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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.

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), reactions times (RTs) are usually shorter when the target appears at the same position as the cue, which would indicate that attention has been involuntary 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) which may also have a different impact on IOR insofar as distinct expressions may not have the same attentional status (e.g., Whalen et al., 2001; Vuilleumier, 2002; Palermo & Rhodes, 2007).

A second important confound across studies is that even if they obviously differ regarding the task relevance of the emotional nature of the target, detection and localization tasks also differ from emotional discrimination tasks on the depth of feature processing required. Apart from emotional relevance, Pérez-Dueñas et al.'s (2009, 2014) studies were also the only studies requiring facial fine-grained processing (e.g., Atkinson & Adolphs, 2011). Therefore, one important unresolved question is whether emotional relevance is a key condition for emotional targets to modulate IOR, or if fine-grained facial processing is the critical factor.

In the light of the above considerations, the current study aimed at providing a more systematic investigation of the potential modulations of both the size and time course of the IOR effect as a function of the affective nature of the target stimuli. One key question here was whether the absence of emotional IOR modulation reported in some of the previous studies was merely due to the use of one single SOA or whether some IOR modulations could have been spotted if a larger set of SOAs had been explored. A second important aim was to further investigate the separate roles of emotional task relevance and depth of facial processing on the modulation of IOR by emotional faces.

For these purposes, in four experiments, we randomly presented various pictures of neutral and fearful faces as targets in standard spatial cueing procedures suitable to observe IOR. The experiments were designed to be as similar as possible but each involved different task requirements: target localization (left/right), face discrimination (face/non-face), emotion discrimination (fearful/neutral), or gender discrimination (male/female). Different aspects of the targets were therefore made task-relevant (location, global face configuration, emotional expression and gender), allowing us to track the impact of emotional task relevance and depth of facial processing on the modulation of IOR by fearful faces. Also, three different SOAs (500, 750 and 1000 ms) were used in order to better characterize the time course of the IOR modulation for these different task requirements. Finally, we opted for random presentations and the use of a wide range of stimuli with the idea of increasing the ecological validity of the experiments, and fearful expressions were chosen due to their special processing status as social signals of threat (e.g., Whalen et al., 2001; Anderson, Christoff, Panitz, De Rosa, & Gabrieli, 2003).

2. Experiment 1: localization task

In Experiment 1, non-face stimuli, neutral faces and fearful faces were randomly presented as targets in a target localization (left or right) task. Using a similar task and design (without fearful faces), Taylor and Therrien (2005, 2008) showed that emotionally neutral faces do not escape the effects of IOR more readily than non-face configurations at various SOAs. On the contrary, Rutherford and Raymond (2010) reported that IOR could be reduced when localizing negative targets (pictures of spiders or angry faces) versus neutral ones but exclusively when emotional and neutral targets were presented separately in a between-group design. Thus, it could be expected that the IOR would not be different for the different types of targets used in the present experiment. However, Taylor and Therrien (2005, 2008) used a single, high-pass filtered image of a human face (whose ecological validity and general relevance might be questioned) as targets, and Rutherford and Raymond (2010) investigated a unique 1000-ms SOA in their within-subject designs. This leaves open the possibilities that more naturalistic and varied faces can lead to a reduced IOR when compared to non-face stimuli and/or that emotional modulations of IOR can be observed at shorter SOAs.

2.1. Method

2.1.1. Participants

Participants in this and the subsequent experiments were recruited from students of Clermont Université. They contributed data in exchange for course credit, gave their informed consent (but were naïve to the experimental purpose) and reported normal or corrected-to-normal vision. Twenty right-handed participants (1 male, mean age $= 22.7 \pm 2.8$ SD) took part in Experiment 1. The data from one participant were removed due to an average percentage of correct responses smaller than two standard deviations below the group mean.

2.1.2. Apparatus and stimuli

Participants were seated in a quiet room with low ambient illumination; in front of a 14-in VGA monitor (1024×1280 resolution, 60 Hz) at a distance of approximately 60 cm. The presentation of the stimuli, timing operations and data collection were controlled by E-Prime 2.0 software (Psychology Software Tools, Pittsburgh, PA, United States).

One-hundred and twenty photographs of faces (30 male, 30 female, each with a neutral and a fearful expression) and 10 oval non-face stimuli ("blurred" oval shapes made of superimposed visual white noises of different - high and low - spatial frequencies) served as targets. Faces were obtained from the Karolinska Directed Emotional Faces database (KDEF, Lundqvist, Flykt, & Öhman, 1998), converted to gray scale, and cropped to fit within an oval shape close to the overall shape of the face stimuli (to omit extraneous cues such as the ears, hairline, and neck). Face and non-face stimuli covered a visual angle of about $3.2° \times 3.8°$. An open black oval ($3.2° \times 3.8°$) served as a cue in all conditions. All cues and targets appeared in black empty squares ($4.2° \times 4.2°$). The stimuli were presented on a gray background, and mean luminance and contrast across the different stimulus categories were equated (Adobe Photoshop® software).

2.1.3. Procedure

A trial began with a fixation cross (a black plus sign), displayed for 750 ms in the center of the screen, flanked on its left and right sides by two black empty squares that remained on the screen throughout the trial (until the offset of the target, see Fig. 1). The center of each square was 5° from the center of the fixation cross. Then, the cue appeared for 200 ms in one of the two frames, with equal probability. After cue offset, the fixation cross remained for 50 ms and changed into a black dot for 150 ms to encourage central orienting (see Prime, Visser, & Ward, 2006). The fixation cross then reappeared for either 100, 350 or 600 ms before the target stimulus (neutral face, fearful face or non-face stimulus, one third each) was displayed for 200 ms, either in the previously cued (valid) or uncued (invalid) location, with equal probability. Therefore, the SOAs were 500 (short SOA), 750 (medium SOA), or 1000 ms (long SOA). After target offset, a question mark was displayed in the center of the screen. After the participant's response or after 2 s, the question mark turned to an equal sign and remained so until the participant pressed the spacebar with his/her left hand to initiate the next trial.

The total of 720 randomized trials was divided equally into 40 trials for each combination of cueing (cued vs. uncued location), target type (non-face, neutral face, fearful face) and SOA (short, middle, long). The gender of the target faces was fully balanced across the experimental conditions. The experiment began with 12 practice trials, followed by 5 blocks of 144 trials (in which all possible combinations of the experimental variables appeared with equal probability) separated by rest periods that the participants could end by pressing the spacebar.

The participants performed a target localization task, in which they were asked to press, as quickly and as accurately as possible, the left or right mouse button to report left and right, respectively. In this and subsequent experiments, participants were informed that the position of the cue was not predictive of where the target would appear. They

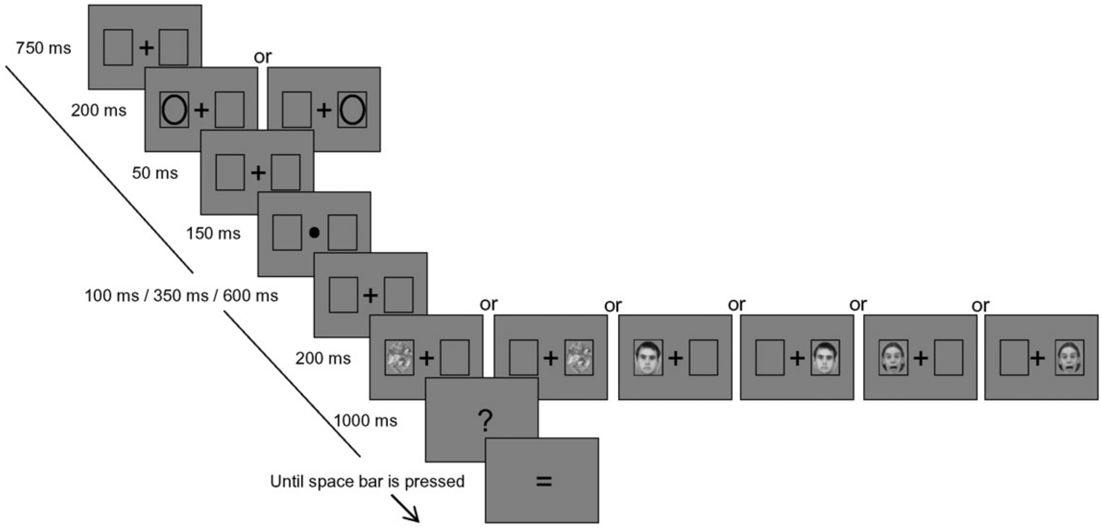

Fig. 1. Sequence of events in a typical experimental trial (in Experiments 3 and 4, non-face targets were excluded).

were asked to center their attention on the fixation cross and to avoid looking directly at the cue or at the target.

