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Stroop interference is affected in inhibition of return

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In previous research, we have shown that the processing of targets that are presented to locations subject to inhibition of return (IOR) is affected by an inhibitory tagging mechanism. This mechanism acts by disconnecting activated representations of stimuli at inhibited locations from their associated responses. In two experiments, we assessed whether this inhibitory tagging mechanism of visual attention is also applied to task-irrelevant but prepotent dimensions of target stimuli, such as words in the Stroop task. To test this hypothesis, we examined the Stroop effect in an IOR procedure. The results showed that (1) IOR can be found in a color discrimination task, (2) the Stroop interference was reduced (Experiment 1) or eliminated (Experiment 2) when stimuli appeared at cued locations, as compared with cases in which they were presented at uncued locations, and (3) the effect of inhibitory tagging was limited to the shortest stimulus onset asynchrony value, replicating previous findings. These results agree with the idea that inhibitory tagging, occurring in IOR, affects the efficiency with which color words compete for responses in Stroop-like situations.

Inhibition of return (IOR) reflects a mechanism that biases attention to explore novel locations. To illustrate, in a standard IOR task, participants are presented with three boxes arranged horizontally, one in the center acting as a fixation point and two in the periphery acting as peripheral cues. Following the fixation display, one of the peripheral boxes brightens briefly to attract attention to that location. If after a short interval, the target is presented in the previously cued location, facilitation in target responses is commonly observed. However, if the cue–target interval is rather long (usually longer than 300 msec), inhibition is then obtained (Posner & Cohen, 1984). This inhibitory mechanism of visual attention is thought to enhance the efficiency of visual research by creating a bias toward novelty, so that attention is less likely to return to already explored locations and/or objects (Maylor, 1985; Tipper, Driver, & Weaver, 1991).

IOR effects have been found whenever a judgment about location is required, irrespective of whether participants are told to make manual detection responses (Maylor & Hockey, 1987) or eye movements (Abrams & Dobkin, 1994) to the location of the target. However, recent research has shown that IOR is not a unitary phenomenon, and the effect has been extended to a great variety of tasks and situations (for a review, see Taylor & Klein, 1998). For instance, there is now compelling evidence that IOR is found in tasks that require some kind of discrimination responses, such as lexical decisions (Chasteen & Pratt, 1999; Fuentes, Vivas, & Humphreys, 1999a, 1999b), color discrimination (Law, Pratt, & Abrams, 1995), and other kinds of discrimination responses (Lupiáñez, Milan, Tornay, Madrid, & Tudela, 1997; Pratt, 1995).

If IOR is found when responses more sophisticated than simple location detection responses are involved, one might expect that IOR affects the processing of inhibited stimuli at different levels. Fuentes et al. (1999b) investigated this hypothesis by combining either a semantic priming paradigm or a flanker task with an IOR procedure. When stimuli were presented at locations supposedly subject to IOR, well-documented effects, such as semantic priming or flanker interference, were reversed under certain conditions. For instance, in the semantic priming task, standard positive priming was found when the prime word appeared at the uncued location, but it turned negative when it fell at the cued location, although this effect occurred only with a short prime–target interval. Similarly, for the flanker task, when distractors appeared at the uncued location (while participants responded to a central target), the standard flanker effect emerged—that is, incompatible distractors produced longer reaction times (RTs) than did compatible distractors. However, when distractors appeared at the cued location, a reversed compatibility effect was found: RTs were now faster in the incompatible condition than in the compatible condition. Fuentes et al. (1999b) explained these patterns of results according to an *inhibitory tagging* mechanism involved in IOR.

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Nonetheless, it is important to note that the inhibitory tagging mechanism must be distinguished from IOR per se. IOR is the delay in orienting attention to a previously attended location as the result of the organism's being biased toward novelty. In contrast, the inhibitory tagging is a mechanism that operates in IOR and, we assume, affects target processing when targets are presented at locations subject to IOR. This mechanism seems to temporally prevent stimuli at inhibited locations from connecting with their associated responses. A proof that the inhibitory tagging disconnects rather than suppresses activated representations of stimuli at cued locations is provided by the pattern of results Fuentes et al. (1999b) found in the semantic priming experiments. Primes (i.e., the word DOG) at cued locations produced negative semantic priming—that is, longer RTs in the related condition (i.e., *cat* as the target word) than in the unrelated condition (i.e., *finger* as the target word) when the target shortly followed them. If IOR modulated the early processing of the word DOG, so that there was less semantic activation over trials, we should have found a decrease in the magnitude of semantic priming at cued locations. However, an alternative account proposed by the authors is that the word DOG activated its semantic representation but the output from this representation to decision-making processes was inhibited. A spread of this inhibitory tag to related representations, such as *cat*, would then slow responses to the semantically related target (i.e., the word *cat*), as compared with the unrelated target (i.e., the word *finger*), hence producing the negative effect. When the prime–target interval increased and the inhibitory tagging effect was over, activated representation of the prime and semantically related stimuli produced the standard positive priming effect. Thus, the inhibitory tagging mechanism can provide a general account of IOR in a variety of tasks ranging from simple detection to more complex tasks, like the ones described above.

