

# Inhibition of object identity in inhibition of return: Implications for encoding and retrieving inhibitory processes

SARAH GRISON

*University of Illinois at Urbana-Champaign, Urbana, Illinois*

MATTHEW A. PAUL

*University of Wales, Bangor, Wales*

KLAUS KESSLER

*University of Düsseldorf, Düsseldorf, Germany*

and

STEVEN P. TIPPER

*University of Wales, Bangor, Wales*

Inhibition of return (IOR) effects, in which participants detect a target in a cued box more slowly than one 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, in the present research we 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 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 *retrieving* information about a target face. Accordingly, we propose that episodic retrieval of inhibition associated with object identity may mediate behavior in cuing tasks.

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 a 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 was deemed to be irrelevant to current behavioral goals.

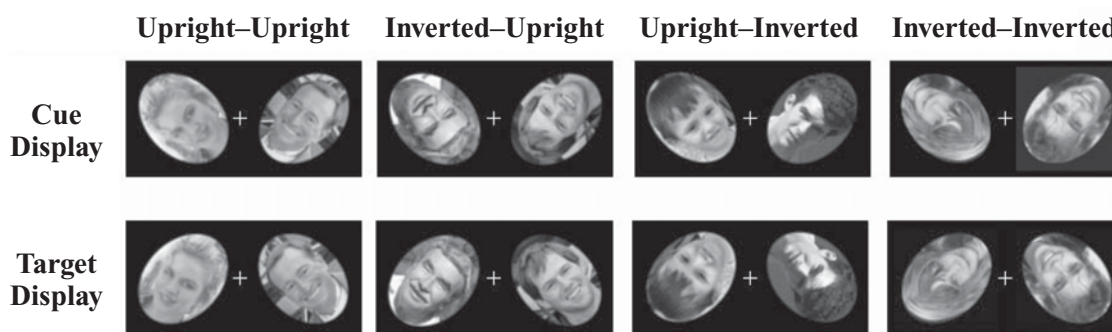
Posner and Cohen (1984) demonstrated the existence of just such a mechanism using a simple cuing paradigm. When a square to the left or right of fixation was flashed with an irrelevant cue, detection of a target appearing less than 300 msec later was *faster* in the cued square, presumably because attention was still oriented to that information. However, detection of a target appearing

more than 300 msec later was *slower* in the cued square, suggesting 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 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. Although Posner and Cohen originally described IOR effects as revealing inhibitory mechanisms that aid novelty detection in orienting tasks, subsequent research has revealed the generality of the mechanism, which also impacts performance in visual search tasks (Klein, 1988; Klein & MacInnes, 1999; Müller & von Mühlenen, 2000; Takeda & Yagi, 2000).

To date, in a variety of studies researchers have debated whether inhibition in cuing 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, 2005). For example, Tipper and his colleagues have demonstrated that after cuing, when an object moved to a new location, inhibition moved with the object, thus revealing object-based IOR effects (Tipper, Driver, & Weaver, 1991; Tipper, Jordan,

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**Figure 1.** A demonstration of the four orientation conditions: upright–upright, inverted–upright, upright–inverted, and inverted–inverted. The participants saw the stimuli in color.

& Weaver, 1999). However, this result could also reveal that inhibition was originally applied to the location of the object and that movement of the object may have updated inhibition of a spatial representation. Similarly, other studies have found greater IOR when an object rather than an empty location was cued (e.g., Jordan & Tipper, 1998; Leek, Reppa, & Tipper, 2003; Reppa & Leek, 2003) and shown that this effect lasted longer as well (Grisson, Tipper, & Kramer, 2005; Paul & Tipper, 2003). In these cases, however, it is possible that objects only 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 present research, a novel cuing task was used to examine whether IOR can reveal inhibition of object identity information. One face was shown to the left of fixation and another to the right (see also Grison, Kessler, et al., 2005; Kessler & Tipper, 2003). In the cue sequence, if a face turned red, this should have initiated orienting to that stimulus, but because the stimulus was irrelevant, inhibition should have also applied to any representations associated with the cued face. Nearly 4 sec later in the target sequence,<sup>1</sup> when the same faces were shown, participants should have been slower to localize a green target shown over the cued rather than the uncued face, as a result of residual inhibition of that stimulus. Importantly, there were four conditions (Figure 1) in which face orientation was manipulated. In the *upright–upright* condition, faces were shown upright

in both the cue and target sequences. For the *inverted–upright* condition, faces were inverted only in the cue sequence. In the *upright–inverted* condition, faces were only shown inverted in the target sequence. Finally, in the *inverted–inverted* condition, inverted faces were presented in both the cue and target sequences. Note that in each condition, the faces were oriented 45° from vertical and the change in orientation between the cue and target sequences was always 90°.

