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ORIGINAL ARTICLE

Reduced habituation to angry faces: increased attentional capture as to override inhibition of return

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Abstract The aim of this paper was to study whether real angry faces do capture attention to the extent of overcoming the inhibition of return (IOR) effect and whether the anxiety level of participants modulates this effect by stressing biases toward threatening stimuli. With this purpose, participants categorized the emotional valence of face targets in a standard spatial cueing procedure suitable to measure IOR. In Experiment 1, participants were selected according to their high vs. low-trait anxiety, whereas in Experiment 2 participants were induced a positive vs. anxiety mood state. The typical IOR effect was observed with neutral and happy face targets, which disappeared with angry face targets. Similar results were observed for all anxiety groups and in both experiments. The results indicate that IOR is overridden when the target is a biologically relevant angry face, as highly relevant targets should suffer less from habituation to attentional capture regardless of anxiety. We suggest that these data show that attentional capture is less likely to habituate for threatening information, so that no cost is measured in detecting new threatening information appearing at recently cued locations.

Introduction

Many theorists argue that any salient enough peripheral onset has the capacity to reflexively and automatically capture attention because orienting of attention would be critical in predation and defense (Ruz & Lupiáñez, 2002). Therefore, onset events benefit from attentional capture so that their processing is prioritized with regard to other less salient events (Itti & Koch, 2001; Schreij, Theeuwes, & Olivers, 2010; Theeuwes, Kramer, Hahn, & Irwin, 1998). However, salience drives attention only during the short time interval immediately following the onset of a visual scene (Donk & van Zoest, 2008), probably because being constantly attracted by any salient event would also be disruptive for adaptive behavior. Therefore, if onsets are, or are not followed by, relevant information we habituate to them, so that it would be less likely that attention is captured again at the same location or by the same object. According to some authors, this reduced capacity of targets to capture attention again underlies the well-known inhibition of return (IOR) effect (Dukewich, 2009; Hu, Samuel, & Chan, 2010; Lupiáñez, 2010).

In addition, detection of threatening stimuli is important because of its obvious survival value. Öhman and Mineka (2001) argued that threatening faces activate the human fear system underlying the fast analysis of the environment that must take place before the escape or avoidance of threat. Thus, everybody is oversensitive in detecting threat, which facilitates the fast and accurate perception of threatening stimuli appearing in the environment (e.g., Lang, Davis, & Öhman, 2000; Mathews & Mackintosh, 1998; Mogg & Bradley, 1998). Several lines of evidence suggest that human brain has been designed to direct more cognitive processing toward threatening faces (e.g., Anderson & Phelps, 2001; Öhman & Mineka, 2001; Shaw, Lien, Ruthruff, & Allen, 2011; Vuilleumier, 2005; Vuilleumier, Armony, Driver, & Dolan, 2001; Vuilleumier & Schwartz, 2001; for a review, see Yiend, 2010). In accordance to this, attentional capture would be less likely to habituate when the stimuli triggering attentional capture

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are biologically relevant stimuli like angry faces, for which in real life we should be always ready to react, due to the potentially negative consequences of ignoring them. Testing this hypothesis was the main goal of the research reported in this paper.

The exogenous cuing paradigm has been widely used to study these mechanisms of spatial attention (Posner, 1980). This paradigm involves responding to a target stimulus, which can appear to the left or to the right of fixation. The target is preceded by a brief cue in one of the possible target locations. When cue and target appear in the same location (cued location trials) participants are faster and more precise responding to targets as compared to when cue and target appear in the opposite location (uncued location trials). This is the so-called 'facilitation effect', which is thought to reflect a benefit in processing of cued trials due to the involuntary, reflexive shift of attention toward the source of stimulation (e.g., Posner, 1980). However, when the cue is not predictive of target location (50 % of cued and uncued location trials), this facilitation effect appears only with short stimulus onset asynchronies (SOA) between cue and target. In fact, with long SOAs participants are slower and less precise responding to targets in cued location trials compared to the uncued ones. This is the so-called 'IOR' effect. The SOA at which IOR first appears depends on task demands. For example, when a detection task is used IOR begins at cue-target SOAs of 300–500 ms, whereas with discrimination tasks IOR is not observed at SOAs shorter than 700–1,000 ms (Lupiáñez, Milán, Tornay, Madrid, & Tudela, 1997). In categorization tasks, the IOR effect has been observed with SOAs of 1,000 ms (Chasteen & Pratt, 1999; Pérez-Dueñas et al., 2009).