Although some of the effects found by Fuentes et al. (1999b) are supposed to be found in IOR, they did not used a direct measure of IOR in their procedure. Participants responded to central targets flanked by distractors at either inhibited or noninhibited locations, so that activation from targets and distractors might have been kept separate by binding their activation to different spatial locations.

In the present study, we employed a procedure, the Stroop task, that allowed us to test competing hypotheses, depending on whether inhibitory tagging affects only task-relevant features of a target (i.e., the color) or both task-relevant and task-irrelevant (i.e., the word meaning) features of a target (i.e., the word BLUE painted in red) presented at cued locations. Since Fuentes et al. (1999b) assumed that the inhibitory tagging affects the links between activated representations of inhibited stimuli and their associated responses, we expected that a task that reflected response competition between different features of a unique object (the Stroop task) would be affected in IOR. In order to test the above hypothesis, in a first experiment, we combined an IOR procedure with a computerized version of the Stroop task. In a second experiment, we combined an IOR procedure with a nonintegrated computerized version of the Stroop task. By presenting the irrelevant dimension (the word) separate from the relevant one (the color) with different stimulus onset asynchrony (SOA) values, we could look at the time course of inhibitory tagging and, therefore, test the generality of Fuentes et al.'s (1999b) findings that inhibitory tagging is a short-lasting mechanism.

EXPERIMENT 1

In Experiment 1, we sought to test the hypotheses that a mechanism of inhibitory tagging, involved in IOR, only affects processing of task-relevant features of the target or that it affects both task-relevant and task-irrelevant features of the target. In order to assess these suggestions, we used a procedure sensitive to response competition between stimulus dimensions. That is, we combined an IOR procedure with a Stroop task (Stroop, 1935). In this task, participants were asked to respond according to the color of targets (for a review, see MacLeod, 1991). If, as Fuentes et al. (1999b) pointed out, there is a disconnection of the links between the stimulus attributes and the response system when those stimuli are presented at inhibited locations, the following hypotheses can be advanced. If IOR affects only the processing of task-relevant features—that is, processing of the stimulus color—the results should show a general slowing in responses to stimuli falling at cued locations. Thus, we should find the typical IOR effect for all the Stroop conditions: congruent (a color word painted in a congruent color; i.e., the word RED in red color), neutral (a string of Xs painted in one of three colors), and incongruent (a color word painted in an incongruent color; i.e., the word RED in blue color). On the other hand, if IOR affects both kinds of information, the task-relevant dimension (the color) as well as the task-irrelevant dimension (the word), we would expect RTs at cued locations to be slower for the neutral and congruent conditions (since the irrelevant dimension is not involved or does not interfere, respectively), as compared with uncued locations. In contrast, responses in the incongruent condition would benefit from the disconnection between the activated word meaning and the response mechanisms.

To illustrate, let us assume that $t1$ msec are required for color processing, $t2$ msec for resolving the color–word conflict, and $t3$ msec for reorienting attention to the previously attended (cued) location—that is, IOR (see Table 1). At uncued locations, neutral trials would require $t1$ msec, whereas incongruent trials would require $t1 + t2$ msec, producing the standard Stroop effect. At cued locations, neutral trials would require $t1 + t3$ msec, producing IOR effects when compared with the neutral condition at the uncued location. However, according to our account, in the incongruent condition, the connection between semantic information and the response sys-

Table 1
Predictions of the Inhibitory Tagging Account for the Experimental Conditions of Experiment 1 and the Short Stimulus Onset Asynchrony (SOA) of Experiment 2

	Experiment 1		Experiment 2 (250-msec SOA)	
Location	Incongruent	Neutral	Incongruent	Neutral
Uncued	$t1 + t2$	$t1$	$t1 + t2$	$t1$
Cued	$t1 + t3$	$t1 + t3$	$t1$	$t1$

Note—$t1$, time for color processing; $t2$, time to resolve the color–word conflict; $t3$, inhibition of return (IOR). In Experiment 2, $t3$ is expected to have a minimal, if any, impact in the total processing time, because the distractor is presented separate from the target and the target itself is not subject to IOR.

tem would be blocked at this inhibited location, so that the time required for this condition would be $t1 + t3$ msec. If the above is true, we would expect both a reduction in the Stroop effect at the cued location, as compared with the uncued location, and slight differences between the cued-incongruent and uncued-incongruent conditions, differences that depend on the size of $t2$ and $t3$.

Method

Participants. Twenty-two undergraduate students from the University of Almería participated in the experiment. They received course credit for their participation, and all of them had normal or corrected-to-normal vision.