If inhibition in such a task is merely applied to location or object file representations, 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 also 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, this would most likely occur when a cued face is presented upright and is thus 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 can be inhibited when faces are 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. The participants were 12 males and 44 females, between 18 and 35 years of age, with a mean age of 19.7 years. All had normal or corrected-to-normal visual acuity and color vision. Fourteen participants were randomly assigned to each of the 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

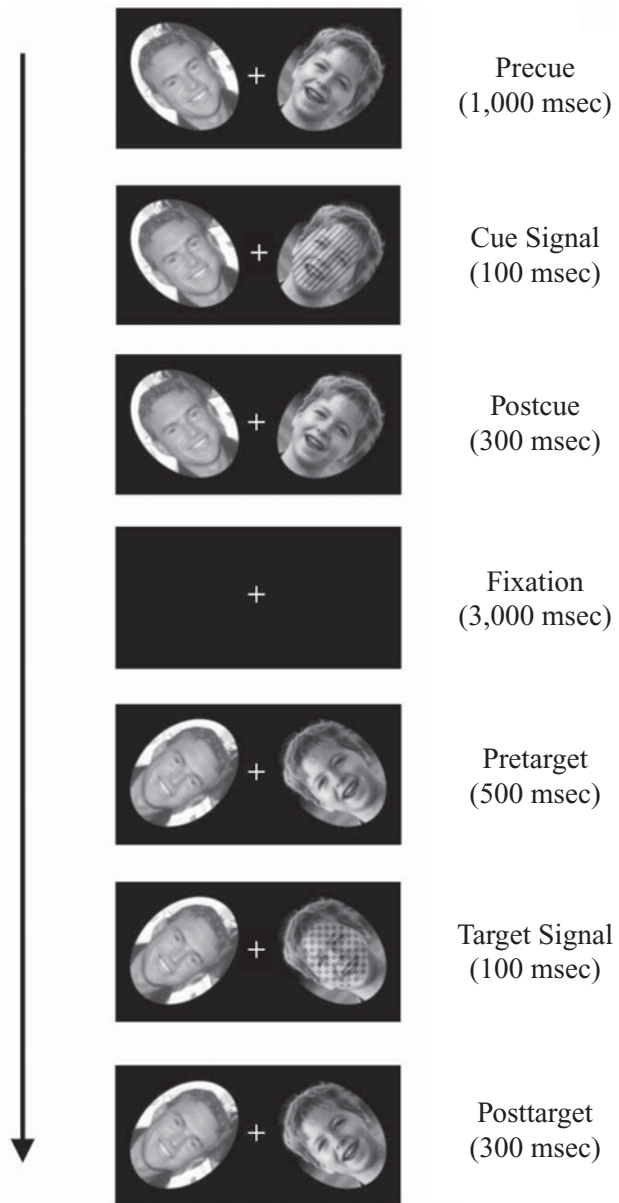
faces were created on the basis of 96 random pairings of two male faces, two female faces, or one male and one female face. Each pair of faces was seen only twice, once in the cue sequence and then again in the target sequence. All faces were presented oriented 45° from vertical, and the change in orientation between the cue and target sequences was always 90°. A chinrest was used to maintain a visual angle of 9° vertically and 7° horizontally for each of the faces, with a lateral separation of 14° from the center of the left face to the center of the right face. The visual angle for the entire display subtended 9° vertically and 21° horizontally. The imperative signals were a semitransparent red oval (i.e., “no-go” signal) or green oval (i.e., “go” signal), each measuring 5.5° vertically and 5° 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 (Psychology Software Tools, 2000) was used to create the experiment, display stimuli on a 19 in. super VGA monitor, control timing, and log responses by means of a keyboard.