This effect was called 'IOR' because it was thought to reflect a bias against returning attention to previously explored locations (Klein, 2000; Posner, Rafal, Choate, & Vaughan, 1985). Nevertheless, this intuitive hypothesis has been heavily contested by evidence showing that IOR can be observed even if attention is not disengaged from the cued location, so that no return of attention is necessary (Berger, Henik, & Rafal, 2005; Berlucchi, Chelazzi, & Tassinari, 2000; Chica & Lupiáñez, 2004; Chica, Lupiáñez, & Bartolomeo, 2006; Lupiáñez et al., 2004; Rafal, Davies, & Lauder, 2006). These studies have led to argue that IOR rather indexes a cost in detecting/encoding new events at recently cued locations (Lupiáñez et al., 2013) and would operate independent of the orienting of attention no matter whether orienting is endogenous (Berger et al., 2005; Chica & Lupiáñez, 2009; Chica et al., 2006) or exogenous (Martín-Arévalo et al., 2013). A unique prediction from this account of the IOR effect is that it should be reduced or eliminated when the target is a highly relevant target for which no (or at least reduced) habituation should occur, like angry faces.

In fact, this cuing paradigm has been used with emotional stimuli as cue to study whether the IOR effect is modulated by biological importance of cues as in the case of fearful faces (Stoyanova, Pratt, & Anderson, 2007), animals, or angry faces (Lange, Heuer, Reinecke, Becker, & Rinck, 2008) in detection tasks. These researchers found that the IOR effect was not modulated by the threatening nature of the cues. However, a different pattern of results was observed with emotional schematic faces as cue in a study investigating attentional biases in anxiety (Fox, Russo, & Dutton, 2002). In this case, the threatening nature of the cue (an angry face) eliminated the IOR effect for both high- and low-trait anxious groups (Experiment 2) or only for high-anxiety participants (Experiment 3) in a localization task. This result was interpreted as reflecting reluctance to disengage attention from negative stimuli. Likewise, Bertels, Kolinsky, Bernaerts, and Morais (2011) found abolished IOR in healthy people when a negative spoken word was presented as cue. However, they argued that these finding are difficult to reconcile with difficulties to disengage attention from negative stimuli because the lack of IOR was entirely due to shorter RTs elicited on cued trials by negative words compared to positive and neutral words with no difference being observed for uncued trials.

Nevertheless, the above results are coherent with an evolutionary perspective considering that it would be unadaptative for healthy participants to prevent attention from being captured again at a previously cued location when a threatening stimulus appears. From this perspective, it makes sense that participants do not show reduced habituation (i.e., IOR) for highly relevant targets as negative stimuli. However, as some researchers have noted (e.g., Baijal & Srinivasan, 2011; Fox, Russo, Bowles, & Dutton, 2001; Pérez-Dueñas et al., 2009), manipulating emotional valence of the cue might not be the best method to study attentional capture by threatening stimuli because, when the salient cue is presented before the target, attention is inevitably directed toward the exogenous cue, independently of its kind, thus leading to a ceiling effect. For this reason, it might not be possible to measure the privileged status of threatening stimuli regarding attentional capture and reduced habituation of that attentional capture.

Alternatively, for a direct examination of this hypothesis, an ideal situation would be one in which attentional capture is somehow hindered, thus avoiding that any stimulus is highly effective in capturing attention. Such a situation might be presenting emotional vs. neutral stimuli at a previously cued location where IOR is observed. Considering that IOR reflects a reduced attentional capture by the target (Lupiáñez et al., 2013; Lupiáñez, Ruz, Funes, & Milliken, 2007), if threatening stimuli do have an advantage in capturing attention, IOR might be overcome by the privileged capacity of threatening stimuli to capture attention when they are the target, so that no IOR is observed for these stimuli.

To our knowledge, only three previous papers have measured IOR with emotional targets to investigate whether target saliency modulated the IOR effect. Pérez-Dueñas et al. (2009) presented neutral, positive and negative anxiety-related words as target, which participants were to categorize as either neutral or emotional (emotional categorization task). A reduced IOR effect was observed for anxiety-related word targets in high-anxiety trait individuals, as compared to positive words; whereas no modulation was observed in low-anxiety trait individuals. The fact that the IOR effect was eliminated for threatening targets in anxious people was interpreted as reflecting the high capacity of negative stimuli to capture attention in high-anxiety trait people, as to overcome the IOR effect.

