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Inhibition of object identity in inhibition of return:

Implications for encoding and retrieving inhibitory processes

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Abstract

Inhibition of Return (IOR) effects, where participants detect a target in a cued box more slowly than in an uncued box, suggest that behavior is aided by inhibition of recently attended, irrelevant, locations. To investigate the controversial question of whether inhibition can be applied to object identity in these tasks, the current research presented faces upright or inverted during cue and/or target sequences. IOR was greater when both cue and target faces were upright than when cue and/or target faces were inverted. Because the only difference between the conditions was in the ease of facial recognition, this result indicates that inhibition was applied to object identity. Interestingly, inhibition of object identity affected IOR both when *encoding* a cue face and when *retrieving* information about a target face. Accordingly, it is proposed that episodic retrieval of inhibition associated with object identity may mediate behavior in cueing tasks.

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For humans to interact appropriately in this complex visual world, we must rely on our ability to find items of interest before appropriate action can occur. For example, before one can grasp a pen, it must be located in a cluttered office, or for the chimpanzee to grasp a fruit, it must be located in the dense forest. Importantly, research has shown that cognitive mechanisms exist that aid this process, by promoting attentional processing of novel information and preventing attention to information that has previously been processed and deemed to be irrelevant to current behavioral goals.

Posner and Cohen (1984) demonstrated the existence of just such a mechanism using a simple cueing paradigm. When a square to the left or right of fixation was flashed with an irrelevant cue, detection of a target appearing less than 300 ms later was *faster* in the cued square, presumably because attention was still oriented to that information. However, detection of a target appearing more than 300 ms later was *slower* in the cued square, which suggests that when attention had time to disengage from the cue, inhibition impeded subsequent processing of that information (for reviews see Klein, 2000; Lupiáñez, Tudela, & Rueda, 1999). Posner and Cohen (1984) suggested that this inhibition of return (IOR) effect reflected inhibition of a location on an internal spatial map, which prevented processing of a particular place and promoted attentional processing of

new locations. While Posner and Cohen (1984) originally described inhibition in IOR as a mechanism to allow novelty detection in orienting tasks, subsequent research has revealed the generality of the mechanism, as it also impacts performance in visual search tasks (Klein, 1988; Klein & MacInnes, 1999; Müller & von Mühlenen, 2000; Takeda & Yagi, 2000).

To date, a variety of research has debated whether inhibition in cueing tasks can only be applied to spatial information (List & Robertson, 2001; Schendel, Robertson, & Treisman, 2001) or whether object-based representations may also be inhibited (for a review see Grison, Kessler, Paul, Jordan, & Tipper, in press). For example, Tipper and his colleagues demonstrated that after cueing, when an object moved to a new location, inhibition moved with the object to reveal object-based IOR effects (Tipper, Driver, & Weaver, 1991; Tipper, Jordan, & Weaver, 1999). However this result could also reveal that inhibition was originally applied to the location of the object and the movement of the object may have updated inhibition of a spatial representation. Similarly, other studies found larger IOR when an object versus an empty location was cued (e.g., Jordan & Tipper, 1998; Leek, Reppa, & Tipper, 2003; Reppa & Leek, 2003) and showed that this effect lasted longer as well (Grison, Tipper, & Kramer, 2004; Paul & Tipper, 2003). But in these cases, it is possible that objects provided stable landmarks that marked the location of spatial inhibition and helped maintain it for greater lengths of time.

Furthermore, even if one were to accept the controversial notion that IOR can reveal inhibition of objects, it is still unclear what object representations are inhibited. The general view is that object files (Kahneman, Treisman, & Gibbs, 1992), are encoded in parallel across the visual scene, via Gestalt grouping mechanisms (e.g., common fate, feature similarity, etc.) and become candidates for subsequent processes of object identification. It is thought that these low-level representations are inhibited during orienting and visual search (Driver, Davis, Russell, Turatto, & Freeman, 2001). By contrast, there is little evidence that inhibition can be associated with higher-level representations such as the identity of an object.

