatically retrieved from memory along with the original inhibitory state. This retrieval of the inhibitory state can allow the inhibitory processes that functioned during the cue presentation to function once again in a transient manner long after the original viewing of the cue. This reinstantiation

of the inhibitory state then leads to inhibition at the location that was cued possibly several minutes earlier and leads to a bias to search novel locations.

To find existence of this "long-term" IOR, Tipper et al. (2003) believed it necessary to move away from the simple, sparse displays used in typical IOR studies: "We recognized the need to make each processing episode distinct to ensure robust memory encoding and successful retrieval" (p. 19). To achieve this, their procedures differed from typical IOR procedures in two important ways. First, face stimuli, as opposed to the typical sparse displays of placeholder boxes, were presented on each cueing trial to encourage deep processing and encoding in episodic memory. Second, each face was presented only once during the cueing trials to ensure that each "cued" event was encoded as a distinct episode.

Because of the uniqueness of the Tipper et al. (2003) procedure, a detailed description is useful. During an initial "cue phase", the trial displays consisted of two faces presented for 1,500 ms, one to the left and one to the right of fixation. The cue was a circle superimposed on one of the faces appearing 1,000 ms after the onset of the faces and lasting 200 ms. On most trials the cue was red, indicating that there was to be no response—referred to as a "no-go cue trial". The corresponding target display for that cue appeared during a "target phase", which consisted of the same two faces appearing for 1,000 ms in their same positions. As with the cue, the target was a circle superimposed on one of the faces. It appeared 500 ms after the onset of the faces and appeared for 200 ms. On most trials, the target was green indicating that a target localization response was required—referred to as a "go target trial". The cue–target SOA was 1,800 ms (Experiment 1A), 3 min (Experiment 1B), or 13 min (Experiment 1C). For the 1,800-ms SOA, IOR was found for targets presented in both the left and the right visual fields. Specifically, target responses to faces with green target circles were slower if the red cue circle had appeared on the same face than if the red cue circle had appeared on the other face. For both

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the 3-min and the 13-min SOAs, which had many irrelevant intervening cue and target trials, Tipper et al. still found IOR for targets presented in the left visual field (LVF), though not for targets presented in the right visual field (RVF). They proposed that long-term IOR was found only for the LVF because the right hemisphere more effectively processes faces and stores face representations. Thus, during the cue phase, faces presented to the LVF received greater processing, producing more stable memory representations and stronger encoding of the associated inhibitory states.

The Tipper et al. (2003) findings raise an important question: Is the inhibition found in standard IOR studies the same inhibition that is retrieved in long-term IOR? The theory put forth by Tipper et al., with long-term IOR arising from a retrieval or a reinstantiation of the original inhibitory state, clearly claims that this is so. However, with standard and long-term IOR examined with significantly different experimental procedures it is entirely possible that a different inhibitory effect is produced in long-term IOR. As a first step in answering this question, we examine whether long-term IOR is restricted, as suggested by Tipper et al., to richly encoded events or whether long-term IOR can be observed with the simple displays typically used in standard IOR paradigms.

EXPERIMENT 1

To determine whether long-term IOR can be found with the simple and sparse displays that characterize standard IOR paradigms, the present experiment used a display that consisted of four peripheral placeholders located around a central fixation point. Over most of the trials, no-go (do not respond) stimuli (red circles) and go (respond) stimuli (green circles) appeared in the top and bottom placeholders. With an SOA of 1,500 ms, these trials were used to measure "standard IOR"—the IOR typically found at SOAs less than 3,000 ms. Interspersed with the standard IOR trials, no-go and go stimuli

appeared less frequently in the left and right placeholders. With SOAs of 10,500 ms and 13,500 ms, these trials were used to measure long-term IOR.

Because Tipper et al. (2003) used context-rich displays, we further examined whether some distinction—beyond the inherent spatial distinction—between the top/bottom and left/right placeholders might be necessary to produce long-term IOR. To examine this issue, one group of subjects—the "nondistinct" group—were presented with displays consisting of four identical square-shaped placeholders. For the second group of subjects—the "distinct" group—the displays consisted of diamond-shaped top and bottom placeholders and square-shaped left and right placeholders. The placeholders for the nondistinct group then were not distinct in terms of object identity, but only in terms of their spatial location. In contrast, the placeholders for the distinct group were distinct in both their spatial identity (diamonds vs. squares) and their spatial location.

Method

Participants
A total of 30 undergraduate students from the University of Toronto participated in exchange for course credit. All were naïve to the purpose of the experiment, had normal or corrected-to-normal vision, and were under the age of 30 years. Half of the participants were assigned to the distinct group and half to the nondistinct group.

Apparatus
The experiment was conducted on a personal computer in a dimly lit, sound-attenuated room. The distance between the cathode-ray tube and the head/chin rest was fixed at 44 cm.