Stimuli. The stimuli were presented on a color monitor (VGA) of an IMB PC-compatible computer, and responses were recorded through the computer keyboard. The stimuli consisted of a string of four Xs in blue, red, or green color for the neutral condition and of a word (VERDE [green], ROJO [red], or AZUL [blue]) in blue, red, or green color for the congruent (i.e., the word ROJO in red color) and incongruent (i.e., the word ROJO in blue color) conditions.

Procedure. On each trial, a central fixation cross appeared for 500 msec, followed by three white boxes for 1,000 msec (see Figure 1). Then, one of the peripheral boxes became thicker (the peripheral cue) for 300 msec. After an interval of 200 msec with three white boxes, the central box became thicker (the central cue[1]) for 300 msec, followed by a further interstimulus interval (ISI) of 450 msec before the target display was presented. The target stimuli were presented until a response was made. The participants were asked to press a color key (a little patch attached to adjacent keys on the keyboard) according to the stimulus color.

The participants ran one practice block of 36 trials, followed by two experimental blocks of 144 trials. In the experimental blocks, in half of the trials (72 trials), the target appeared at the cued location and, in the other half, at the uncued location. In each set of 72 trials, there were 24 trials in each congruence condition (congruent, neutral, and incongruent).

Results and Discussion

The mean of the median correct RTs and the percentage of errors are shown in Table 2. Correct RTs were submitted to a repeated measures analysis of variance (ANOVA), with location (cued vs. uncued) and congruence (con-

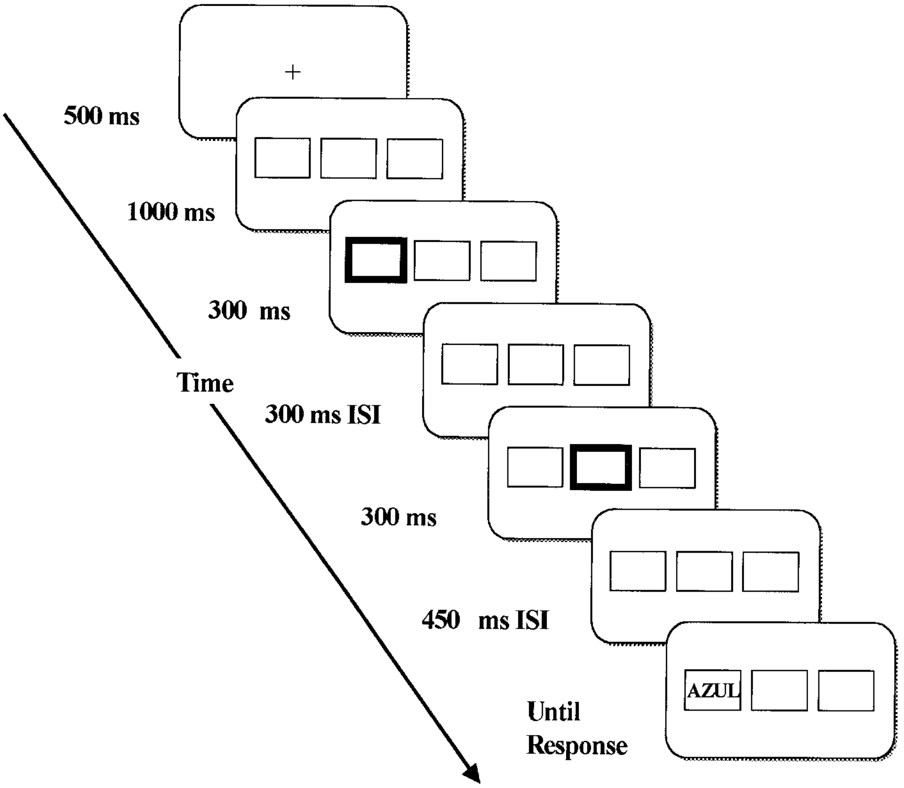

Figure 1. Sequence of events and exposure duration of stimuli for a cued trial in Experiment 1.

Table 2
Mean of Median Reaction Times and Percentage of Errors as a Function of Location and Congruency in Experiment 1

	Congruent		Incongruent		Neutral		
Location	*M*	PE	*M*	PE	*M*	PE	Stroop Effect
Uncued	649	1.5	753	3.3	645	2.7	108
Cued	674	2.7	758	4.4	688	2.7	70

Note—Stroop effect = incongruent − neutral.

gruent, neutral, and incongruent) as the within-subjects factors. The results showed a main effect of location [$F(1,21) = 17.15$, $p < .001$]. RTs were slower when stimuli appeared at the cued location than when they appeared at the uncued location (707 vs. 682 msec)—that is, we found IOR. There was also a main effect of congruence [$F(1,21) = 22.54$, $p < .0001$]. Post hoc comparisons verified that RTs were significantly slower for the incongruent (756 msec) condition than for both the congruent (661 msec) and the neutral (667 msec) conditions ($ps < .001$). There were no significant differences between the congruent and the neutral conditions ($F < 1$).