Accordingly, in the current research, a novel cueing task was used to examine whether IOR can reveal inhibition of object identity information. Here, one face was shown to the left of fixation and another to the right (see also Grison et al., in press; Grison et al., 2004; Kessler & Tipper, 2003). In the cue sequence, if a face turned red this should initiate orienting to that stimulus, but because it is irrelevant, inhibition should be applied to any representations associated with the cued face. Nearly four seconds later in the target sequence,¹ when the same faces were shown, participants should be slower to localize a green target shown over the cued versus uncued face due to residual inhibition of that stimulus. Importantly, there were four conditions (Figure 1) that manipulated face orientation. In the *upright-upright* condition, faces were shown upright in both the

cue and target sequences. The *inverted-upright* condition showed faces inverted only in the cue sequence. In the *upright-inverted* condition, faces were only inverted in the target sequence. Finally, the *inverted-inverted* condition presented inverted faces in both the cue and target sequences. Notice that in each condition the faces were oriented 45 degrees from vertical and that the change in orientation between the cue and target sequence was always 90 degrees

Figure 1 about here

If inhibition in this task is merely applied to location or object file representations, then IOR effects should not differ between the orientation conditions because the physical change on the retina was equivalent in all conditions. However, if inhibition can be applied to object identity, the magnitude of IOR should vary across the conditions because humans easily process upright faces, but have difficulty recognizing inverted faces (Yin, 1969). Specifically, if inhibition can be associated with object identity, then this is most likely to occur when a cued face is presented upright and is easily recognized in both the cue and target sequences. Accordingly, IOR should be greatest in the upright-upright condition when inhibition can be associated with all potential frames-of-reference, such as object identity, spatial location, and low level object file information. By contrast, IOR should be less in the remaining three conditions, reflecting the fact

that only locations and object files could be inhibited when faces were inverted and hard to recognize in the cue and/or target sequences.

Method

Participants.

Fifty-six undergraduates from the University of Wales, Bangor, participated in exchange for course credit. There were 12 males and 44 females, between 18 and 35 years old, with a mean age of 19.7 years. All participants had normal or corrected-to-normal visual acuity and color vision. Fourteen participants were randomly assigned to one of four orientation conditions.

Stimuli and Apparatus

The stimuli were 192 color photographs of faces, half showing males and half females. Two faces were presented simultaneously, centered in a horizontal row against a black background. Pairs of faces were created based on 96 random pairings of two male faces, two female faces, or one male and one female face. Each pair of faces was seen only twice, once in the cue sequence and then again in the target sequence. A chin-rest was used to maintain a visual angle of 9 degrees vertically and 7 degrees horizontally for each of the faces, with a lateral separation of 14 degrees from the center of the left face to the center of the right face. The visual angle for the entire display subtended 9 degrees vertically and 21 degrees horizontally. The imperative signals were a semi-transparent red oval (i.e., 'no go' signal) or green oval (i.e., 'go' signal), measuring 5.5 degrees

vertically and 5 degrees horizontally, placed over a face. The experiment was performed on an IBM-compatible personal computer with a Pentium II 266 MHz processor and 160 MB RAM. E-Prime programming software (2000) was used to create the experiment, display stimuli on a 19-inch superVGA monitor, control timing, and log responses through a keyboard.

Design

The effect of orientation during the cue and target sequences was manipulated between-subjects, resulting in four orientation conditions: upright-upright, inverted-upright, upright-inverted, and inverted-inverted. For each of these conditions there were 96 experimental trials, each with a cue and a target sequence. Eighty trials per orientation condition allowed measurement of IOR effects, because a red cue signal that required a 'no go' response was followed by a green target signal that required a 'go' response. These trials were equally drawn from a 2 x 2 repeated measures design: target cueing: (uncued/cued) x target location: (left/right). Accordingly, on half of the trials, the target appeared on an uncued face and on half of the trials it appeared on a cued face. Furthermore, on half of the trials the target appeared on the left face and on half of the trials it was shown on the right face. Sixteen trials in each orientation condition were catch trials designed to reduce target predictability. Of these, half were an *early response* catch condition, where a green target appeared in the cue

and target sequences, and half were a *no-go* catch condition, where a red cue appeared in the cue and target sequences.