Design and procedure
The basic trial sequence is shown in Figure 1. The initial display consisted of a white central fixation cross (subtending 0.4 deg of visual angle) and four white peripheral placeholders (4.8 deg from the fixation cross) on a black background. For the distinct group, the horizontally aligned placeholders were squares (each 2 deg wide), and the
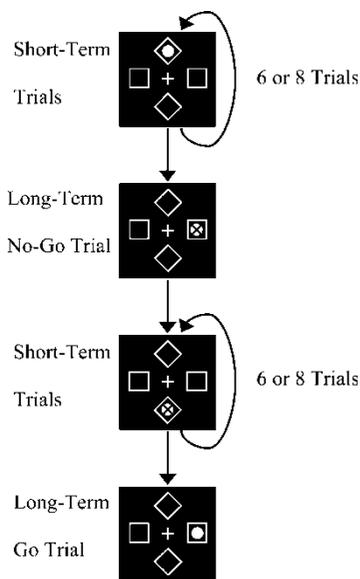
Figure 1. *Sample illustration of the trial sequence for the distinct group of Experiment 1. Each of the six or eight standard trials consisted of a red or green circle presented in either the top or the bottom placeholder. In the figure, a green circle is represented by a white circle, and a red circle is represented by a white circle with a black X through it. An X did not actually appear in the display. The number of standard trials in each set was randomized, as was the colour and position of each stimulus. The sequence for the nondistinct group was identical with the exception that all four placeholders were square-shaped. See the text for details.*

vertically aligned placeholders were diamonds (same size as the squares but rotated 90°). For the nondistinct group, all of the placeholders were squares. In these placeholders, either a no-go stimulus (filled-in red circle, 0.6 deg in diameter) or a go stimulus (filled-in green circle, 0.6 deg in diameter) would appear for 100 ms. The stimuli were presented in the following pattern: (a) six or eight stimuli in the vertically aligned diamond placeholders (red/green colour and up/down location were randomized); (b) one no-go stimulus presented in one of the horizontally aligned square placeholders (left/right location randomized); (c) six or eight stimuli in the vertically aligned diamond placeholders (red/green colour and up/down location again randomized); and (d) one go stimulus presented in one of the horizontally aligned square placeholders (left/right location

randomized). The general pattern would then repeat, and the experiment consisted of 80 repetitions of this pattern. The colours and locations were randomized at the start of each pattern. The participants were instructed to: (a) stay fixated on the fixation location (monitored with a closed-circuit TV camera); (b) press the spacebar as quickly as possible upon detecting a go stimulus; and (c) withhold responding upon detecting a no-go stimulus.

The SOA between each stimulus was held constant at 1,500 ms. Thus, the SOA for examining the standard IOR was 1,500 ms whereas the SOA for examining long-term IOR was either 10,500 ms (7 stimuli × 1,500 ms) or 13,500 ms (9 stimuli × 1,500 ms). Note that for the standard conditions, this design allowed us also to compare IOR for no-go/go (red, do-not-respond stimulus followed by a green, respond stimulus) and go/go (green, respond stimulus followed by a green, respond stimulus) combinations, whereas, for the long-term conditions, only no-go/go combinations could be examined.

Results

The proportion of errors (failure to respond) on target (go) trials never exceeded .013 in any condition. These error trials were excluded from the reaction time (RT) analysis. For no-go trials, the proportion of false alarms was less than .021 in each condition. Combinations of go/no-go and no-go/no-go trials were not analysed.

The mean RTs for go trials appear in Table 1, and cueing effects appear in Figure 2. Cueing effect is defined as uncued RT minus cued RT. Mean RTs were analysed with a 2 (group: distinct, nondistinct)×3 (condition: standard no-go/go, standard go/go, long-term no-go/go)×2 (target location: cued, uncued) mixed analysis of variance (ANOVA). Long-term trials with six and eight intervening trials were collapsed together because there were not enough observations per condition to analyse separately.

A main effect of group was found, $F(1, 28) = 7.0$, $MSE = 3,263$, $p < .05$, indicating that the distinct group (359 ms) responded more quickly than the

Table 1. *Experiment 1: Mean reaction times[a] and proportion of errors as a function of group, condition, and target location*

		Target location			
		Cued		Uncued	
Group	Condition	RT	Errors	RT	Errors
Distinct	Standard go/go	342 (11)	.005 (.003)	347 (10)	.005 (.003)
	Standard no-go/go	383 (12)	.003 (.002)	359 (11)	.003 (.002)
	Long-term no-go/go	365 (11)	.001 (.002)	355 (10)	.001 (.003)
Nondistinct	Standard go/go	387 (11)	.010 (.003)	391 (10)	.013 (.003)
	Standard no-go/go	415 (12)	.008 (.002)	394 (11)	.004 (.002)
	Long-term no-go/go	404 (11)	.007 (.002)	395 (10)	.007 (.003)

Note: Standard errors are shown in parentheses beside their respective means.
[a]In ms.

nondistinct group (398 ms). However, group did not interact with any of the other variables indicating that the condition and target location effects were the same for both groups: group by condition, $F(2, 56) = 1.7$, $MSE = 232$, $p = .19$; group by target location, $F < 1$; group by condition by target location, $F < 1$.