2.1.4. Data analysis

In this and the subsequent experiments, only response times (RTs) from trials with a correct response were included in the analyses. For each participant, trials with RTs faster than 200 ms or slower than three standard deviations above his/her mean RT were treated as errors and excluded from the RT analyses. The effects of the experimental variables on RTs and error rates were assessed by ANOVAs using cueing (cued, uncued location), target type (neutral face, fearful face, non-face for Experiments 1 and 2; neutral face, fearful face, for Experiments 3 and 4) and SOA (short, medium, long) as within-subject factors. Whenever the assumption of sphericity was violated, p-values were adjusted using the Greenhouse–Geisser correction (and ε are reported). An alpha level of .05 was used for all statistical tests.

2.2. Results and discussion

Only 0.7% of the trials were excluded due to too slow or too fast RTs. Mean correct RTs (see Table 1) were on average 28 ms faster for uncued than for cued targets ($F(1,18) = 25.38$, $p < .001$, $\eta_p^2 = .58$), indicating the presence of IOR. The main effect of target type ($F(2,36) = 5.23$, $p < .05$, $\eta_p^2 = .22$) was significant, revealing faster RTs for localizing faces than non-faces (neutral faces vs. non-faces: $t(18) = 2.07$, $p = .05$; fearful faces vs. non-face: $t(18) = 3.55$, $p < .01$; neutral faces vs. fearful faces: $t < 1$). There was also a significant main effect of SOA ($F(2,36) = 47.25$, $p < .001$, $\varepsilon = .600$, $\eta_p^2 = .72$), with overall RTs decreasing with increasing SOA. Increasing SOA generally produces an overall speeding effect on RTs, due to global alerting/preparatory effects and reduced temporal uncertainty. Note that this classical foreperiod effect (Niemi & Näätänen, 1981) was found in this and all the following experiments. Importantly, none of the interactions involving target type and cueing were significant (target type x cueing: $F < 1$; target type x cueing x SOA: $F(4,72) = 1.43$, $\varepsilon = .699$, $p > .20$).

Since we were mainly interested in the effect of the expression of the faces on IOR, and in order to ease the comparison with the following experiments which did not include non-face targets, we performed a second ANOVA on RTs without the non-face target data (target type: neutral face, fearful face; see Fig. 2A). Again, the main effects of cueing and SOA reached significance ($F(1,18) = 18.51$, $p < .001$, $\eta_p^2 = 0.51$, and $F(2,36) = 39.73$, $\varepsilon = .586$, $p < .001$, $\eta_p^2 = 0.69$, respectively), indicative of overall IOR and foreperiod effects, respectively. The effect of target type was not significant ($F < 1$). Likewise, none of the interactions involving target type and cueing were significant (target type x cueing: $F < 1$; target type x cueing x SOA: $F(2,36) = 1.22$, $\varepsilon = .777$, $p > .30$).

With respect to error rates (2.19% on average, see Table 1), the same ANOVAs (with and without non-face targets) led to no significant effect.

Table 1
Localization mean correct RTs (in milliseconds) and percent error rates (standard errors in brackets) in Experiment 1 as a function of target type (non-face, neutral face, fearful face), target location (cued, uncued), and cue-target stimulus onset asynchrony (SOA: 500, 750, 1000 ms).

Target type	Target location	Cue-target SOA					
		500 ms		750 ms		1000 ms	
		RTs	Errors	RTs	Errors	RTs	Errors
Non-face	Cued	601 (35)	1.75 (0.48)	557 (33)	1.75 (0.52)	553 (33)	2.44 (0.89)
	Uncued	567 (33)	2.31 (0.6)	542 (35)	1.59 (0.39)	520 (32)	2.97 (0.84)
	IOR	34***		15*		33**	
Neutral face	Cued	600 (34)	2.26 (0.66)	548 (33)	1.48 (0.54)	542 (30)	2.27 (0.58)
	Uncued	564 (37)	2.93 (0.8)	530 (33)	1.91 (0.33)	518 (32)	2.57 (0.69)
	IOR	36**		18*		24**	
Fearful face	Cued	587 (34)	2.5 (0.81)	555 (34)	1.87 (0.51)	547 (32)	1.46 (0.55)
	Uncued	557 (34)	2.65 (0.52)	523 (33)	2.17 (0.56)	523 (33)	2.59 (0.6)
	IOR	30***		32***		24*	

*** p < .001.
** p < .01.
* p < .05.

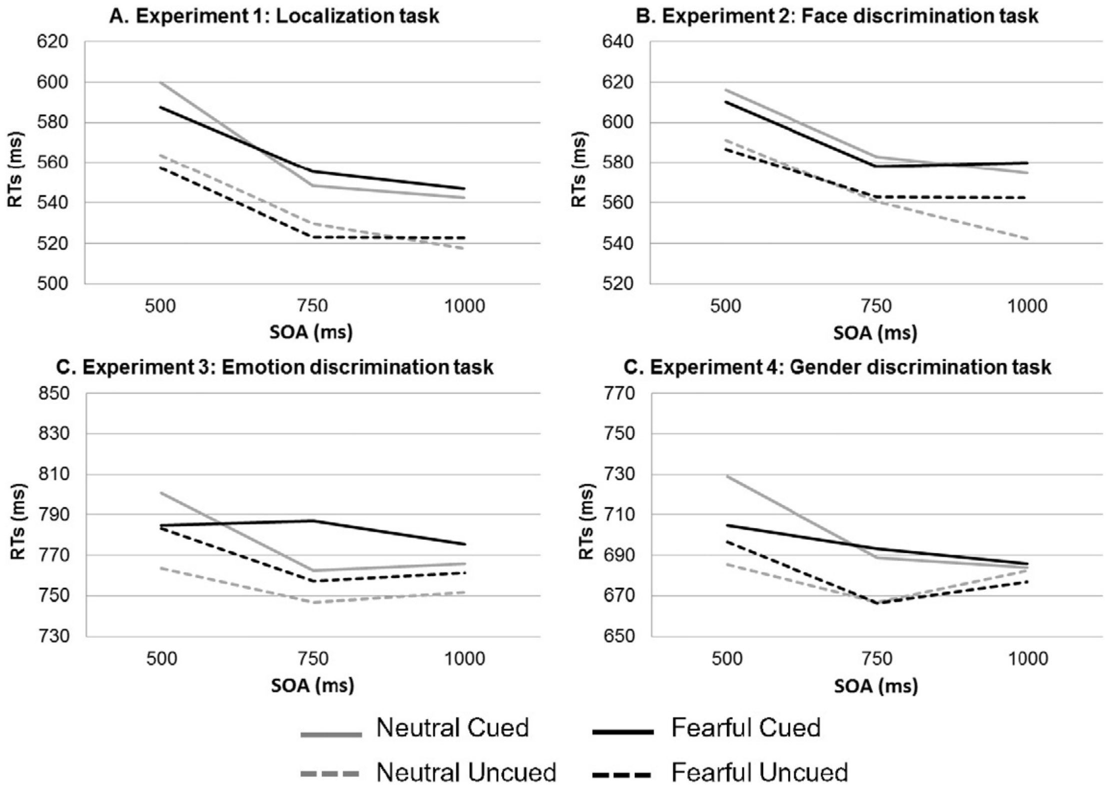

Fig. 2. Mean correct reaction times (RTs) for the four different tasks as a function of cueing (cued or uncued location), target type (neutral or fearful face), and SOA (500 ms, 750 ms or 1000 ms).