Rutherford and Raymond (2010) observed a similar modulation over the IOR effect for emotional (spiders or angry faces) as compared to neutral targets. In different experiments, participants were to localize the target, which could be either neutral or emotionally relevant (neutral objects, spiders, neutral, happy or angry faces). Interestingly, target emotionality only had an influence on the IOR effect when valence was presented in blocks so that participants were exposed to the negative stimuli in a continued way. In this case, threatening targets significantly reduced the size of the IOR effect, perhaps because anxiety was induced in participants due to the threatening context, although the anxiety level was not measured. Finally, Baijal and Srinivasan (2011) found that IOR was reduced for schematic sad faces compared to happy ones in a detection task where the emotional content was irrelevant for the task, especially in the left visual field. This result provides strong evidence for the rapid attentional capture of negative stimuli even when target was not relevant for the task. However, the anxiety level of the participants was not measured in this study.

Note that for most studies where emotional valence of the target was manipulated, the anxiety level of the participants was not measured and a detection or localization task was used. Therefore, the target emotionality was completely irrelevant and the anxiety level of the participants was not taking into account in most studies. Perhaps if a different task had been used for which emotional meaning of stimuli is relevant or anxiety level of the participants had been manipulated, a different pattern of results might have been observed. The emotional meaning was relevant to the task only in our previous study (Pérez-Dueñas et al., 2009) in which an emotional word categorization task was used. However, as some researchers have argued (e.g., Bradley et al., 1997), words are not naturalistic and ecologically valid stimuli, which could explain why the absent IOR was only observed for high-anxiety trait individuals, for whom the anxiety word meaning was highly relevant. On the other hand, according to theoretical models of anxiety, anxious people are biased in the initial orientation of attentive resources toward threat-related stimuli (Eysenck, 1992; Mathews & MacLeod, 1994; Williams, Watts, MacLeod, & Mathews, 1997). This view has been supported by empirical studies showing that anxious individuals have a greater attentional bias for threatening stimuli than non-anxious individuals (for review, see Bar-Haim et al., 2007).

Therefore, the aims of the present study were to investigate whether more ecological stimuli as real angry faces do capture attention as to override IOR, and whether this depends on anxiety state and/or trait, due to their associated biases toward threatening stimuli, or is independent of it, due to the evolutionary relevance of angry faces as compared to the meaning of words. If angry faces capture attention more effectively in high anxious people because they are more sensitive toward this kind of threatening information than low anxious people, there will be difference between groups and the reduction in the IOR effect would be larger for the high-anxiety group. With this purpose, people with high and low trait (Experiment 1) and state anxiety (Experiment 2) carried out an emotional categorization task of angry, happy and neutral faces targets in a cuing paradigm with a long SOA of 1,000 ms and temporal and spatial uncertain (50 % of trials with a 100 ms SOA and 50 % with a 1,000 ms SOA; 50 % cued location trials and 50 % uncued location trials), a procedure that is suitable to measure the IOR effect. These targets allow the comparison between emotional and non-emotional faces, and between negative and positive (angry vs. happy) emotional faces with the same person portraying different expressions.

We expect the participants to show an IOR effect for happy and neutral faces (i.e., to be slower and less precise on cued location trials as compared to uncued location ones). On the other hand, we expect this IOR effect to disappear or be attenuated for angry faces if angry faces have a privileged capacity to capture attention in accordance to the evolutionary perspective (e.g., Öhman & Mineka, 2001). Although threatening facial expressions are a general strong attractor of attention, according to theoretical models of anxiety (Eysenck, 1992; Mogg & Bradley, 1998; Mathews & MacLeod, 1994; Williams et al., 1997) and following the previous studies (Pérez-Dueñas et al., 2009) we anticipate that the magnitude of this effect might be modulated by anxiety. So the reduction in the IOR effect for angry faces might be larger in the high-trait anxiety group in Experiment 1 and in the high-state anxiety group in Experiment 2.

