



# When do fearful faces override inhibition of return?



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## ABSTRACT

Inhibition of return (IOR) occurs when more than about 300 ms elapses between the cue and the target in atypical peripheral cueing task: reaction times (RTs) become longer when the cue and target locations are the same versus different. IOR could serve the adaptive role of optimizing visual search by discouraging the re-inspection of previously attended locations. As such, IOR should not reduce our chances of noticing relevant event information and emotional stimuli, in particular. However, previous studies have led to inconsistent results. The present study offers a systematic investigation of the conditions under which target fearful faces can modulate either the magnitude or the time course of the IOR effect. Notably, we manipulated the depth of facial processing required to perform the task and/or the task relevance of the facial expressions. When participants localized target faces (Experiment 1) or discriminated them from non-face stimuli (Experiment 2), their emotional expression had no impact on IOR whatsoever. However, IOR occurred later for fearful versus neutral faces when the participants performed emotion (Experiment 3) or gender (Experiment 4) discrimination tasks. These findings are discussed with regard to the mechanisms responsible for IOR and to the processing of emotional facial expressions.

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## 1. Introduction

Our visual environment is prodigiously rich and our processing capacities regrettably limited. Different attentional mechanisms are needed to select which information will undergo elaborate processing and access consciousness. Even if visually salient stimuli are in general particularly prone to capture attention, higher order processes (e.g., the expectancies or intentions of the observer) can modulate this effect (e.g., Folk, Remington, & Johnston, 1992). Moreover, the emotional nature of the competing information may also weigh in the contest. Indeed, stimuli which could have an impact on the observer's well-being or survival should in principle be subject to rapid and efficient selection. The present study is part of a recent and active effort aimed at understanding how these so-called bottom-up, top-down and emotional factors interact to promote flexible and adaptive behavior (Pourtois, Schettino, & Vuilleumier, 2013).

One of the most used methods to study attentional mechanisms is the cost and benefit paradigm (Posner, 1980). In this paradigm, a peripheral onset-cue is presented, followed after a variable temporal interval (or stimulus onset asynchrony, SOA) by a target requiring a speeded detection response. The participants are informed that the position of

the cue is not predictive of the position of the target. Yet, at short SOAs (i.e., about 100–300 ms), reaction times (RTs) are usually shorter when the target appears at the same position as the cue, which would indicate that attention has been involuntarily oriented in accordance with the (uninformative) peripheral cue. Interestingly, at longer SOAs (i.e., more than about 300 ms, Posner & Cohen, 1984), detection RTs (or discrimination RTs, see Lupiáñez, Milán, Tornay, Madrid, & Tudela, 1997) become longer to targets appearing at cued versus uncued locations.

This latter effect was coined “inhibition of return” (IOR) by Posner, Rafal, Choate, and Vaughan (1985). Its canonical interpretation is that attention is initially involuntarily captured by the cue, then disengaged, and finally inhibited to return to the position previously occupied by the cue (e.g., Berlucchi, 2006). This inhibition would be associated with impaired perceptual processes, affecting the detection of stimuli appearing at cued locations (e.g., Prime & Ward, 2006). However, even if this original explanation is still acknowledged by many researchers in the field, recent evidence indicates that IOR may rather result from multiple mechanisms, or from a single mechanism that impacts multiple stages of processing depending on the task parameters (see Berlucchi, 2006; Lupiáñez, 2010, for reviews). For example, Lupiáñez (2010) proposes that peripheral cues produce three effects (detection cost, spatial selection benefit and spatial orienting benefit), each following a different time course, and having a different contribution to performance as a function of the task set and the nature of the target. IOR could also reflect a bias against making saccades towards the location of the cue

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(e.g., Abrams & Dobkin, 1995; Rafal, Calabresi, Brennan, & Sciolto, 1989; Chica, Taylor, Lupiáñez, & Klein, 2010) or a reluctance to respond (a criterion shift) to stimuli appearing at cued locations (Klein & Taylor, 1994; see Klein, 2000, for a review).

Nonetheless, regardless of the mechanisms involved, it seems widely assumed that IOR subserves adaptive behavior. IOR would operate to encourage orienting towards novel objects and events (Posner & Cohen, 1984) and discourage wasteful re-inspections of previously attended locations (Klein, 1988). IOR would thus act as a “foraging facilitator” (Klein & MacInnes, 1999; Wang & Klein, 2010), making visual search more efficient. More conservative response criterion for cued locations would also provide the chance to gather extra information from other locations (Klein & Taylor, 1994) and allow the adjustment of decisions and behavior, precluding inaccurate or needless responses to already examined locations or objects (Ivanoff & Taylor, 2006).

If IOR is indeed ascribed evolutionary significance, its size and/or time course should be affected by the nature (the meaning, the emotional content) of the cue and/or the target: IOR should not reduce our chances of noticing event information that could be relevant for our well-being or survival, and in particular, human faces or threatening events. Indeed, faces are particularly salient stimuli, conveying crucial information for social interactions, and due to their biological and social significance, faces may enjoy a privileged processing status: detecting facial configurations is usually fast and efficient (e.g., Pegna, Khateb, Michel, & Landis, 2004) and faces would more likely attract attention to their location than other more common objects (e.g., Ro, Russell, & Lavie, 2001; Theeuwes & Van der Stigchel, 2006; see Palermo & Rhodes, 2007 for a review). Visual detection, perceptual sensory analysis and attention are also typically heightened (attention being more easily captured, and/or more difficultly disengaged) for threatening (angry or fearful faces, spiders, snakes...) relative to neutral stimuli in various tasks (e.g., dot probe tasks, visual search, attentional blink...; see Pourtois et al., 2013, for a review). Several findings suggest these effects do not reflect faster recognition or response selection once attention has been focused, but rather depend on a coarse perceptual analysis which can operate outside or before attentive fixation (see Domínguez-Borràs & Vuilleumier, 2013). At the brain level, the amygdala, a subcortical structure central to emotion appraisal and learning, could be at least partly responsible for the emotional enhancement of visual perception. The amygdala could act through direct feedback projections to visual areas (including V1) or indirect projections to the dorsal frontoparietal attentional network. Importantly, amygdala may activate to emotional stimuli without explicit attention in many (though not all) situations and this activation may occur before or in parallel with the recruitment of endogenous and exogenous attentional systems (Pourtois et al., 2013). Since its discovery, IOR has been subject to a great number of studies (see Lupianez, Klein, & Bartolomeo, 2006), but the impact of the meaning or emotional content of the cues and/or targets on IOR has received little attention so far.