Thus the RT findings do not appear to be compromised by a speed-accuracy trade-off.

To sum up, in accordance with previous results showing rapid and efficient detection of face stimuli (e.g., Purcell & Stewart, 1988), our participants were overall faster to localize faces rather than non-face stimuli. Moreover, concerning IOR, the present results are consistent with those reported by Taylor and Therrien (2005); Taylor & Therrien, 2008 and Rutherford and Raymond (2010): it appeared that when the observer is involved in a localization task, faces, regardless of the emotional expression they depict, cannot deter IOR once initiated by an irrelevant cue. One reason for this lack of IOR modulation might be that under target localization requirements, the processing of the irrelevant emotional features of the target either didn't take place at all, or was too superficial and insufficient to interact with the mechanisms responsible for IOR. Such a proposal is strengthened by the fact that none of the main or interaction effects involving the emotional vs. neutral target type factor reached significance.

In line with the idea that the influence of target identity on IOR may depend on the task demands, IOR can emerge later (or be larger, depending on the specificities of the task design and of the trial events) for neutral faces when they appear as targets in a face/non-face discrimination task but not in a localization task (Taylor & Therrien, 2008). However, compared with localization tasks, discrimination tasks not only require a deeper processing of the targets but also make the identity ("faceness") of the target task-relevant. Would engaging the participants in a deeper level of target processing by merely drawing their attention on the nature (face/non-face) of the targets be sufficient to allow emotional targets to have an impact on the IOR effect, even if emotional expressions are task-irrelevant? Since to our knowledge, emotional stimuli have never been presented in such discrimination tasks, this is what we investigated in Experiment 2.

3. Experiment 2: face discrimination task

Experiment 2 was very similar to Experiment 1 except that the participants were asked to perform a face/non-face discrimination task.

3.1. Method

3.1.1. Participants

Twenty right-handed participants (1 male, mean age = 20.6 ± 2 SD) took part in Experiment 2. None had participated in Experiment 1. The data from one participant were removed due to an average percentage of correct responses smaller than two standard deviations below the group mean, and an average RT faster than two standard deviations below the group mean.

3.1.2. Apparatus and stimuli

The apparatus and stimuli were identical to those used in Experiment 1.

3.1.3. Procedure

The trial sequence was identical to that of Experiment 1, but the structure of the experiment was slightly different to allow for face and non-face responses to be equiprobable. A total of 768 randomized experimental trials was divided equally into 64 trials for each combination of cueing (cued vs. uncued location), target type (face, non-face) and SOA (short, middle, long). The expression depicted by the target faces (neutral or fearful), as well as their gender, were fully balanced across the experimental conditions (cueing x SOA). Twelve practice trials were followed by 5 blocks of 192 trials each.

The participants had to indicate, as quickly and as accurately as possible, whether the target stimulus was a face or not by pressing a pre-assigned mouse button. Ten participants pressed the left button for

Table 2
Face discrimination mean correct RTs (in milliseconds) and percent error rates (standard errors in brackets) in Experiment 2 as a function of target type (non-face, neutral face, fearful face), target location (cued, uncued), and cue-target stimulus onset asynchrony (SOA: 500, 750, 1000 ms).

Target type	Target location	Cue-target SOA					
		500 ms		750 ms		1000 ms	
		RTs	Errors	RTs	Errors	RTs	Errors
Non face	Cued	619 (22)	3.51 (0.74)	588 (22)	3.76 (0.75)	585 (20)	3.68 (0.74)
	Uncued	605(20)	4.5 (0.88)	576 (23)	3.81 (0.76)	568 (21)	3.82 (0.73)
	IOR	15*		12*		16**	
Neutral face	Cued	616 (21)	4.19 (0.87)	583 (22)	4.97 (1.23)	575 (23)	3.45 (1.19)
	Uncued	590 (20)	4.17 (0.7)	560 (21)	5.99 (1.12)	542 (17)	3.33 (0.7)
	IOR	25**		22**		32**	
Fearful face	Cued	610 (21)	5.33 (0.86)	577 (21)	4.54 (1.23)	580 (21)	5.32 (0.95)
	Uncued	587 (19)	3.98 (0.92)	563 (22)	4.44 (1.27)	563 (20)	4.99 (1.01)
	IOR	23**		14*		17*	

** $p < .01$.
* $p < .05$.

faces and the right button for non-faces; the button assignment was reversed for the remaining participants. In all other respects, the procedure was the same as that of Experiment 1.

3.2. Results and discussion

Only 0.9% of the trials were excluded due to too slow or too fast RTs. RTs (see Table 2) were on average 19 ms faster for uncued than for cued targets ($F(1,18) = 44.9$, $p < .001$, $\eta_p^2 = .71$), indicating the presence of IOR. The main effect of SOA (decline in RTs as SOA became longer) was again significant ($F(2,36) = 50.68$, $p < .001$, $\eta_p^2 = .74$). The interaction between target type and cueing was close to significance ($F(2,36) = .21$, $p = .052$, $\eta_p^2 = .15$) but not the interaction between the three factors ($F(4,72) < 1$). Across SOAs, IOR was present for all types of target (non-faces: $t(18) = 4.7$, neutral faces: $t(18) = 5.56$, fearful faces: $t(18) = 3.31$; all ps < .001), but appeared larger for neutral faces (27 ms) than for non-faces (14 ms; $t(18) = 3.27$, $p < .01$). IOR for fearful faces (19 ms) was of intermediate size, but did not differ significantly from any of the other two target types (both ps > .25).

Again, we performed a second ANOVA on RTs without the non-face target data (target type: neutral face, fearful face; see Fig. 2B). Just as in the previous analysis, the main effects of cueing and SOA reached significance ($F(1,18) = 34.62$, $p < .001$, $\eta_p^2 = 0.66$, and $F(2,36) = 45.97$, $p < .001$, $\eta_p^2 = 0.73$, respectively), indicative of overall IOR and foreperiod effects. However, neither the effect of target type, nor the interactions involving this factor were significant (all ps > .27).

The same ANOVAs (with and without non-face targets) performed on error rates (4.32% on average, see Table 2) led to no significant effects.

The present results resemble those obtained by Taylor and Therrien (2008): across SOAs, we observed an overall larger IOR for neutral faces than for non-faces when face configuration was made task-relevant. Note however that Taylor and Therrien (2008) observed a similar effect when only one 1000 ms SOA was used (Experiments 1 and 2). When they investigated IOR modulation at various SOAs (Experiment 3), they did not replicate this size effect but rather found that IOR emerged later for faces than for non-faces. Again, important methodological differences between the experiments designed by these authors and the current one (such as the use of the face of a single versus 60 individuals) could be responsible for the discrepancies.

Paired t-test comparing RTs (averaged across SOAS) for the three target types at uncued locations revealed that RTs were faster for neutral faces (565 ms) than for non-faces (586 ms; $t(18) = 2.52$, $p < 0.05$; neutral faces versus fearful faces: $p > .20$). At cued locations, however, no significant difference was found (all ps > 0.28). Thus, it seems that a larger IOR effect occurred for neutral faces because the slight RT advantage for face targets that would otherwise happen is reduced or suppressed at cued locations. In other words, these results suggest that even if making face configuration task-relevant can lead to different IOR effects for face and non-face targets, faces cannot overcome the IOR initiated by the presentation of an irrelevant cue.