Procedure

Participants sat in a dimly lit room 57 cm from the computer monitor. They completed a practice session of 12 trials before beginning the 96 experimental trials, which lasted about 20 minutes. The procedure (Figure 2) began with the cue sequence, where a black display was shown for 1000 ms followed by a 100 ms tone to indicate the start of a new trial. After a fixation display of 1500 ms, a pair of pre-cue faces was presented for 1000 ms. Then a semi-transparent red cue signal appeared over one face for 100 ms. After removal of the cue, the original faces were seen for a further 300 ms as the post-cue. Participants were expected to withhold response to a red cue. However, in the early response catch trials they had 1000 ms from cue onset to respond to the location of a green cue by pressing the left or right key on the keyboard with the corresponding index finger. A 3000 ms fixation screen was then shown before the target sequence began. In the target sequence, the same faces were re-presented for 500 ms as the pre-target, but re-oriented by 90 degrees. A semi-transparent green target signal then appeared over one of the faces for 100 ms. After the target was removed, the original faces were seen as the post-target for another 300 ms. There was 1000 ms from target onset to respond to the location of a green target signal by pressing the left or right key on the keyboard with the

corresponding index finger. However, in the case of no-go catch conditions, participants were told to withhold response to a red target signal. A trial was recorded as an error if on either the cue or target sequences: no response was made when one was expected (i.e., miss), if a response was made when it should not have been (i.e., false alarm), or if a response was made before target onset (i.e., anticipation). In these cases, a 200 ms error tone sounded and the trial ended.

Figure 2 about here

Results

The data from catch conditions were not analyzed nor were any cue or target trials in which an error was made. Separate repeated measures ANOVAs were initially conducted on target response time (RT) (Table 1) with orientation condition (upright-upright/inverted-upright/upright-inverted/inverted-inverted) as the between-participants factor and a 2 x 2 repeated measures within-subject design: target cueing: (uncued/cued) x target location: (left/right). The RT data showed an effect of cueing, $F(1, 52) = 81.9, p < .01$, indicating slower responses to cued (417 ms) versus uncued targets (391 ms), which revealed significant IOR effects (-26 ms) across the four orientation conditions. Importantly, RTs for cued and uncued targets were modulated by orientation, $F(3, 52) = 3.8, p < .02$.

Planned contrasts showed greater IOR in the upright-upright (-41 ms) versus the inverted-upright (-23 ms), $p < .03$, upright-inverted (-22 ms), $p < .03$, and inverted-inverted conditions (-15 ms), $p < .01$ (Figure 3).

Further analysis confirmed that IOR effects were greater when face stimuli were shown upright in the cue and target sequences. When examining IOR at a certain location (left/right) based on the cue orientation (upright/inverted), IOR was indeed larger for upright (-32 ms) versus inverted cues (-19 ms), $F(1, 26) = 6.3, p < .02$. Similarly, when IOR effects for a given location (left/right) were examined based on target orientation (upright/inverted), IOR was again greater for upright (-32 ms) than inverted targets (-19 ms), $F(1, 26) = 6.5, p < .02$.

Separate repeated measures ANOVAs were also conducted on target error rates (Table 1) using the same design as for RT analyses. There was a main effect of orientation, $F(3, 52) = 5.9, p < .01$. Analysis of simple effects showed greater errors in the upright-upright (3.1 percent) than the inverted-upright condition (0.4 percent), $p < .01$, and in the inverted-inverted (2.7 percent) versus the inverted-upright condition (0.4 percent), $p < .01$. Finally, cueing was modulated by target location, $F(1, 52) = 5.3, p < .05$, where planned contrasts indicated greater errors for uncued (2.2 percent) versus cued targets (1.9 percent) in the right location, $p < .01$.

Table 1 about here

Figure 3 about here

Discussion

IOR effects in cueing tasks are thought to reveal how processing of potentially relevant novel information is aided by inhibition of previously attended information that is task-irrelevant. However, the nature of these inhibited representations is still a controversial topic. Inhibition may only be applied to spatial locations or low-level object representations, or, as proposed here, higher-level object identity information may also be inhibited. The current research used a novel cueing task that presented upright or inverted faces in the cue and/or target sequences of a cueing task to explore whether IOR effects might reveal inhibition of object identity.