### Design

The effect of orientation during the cue and target sequences was manipulated between-participants, 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 (target cuing: uncued/cued)  $\times$  2 (target location: left/right) repeated measures design. Accordingly, on half of the trials, the target appeared on an uncued face, and on the other half it appeared on a cued face. Furthermore, on half of the trials the target appeared on the left face, and on the other half 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, in which a green target appeared in the cue and target sequences, and half were a *no-go* catch condition, in which a red cue appeared in the cue and target sequences.

### Procedure

The 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 min. The procedure (Figure 2) began with the cue sequence, in which a black display was shown for 1,000 msec, followed by a 100-msec tone to indicate the start of a new trial. After a fixation display of 1,500 msec, a pair of precue faces was presented for 1,000 msec. Then a semitransparent red cue signal appeared over one face for 100 msec. After removal of the cue, the original faces were seen for a further 300 msec as the postcue. The participants were expected to withhold response to a red cue. However, in the early-response catch trials they had 1,000 msec from cue onset to respond to the location of a green cue by pressing a designated left or right key on the keyboard with the corresponding index finger. A 3,000 msec fixation screen was then shown before the target sequence began. In the target sequence, the same faces were re-presented for 500 msec as the pretarget, but they were reoriented 90° from their cue presentation. A semitransparent green target signal then appeared over one of the faces for 100 msec. After the target was removed, the original faces were seen as the posttarget for another 300 msec. From target onset, the participants had 1,000 msec 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 the no-go catch condition, the 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 sequence (1) no response was



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

made when one was expected (i.e., a miss); (2) a response was made when it should not have been (i.e., a false alarm); or (3) a response was made before target onset (i.e., an anticipation). In these cases, a 200 msec error tone sounded, and the trial ended.

## 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 analyses of variance

**Table 1**  
Means (*M*) and Standard Deviations (*SD*) of Target Reaction Times (RT, in Milliseconds)  
and Percentage Error Rates (ER) in Each of the Orientation Conditions

	Upright–Upright				Inverted–Upright				Upright–Inverted				Inverted–Inverted			
	RT		ER		RT		ER		RT		ER		RT		ER	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Uncued																
Left	366	42	2.3	2.7	400	76	0.0	0.0	412	55	0.8	3.0	385	60	1.5	3.3
Right	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																
Left	408	50	3.5	4.1	415	64	1.5	3.3	434	65	3.5	4.1	395	46	3.1	4.2
Right	411	54	2.7	4.2	421	74	0.0	0.0	432	48	2.8	5.4	415	74	1.9	2.6

(ANOVAs) were initially conducted on target response time (RT; see Table 1), with orientation condition (upright–upright/inverted–upright/upright–inverted/inverted–inverted) as the between-participants factor and a 2 (target cuing: uncued/cued)  $\times$  2 (target location: left/right) repeated measures within-participants design. The RT data showed an effect of cuing [ $F(1,52) = 81.9, p < .01$ ] that indicated slower responses to cued (417 msec) than to uncued (391 msec) targets, thus revealing significant IOR effects (–26 msec) 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 msec) than in the inverted–upright (–23 msec,  $p < .03$ ), upright–inverted (–22 msec,  $p < .03$ ), and inverted–inverted (–15 msec,  $p < .01$ ) conditions (see Figure 3).

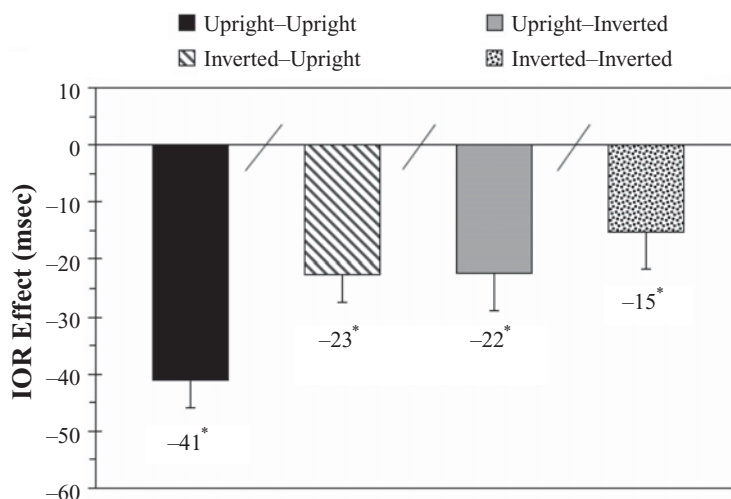
Further analysis confirmed that IOR effects were greater when face stimuli were shown upright in the cue and target sequences. When examining IOR at a certain location (left/right) on the basis of cue orientation (upright/inverted), IOR was indeed greater for upright (–32 msec) than for inverted (–19 msec) cues [ $F(1,26) = 6.3, p < .02$ ]. Similarly, when IOR effects for a given location were examined on the basis of target orientation, IOR