Regarding the influence of emotion on IOR, just as in Experiment 1, the emotional expressions of the faces modulated neither the magnitude nor the time course of the IOR. Importantly, even if the two tasks we used so far differ in terms of the depth of face processing they required, the emotional aspects of the targets were task irrelevant in both cases. Yet, Taylor and Therrien's (2008) study as well as Experiments 1 and 2 suggest that a given stimulus dimension ("faceness" in the present case) has to be task-relevant to observe IOR modulations. Moreover, Pérez-Dueñas et al. (2014), the only ones to report that IOR could be abolished SOA for emotional targets (angry faces) at a single 1000 ms in an unselected sample of participants, were also the only ones to ask their participants to explicitly process the emotional expression of face targets. This led us to suggest that task relevance of emotion

Table 3
Emotion discrimination mean correct RTs (in milliseconds) and percent error rates (standard errors in brackets) in Experiment 3 as a function of target type (neutral face, fearful face), target location (cued, uncued), and cue-target stimulus onset asynchrony (SOA: 500, 750, 1000 ms).

Target type	Target location	Cue-target SOA					
		500 ms		750 ms		1000 ms	
		RTs	Errors	RTs	Errors	RTs	Errors
Neutral face	Cued	801 (23)	14.78 (1.66)	762 (21)	9.74 (1.41)	766 (21)	8.18 (1.59)
	Uncued	763 (21)	8.17 (1.23)	747 (23)	8.89 (1.37)	752 (20)	6.25 (0.93)
	IOR	37***		16*		14	
Fearful face	Cued	785 (23)	11.66 (1.52)	787 (22)	13.58 (1.77)	776 (21)	12.5 (1.77)
	Uncued	783 (27)	12.02 (1.7)	757 (21)	10.34 (1.41)	761 (21)	14.54 (1.63)
	IOR	2		29**		14	

*** $p < .001$.
** $p < .01$.
* $p < .05$.

might be a prerequisite for the emotional content of the target to affect the magnitude and/or the time course of IOR. This is what we investigated in Experiment 3.

4. Experiment 3: emotion discrimination task

The design of Experiment 3 was exactly the same as the one of Experiments 1 and 2 except that non-face trials were removed and that the participants were required to categorize the target faces as neutral or fearful. If explicit emotional processing is truly a decisive factor, these changes in the task requirements may be sufficient to unveil IOR modulations by emotion.

4.1. Method

4.1.1. Participants

Thirty-one right-handed participants (2 male, mean age $= 20 \pm 1.4$ SD) took part in Experiment 3. None had participated in Experiment 1 or 2. The data from five participants were removed, three due to an average percentage of correct responses smaller than two standard deviations below the group mean, two due to an average RT slower than two standard deviations below the group mean.

4.1.2. Apparatus and stimuli

The apparatus and stimuli were the same as those of Experiments 1 and 2.

4.1.3. Procedure

The trial sequence was identical to that of Experiments 1 and 2. Regarding the structure of the experiment, non-face trials were removed from the design of Experiment 2. Thus, a total of 384 randomized experimental trials was divided equally into 32 trials for each combination of cueing (cued vs. uncued location), target type (neutral face, fearful face) and SOA (short, middle, long). The gender of the target faces was again fully balanced across the experimental conditions. Twelve practice trials were followed by 4 blocks of 96 trials each.

The participants indicated, as quickly and as accurately as possible, whether the target face had a neutral or a fearful expression. Half of the participants pressed the left mouse button for fearful faces and the right button for neutral faces; the reverse was true for the other half. In all other respects, the procedure was identical to that of Experiments 1 and 2.

4.2. Results and discussion

4.14% of the trials were excluded due to too slow or too fast RTs. The mean correct RT analysis (see Table 3) revealed the overall presence of IOR (20 ms; main effect of cueing: $F(1,25) = 11.96$, $p < .01$, $\eta_p^2 = .32$) and the typical foreperiod effect (main effect of SOA: $F(2,50) = 12.81$, $p < .001$, $\varepsilon = 0.825$, $\eta_p^2 = .34$). Crucially, the last significant effect of this analysis was the interaction of target type with cueing and SOA ($F(2,50) = 4.15$, $p < .05$, $\eta_p^2 = .14$), suggesting that the effect of target type on IOR could change as a function of SOA (see Fig. 2C). Therefore, for each SOA, RTs were introduced into separate repeated measures ANOVAs, with target type (neutral face, fearful face) and cueing (cued vs. uncued location) as independent variables. At the short SOA (500 ms), the main effect of cueing was significant ($F(1,25) = 6.64$, $p < .05$, $\eta_p^2 = .21$) but so was the interaction between the two factors ($F(1,25) = 6.99$, $p < .05$, $\eta_p^2 = .22$): IOR was present for neutral faces (37 ms; $t(25) = 3.8$, $p < .001$), but completely absent for fearful faces (2 ms; $t(25) = 0.16$, $p > .80$). at the medium SOA (750 ms), only the main effect of cueing was significant ($F(1,25) = 12.44$, $p < .01$, $\eta_p^2 = .33$), indicating that IOR was present (22 ms) and did not vary as a function of target type (cueing x target type interaction: $F(1,25) = 2.25$, $p > .12$). Finally, at the long SOA (1000 ms), only the main effect of cueing was marginally significant ($F(1,25) = 3.39$, $p = .077$, $\eta_p^2 = .12$), reflecting a vanishing IOR (14 ms) for both types of target.

With respect to error rates (10.89% on average, see Table 3), the interaction of target type with cueing and SOA was significant ($F(2,50) = 4.82$, $p < .05$, $\eta_p^2 = .16$). Therefore, we performed separate repeated measures ANOVAs for each SOA, with target type (neutral face, fearful face) and cueing (cued vs. uncued location) as independent variables. At the short SOA (500 ms), the main effect of cueing ($F(1,25) = 6.77$, $p < .05$, $\eta_p^2 = 0.21$) and the interaction between the two factors ($F(1,25) = 7.80$, $p < .05$, $\eta_p^2 = .24$) were significant. At the medium SOA (750 ms), only the main effect of cueing was close to significance ($F(1,25) = 3.57$, $p < .07$, $\eta_p^2 = .12$). Finally, at the long SOA (1000 ms), none of the effects reached significance. Importantly, significant results found when error rates were analyzed always mirrored the pattern of results observed in the analyses of mean correct RTs. In consequence, the RT findings do not appear to be compromised by a speed-accuracy trade-off.

To sum up, in sharp contrast with the null effects we observed with a target localization task in Experiment 1, and with a face/non-face discrimination task in Experiment 2,we found that IOR occurred later for fearful faces than for neutral faces when an emotion discrimination task was used. Precisely, a large IOR effect was present for neutral faces but not for fearful faces with a SOA of 500 ms; with a SOA of 750 ms, robust IOR of similar magnitude was observed for both types of targets; and with a SOA of 1000 ms, IOR was only marginally significant for both types of targets. The present results are thus consistent with those by Pérez-Dueñas et al. (2014), since they indicate that IOR can be affected by the emotional content of target stimuli provided that the participants are engaged in explicit emotional processing.[1]

However, the three different tasks we used so far differ not only with regards to the task relevance of emotional processing, but also on the depth of face processing required to be executed. As already mentioned, target localization tasks merely require the localization of any onset regardless of its identity. Face/non-face and emotion discrimination tasks both require participants to process the physical features of the targets but decoding emotional expressions surely necessitates more fine-grained processing (e.g., Atkinson & Adolphs, 2011). In order to better investigate whether task relevance is a necessary condition for emotional faces to modulate IOR, Experiment 4 was conceived to be similar to Experiment 3 in terms of depth of face processing, but different in terms of emotional task relevance.