Most important, the results showed a significant location × congruence interaction [$F(1,21) = 4.7$, $p < .05$]. The analysis of simple main effects showed an overall effect of congruence when targets appeared at cued and at uncued locations [$F(1,21) = 15.17$, $p < .0001$, and $F(1,21) = 24.67$, $p < .0001$, respectively]. In both cases, post hoc comparisons showed that the incongruent condition produced longer RTs than both the congruent and the neutral conditions ($ps < .001$), whereas no differences were found between the congruent and the neutral conditions. However, the interaction was due to a reduction in the interference effect in the cued location, as compared with the uncued location (70 vs. 108 msec, see Table 2). That reduction in the interference effect was further supported by the significant location (cued vs. uncued) × congruence (incongruent vs. neutral) partial interaction [$F(1,21) = 7.32$, $p < .05$].

Because, in our account, we assumed slight differences between the cued-incongruent and uncued-incongruent conditions—that is, differences in the IOR effect in the incongruent conditions—we analyzed IOR in each Stroop condition. The results showed IOR effects in both the congruent (25 msec) and the neutral (43 msec) conditions [$F(1,21) = 7.3$, $p < .05$, and $F(1,21) = 31.4$, $p < .001$, respectively]. However the effect failed to be significant in the incongruent condition (5 msec; $F < 1$).

The analysis of errors showed marginal main effects of location [$F(1,21) = 3.36$, $p < .09$] and congruence [$F(1,21) = 2.98$, $p < .07$]. Errors were in the same direction as that shown in the RT data. Percentage of errors was higher at the cued than at the uncued location (3.25% vs. 2.49%) and higher in the incongruent condition (3.83%) than in the congruent and neutral conditions (2.13% and 2.65%, respectively). The location × congruence interaction was not significant ($F < 1$).

The results showed a general effect of IOR—that is, RTs were slower when targets were presented at the cued location, relative to those presented at the uncued location. There was also a main Stroop effect—that is, RTs were slower in the incongruent condition than in the neutral condition. As previous studies on Stroop effects have shown, there were no differences between the congruent condition and the neutral condition (for a review, see MacLeod, 1991).

Importantly, the present results exhibited a reduction of Stroop interference when stimuli appeared at cued locations, as compared with uncued locations. This reduction in the amount of interference was due mainly to an increase in RTs in the neutral condition (see also the congruent condition) at the cued location, relative to the uncued location, whereas RTs in the incongruent condition did not increase. This pattern of results is what we might expect if there was inhibition of the links between the different attributes of the Stroop stimuli and their associated responses.

These results suggest that when stimuli fell at inhibited locations, IOR modulated the processing of those stimuli in some way. We propose that an inhibitory tagging mechanism may account for these results.

However, an alternative to the inhibitory tagging account is that IOR affected the way Stroop stimuli were perceived. We find two arguments that are difficult to reconcile with such a perceptual account. First, Fuentes et al. (1999b) showed that prime words presented at locations subject to IOR still produce semantic priming effects. Second, if stimuli at cued locations were perceived less efficiently, we should expect longer RTs with incongruent trials when they appeared at cued locations than when they appeared at uncued (noninhibited) locations—that is, IOR should be observed with incongruent trials as well. That was not the case; the IOR effect was limited to both the congruent and the neutral conditions. However, this last result leads to the possibility that the present pattern of results can be accounted for without any reference to any mechanism involved in IOR. One might argue that resolution of the conflict produced by the words when trying to identify the color could prevent the manifestation of any visual orientation effect—in this case, IOR. That might explain why standard IOR is observed with neutral and congruent stimuli, where conflict does not occur, but not with incongruent stimuli characterized by producing conflict between the color and the word.

Nonetheless, we find it hard to assume that later-acting processes that are involved in resolving the conflict produced by the word could eliminate an effect like IOR, which usually manifests with the mere onset of a stimulus. In contrast to that is the fact that Fuentes et al. (1999a), using the same target words, reported that the magnitude of IOR was larger when the task required more complex target processing (as in lexical decisions) than merely detecting the target onset. In line with this, we should expect larger IOR with incongruent trials than with congruent and neutral trials, because the former would involve more complex processing than do the latter. Thus, we want to claim that the lack of IOR in the incongruent condition is the indirect consequence of responses being *facilitated* by the effect of an inhibitory mechanism that prevents the irrelevant dimension of the target from being competitive for response. We call this mechanism *inhibitory tagging* (Fuentes et al., 1999b).

However, stronger support for the occurrence of this indirect facilitation effect with incongruent trials presented at inhibited (cued) locations would require more direct evidence. Experiment 2 was conducted to provide this.