was again greater for upright (–32 msec) than for inverted (–19 msec) targets [ $F(1,26) = 6.5, p < .02$ ].

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

## DISCUSSION

IOR effects in cuing 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



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

level object identity information may also be inhibited. The present research involved a novel cuing task that presented upright or inverted faces in the cue and/or target sequences of a cuing 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 have been 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. Accordingly, robust IOR effects in the upright–upright condition may have been elicited because inhibition was 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 reduced 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 in which eyes were cued in inverted or upright faces or objectless locations were cued in inverted or upright scenes (Grisson, Tipper, & Kramer, 2005). Across several experiments, short-term IOR was observed over 2 sec in all of these conditions. Importantly, the effects were greater for upright than for inverted faces, thus confirming that object identity could be inhibited in cuing tasks and that inversion reduced this ability, resulting in inhibition of only locations and object files. However, IOR was no different for upright than for 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 cuing tasks. Although a variety of research has indicated that the superior colliculus mediates inhibition in IOR (Rafal, Calabresi, Brennan, & Sciolto, 1989; Sapir, Soroker, Berger, & Henik, 1999), the present findings demonstrate that processing cannot be solely mediated by this midbrain 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 present re-

sults indicate that our observation of inhibitory processes in IOR effects depended on identification of face stimuli.

The present results may also provide insight into the cognitive mechanisms mediating inhibition in IOR. Specifically, we propose that in a cuing task, the inhibitory state associated with irrelevant cue representations, such as spatial location, low-level object information, or object identity, may be implicitly encoded into episodic memory. Indeed, IOR in the present research was greater when participants could recognize and inhibit a cued face during *encoding* (i.e., in the upright–upright vs. the inverted–upright condition, and across the four orientation conditions when a cue face was shown upright vs. 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 re-create the prior processing state associated with a cued face and allow for inhibition to impact behavior.<sup>2</sup> Again, IOR in the present study was greater when participants could recognize and *retrieve* information about an inhibited target face (i.e., the upright–upright vs. the upright–inverted condition, and across the four orientation conditions when a target face was presented upright vs. inverted). Finally, because the smallest effects were seen in the inverted–inverted condition, when faces were hard to recognize in both the cue and target sequences, our results support 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 cuing tasks similar to that described here, we have found the first evidence of IOR effects over delays of several minutes and for dozens of items (Grisson, Kessler, et al., 2005; Tipper, Grison, & Kessler, 2003). Importantly, these long-term effects were only seen when cuing objects rather than empty locations in a scene (Grisson, Kessler, et al., 2005; Grison, Tipper, & Kramer, 2005). Long-term IOR can be explained by the same mechanism mediating the present short-term effects—namely, episodic retrieval of prior inhibitory processes. However, in the former case, whereas 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 may not be.

In sum, the results reported here provide insight into the processes mediating correct performance in short-term cuing tasks. Specifically, the present research suggests that behavior is not merely the result of inhibition of location and low-level object file information. Instead, our results are among the first to demonstrate that inhibition affects behavior in cuing tasks by accessing

higher level representations, such as object identity. Additionally, these findings 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 4 sec later. Most importantly, we propose that the ability to store object identity representations along with associated inhibition in episodic memory may influence behavior over long periods of time.

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## NOTES

1. Research has shown that short-term IOR effects can last between 3 and 5 sec (for reviews, see Grison, Kessler, et al., 2005; 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).

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