5. Experiment 4: gender discrimination task

In this last experiment, participants judged the facial gender of the targets (e.g., Gorno-Tempini et al., 2001; Critchley et al., 2000). If emotional relevance is a key condition for emotional targets to override IOR, results of Experiment 4 might be more similar to the ones of Experiments 1 and 2, where emotion was also task irrelevant. On the contrary, if fine-grained facial processing is the critical factor for emotional faces to modulate IOR, then the results of Experiment 4 might resemble those of Experiment 3.

[1] Note however that Pérez-Dueñas et al. (2014) reported that IOR was absent for angry (but not neutral) faces at a SOA of 1000 ms while at the very same SOA, we found (vanishing) IOR of equivalent magnitude for fearful and neutral faces. Two main factors could be responsible for this discrepancy. First, fearful and angry facial expressions are thought to signal qualitatively different threats: anger directly represents an immediate threat for the observer (an aggressor), while fear signals the presence of an undetermined danger in the environment. Because they are ambiguous and require more detailed processing to determine appropriate responding, fearful faces would have a specific link with the attentional system (e.g., Whalen et al., 2001). Second, Pérez-Dueñas et al. (2014) investigated IOR at one single SOA while three SOAs were included in our experiment. The range of SOAs used in an experiment has proven to have an impact on the time course of the IOR (e.g., Cheal and Chastain, 2002). It could result from the fact that the temporal predictability of the onset of the target event is higher when a unique versus several SOAs are used, a difference which is known to have various repercussions on perception and action (see Nobre, Correa & Coull, 2007).

5.1. Method

5.1.1. Participants

Thirty-one right-handed participants (3 male, mean age = 20.1 ± 2.1 SD) took part in Experiment 4. None had participated in the previous experiments. The data from four participants were removed, two due to an average percentage of correct responses smaller than two standard deviations below the group mean, one due to an average RT slower than two standard deviations below the group mean, and one due to a technical problem during the experiment.

5.1.2. Apparatus and stimuli

The apparatus and stimuli were the same as those of Experiments 1 to 3.

5.1.3. Procedure

The procedure was the same as that of Experiment 3, but participants performed a target gender discrimination task: they indicated, as quickly and as accurately as possible, whether the target face was a male or a female face. Fourteen participants pressed the right mouse button for male faces and the left mouse button for female faces; the button assignment was reversed for the remaining participants.

5.2. Results and discussion

2.15% of the trials were excluded due to too slow or too fast RTs. Mean correct RTs were on average faster in Experiment 4 (688 ms ± 25) than in Experiment 3 (770 ms ± 21; $t(51) = 2.52$, $p < .05$). Apart from that, the results of Experiment 4 were very similar to those of Experiment 3 (see Table 4 and Fig. 2D). Again, we found a main effect of cueing (overall IOR: 18 ms; $F(1,26) = 18.46$, $p < .001$, $\eta_p^2 = .41$) and SOA ($F(2,52) = 15.80$, $p < .001$, $\varepsilon = 1.89$,$\eta_p^2 = .38$), as well as an interaction between the three variables ($F(2,52) = 5.66$, $p < .05$, $\varepsilon = .670$, $\eta_p^2 = .18$). a repeated measures ANOVA with target type (neutral face, fearful face) and cueing (cued vs. uncued location) as independent variables was therefore run for each SOA separately. Just as in Experiment 3, at the short SOA (500 ms), both the main effect of cueing ($F(1,26) = 7.59$, $p < .05$, $\eta_p^2 = .23$) and the interaction between the two factors ($F(1,26) = 5.35$, $p < .05$, $\eta_p^2 = .17$) were significant. IOR was present for neutral faces (43 ms; $t(26) = 2.77$, $p = .01$), but not for fearful faces (8 ms; $t(26) = 1.19$, $p > .24$). At the medium SOA (750 ms), only the main effect of cueing was significant ($F(1,26) = 9.06$, $p < .01$, $\eta_p^2 = .26$), indicating that IOR was present (24 ms) and did not vary as a function of target type. Finally, at the long SOA (1000 ms), none of the effects reached significance (all $Fs > .20$). RTs for uncued targets were no longer significantly faster than RTs for cued targets (average difference: 5 ms).

With respect to error rates (12.4% on average, see Table 4), the only significant effect was the main effect of SOA ($F(2,52) = 8.45$, $p < .001$, $\varepsilon = 1.682$, $\eta_p^2 = 0.25$): error rates decreased as the SOA increased.

To sum up, the results of Experiment 4 strikingly resemble those of Experiment 3: with a SOA of 500 ms, IOR was large for neutral faces but completely absent for fearful faces; at a SOA of 750 ms, both types of targets led to a robust IOR effect; and with a SOA of 1000 ms, IOR disappeared for both types of targets. Thus, just as with an emotion discrimination task, IOR occurred later for fearful faces when a gender discrimination task was used. These results clearly show that task relevance of the emotional dimension of the targets might be sufficient but not necessary to observe emotional modulations of IOR. Instead, the implicit processing of emotional features taking place in a non-emotional gender discrimination task has proved to modulate IOR to the same extent as when emotional features are explicitly processed. Consequently, these results clearly indicate that the common stage of facial processing required for both explicit gender and explicit emotional discriminations, i.e., full structural encoding, is the one required for emotional faces to be able to modulate the time course of IOR.

6. General discussion

In four experiments we tested under which task conditions fearful target faces might or might not modulate the magnitude and/or the time course of IOR, using a range of different SOAs (500, 750 and 1000 ms). Experiment 1, showed that emotional faces have no impact on IOR whatsoever when the participants perform a target localization task. These first results are consistent with those of previous experiments also using simple tasks which didn't require any explicit face processing (detection and localization tasks; Baijal and Srinivasan, 2011; Hu et al., 2014; Rutherford & Raymond, 2010). They also complement them by showing that emotional modulations cannot be spotted with such tasks even when looking at different SOAs. Experiment 2, which involved a face/non-face discrimination task, again led to similar results despite the fact that the participants were engaged in a deeper target processing. At this point, it thus seemed that, as long as the emotional aspects of the faces are irrelevant for the task at hand, participants can somehow ignore them, so that they are not able to overcome the IOR effect. In line with this proposal, when in Experiment 3 the emotional aspects of the target faces were made task-relevant by asking the participants to discriminate neutral from fearful expressions, IOR was dramatically modulated by emotion: at the shortest SOA, a large IOR was present for neutral faces but completely absent for fearful faces. At longer SOAs, an IOR effect arose for fearful faces, similar to the one found for neutral faces. This finding is in agreement with a recent study by Pérez-Dueñas et al. (2014), in which IOR also disappeared for negative emotional (angry) faces compared to neutral and positive (happy) ones in a similar emotional discrimination task. However, since these authors used a single 1000 ms SOA, the current results also extend their findings by showing that IOR modulation by emotion only occurred at the shortest SOA (500 ms) when several SOAs are intermixed. So far, the results thus converged towards the idea that emotional expression has to be explicitly processed for a fearful face to override IOR. However, it remained possible that the modulation took place merely because the emotional discrimination task, compared with all the other tasks used so far, demanded a more detailed (fined-grained) processing of the targets' facial features. Therefore, in Experiment 4 participants performed a gender discrimination task in which, the depth of face processing is thought to be similar to the one required for an emotion categorization task but the faces emotional expression is incidental to the task at hand (e.g., Gorno-Tempini et al., 2001; Critchley et al., 2000). The results of Experiment 4 strikingly mirrored those of Experiment 3: IOR completely disappeared for negative faces at the shortest SOA, where the effect was already present for neutral targets. Thus, emotional task relevance appears to be a sufficient but not a necessary condition for fearful faces to override IOR. An incidental (implicit) but sufficiently deep processing of facial emotional features seems to be the critical factor.