A main effect was found for condition, $F(2, 56) = 27.6$, $MSE = 232$, $p < .001$. Linear contrasts indicated that the long-term no-go/go condition (380 ms) produced faster RTs than did the standard no-go/go condition (388 ms), $F(1, 28) = 7.8$, $MSE = 490$, $p < .05$, and slower RTs than the standard go/go condition (367 ms), $F(1, 28) = 24.3$,

Figure 2. *Experiment 1: RT cueing effect (in ms) as a function of group (distinct, nondistinct) and condition (standard no-go/go, standard go/go, long-term no-go/go). Cueing effect is defined as uncued RT minus cued RT.*

$MSE = 385$, $p < .001$. A main effect was also found for target location, $F(1, 28) = 31.7$, $MSE = 115$, $p < .001$, indicating that RTs for targets appearing in cued locations (383 ms) were slower than RTs for targets appearing in uncued locations (374 ms)—the typical IOR effect. Of most importance, the interaction of condition and target location was significant, $F(2, 56) = 30.7$, $MSE = 94$, $p < .001$. The interaction reflects the finding of significant IOR (cued trials slower than uncued trials) in both the standard no-go/go (-23 ms), $t(29) = 12.2$, $SEM = 1.9$, $p < .001$, and the long-term no-go/go (-9 ms) conditions, $t(29) = 2.9$, $SEM = 3.2$, $p < .01$, but not in the standard go/go (5 ms) condition, $t(29) = 1.9$, $SEM = 2.4$, $p = .06$ (marginal, but a facilitatory effect rather than an inhibitory effect).

Tipper et al. (2003) found long-term IOR for targets presented in the LVF, but not in the RVF. We examined the effect of presentation side on IOR for the current experiment and found the same pattern of results as that of Tipper et al. For targets presented in the LVF, significant IOR was observed (-13 ms), $t(29) = 2.4$, $SEM = 4.9$, $p < .05$. However, for targets presented in the RVF, IOR was not significant (-4 ms), $t(29) = 1.1$, $SEM = 4.4$, $p = .27$.

The mean proportions of errors were also analysed with a 2 (group: distinct, nondistinct) $\times$ 3 (condition: standard no-go/go, standard go/go, long-term no-go/go) $\times$ 2 (target location: cued, uncued) mixed analysis of variance (ANOVA).
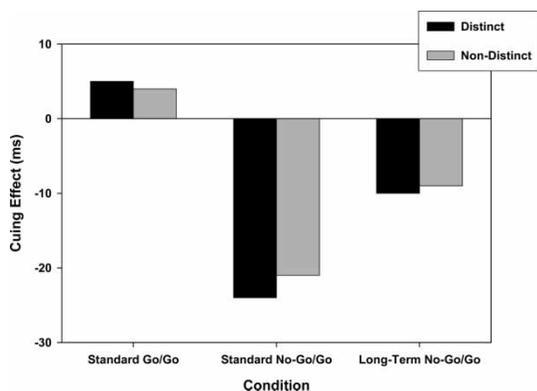
The mean proportions of errors appear in Table 1. There was a significant main effect of condition, $F(2, 56) = 4.6$, $MSE = .0002$, $p < .05$. Linear contrasts indicated that the proportion of errors did not differ for the standard no-go/go (.005) and long-term no-go/go (.003) conditions, $F < 1$, however, fewer errors were produced in the long-term no-go/go condition than in the standard go/go condition (.008), $F(1, 28) = 9.9$, $MSE = .0006$, $p < .05$. None of the effects involving target location were significant, showing that the cueing manipulation had no impact on the proportion of errors produced: target location, $F < 1$; group by target location, $F < 1$; condition by target location, $F < 1$; group by condition by target location, $F < 1$. None of the other effects were significant: group, $F < 1$; group by condition, $F < 1$.

Discussion

Experiment 1 demonstrated that standard IOR and long-term IOR lasting 10,500 to 13,500 ms can be observed using the same experimental procedure. Furthermore, this finding provides evidence that the context-rich displays (unique faces on every trial) that were used by Tipper et al. (2003, see also Morgan, Paul, & Tipper, 2005) are not necessary to produce long-term IOR. Rather, simple geometric objects that are spatially distinct also yield the effect. Furthermore, the observance of long-term IOR for both the distinct and the nondistinct groups suggests that distinctive objects are not necessary to elicit long-term IOR. Rather, distinctiveness of the long-term events in terms of their unique spatial location is sufficient for the encoding and retrieval of cueing events. In sum, the long-term IOR found here appears to be a relatively general phenomenon rather than one restricted to situations in which visual cues are deeply encoded with complex objects like faces.