EXPERIMENT 2

In the previous experiment, we explained the reduction of the Stroop effect at the cued location by assuming that inhibitory tagging was ameliorating the intrusive effect the word had on the response to the color. Thus, when the target appeared in the cued location, the inhibitory tagging mechanism blocked the access of the word to the response system. As a consequence, we found no differences between cued and uncued locations for incongruent trials, a result that we attributed to responses being indirectly facilitated in those trials. The alternative explanation would be that resolving the conflict produced in the Stroop task would avoid the manifestation of any attentional orientation effect.

In the present experiment, we tried to find more direct evidence of that indirect facilitation of responding when incongruent stimuli are presented at cued locations. An appropriate way of getting this evidence might be to use a procedure that reduces the necessity for attentional shifts in order to respond to targets. In line with this, we chose a version of the Stroop task in which the distractor stimulus (a color word, or a string of Xs) is presented before the target (a color patch). Thus, responses are now made to nonverbal stimuli in all the conditions. The distractor could be presented at either the cued or the uncued location, followed by the target, which was always presented just below the distractor location. Importantly, for the purpose of the present research, by presenting the color target in close proximity to the distractor location, we were able to reduce the necessity for attentional shifts in responding to targets, once attention has been moved to the distractor location. This would affect the size of $t3$ in our predictions (see Table 1), which would be either completely eliminated or greatly reduced. Therefore, any difference in Stroop effect as a function of location would be the direct consequence of IOR's affecting distractor stimuli, not target stimuli.

Consequently, if the lack of differences found in Experiment 1 between cued-incongruent and uncued-incongruent trials was due to a lack of attentional orientation effects when Stroop trials induced conflict (i.e., in the incongruent condition), we should find no differences between the two types of trials in this experiment either. Thus, any reduction in the Stroop effect when the distractor is presented at the cued location, as compared with when it is presented at the uncued location, should be due solely to shifts in the neutral trials in the two locations. Since targets are not expected to be subject to IOR effects, no differences are expected between cued-neutral and uncued-neutral trials either.

In contrast, if the reduction of the Stroop interference found in Experiment 1 was due to the word's being affected by inhibitory tagging, we should find (1) a reduction, or total elimination,[2] of the Stroop effect at cued, as compared with uncued, locations and (2) a facilitation effect of cued, as compared with uncued, locations in the incongruent condition. The latter effect would be the indirect consequence of amelioration of the impact of the word in the conflict condition by the action of the inhibitory tagging mechanism.[3]

To illustrate, according to our account, at uncued locations neutral trials will require $t1$ msec, whereas incongruent trials will require $t1 + t2$ msec, producing the standard Stroop effect. At cued locations, we do not expect IOR effects on target responses. Thus, both neutral and incongruent trials will require $t1$ msec (see Table 1).

Note that Fuentes et al. (1999b) proposed that inhibitory tagging is a short-lasting phenomenon, producing a temporal disconnection of the stimulus subject to IOR from the response system. Therefore, according to their claim, we should expect to find an interaction between the Stroop effect and the cue location only at the shortest distractor–target SOA value (see Fuentes et al., 1999b, Experiment 2b [250-msec SOA]). With longer SOAs, we would expect to find the same pattern of results whether stimuli are presented at cued or uncued locations.

Method

Participants. One hundred and twelve undergraduate students from the University of Almería participated in the experiment. They received course credit for their participation, and all of them had normal or corrected-to-normal vision.

Stimuli. The stimuli were the same as those in Experiment 2, except that we introduced a distractor stimulus that consisted of a color word (VERDE [green], ROJO [red], and AZUL [blue]) or a string of four Xs. The distractor appeared always in white. The target consisted of a color patch (a rectangle in green, red, or blue color). The distractor word was always incongruent with the color patch, so the target could be neutral (i.e., a string of Xs followed by a red patch) or incongruent (i.e., the word AZUL followed by a red patch) with the prime stimulus. The participants had to press a color key according to the color patch.

Procedure. The sequence of events and the time intervals until the second, central cue appeared were similar to those in Experiment 1. However, after a further ISI of 450 msec, a distractor stimulus was presented in one of the lateral boxes for 150 msec (see Figure 2). Note that the peripheral cue–distractor SOA was 1,250 msec, the same interval as in Experiment 1. Finally, the target could appear 100, 200, 450, or 2,500 msec after the offset of the distractor (producing SOA values of 250, 350, 600, and 2,650 msec, respectively) and remained on until a response was made.

Each participant received a practice block of 32 trials, followed by an experimental block of 176 trials. In half of the trials, the distractor appeared at the cued location, and in the other half, it appeared at the uncued location. There were 88 trials (16 for the practice block) in each congruence condition (incongruent and neutral).