What do these findings tell us about the mechanisms responsible for IOR? As mentioned in the introduction, IOR can be explained in many different ways and a variety of potential causes, mechanisms, effects and components have been proposed for this phenomenon (see Lupiáñez, 2010, for a review; see also Dukewich & Klein, 2015 for a critical survey). Although there are some disagreements, it has been proposed that IOR mainly reflects an output (motoric or decision-making) bias when eye movements are executed and the response is oculomotor and an input (attentional or perceptual) bias when the eyes remained fixed and the response is manual (e.g., Hilchey, Hashish, MacLean, Satel, Ivanoff, & Klein, 2014). In the current experiments, we tried to discourage eye-movements through specific instructions as well as short target durations. Therefore, even if we cannot be certain that motoric or decision-making bias can be definitely excluded (since eye-movements were not actually recorded), we will restrict the following discussion to views presenting IOR as an attentional/perceptual bias.

The traditional Attention Disengagement view of IOR brings about no predictions regarding manipulations affecting the target type, such

Table 4
Gender discrimination mean correct RTs (in milliseconds) and percent error rates (standard errors in brackets) in Experiment 4 as a function of target type (neutral face, fearful face), target location (cued, uncued), and cue-target stimulus onset asynchrony (SOA: 500, 750, 1000 ms).

Target type	Target location	Cue-Target SOA					
		500 ms		750 ms		1000 ms	
		RTs	Errors	RTs	Errors	RTs	Errors
Neutral face	Cued	729 (31)	15.63 (1.27)	689 (23)	12.15 (1.25)	684 (23)	11.92 (1.38)
	Uncued	685 (23)	13.77 (1.37)	667 (25)	12.38 (1.29)	683 (25)	9.95 (1.18)
	IOR	43*		22*		1**	
Fearful face	Cued	704 (28)	14.24 (1.22)	693 (25)	12.27 (1.28)	686 (25)	10.65 (1.16)
	Uncued	696 (25)	12.73 (1.19)	666 (28)	13.43 (1.36)	677 (24)	9.61 (1.12)
	IOR	8		27*		9	

** $p < .01$.
* $p < .05$.

as social or emotional saliency, as the processes responsible for cueing effects (attentional orienting, reorienting and inhibition to reorient to the cued location; see Klein, 2000; Lupiáñez, 2010) are all taking place *prior* to target appearance. Thus, even when acknowledging the ability of target processing demands to modulate cueing effects (e.g. to account for the different magnitude and time course of IOR for mere detection compared to discrimination tasks) the authors proposed that attentional control settings (ACS) might operate to readjust the dynamics of the attentional orienting-reorienting mechanism, but once again, prior to target appearance, and affecting equally all events appearing in a given block of trials (e.g. Klein, 2000). Therefore, this view leaves unexplained cueing modulations taking place when different targets are presented within blocks (such as in the current study), that is, under conditions where ACS cannot operate.

A view of IOR as the net result of the contribution of (two or more) attentional facilitation and inhibition processes initiated by the cue (respectively decreasing and increasing across SOAs; see Klein, 2000) would imply that the resulting IOR does not reach its maximum magnitude in one step but rises progressively after the presentation of the cue (i.e., the transition from maximal facilitation effects at shorter SOAs to maximal inhibition effects at longer SOAs is incremental). In such a case, the emotional modulation of IOR observed for negative faces could result from the fact that these emotional targets escape more readily the effects of a developing IOR (because they suffer less/benefit more from a given level of rising inhibition/falling facilitation) than the effects of a full-scale IOR. One problem with that interpretation is that if that were the case, the IOR effect for neutral faces should also have been smaller at the shortest SOA compared to larger ones. However, even though the differences were not statistically significant, IOR for neutral targets appeared rather larger at the shortest SOA compared to the middle one (see Fig. 2 C: $F(1,25) = 2.47$, $p > .12$; and D: $F(1,26) = 1.36$, $p > .25$). This might indicate that the process responsible for IOR prior to target onset was already maximal (instead of minimal) at the shortest SOA. Another problem is that at a very short SOAs (100 ms) where significant facilitation typically occurs, Pérez-Dueñas et al. (2014) reported no differential effect of the emotionality of the cue (whereas IOR was absent for angry faces at the long SOA — 1000 ms).

By contrast, recent views of IOR (Dukewich, 2009; Lupiáñez, 2010) have made explicit predictions regarding some processes related to the target, even in the absence of ACS, which could account for the current findings. In these views, IOR emerges not as a result of an attentional inhibitory process acting at the cued location after its presentation, but due to a process of habituation or detection cost. According to Lupiáñez (2010) the cue might produce the activation of a spatial or object representation, so that when a subsequent target event occurs at that same location, the difference in activation between the first and the second event is smaller (less salient) than the target activation occurring at a completely new location. This would lead to a detection cost of cued (old) targets compared to uncued (novel) ones. Reduced or suppressed IOR for emotionally negative stimuli would indicate that this detection cost/pre-activation effect is less deleterious for these stimuli, in line with the results of previous studies showing that they can more easily trigger (stronger) temporary object representations (e.g., Silvert, Naveteur, Honoré, Sequeira and Boucart, 2004). Therefore, under those task conditions that either directly or indirectly lead to a rich emotional processing of the target (i.e., Experiments 3 and 4, respectively) a strong attentional capture process towards them might take place, allowing to overcome the negative perceptual consequences of the cue (the detection cost). This explanation has been proposed to account for similar IOR disappearance effects with negative stimuli (Hu et al., 2014; Pérez-Dueñas et al., 2009, 2014).

The inclusion of several SOAs in our study allowed us to better specify that IOR abolishment for deeply processed fearful faces was only obtained at the shortest 500 ms SOA, but not later on (at 750 and 1000 ms SOAs) when IOR didn't differ anymore from the cueing effect obtained for emotionally neutral targets. This finding improves our knowledge about the time course of the attentional capture process produced by these emotional targets under emotional and gender discriminations. A complete and coherent explanation of such IOR time course modulation must take into account differences in the processes related to the target types that differ between short SOAs and long SOAs. One explanation might be related to the fact that spatial cues, apart from orienting attention, are known to work as preparatory cues that help the participant to anticipate and get ready to the oncoming target. When the SOA is short, cues are typically less efficient in this preparatory function compared to larger SOAs, thus leading to the so-called foreperiod effect (Niemi and Näätänen, 1981). This effect was present in all four experiments here, with overall RTs decreasing with increasing SOAs. We believe that this foreperiod effect might account for the IOR delay pattern observed for emotional cues in emotional and gender discrimination tasks. In more qualitative terms, the preparatory process occurring at long SOAs might let participants to be less emotionally disrupted by the presentation of fearful faces and to avoid distraction, thus leaving more resources available to concentrate on the categorization requirements, thus leading to overall faster RTs. By contrast, when the SOA is shorter, faces might appear before the participants get fully prepared, so that the capture by fearful faces cannot be efficiently prevented at a cost of hindering the discrimination process (increasing general RTs). This exacerbated attentional capture towards the emotional target might be sufficient to overcome the negative spatial influence of the cue on cued trials, thus leading to the reduction of IOR.