Consistent with Tipper et al. (2003), but inconsistent with Morgan et al. (2005), we found long-term IOR for targets presented in the LVF but not for those presented in the RVF. To explain their visual field effect, Tipper et al. proposed that long-term IOR was found only for the LVF because the right hemisphere more effectively processes faces and stores face representations. However, this explanation obviously does not hold for our results as our targets consisted of simple coloured circles. We note that this visual field effect has been observed in studies using standard IOR durations (Spalek & Hammad, 2004, 2005). Spalek and Hammad (2005) suggest that the effect occurs because of a left-to-right anticipation bias in English populations that has developed as a consequence of many years of reading English text from left to right. If the anticipation bias present during a cue trial can be stored in memory, then possibly it can be retrieved during later target presentation. This explanation is speculative at this point, but what is clear is that a hemispheric face-processing bias cannot explain the visual field effect observed in the current study.

The 10,500-ms and 13,500-ms SOAs used here are much shorter than those (3 and 13 min) used by Tipper et al. (2003), which raises the possibility that the mechanisms that underlie our findings might be different from those that underlie Tipper et al.'s findings. Importantly, we note that similar effects (e.g., long-term IOR for LVF but not RVF) for the SOAs used here and for the SOAs used by Tipper et al. do not necessitate the conclusion that the same cognitive and/or neural mechanisms underlie both effects. That is, different mechanisms could underlie our results, those of Tipper et al., and, for that matter, those of Morgan et al. (2005) who examined long-term IOR using SOAs of approximately 21 s. However, the most parsimonious explanation is that the same mechanisms underlie long-term IOR at each of these SOAs. Therefore, our approach is to assume that the same mechanisms underlie IOR for both our long-term SOAs and for Tipper et al.'s long-term SOAs until there is evidence to suggest otherwise (and we are not aware of any such evidence). Finally, we apply this same logic when theorizing about the mechanisms underlying IOR of standard durations (2 to 3 s) and that of long-term IOR. If there is no behavioural or neural evidence to indicate otherwise, we will assume that the same mechanisms underlie both standard and long-term IOR.

The finding of IOR at SOAs of greater than 10 s, using the more typical sparse displays, is somewhat at odds with the literature that suggests that IOR lasts for less than 3 s. However, there is a paucity of research on IOR beyond SOAs of 3,000 ms. In addition, recent work in our laboratory has suggested that constant shifts of attention (similar to that which occurs in the present method) may actually help preserve IOR (Dodd, 2005), although more work is needed before any definitive conclusions can be reached.

In addition to the finding of long-term IOR in a more typical IOR procedure, the present results also revealed an interesting difference between the no-go/go (red, do-not-respond stimulus followed by a green, respond stimulus) and go/go (green, respond stimulus followed by a green, respond stimulus) standard conditions. Specifically, while the standard no-go/go conditions generated the expected IOR effect, IOR was not found for the standard go/go conditions. This is despite previous reports of IOR in go/go conditions (e.g., Maylor & Hockey, 1985; Pratt & Castel, 2001; Tanaka & Shimojo, 1996).

One clue that might help explain our findings is provided by Pratt and Castel (2001). Using exclusively go/go conditions, they found IOR with their localization responses, but only when the preceding go target differed from the current go target along a single feature dimension, either colour or orientation (the other go/go studies had used simple detection responses). Possibly then the reason that we found IOR in our standard no-go/go conditions is because the colour feature changed from the no-go (red) to the go (green) trial, whereas the reason we failed to find IOR in go/go conditions is because the colour feature did not change (green in both trials). Though this change in the colour feature may underlie findings of IOR in no-go/go conditions, another possibility exists. Note that the colour feature is confounded with the required response. Therefore, a second account for our findings is that the change in the response required from the no-go (do not respond) to the go (respond) trial produces IOR, whereas the reason we failed to find IOR in go/go conditions is that the required response did not change (respond in both trials). This issue was addressed in Experiment 2.

EXPERIMENT 2

Other than their general claim that a rich context was necessary for memory retrieval and the production of long-term IOR, Tipper et al. (2003) did not specify what specific information must be retrieved. The results of Experiment 1 suggest that either the colour of the cue or the required response could be the critical information. Experiment 2 was designed to address whether a change in the colour dimension or a change in the required response is necessary for producing IOR, at both the standard and the long-term conditions. This allows us to compare whether a factor that affects standard IOR also affects long-term IOR.

To determine the critical information needed for producing long-term IOR, the design of Experiment 2 was modified from that of Experiment 1. The key difference between the experiments is that the present one uses three colours, rather than two, for stimuli. The task was to respond (go) if the circle stimulus was blue or green, but not to respond (no-go) if the stimulus was red. This created two types of go/go conditions: first, the "same-colour go/go" condition (green−green or blue−blue), where both the colour feature and response required remained the same; and second, the "different-colour go/go" condition (green−blue or blue−green), where the colour feature changed but the required response remained the same. Again, we had a no-go/go condition (red−green or red−blue) in which both the colour feature and the response required changed. This design allows us to determine the critical factor by addressing whether a change in the colour dimension or a change in the required response is necessary for producing both standard and long-term IOR.