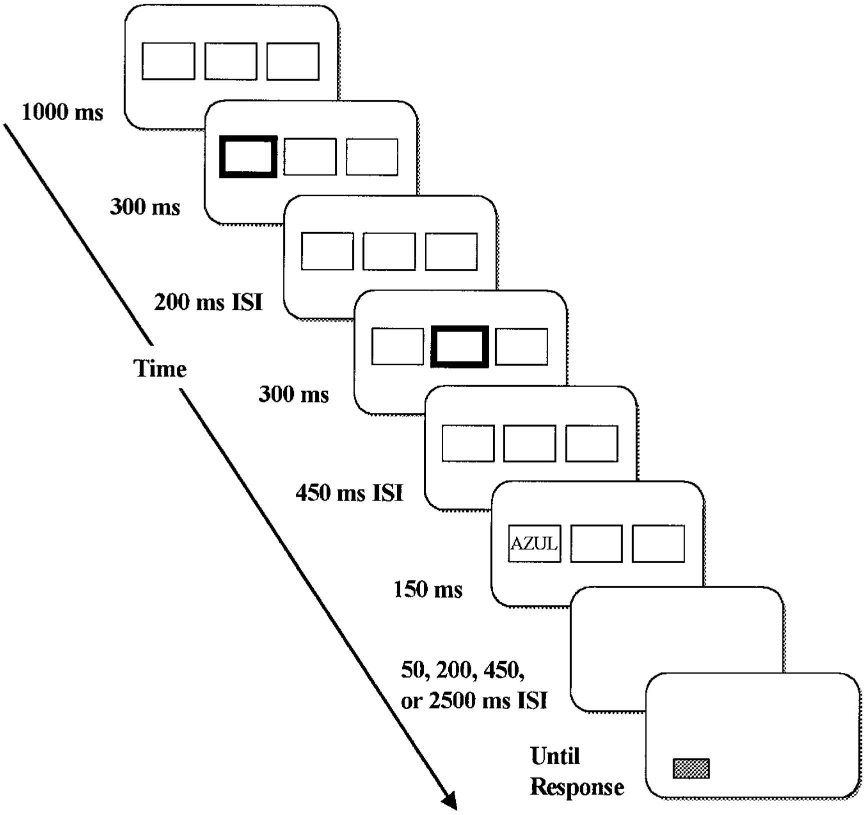

Figure 2. Sequence of events and exposure duration of stimuli for a cued trial in Experiment 2.

Results and Discussion

The mean of the median correct RTs and the percentage of errors are shown in Table 3. Correct RTs were submitted to a mixed ANOVA with SOA (250, 350, 600, and 2,650 msec) as the between-subjects factor and location (cued and uncued) and congruence (incongruent and neutral) as the within-subjects factors. None of the main effects of location and congruence reached statistical significance (Fs < 1). However, the following interactions were significant: SOA × congruence, location × congruence, and SOA × location × congruence [$F(3,108) = 14.23$, $p < .001$; $F(1,108) = 5.22$, $p < .05$; and $F(3,108) = 3.02$, $p < .05$, respectively]. The SOA × congruence interaction was due mainly to a Stroop effect for the 250- and 350-msec SOA values (20 and 17 msec, respectively), which vanished for the 600-msec SOA (4 msec) and became negative for the 2,650-msec SOA (−31 msec). That is, in the 2,650-msec SOA group, RTs were slower for the neutral condition than for the incongruent condition. The location × congruence interaction showed a tendency for an interference Stroop effect (8 msec) when the distractor appeared at the uncued location, an effect that turned negative (−3 msec) when the distractor was presented at the cued location. Nevertheless, these effects were modulated by the three-way SOA × location × congruence interaction. To further analyze this interaction, a separate ANOVA was conducted for each SOA, with location and congruence as within-subjects factors.

Table 3
Mean of Median Reaction Times and Percentage of Errors as a Function of Location, Congruency, and Stimulus Onset Asynchrony (SOA) in Experiment 2

	Incongruent		Neutral		
Location	*M*	PE	*M*	PE	SE
		250-msec SOA			
Uncued	658	3.2	620	2.1	38
Cued	637	3.0	634	2.9	3
		350-msec SOA			
Uncued	585	4.1	568	4.1	17
Cued	591	4.1	574	3.7	17
		600-msec SOA			
Uncued	609	3.4	600	1.6	9
Cued	600	3.4	601	3.0	−1
		2,650-msec SOA			
Uncued	585	3.3	616	3.7	−31
Cued	587	2.8	618	2.4	−31

Note—Stroop effect (SE) = incongruent − neutral.