The different tasks we used also appear to have an effect on the overall time course of IOR. At the longest 1000-ms SOA of the current experiments, IOR was significant in Experiments 1 and 2, but only marginally significant or eliminated (for both types of target) in Experiments 3 and 4 respectively. IOR is usually a long lasting phenomenon which may last for about 3 s in detection task (see Samuel & Kat, 2003, for a review). However, it has been proposed that the measured duration of IOR varies as a function of how it is measured (Samuel & Kat, 2003), and although it has not been thoroughly investigated, the fact that IOR disappears earlier with more difficult discrimination tasks is something previously reported (Lupiáñez et al., 1997, Experiment 4B). Facial emotion or gender discrimination tasks are more difficult than the simple color discrimination used by Lupiáñez et al. (1997) and to our knowledge, have never been used in IOR studies before. The only exception is an experiment by Pérez-Dueñas et al. (2014) using an emotion discrimination task and they reported that IOR was absent for angry (but not neutral) faces at a SOA of 1000 ms. However, Pérez-Dueñas et al. (2014) investigated IOR at one single SOA while three SOAs were included in our experiments, and the range of SOAs used in an experiment has proven to have an impact on the time course of the IOR (e.g., Cheal and Chastain, 2002). Therefore, even if more work is needed to fully understand the cause of the relatively early disappearance of IOR we observed, a tentative explanation could be that within the emotional context of Experiments 3 and 4, inhibition is shortest lived, being maximal at the shortest SOA and decreasing with increasing SOAs. That would explain the largest IOR effect we observed at the shortest SOA for the neutral faces and its reduction with increasing SOAs. For the fearful faces, the inhibitory effect could have been counteracted at the short SOA by the privileged capacity of unexpected threatening stimuli to capture attention. Of course we acknowledge that this interpretation is ad-hoc and require further investigation. Anyhow, the current results altogether strengthen the idea that the processes triggered by an abrupt onset peripheral cue can manifest in many different ways depending on the timing and nature of the sequence of events following this cue, on processes that occur after target onset (processes which depend on the task and on the nature of the targets), and on their interaction with cue-initiated processes.

The pattern of results obtained in the present study might also have potential implications and raise new questions about the processing of facial expressions and how it interacts with attention. The lack of IOR modulation by emotional faces when participants perform a localization or a face-non face discrimination task could favor the view that facial expressions are not processed at all in these tasks. Alternatively, they could also suggest that some form of emotional expression processing took place, but without necessarily interacting with the mechanisms responsible for IOR. Indeed, even if several factors influencing emotion-attention interactions have been identified, the exact influence they exert is not precisely defined yet. In this framework, Pourtois et al. (2013) recently suggested that such an interaction would involve two processing stages. The amygdala could first perform an early discrimination between emotional and neutral stimuli in an automatic manner, that is, regardless of the attentional resources available for their processing or of their task relevance. This early automatic discrimination could then modulate the activity of the visual cortex, increasing the processing efficiency for emotional stimuli. Importantly, this second effect may come together with other modulatory influences, including influences related to the task demands. Yet, the few studies which have directly compared the electrophysiological brain responses to emotional expressions under different task requirements (passive viewing, gender or emotional categorizations, Valdés-Conroy, Aguado, Fernández-Cahill, Romero-Ferreiro and Diéguez-Risco, 2014; passive viewing, face-non face discrimination, gender and emotional categorizations, Rellecke, Sommer & Schacht, 2012) suggest that the early visual event-related potentials (such as the P1 component) would discriminate emotional from neutral faces *regardless* of the task demands. This would be consistent with the view that the perceptual encoding of emotional (threat-related) expression is *automatically* increased.

However, various studies (which did not investigate the effects of task demands directly) also failed to demonstrate an emotional effect on the P1 component (for review see, Eimer and Holmes, 2007), and a recent meta-analysis led to the conclusion that behavioral indices of automatic attention to (irrelevant) emotional stimuli may directly depend on the cognitive nature of the ongoing task (but not on the difficulty of this task; Carretié, 2014). Note also that the different patterns of electrophysiological and/or behavioral results may sometimes result from an interaction between the task to be performed and the location of the face in the visual field (foveal, parafoveal or peripheral). For example, Wijers and Banis (2012) reported that in a gender discrimination task, emotional effects arose at the P1 stage for foveal faces but occurred later for parafoveal faces, while at the same time responses were faster for fearful relative to neutral faces, independent of stimulus location. Unfortunately, to our knowledge, the influence of task demands on the emotional processing of parafoveal faces like the ones used here has not been directly explored yet. Therefore, when we found no emotional modulation of IOR in localization and face-non face discrimination tasks, it seems tricky to conclude that the emotional dimension was not processed at all. At the same time, our results unambiguously indicate that, if this processing took place, it was not up to a level sufficient to overcome or delay the IOR effect (a level that could however be reached when a deeper face processing is engaged to perform emotion or gender discrimination task). Future research using ERP and neuroimaging measures in the context of localization or face/non face cueing paradigms similar to Experiments 1 and 2 of the present study would provide important evidence to dissociate between these two alternative explanations.

7. Conclusions

To conclude, the present study aimed at isolating the conditions under which fearful facial targets are able to overcome the robust IOR effect. Its main contribution is that it unequivocally demonstrates that IOR is not *imperatively* modulated (neither in magnitude nor in time course) by the presence of negative emotional target faces. Indeed, while this kind of target produced similar IOR effects as emotionally neutral faces for simple localization and face/non-face discrimination tasks, they were able to completely override IOR at short SOAs on emotional and gender discrimination tasks, where fine-grained processing of facial features was required. A potential limitation of this study is that even if the experiments were designed to discourage eye-movements, we cannot ensure that they never occurred. Further research would thus be necessary to isolate the possible role of oculomotor system in the effects we reported here. The current findings might nonetheless have important implications to better delimitate the mechanisms responsible for IOR, as well as to better qualify the different stages of emotional stimuli processing and how/when they interact with attentional processes.

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References

Abrams, R. A., & Dobkin, R. S. (1995). The gap effect and inhibition of return: Interactive effects on eye movement latencies. *Experimental Brain Research*, *98*, 483–487.

Anderson, A. K., Christoff, K., Panitz, D., De Rosa, E., & Gabrieli, J. D. (2003). Neural correlates of the automatic processing of threat facial signals. *Journal of Neuroscience*, *23*, 5627–5633.

Atkinson, A. P., & Adolphs, R. (2011). The neuropsychology of face perception: Beyond simple dissociations and functional selectivity. *Philosophical Transactions of the Royal Society B*, *366*, 1726–1738.

Baijal, S., & Srinivasan, N. (2011). Emotional and hemispheric asymmetries in shifts of attention: An ERP study. *Cognition and Emotion*, *25*, 280–294.

Berlucchi, G. (2006). Inhibition of return: A phenomenon in search of a mechanism and a better name. *Cognitive Neuropsychology*, *23*, 1065–1074.

Brosch, T., & Van Bavel, J. J. (2012). The flexibility of emotional attention: accessible social identities guide rapid attentional orienting. *Cognition*, *125*, 309–316.

Carretié, L. (2014). Exogenous (automatic) attention to emotional stimuli: A review. *Cognitive, Affective, & Behavioral Neuroscience* [Epub ahead of print].

Cheal, M., & Chastain, G. (2002). Timing of facilitatory and inhibitory effects of visual attention. *Visual Cognition*, *9*, 969–1002.

Chica, A. B., Taylor, T. L., Lupiáñez, J., & Klein, R. M. (2010). Two mechanisms underlying inhibition of return. *Experimental Brain Research*, *201*, 25–35.

Critchley, H., Daly, E., Phillips, M., Brammer, M., Bullmore, E., Williams, S., ... Murphy, D. (2000). Explicit and implicit neural mechanisms for processing of social information from facial expressions: A functional magnetic resonance imaging study. *Human Brain Mapping*, *9*, 93–105.

Domínguez-Borràs, J., & Vuilleumier, P. (2013). Affective biases in attention and perception. In P. Vuilleumier, & J. L. Armony (Eds.), *Handbook of Human Affective Neuroscience* (pp. 331–356). New York: Cambridge University Press.

Dukewich, K. R. (2009). Reconceptualizing inhibition of return as habituation of the orienting response. *Psychonomic Bulletin & Review*, *16*, 238–251.

Dukewich, K. R., & Klein, R. M. (2015). Inhibition of return: A phenomenon in search of a definition and a theoretical framework. *Attention, Perception, & Psychophysics*. http://dx.doi.org/10.3758/s13414-015-0835-3.

Eimer, M., & Holmes, A. (2007). Event-related brain potential correlates of emotional face processing. *Neuropsychologia*, *45*, 15–31.