Method

Participants
A total of 13 undergraduate students from the University of Toronto participated in exchange for course credit. All were naïve to the purpose

of the experiment, had normal or correct-to-normal vision, and were under the age of 30 years.

Apparatus, design, and procedure

The apparatus and procedure were identical to the nondistinct display conditions of Experiment 1 except as follows. Circle stimuli could appear in three colours (green, blue, or red). The task was to respond if the circle was green or blue, but not red. Green circles were presented on 42% of the trials, blue circles on 42% of the trials, and red circles on 16% of the trials. This produced 84% go (respond) trials, and 16% no-go (do not respond) trials. Presentation order of coloured circles was randomized. This design in terms of colours used, proportion of trials with each colour, and proportion of trials requiring a response was identical for the standard and long-term conditions.

Results

The proportion of errors (failure to respond) on target (go) trials never exceeded .014 in any condition. These error trials were excluded from the RT analysis. For no-go trials, false alarms were less than .18 in each condition. Note we did not have a sufficient number of observations per cell in the long-term conditions to examine the impact of presentation side on IOR, as we did in Experiment 1.

The mean RTs for go trials appear in Table 2, and cueing effects appear in Figure 3. The mean RTs were analysed with a 2 (duration: standard, long-term) $\times$ 3 (condition: same-colour go/go, different-colour go/go, no-go/go) $\times$ 2 (target location: cued, uncued) ANOVA. As with Experiment 1, long-term trials with six and eight intervening standard trials were collapsed together due to the small number of trials at each interval.

The main effect of duration was significant, $F(1, 12) = 4.8$, $MSE = 245$, $p < .05$, with slower RTs for the long-term (380 ms) than for the standard duration (375 ms). The main effect of condition was significant, $F(2, 24) = 37.7$, $MSE = 231$, $p < .001$. Linear contrasts indicated that the no-go/go conditions produced slower RTs

(392 ms) than did the same-colour go/go conditions (367 ms), $F(1, 12) = 76.5$, $MSE = 409$, $p < .001$, and slower RTs than the different-colour go/go conditions (372 ms), $F(1, 12) = 35.4$, $MSE = 561$, $p < .001$. A main effect was also found for target location, $F(1, 12) = 14.2$, $MSE = 179$, $p < .005$, indicating that RTs for targets appearing in cued locations (381 ms) were slower than RTs for targets appearing in uncued locations (373 ms)—the typical IOR effect. Of most importance, there was a significant interaction of condition and target location, $F(2, 24) = 66.7$, $MSE = 62.0$, $p < .001$. The interaction reflects the finding of significant IOR in both the standard no-go/go condition (−40 ms), $t(12) = 7.2$, $SEM = 5.4$, $p < .001$, and the long-term no-go/go condition (−21 ms), $t(12) = 3.4$, $SEM = 7.4$, $p < .005$, but not in any of the go/go conditions: standard same-colour go/go, $t < 1$; standard different-colour go/go, $t < 1$; long-term same-colour go/go, $t(12) = 1.4$, $SEM = 5.4$, $p = .19$; long-term different-colour go/go, $t < 1$. None of the other interactions were significant: duration by target location, $F(1, 12) = 1.8$, $MSE = 185$, $p = .21$; duration by condition, $F(2, 24) = 3.0$, $MSE = 625$, $p = .07$ (marginal); duration by condition by target location, $F(2, 24) = 1.5$, $MSE = 262$, $p = .24$.

The mean proportion of errors were also analysed with a 2 (duration: standard, long-term) $\times$ 3 (condition: same-colour go/go, different-colour go/go, no-go/go) $\times$ 2 (target location: cued, uncued) ANOVA. The mean proportions of errors appear in Table 2. The main effect of duration was significant, $F(1, 12) = 5.6$, $MSE = .0053$, $p < .05$, indicating that more errors were produced in the standard (.011) than in the long-term condition (.005). None of the effects involving target location were significant, showing that the cueing manipulation had no impact on the proportion of errors produced: target location, $F < 1$; duration by target location, $F < 1$; condition by target location, $F < 1$; duration by condition by target location, $F < 1$. No other effects were significant: condition, $F(2, 24) = 1.2$, $MSE = .0092$, $p = .31$, duration by condition, $F < 1$.

Table 2. *Experiment 2: Mean reaction times[a] and proportion of errors as a function of duration, condition, and target location*

		Target location			
		Cued		Uncued	
Duration	Condition	RT	Errors	RT	Errors
Standard	Same-colour go/go	361 (20)	.013 (.003)	362 (22)	.012 (.005)
	Different-colour go/go	369 (23)	.014 (.004)	368 (23)	.012 (.003)
	No-go/go	414 (27)	.009 (.006)	374 (26)	.005 (.004)
Long-term	Same-colour go/go	370 (24)	.005 (.004)	377 (22)	.004 (.003)
	Different-colour go/go	376 (21)	.006 (.004)	377 (21)	.003 (.003)
	No-go/go	402 (21)	.009 (.005)	381 (23)	.002 (.002)

Note: Standard errors are shown in parentheses beside their respective means.
[a]In ms.