250-msec SOA. The main effect of congruence reached statistical significance [$F(1,27) = 16.73$, $p < .001$]. The incongruent condition produced longer RTs than did the neutral condition (647 vs. 627 msec)—that is, we observed the Stroop effect. There was also a significant location × congruence interaction [$F(1,27) =$

25.48, $p < .001$]. The analysis of the simple main effects showed a significant Stroop interference when the distractor was presented at the uncued location (38 msec), but not when it was presented at the cued location [3 msec; $F(1,27) = 34.59$, $p < .001$, and $F < 1$, respectively]. The results showed also a main effect of location for both the incongruent and the neutral conditions. Importantly, these effects went in opposite directions. That is, for neutral stimuli, RTs were longer when the distractor appeared at the cued, as compared with the uncued, location [14 msec of difference; $F(1,27) = 9.14$, $p < .05$], and the opposite occurred for the incongruent stimuli [-21 msec of difference; $F(1,27) = 8.68$, $p < .05$].

350-msec SOA. The main effect of congruence was significant [$F(1,27) = 9.49$, $p < .001$]. RTs were slower for the incongruent condition than for the neutral condition (588 vs. 571 msec). No other effects were significant (Fs < 1).

600-msec SOA. The results did not show any significant effect of location or congruence or a location × congruence interaction [$F(1,27) = 1.46$, $p > .05$; $F(1,27) = 0.99$, $p > .05$; and $F(1,27) = 1.42$, $p > .05$, respectively].

2,650-msec SOA. The main effect of congruence was significant [$F(1,27) = 11.32$, $p < .001$]. However, in this case, the neutral condition produced longer RTs than did the incongruent condition (617 vs. 586 msec).

The overall error analysis showed only a marginal main effect of congruence [$F(1,108) = 3.62$, $p = .06$]. The incongruent condition produced more errors than did the neutral condition (3.4% vs. 2.9%). No other effects reached statistical significance.

The results obtained in Experiment 2 are in agreement with the inhibitory tagging account formalized in Table 1. For the 250-msec SOA, we observed an elimination of the Stroop effect when the distractor was presented at the cued location. This result was replicated by Fuentes, Boucart, Vivas, Alvarez, and Zimmerman's (2000) study. In this study, both the distractor and the target formed part of the same object, but congruent trials were not included. Thus, the exclusion of congruent trials has proved to be useful in reducing the impact of the word in the conflict condition.

Most important, we observed a facilitation effect in the cued location, relative to the uncued location, for the incongruent stimuli. This result goes against any account that assumes that visual orientation effects do not manifest when conflict in the Stroop task is involved. In contrast, the facilitation effect in incongruent trials is what we should expect if the activated representation of the distractor word is blocked from the response mechanisms by the occurrence of an inhibitory tagging effect.

Contrary to our expectations, we observed a small but significant IOR effect in the neutral condition. This might have occurred because of a residual IOR effect favored by the short interval between the distractor and the target we used. Support for this comes from the fact that IOR was 43 msec in Experiment 1 and only 14 msec in the present experiment for neutral trials.

The results obtained with the 350-msec SOA (Experiment 2) are in agreement with inhibitory tagging's exerting a temporary effect (see also Fuentes et al., 1999b). Thus, when we increased the distractor–target SOA up to 350 msec, we found a significant Stroop effect, but it did not interact with location anymore. A further increase to a 600-msec SOA eliminated the effect completely. These results are in agreement with Dyer's (1971) report showing a decrease of Stroop interference with increasing distractor–target intervals. However, unlike Dyer's results, we found a negative Stroop effect at the longest, 2,650-msec SOA. This latter result is compatible with strategic processing being involved in the Stroop task with long distractor–target intervals, at least when congruent trials are not included. Thus, as soon as the distractor is presented, participants can assume in advance that there are only two possible correct responses when the distractor is a word (note that congruent stimuli are never presented) but that there are three possible correct responses when the distractor is a string of Xs. The reduction in the set of possible correct responses with words, as compared with Xs, could produce a benefit in RTs in the former condition, as compared with the latter condition.

GENERAL DISCUSSION

We conducted two experiments in which we combined an IOR procedure with two different computerized versions of the Stroop task. In Experiment 1, we found a reduction of the Stroop interference when stimuli appeared at locations subject to IOR. In Experiment 2, in the shortest, 250-msec SOA, a complete elimination of the Stroop interference occurred when the distractor appeared at the inhibited location, whereas at longer SOA values (350 and 2,650 msec), the Stroop effect (positive or negative) did not interact with location. We suggest that these results can be accounted for in terms of the action of an inhibitory tagging mechanism in IOR.