Everaert, T., Spruyt, A., & De Houwer, J. (2013). On the malleability of automatic attentional biases: Effects of feature-specific attention allocation. *Cognition and Emotion*, *27*, 385–400.

Folk, C. L., Remington, R. W., & Johnston, J. C. (1992). Involuntary covert orienting is contingent on attentional control settings. *Journal of Experimental Psychology: Human Perception and Performance*, *18*, 1030–1044.

Fox, E., Russo, R., & Dutton, K. (2002). Attentional bias for threat: Evidence for delayed disengagement from emotional faces. *Cognition and Emotion*, *16*, 355–379.

Frühholz, S., Jellinghaus, A., & Herrmann, M. (2011). Time course of implicit and explicit processing of emotional faces and emotional words. *Biological Psychology*, *87*, 265–274.

Gorno-Tempini, M. L., Pradelli, S., Serafini, M., Pagnoni, G., Baraldi, P., Porro, C., ... Nichelli, P. (2001). Explicit and incidental facial expression processing: An fMRI study. *NeuroImage*, *14*, 465–473.

Hilchey, M. D., Hashish, M., MacLean, G. H., Satel, J., Ivanoff, J., & Klein, R. M. (2014). On the role of eye movement monitoring and discouragement on inhibition of return in a go/no-go task. *Vision Research*, *96*, 133–139.

Hu, F. K., He, S., Fan, Z., & Lupiáñez, J. (2014). Beyond the inhibition of return of attention: Reduced habituation to threatening faces in schizophrenia. *Frontiers in Psychiatry*, *29*, 5–7.

Ivanoff, J., & Taylor, T. L. (2006). Inhibition of return promotes stop signal inhibition by delaying responses. *Visual Cognition*, *13*, 503–512.

Klein, R. M. (1988). Inhibitory tagging system facilitates visual search. *Nature*, *334*, 430–431.

Klein, R. M. (2000). Inhibition of return. *Trends in Cognitive Sciences*, *4*, 138–147.

Klein, R. M., & MacInnes, W. J. (1999). Inhibition of return is a foraging facilitator in visual search. *Psychological Science*, *10*, 346–352.

Klein, R. M., & Taylor, T. L. (1994). Categories of cognitive inhibition, with reference to attention. In D. Dagenbach, & T. H. Carr (Eds.), *Inhibitory processes in attention, memory, and language* (pp. 113–150). Academic Press.

Lange, W. G., Heuer, K., Reinecke, A., Becker, E. S., & Rinck, M. (2008). Inhibition of return is unimpressed by emotional cues. *Cognition and Emotion*, *22*, 1433–1456.

Lundqvist, D., Flykt, A., & Öhman, A. (1998). The Karolinska Directed Emotional Faces—KDEF [CD-ROM]. *Department of Clinical Neuroscience, Psychology Section*. Karolinska Institute: Stockholm, Sweden.

Lupiáñez, J. (2010). Inhibition of return. In K. Nobre, & J. T. Coull (Eds.), *Attention and time* (pp. 17–34). Cambridge, MA: Oxford University Press.

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

Lupianez, J., Klein, R. M., & Bartolomeo, P. (2006). Inhibition of return: Twenty years after. *Cognitive Neuropsychology*, *23*, 1003–1014.

Niemi, P., & Näätänen, R. (1981). Foreperiod and simple reaction time. *Psychological Bulletin*, *89*, 133–162.

Nobre, A., Correa, A., & Coull, J. (2007). The hazards of time. *Current Opinion in Neurobiology*, *17*, 465–470.

Okon-Singer, H., Lichtenstein-Vidne, L., & Cohen, N. (2013). Dynamic modulation of emotional processing. *Biological Psychology*, *92*, 480–491.

Palermo, R., & Rhodes, G. (2007). Are you always on my mind? A review of how face perception and attention interact. *Neuropsychologia*, *45*, 75–92.

Pegna, A. J., Khateb, A., Michel, C. M., & Landis, T. (2004). Visual recognition of faces, objects, and words using degraded stimuli: Where and when it occurs. *Human Brain Mapping*, *22*, 300–311.

Pérez-Dueñas, C., Acosta, A., & Lupiáñez, J. (2009). Attentional capture and trait anxiety: Evidence from inhibition of return. *Journal of Anxiety Disorders*, *23*, 782–790.

Pérez-Dueñas, C., Acosta, A., & Lupiáñez, J. (2014). Reduced habituation to angry faces: Increased attentional capture as to override inhibition of return. *Psychological Research*, *78*, 196–208.

Posner, M. I. (1980). Orienting of attention. *Quarterly Journal of Experimental Psychology*, *32*, 3–25.

Posner, M. I., & Cohen, Y. (1984). Components of visual orienting. In H. Bouma, & D. Bouwhuis (Eds.), *Attention and performance X*. London: Lawrence Erlbaum.

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

Pourtois, G., Schettino, A., & Vuilleumier, P. (2013). Brain mechanisms for emotional influences on perception and attention: What is magic and what is not. *Biological Psychology*, *92*, 492–512.

Prime, D. J., Visser, T. A. W., & Ward, L. M. (2006). Reorienting attention and inhibition of return. *Perception & Psychophysics*, *68*, 1310–1323.

Purcell, D. G., & Stewart, A. L. (1988). The face-detection effect: Configuration enhances detection. *Perception & Psychophysics*, *43*, 355–366.

Rafal, R. D., Calabresi, P. A., Brennan, C. W., & Sciolto, T. K. (1989). Saccade preparation inhibits reorienting to recently attended locations. *Journal of Experimental Psychology: Human Perception and Performance*, *15*, 673–685.

Rellecke, J., Sommer, W., & Schacht, A. (2012). Does processing of emotional facial expressions depend on intention? Time-resolved evidence from event-related brain potentials. *Biological Psychology*, *90*, 23–32.

Ro, T., Russell, C., & Lavie, N. (2001). Changing faces: A detection advantage in the flicker paradigm. *Psychological Science*, *12*, 94–99.

Rutherford, H. J. V., & Raymond, J. E. (2010). Effects of spatial cues on locating emotional targets. *Visual Cognition*, *18*, 389–412.

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

Silvert, L., Naveteur, J., Honoré, J., Sequeira, H., & Boucart, M. (2004). Emotional stimuli in rapid serial visual presentation. *Visual Cognition*, *11*, 433–460.

Stoyanova, R. S., Pratt, J., & Anderson, A. K. (2007). Inhibition of return to social signals of fear. *Emotion*, *7*, 49–56.

Taylor, T. L., & Therrien, M. E. (2005). Inhibition of return for faces. *Perception & Psychophysics*, *67*, 1414–1422.

Taylor, T. L., & Therrien, M. E. (2008). Inhibition of return for the discrimination of faces. *Perception & Psychophysics*, *70*, 279–290.

Theeuwes, J., & Van der Stigchel, S. (2006). Faces capture attention: Evidence from inhibition-of-return. *Visual Cognition*, *13*, 657–665.

Valdés-Conroy, B., Aguado, L., Fernández-Cahill, M., Romero-Ferreiro, V., & Diéguez-Risco, T. (2014). Following the time course of face gender and expression processing: A task-dependent ERP study. *International Journal of Psychophysiology*, *92*, 59–66.

Vuilleumier, P. (2002). Facial expression and selective attention. *Current Opinion in Psychiatry*, *15*, 291–300.

Wang, Z., & Klein, R. M. (2010). Searching for inhibition of return in visual search: A review. *Vision Research*, *50*, 220–228.

Whalen, P. J., Shin, L. M., McInerney, S. C., Fischer, H., Wright, C. I., & Rauch, S. L. (2001). A functional MRI study of human amygdala responses to facial expressions of fear vs. anger. *Emotion*, *1*, 70–83.

Wijers, A. A., & Banis, S. (2012). Foveal and parafoveal spatial attention and its impact on the processing of facial expression: An ERP study. *Clinical Neurophysiology*, *123*, 513–526.