A few studies have measured the effects of emotional cues on IOR, usually with the stated purpose of exploring the specifics of spatial orienting towards socially or biologically significant stimuli (e.g., neutral or emotional faces, snakes, spiders...; Fox, Russo, & Dutton, 2002; Stoyanova, Pratt, & Anderson, 2007; Lange, Heuer, Reinecke, Becker, & Rinck, 2008; Hu, He, Fan, & Lupiáñez, 2014, Experiment 1). The rationale was that if those stimuli catch and hold attention more efficiently than less relevant ones in the location where they appear, the IOR effect should be abolished, reduced, or delayed when they serve as cues: targets appearing in their location could rather be advantaged compared to targets appearing somewhere else in the visual field. However, contrary to what had been expected, the results rather indicated that manipulations of the emotional nature of the cue have no conspicuous impact on the magnitude and time course of IOR.

In another group of studies, the emotional nature of the targets has been manipulated, following the rationale that if emotionally relevant stimuli are particularly prone to capture or attract attention in an

automatic manner, then they should be able to override the IOR effect. Studies using simple target detection and localization tasks have found only partial evidence of IOR modulation by the emotional nature of the target. For example, in one study IOR was reduced in a detection task for schematic target faces bearing sad versus happy expressions, but only when they appeared in the left visual field (Baijal & Srinivasan, 2011). In another study, IOR was smaller when localizing negative (pictures of spiders or angry faces) versus neutral (objects or neutral faces) targets, but only after sustained exposure to these stimuli (i.e., when presented in blocks), not if the target type varied pseudo randomly within blocks (Rutherford & Raymond, 2010). The authors therefore suggested that the magnitude of the IOR effect depends more on the affective context set up (by repeated exposure to negative stimuli) before attentional orienting is initiated than on the emotional content of targets on current trials. Finally, in Hu et al.'s (2014) study (Experiment 2), threatening faces (compared to scrambled faces in a detection task) completely abolished IOR in schizophrenic patients but produced a very small non-significant IOR modulation in healthy participants.

Interestingly, in previous studies the emotional nature of the cue or the target was always task irrelevant: the tasks didn't require any explicit processing of the emotional dimensions of the stimuli. As far as we know, only two studies have tested the impact of emotional targets on IOR with experimental designs in which emotion was task-relevant. Pérez-Dueñas, Acosta, and Lupiáñez (2009) compared IOR for neutral, positive and negative (threat) words presented as targets in an emotional categorization task (emotional vs. neutral). They found that only participants with high trait anxiety failed to show IOR for negative words while no IOR emotional modulation occurred for participants with low trait anxiety. Thus, once again, the effect was restricted to participants with emotional disorders. Yet, the same authors have recently reported evidence that IOR selectively disappeared for angry faces (randomly presented among neutral and happy faces) when the participants had to categorize the faces as emotional or neutral (Pérez-Dueñas, Acosta, & Lupiáñez, 2014). Importantly, this latter effect was independent of the participants' state or trait anxiety levels.

Therefore, based on the preceding results, one general conclusion could be that IOR seems not to be modulated by emotional cues, but can be modulated by emotional targets, especially when emotion becomes relevant for the task and/or for the person. This proposal fits well with a growing body of evidence suggesting that attentional biases towards emotional stimuli might not be as unconditional as ordinarily thought, but instead might depend on the cognitive nature of the task (Carretié, 2014), on the task-relevance of the emotional information (Everaert, Spruyt, & De Houwer, 2013), as well as on its personal relevance (Brosch & Van Bavel, 2012).

However, previous experiments differ in several other methodological aspects which might undermine this conclusion. Firstly, they mostly included a single SOA (1000 ms for Pérez-Dueñas et al., 2009, 2014 and Rutherford & Raymond, 2010; 550 ms for Baijal & Srinivasan, 2011). Yet, non-emotional task manipulations have demonstrated that two forms of IOR modulation can coexist. For example, target discrimination in comparison to target detection usually produces a reduction of IOR together with a later onset of it (e.g., Lupiáñez et al., 1997). As a consequence, finding an IOR effect of similar size for emotional and neutral targets at one given SOA is not sufficient to conclude that emotional targets are unable to modulate IOR at shorter or longer SOAs. Secondly, the previous experiments were designed with a diversity of emotional stimuli (words, drawings or pictures of faces, pictures of spiders or objects). These various stimuli could have influenced IOR in dissimilar ways because they clearly have different emotional and ecological value (Okon-Singer, Lichtenstein-Vidne, & Cohen, 2013) and because the time courses of their emotional processing can differ, especially during the earlier stages of processing (e.g., Frühholz, Jellinghaus, & Herrmann, 2011). Finally, the experiments with facial stimuli involved different emotional expressions (i.e., angry or sad faces)

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