Discussion

Experiment 2 produced two main findings. First, it provided a replication of the long-term IOR finding of Experiment 1. Second, the effect of the feature and response manipulations had qualitatively similar influences on the standard and long-term cueing effects. For both the standard and long-term conditions, IOR was found for the no-go/go condition, but was not found for either the same-colour go/go or the different-colour go/go conditions. The similarity in the effects for the standard and long-term conditions suggests that the same memory retrieval mechanism may

Figure 3. *Experiment 2: RT cueing effect (in ms) as a function of duration (standard, long-term) and condition (same-colour go/go, different-colour go/go, no-go/go). Cueing effect is defined as uncued RT minus cued RT.*

underlie the standard and long-term IOR observed in the present study. Furthermore, the finding of IOR for the no-go/go conditions and the lack of inhibition in either of the go/go conditions indicates that a change in the colour feature does not produce IOR. In contrast, a change in the response (in this case, from "do not respond" to "respond") seems to be necessary to elicit IOR in both standard and long-term cueing situations.

GENERAL DISCUSSION

Our results support Tipper et al.'s (2003) memory retrieval account and extend it in two key ways. First, both of the present experiments showed that the production of long-term IOR was not dependent on the Tipper et al. procedure, which allowed cues to be encoded with unique complex visual objects (faces) on every trial. In fact, a distinction in object identity was not necessary at all. Instead, distinctiveness of the long-term events in terms of their unique location provided enough context to allow for the encoding and retrieval of distinct cueing events. Second, findings from Experiment 2—IOR for the no-go/go conditions and the lack of a cueing effect in either of the go/go (same-colour, different-colour) conditions—indicate that it is the retrieval of responses, not target features, that is critical for producing IOR.
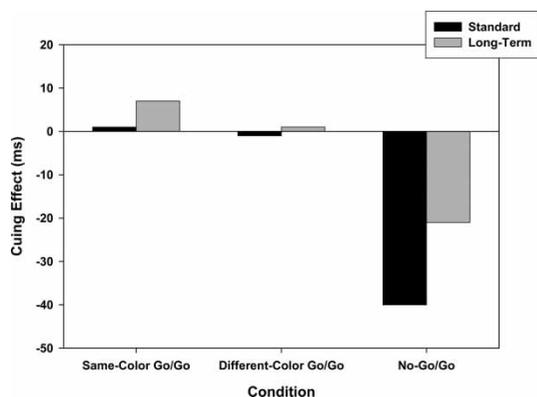
In addition to these empirical findings, we have established an experimental procedure that can be used, as we did with Experiment 2, to directly compare standard and long-term IOR (see also Morgan et al., 2005). As an example, consider that in the current study, the "change in response" consisted of a change from not providing a response (no-go trial) to providing a response (go trial). The question remains, however, whether the absence of a response on the previous trial is necessary or whether a change in the type of response (e.g., from a left-hand to a right-hand response) would be sufficient to elicit IOR.

The present findings of IOR for no-go/go conditions but not for go/go conditions seem reasonable in that one probably should only inhibit previously attended locations if a target object actually does not appear there. If a target is found at a previously searched location (as with our go/go conditions), then it probably is not beneficial to inhibit a return to that location. In contrast, when a previously searched location fails to turn up a target (as with our no-go/go conditions) inhibiting a return to that searched location might be beneficial. In sum, our finding of IOR for no-go/go conditions but not for go/go conditions is consistent with the idea that an inhibitory state may only be generated on no-go trials. Furthermore, consistent with the Tipper et al. (2003) account, long-term IOR should only occur for no-go/go conditions, but not go/go conditions, because only no-go trials contained an inhibitory state that actually can be retrieved from memory.

Though the Tipper et al. (2003) account for long-term IOR is plausible and consistent with our findings, we want to present an alternative retrieval account as it may be more parsimonious, in that it eliminates the need for an inhibitory process. Put quite simply, an irrelevant peripheral stimulus (such as an onset), along with its location and its associated response, is stored in memory, and, given appropriate retrieval cues, this stimulus event along with the response associated with the location of this event will be involuntarily retrieved. If the response stored in memory for a particular location conflicts with the response required on the current task for an item in that same location, responding will be slowed.