Inhibitory Tagging in IOR

Little evidence is found for the effects of IOR on stimulus processing. Recently, we have explored the possibility that stimulus processing is modulated in IOR at different levels (Fuentes & Santiago, 1999; Fuentes & Vivas, 2000; Fuentes et al., 1999a, 1999b). For instance, Fuentes et al. (1999b) observed reversed patterns of semantic priming and flanker interference when prime words and flankers, respectively, were presented at inhibited (cued) locations in an IOR paradigm. In Experiments 1 and 2, we found that IOR also modulates the interference effect produced by incongruent stimuli in a Stroop task (see Hartley & Kieley, 1995, for a similar study combining IOR and Stroop interference in young and elderly adults). Concretely, we observed a significant reduction (Experiment 1) and a complete elimination (Experiment 2) of the Stroop interference for stimuli falling at inhibited (cued) locations. Reduction or elimination of Stroop interference has been exhibited in several relevant studies that have investigated the automatic nature of the Stroop effect (e.g., Besner, Stolz, & Boutilier, 1997; Henik, Friedrich, & Kellogg, 1983). In these experiments, manipulations were aimed at affecting the way participants processed the task-irrelevant dimension. For instance, Besner et al. found that coloring a single letter instead of the whole word reduced and even eliminated the Stroop effect (see Catena, Fuentes, & Tudela, in press, for a replication and extension of these results). In the other study, Henik et al. employed a semantic priming paradigm and demonstrated that naming primes (color words) before a color-naming trial resulted in interference, whereas searching primes for a letter reduced drastically the amount of interference. It is interesting to note that, in our experiments, the only manipulation was the spatial location in which the stimuli were presented.

A second argument that favors the effect of inhibitory tagging on Stroop interference comes from Experiment 2. The results observed in the shortest SOA of Experiment 2 replicated the main findings obtained in Experiment 1. In addition, Stroop interference was completely eliminated at the inhibited location. Several previous studies have shown that the ratio of congruent to incongruent trials affects the Stroop effect considerably, by changing the informative nature of the irrelevant dimension. In Experiment 2, we did not introduce congruent trials. Under these circumstances, the inhibitory tagging mechanism could have been more effective in eliminating interference from incongruent words. Most important, as was predicted by our account, we found a facilitation effect for the cued-incongruent condition, as compared with the uncued-incongruent condition. That is, RTs were faster for incongruent trials when the distractor stimulus was presented at cued locations as opposed to uncued locations. We conclude that the benefit to responding in that condition is incompatible with any account in terms of resolution of the color–word conflict affecting the manifestation of visual orientation effects. In contrast, we propose that the facilitation effect observed with cued-incongruent, as compared with uncued-incongruent, trials is the indirect consequence of inhibitory tagging affecting the links between activated representations of words and the response mechanisms.

The lack of an interaction between the Stroop effect and location in longer SOAs (350 and 2,650 msec in Experiment 2) suggests that inhibitory tagging is a short-lasting phenomenon, which extends the conclusions of Fuentes et al. (1999b) with a semantic priming paradigm to the Stroop task.

The inhibitory tagging mechanism may be especially effective when, in order to respond to target-based features, it is necessary to keep activation from distractors separate from that from targets (for instance, in Experiment 2). One way to do so is to bind the activation from distractors to a spatial location—in this case, subject to IOR. In Experiment 1, however, both the target (the color) and the distractor (the word) appeared at the same inhibited spatial location. This allows us to extend the inhibitory tagging phenomenon to situations in which the target and the distractor form part of the same object.

Fuentes et al. (2000) carried out a study similar to the present one, with both healthy adults and schizophrenic patients. Importantly, the results with healthy adults replicated the main findings of the present study—that is, Stroop interference was eliminated at cued locations for the control group. However, schizophrenic patients, despite showing normal IOR and Stroop interference effects, as compared with the control group, did not show any interaction between IOR and Stroop conditions. Fuentes et al. (2000) accounted for this pattern of results in terms of a failure in the inhibitory tagging mechanism in the schizophrenic group. These results can be added to previous failures of inhibitory processes reported in studies with schizophrenic patients (Posner & DiGirolamo, 1998).

Future research will elucidate under what circumstances the inhibitory tagging is an effective mechanism and whether this inhibitory mechanism can be affected or not in specific populations.

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NOTES

1. The central cue was introduced to ensure that the participants reoriented their attention back to the center (Posner & Cohen, 1984).

2. In Experiment 1, we observed a reduction of the Stroop effect at the cued location, not an elimination of it. However, Fuentes et al. (2000) found a total elimination of the effect in a similar task, but without congruent trials. As Fuentes, Boucart, Vivas, Alvarez, and Zimmerman (2000) noted, congruent trials might bias the participants to read the words throughout the experiment, increasing the impact of the word in resolving the conflict (MacLeod & McDonald, 1995). As a consequence, the Stroop effect is greater in size and probably more resistant to being eliminated. In Experiment 2, we did not include congruent trials. Thus, elimination, rather than reduction of the effect, should be expected.

3. Note that this facilitation effect was not expected in Experiment 1 because, in that experiment, incongruent words were also subject to IOR effects. Thus, the benefit for responding owing to inhibitory tagging could cancel the cost to responding owing to IOR when the stimuli were presented at cued, as compared with uncued, locations.

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