The results clearly showed greatest IOR in the upright-upright condition. Because there were no physical differences between the four orientation conditions with respect to spatial location and object file information, inhibition of these representations cannot explain this result. Instead, the outcome may be explained by inhibition of object identity. Upright faces may have been easily recognized in the cue sequence and therefore inhibition could be applied to that information. Similarly, in the target sequence, presentation of upright faces made recognition easy, which allowed prior inhibition to impact processing of the

target. Therefore, in the upright-upright condition, most robust IOR effects may have resulted from inhibition being applied to several representations, including object identity, location, and object file information. By contrast, in the remaining three conditions the inverted faces were hard to recognize during the cue and/or target sequences, so inhibition could not affect processing of identity information. Therefore, IOR effects were less because inhibition could only be applied to location and object-files. Interestingly, because IOR in the upright-upright condition was significantly greater than in the inverted-inverted condition, it also seems that the presence of similar orientations between the cue and target sequences could not elicit robust IOR without concurrent inhibition of object identity.

It must be noted that the results obtained here were consistent with findings from research where eyes were cued in an inverted or upright face, or an objectless location was cued in an inverted or upright scene (Grison et al., 2004). Across several experiments, short-term IOR was observed over two seconds in all of these conditions. Importantly, the effects were greater for upright versus inverted faces, thus confirming that object identity could be inhibited in cueing tasks and that inversion reduced the ability to inhibit object identity, revealing inhibition of only locations and object files. However, IOR was no different for upright versus inverted scenes, indicating that when it was not possible to access

object identity, inhibition could only be applied to locations and object files and that inversion did not affect inhibition of these lower level representations.

These results have some implications for understanding the neural mechanisms that contribute to IOR effects in cueing tasks. Although a variety of research has indicated that the superior colliculus mediates inhibition in IOR (Rafal, Calabresi, Brennan, & Sciolto, 1989; Sapiro, Soroker, Berger, & Henik, 1999), the current findings demonstrate that processing cannot be solely mediated by this mid-brain structure (see also Klein, 2000; Tipper et al., 1997). This is because processing face identity requires sophisticated analysis in cortical structures such as the fusiform gyrus (Kanwisher, 1998), and the data from this research indicate that the observation of inhibitory processes in IOR effects depended on such processes.

The current results may also provide insight into the cognitive mechanisms mediating inhibition in IOR. Specifically, we propose that in a cueing task, the inhibitory state associated with irrelevant cue representations, such as spatial location, low-level object information, object identity, etc., may be implicitly encoded into episodic memory. Indeed, IOR in the current research was greater when participants could recognize and inhibit a cued face during *encoding* (i.e., in the upright-upright versus the inverted-upright condition, and across the four orientation conditions when a cue face was shown upright versus inverted). We further propose that because inhibition seems to be associated with

object identity during encoding, later retrieval of that information from episodic memory may also access prior inhibitory processes. In effect, this would recreate the prior processing state associated with a cued face and allow for inhibition to impact behavior.² Again, IOR in the current research was larger when participants could recognize and *retrieve* information about an inhibited target face (i.e., the upright-upright versus the upright-inverted condition, and across the four orientation conditions when a target face was presented upright versus inverted). Finally, because smallest effects were seen in the inverted-inverted condition, when faces were hard to recognize in the cue and target sequences, this supports the idea that accessing and inhibiting object identity during initial encoding and later retrieval processes were both important for observing robust IOR.

We further suggest that because inhibition of object identity may be encoded into episodic memory and retrieved with irrelevant information, this process may mediate correct behavior over long periods of time. Indeed, across a variety of experiments using cueing tasks similar to that described here, we have found the first evidence of IOR effects over delays of several minutes and dozens of items (Grison et al., in press; Tipper, Grison, & Kessler, 2003). Importantly, these long-term effects were only seen when cueing objects, not empty locations in a scene (Grison et al., in press; Grison et al., 2004). Long-term IOR can be explained by the same mechanism mediating the current short-term effects,

namely episodic retrieval of prior inhibitory processes. However, in this case, while inhibition of stable object identity information may be encoded and retrieved from memory to impact performance over long periods of time, inhibition of location information does not.