To understand the response retrieval account consider the no-go/go conditions from our experiment. If the no-go cue and go cue appear in different locations (uncued condition), then no response conflict will occur because the retrieved response is associated with a different location from that of the required response for the current go trial. If the no-go and go cues appear at the same location (cued condition) then the response conflict between the retrieved response (do not respond) and the response required on the go trial (respond) will slow responding. Thus, as observed in the present study, we have IOR with slower responding in the cued than in the uncued condition. Next consider the go/go conditions. Here, regardless of whether the first and second go cue appear at the same (cued) or at different (uncued) locations, there is no conflict in the retrieved response and the required response. Thus, IOR should not be present, which is again consistent with the present results.[1]

The response retrieval account and Tipper et al.'s (2003) inhibition retrieval account both employ memory retrieval as the key mechanism, making them more similar to each other than to any other accounts of IOR. However, the response retrieval account differs from Tipper et al.'s account in one fundamental way. Under Tipper et al.'s version, an inhibitory state from a previous cueing event is retrieved from memory and reinstantiated. Under the response retrieval account, an inhibitory state is not retrieved. Rather the target event elicits retrieval of the response associated with its location from the previous cueing event.

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[1] A variation of the response retrieval account might suggest that the go/go conditions would lead to facilitation. That is, if the first and second go cues appear at the same location (cued condition) then the response congruency might speed responding resulting in facilitation (faster responding in the cued than in the uncued condition). This idea is consistent with the marginal facilitation effect observed in Experiment 1 for go/go conditions, though facilitation was not evident in Experiment 2.

The similarity of the pattern of results across the standard and long-term conditions in both experiments suggests that the same memory retrieval mechanism may underlie both standard and long-term IOR. However, this conclusion is premature and really requires a more systematic comparison examining other characteristics of standard and long-term IOR. As we have begun here, future research should make these comparisons using the same procedural paradigm for both standard and long-term IOR. At the moment, we agree with previous studies that suggest that both attentional and motor processes contribute to standard IOR (e.g., Kingstone & Pratt, 1999; Taylor & Klein, 2000). The present work, in conjunction with Tipper et al. (2003), however, does suggest that memory retrieval processes not only underlie long-term IOR but also may contribute to standard IOR.

Our failure to find IOR for go/go tasks appears to be inconsistent with some other studies, which have found IOR for go/go tasks using both saccadic and manual responses (e.g., Coward, Poliakoff, O'Boyle, & Lowe, 2004; Posner & Cohen, 1984). One likely reason comes from work by Pratt and Castel (2001), who found that presenting identical targets twice in a row (i.e., red circle followed by another red circle) diminished or eliminated IOR in simple detection tasks. The present experiments used a mixture of identical and different-coloured targets for the standard IOR tasks, and this probably had a negative effect on IOR magnitudes. In addition, there are several other unique features to our tasks, including the spatially distinct placeholders for shorter and longer SOA trials and the mixture of go-go and no-go trials, which may contribute to these different findings.

Finally, it is interesting to note the parallel histories of IOR and negative priming research (for an expanded discussion of the history of negative priming, see Tipper, 2001). First, early accounts of both phenomena emphasized the role of attention and inhibitory processes. For IOR, as described earlier, the original notion was that attention was inhibited from returning to previously attended locations (Posner et al., 1985). For negative priming, the original notion was that selective attention to a target produced inhibition of a to-be-ignored distractor, and the resulting subbaseline activation of the distractor led to its slower processing should it become the target on the next trial (e.g., Neill, 1977; Tipper, 1985). Our memory retrieval account, stemming from Tipper et al.'s (2003) original work, with its emphasis on encoding, retrieval, and response conflict, represents a shift away from these early ideas that attention and inhibition play the key roles in producing IOR. This shift in emphasis parallels a similar shift in negative priming research in which following the early attention and inhibition ideas, memory accounts were proposed (Neill & Valdes, 1992; Neill, Valdes, Terry, & Gorfein, 1992). For negative priming, the idea was that a distractor on a trial was associated with a "do not respond" response. If that distractor became a target on the next trial, its processing led to retrieval of the "do not respond" response, which conflicted with the current response required ("respond"), slowing task performance. A second parallel in the two phenomena is that it was generally assumed that the inhibition observed in negative priming was a transient phenomenon lasting only 2 or 3 s—a duration very similar to that proposed for IOR. Then in 1991, Tipper, Weaver, Cameron, Brehaut, and Bastedo provided the first evidence that negative priming could be observed for up to 7 s—again, a duration very similar to that observed in the present experiments. Finally, Milliken, Tipper, Houghton, and Lupiáñez (2000) have identified similarities in "location-based" negative priming and IOR. It then may ultimately be proved that the retrieval of motor responses underlies not only identity-based negative priming and IOR, but also location-based negative priming.

In conclusion, this work extends the work of Tipper et al. (2003) in demonstrating the influence of memory on how attention is allocated. It seems that the processing and performance of even the most rudimentary tasks elicit from memory an automatic retrieval of responses used for previous

episodes that are similar to the current task. This retrieval is done in an attempt to facilitate performance on the current task because under normal conditions the response provided on a similar previous task would be the appropriate response on the current task.

REFERENCES

Briand, K. A., Larrison, A. L., & Sereno, A. B. (2000). Inhibition of return in manual and saccadic response systems. *Perception and Psychophysics*, *62*, 1512–1524.