In sum, the results reported here provide insight into the processes mediating correct performance in short-term cueing tasks. Specifically, the current research suggests that behavior is not merely due to inhibition of location and low level object feature information. Instead, these results are among the first to demonstrate that inhibition affects behavior in cueing tasks by accessing higher level representations, such as object identity. Additionally, these findings also suggest that inhibition can be associated with object identity both when encoding information in the original cue sequence, and when retrieving information about a cued face nearly four seconds later. Importantly, it is proposed that the ability to store object identity representations along with associated inhibition in episodic memory may mediate behavior over long periods of time.

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Footnotes

¹ Research has shown that short-term IOR effects can last between three and five seconds (for reviews see Grison et al., in press; Lupiáñez et al., 1999).

² Similar ideas concerning retrieval of prior inhibitory attentional states have been developed to explain negative priming effects (Grison, Tipper, & Hewitt, in press; Neill, 1997; Tipper, 2001).

Table 1

Means and Standard Deviations (SD) (in parentheses) of ms Target Reaction Times (RT) and percentage Error Rates (ER) in each of the orientation conditions.

	Up-Up		Inv-Up		Up-Inv		Inv-Inv	
	RT (SD)	ER (SD)						
Uncued								
<i>Left</i>	366 (42)	2.3 (2.7)	400 (76)	0.0 (0.0)	412 (55)	0.8 (3.0)	385 (60)	1.5 (3.3)
<i>Right</i>	371 (48)	3.9 (5.2)	391 (71)	0.0 (0.0)	410 (39)	0.8 (1.9)	395 (58)	4.2 (3.8)
Cued								
<i>Left</i>	408 (50)	3.5 (4.1)	415 (64)	1.5 (3.3)	434 (65)	3.5 (4.1)	395 (46)	3.1 (4.2)
<i>Right</i>	411 (54)	2.7 (4.2)	421 (74)	0.0 (0.0)	432 (48)	2.8 (5.4)	415 (74)	1.9 (2.6)

Figure Captions

Figure 1. A demonstration of the four orientation conditions: upright-upright, inverted-upright, upright-inverted, and inverted-inverted. Participants saw the stimuli in color.

Figure 2. The procedure used to present the upright-upright condition. In this example a cued condition is shown where the red cue (shown here with black stripes) and green target (shown here with black checks) appear on the same face. The same procedure was used for the three other face orientation conditions. Recall that participants saw the stimuli in color.

Figure 3. IOR effects for the four orientation conditions. * $p < .05$.