Castel, A. D., Chasteen, A. L., Scialfa, C. T., & Pratt, J. (2003). Adult age differences in the time course of inhibition of return. *Journal of Gerontology: Psychological Sciences*, *58*, 256–259.

Coward, R. S., Poliakoff, E., O'Boyle, D. J., & Lowe, C. (2004). The contribution of non-ocular response inhibition to visual inhibition of return. *Experimental Brain Research*, *155*, 124–128.

Dodd, M. D. (2005). *Inhibition of return with multiple shifts of attention*. Unpublished doctoral dissertation, University of Toronto, Toronto, Ontario, Canada.

Kingstone, A., & Pratt, J. (1999). Inhibition of return is composed of attentional and oculomotor processes. *Perception & Psychophysics*, *61*(6), 1046–1054.

Klein, R. M., Castel, A. D., & Pratt, J. (in press). The effects of memory load on the timecourse of inhibition of return. *Psychonomic Bulletin & Review*.

Lupiáñez, J., Milán, E. G., Tornay, F., Madrid, E., & Tudela, P. (1997). Does IOR occur in discrimination tasks?: Yes, it does, but later. *Perception & Psychophysics*, *59*, 1241–1254.

Maylor, E. (1985). Facilitatory and inhibitory component of orienting in visual space. In M. I. Posner & B. B. Morin (Eds.), *Attention and performance XI* (pp. 189–204). Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.

Maylor, E. A., & Hockey, G. R. J. (1985). Inhibitory component of externally controlled covert orienting in visual space. *Journal of Experimental Psychology: Human Perception and Performance*, *11*, 777–787.

McAuliffe, J., & Pratt, J. (2005). The effect of cue duration and inter-stimulus interval in covert orienting of visual attention. *Psychological Research*, *69*, 285–291.

Milliken, B., Tipper, S. P., Houghton, G., & Lupiáñez, J. (2000). Attending, ignoring, and repetition: On the relation between negative priming and inhibition of return. *Perception & Psychophysics*, *62*, 1280–1296.

Morgan, H. M., Paul, M. A., & Tipper, S. P. (2005). Inhibition of return can be associated with object identity but not with object category. *European Journal of Cognitive Psychology*, *17*, 499–520.

Neill, W. T. (1977). Inhibition and facilitation processes in selective attention. *Journal of Experimental Psychology: Human Perception and Performance*, *3*, 444–450.

Neill, W. T., & Valdes, L. A. (1992). Persistence of negative priming: Steady-state or decay? *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *18*, 565–576.

Neill, W. T., Valdes, L. A., Terry, K. M., & Gorfein, D. S. (1992). Persistence of negative priming: II. Evidence for episodic trace retrieval. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *18*, 993–1000.

Posner, M. I., & Cohen, Y. A. (1984). Components of visual orienting. In H. Bouman & D. G. Bouwhuis (Eds.), *Attention and performance X* (pp. 531–556). Hove, UK: Lawrence Erlbaum Associates Ltd.

Posner, M. I., Rafal, R. D., Choate, L. S., & Vaughan, J. (1985). Inhibition of return: Neural basis and function. *Cognitive Neuropsychology*, *2*, 211–228.

Pratt, J., & Castel, A. D. (2001). Responding to feature or location: A re-examination of inhibition of return and facilitation of return. *Vision Research*, *41*, 3903–3908.

Samuel, A. G., & Kat, D. (2003). Inhibition of return: A graphical meta-analysis of its time course and an empirical test of its temporal and spatial properties. *Psychonomic Bulletin & Review*, *10*, 897–906.

Spalek, T. M., & Hammad, S. (2004). Supporting the attentional momentum view of inhibition of return: Is attention biased to go right? *Perception & Psychophysics*, *66*, 219–233.

Spalek, T. M., & Hammad, S. (2005). The left-to-right bias in inhibition of return is due to the direction of reading. *Psychological Science*, *16*, 15–18.

Tanaka, Y., & Shimojo, S. (1996). Location vs. feature: Reaction time reveals dissociation between two visual functions. *Vision Research*, *36*, 2125–2140.

Taylor, T. L., & Klein, R. M. (2000). Visual and motor effects in inhibition of return. *Journal of Experimental Psychology: Human Perception and Performance*, *26*, 1639–1656.

Tipper, S. P. (1985). The negative priming effect: Inhibitory priming by ignored objects. *Quarterly Journal of Experimental Psychology*, *37A*, 571–590.

Tipper, S. P. (2001). Does negative priming reflect inhibitory mechanisms? A review and integration of conflicting views. *Quarterly Journal of Experimental Psychology*, *54A*, 321–343.

Tipper, S. P., Grison, S., & Kessler, K. (2003). Long-term inhibition of return of attention. *Psychological Science*, *14*, 19–25.

Tipper, S. P., Weaver, B., Cameron, S., Brehaut, J. C., & Bastedo, J. (1991). Inhibitory mechanisms of attention in identification and localization tasks: Time course and disruption. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *17*, 681–692.