Figure 1

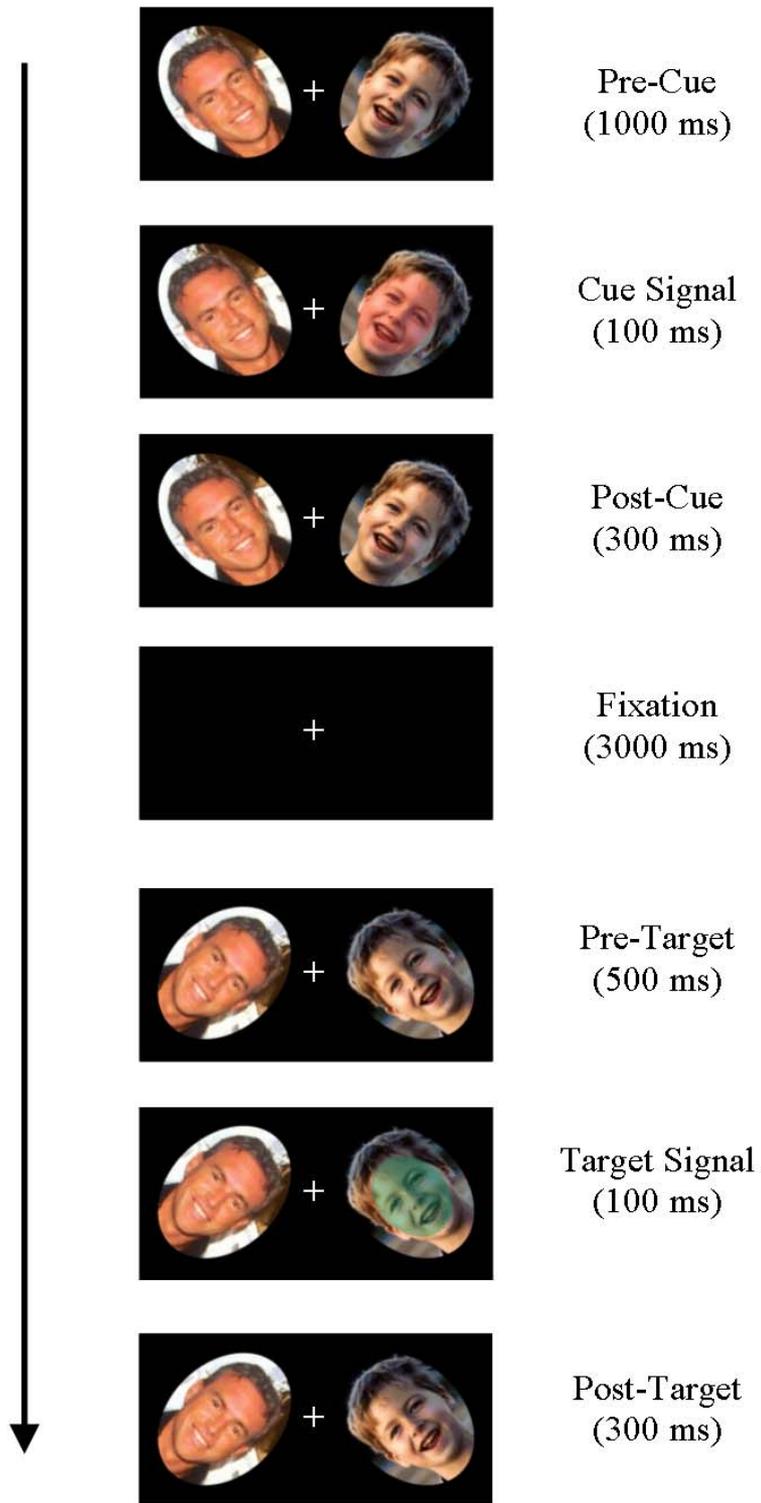


Figure 2

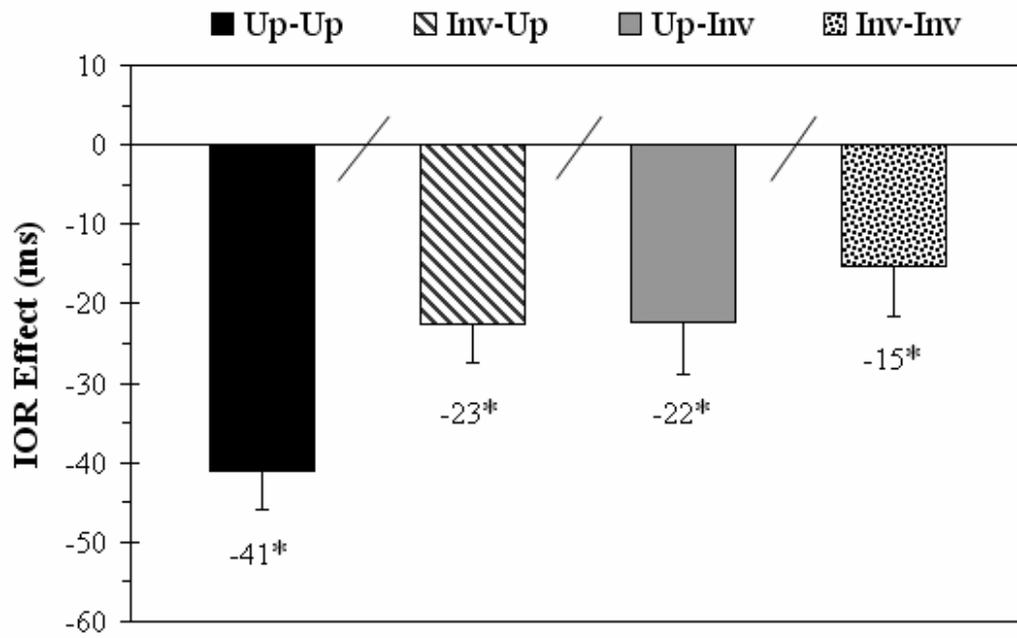


Figure 3.