Experiment 1

Method

Participants

Seventy-two subjects were selected from a pool of 699 students from the first year of Psychology at the University of Granada to participate in the experiment, according to their scores in the Spielberger trait-anxiety scale (STAI-T; Spielberger, Gorsuch, & Lushene, 1994)[1] (mean age 22.12 years, SD 4.77). Participants in the 'high-trait anxiety' group (HA; 30 females and 6 males) were selected on the base of their high-anxiety score (above the 75th percentile according to the norms from the Spanish population). Participants in the 'low-trait anxiety' group (LA; 27 females and 9 males) were selected for having a low score on the scale (below the 25th percentile). Participants received course credits for their participation. Data from one participant who did not respond on 49 % of the trials were eliminated from the analysis. This and the following experiment were conducted according to the ethical standards of the 1964 Declaration of Helsinki.

Apparatus and stimuli

The Spanish version of the Spielberger trait anxiety scale (Spielberger et al., 1994) was used to classify participants as high or low anxiety. The experiment was run on a computer with a 1 GHz Pentium III processor, connected to a 15 in. VGA monitor. E-prime software (Schneider, Eschman, & Zuccolotto, 2002) controlled the presentation of stimuli and data collection.

Each trial included a fixation point, two rectangular boxes, an exogenous cue, and a target. The fixation point was a "+" symbol approximately 5 mm × 5 mm displayed in the middle of the screen. Each box was 140 mm in width × 211 mm in height, subtending a visual angle of 13.13° and 19.37°, respectively, at a viewing distance of 60 cm. The boxes were symmetrically located at both sides of the fixation point at a distance of 15 mm (1.43° of visual angle) from the fixation point to the internal edge of the boxes (e-prime parameters of position: 35 % for the left box and 65 % for the right box on abscise axis). The exogenous cue was made by increasing the white border width of one of the two boxes in 9 mm for 50 ms. This increase from 3 to 12 mm gave the impression of a brief flicker. The target was a photograph of either an emotional (happy or angry) or neutral face. Eight different photographs of four individuals (JB, EM, PE and WF) were used from the set of pictures of facial affect (Ekman & Friesen, 1976). Two photographs were selected from each of the four individuals, one portraying a neutral expression (codes: JB1-3, EM2-4, PE2-4 and WF2-5) and the other portraying an emotional expression, either happy (codes: EM4-7 and WF2-11) or angry (codes: JB1-23 and PE2-21). Thus, there were two angry, two happy and four neutral faces targets and each individual portrayed two expressions. The size of the photographs was adjusted to be the same as the square boxes so they would appear within them.

Procedure

Participants were tested individually in a dark and quiet room. They sat in a chair at approximately 60 cm from the screen. Instructions were provided informing the participants they would be presented with different faces, and for them to categorize them as either emotional or neutral, by pressing either the "Z" or "M" key of the keyboard depending on whether the target was an emotional or a neutral face. The assignment of targets to response keys was counterbalanced across participants within each group. Participants were encouraged to respond as quickly and accurately as possible.

The sequence of events on each trial is depicted on Fig. 1. First appeared the fixation display that included the fixation point and two peripheral boxes, which were displayed on a gray background for 1,000 ms. Then one of the two boxes flickered for 50 ms with a 50 % probability of appearing on each box. Following the flicker, the fixation point and the boxes remained on the screen either for 50 or 950 ms, depending on the SOA for that trial. Following this interval, the target was displayed for 100 ms in the middle of one of the two boxes, again with a 50 % probability on each box. After 100 ms the fixation point and boxes were again displayed alone until the subject's response or for maximum of 1,900 ms. After either a response was emitted or the maximum time elapsed, the screen was cleared and the next trial began. Auditory feedback (a 400 Hz tone of 100 ms) was provided in headphones on error and no response trials (see Fig. 1).

Each session included 1 block of 64 practice trials and 5 blocks of 64 experimental trials, and lasted approximately 30 min. One hundred and sixty experimental trials were cued location trials, where the target appeared in the same spatial location as the cue, and the other 160 experimental trials were uncued location trials where the target appeared in the opposite spatial location to the cue (50 % cued and 50 % uncued). At the end of each block participants were allowed to rest for 10 s.

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[1] The Spanish version of the STAI includes 20 items, each scored from 0 to 3, so that the total varies from 0 to 60, rather than from 20 to 80, as in the English version. The alpha coefficients of the scale are .92 for State Anxiety and .84 for Trait Anxiety.

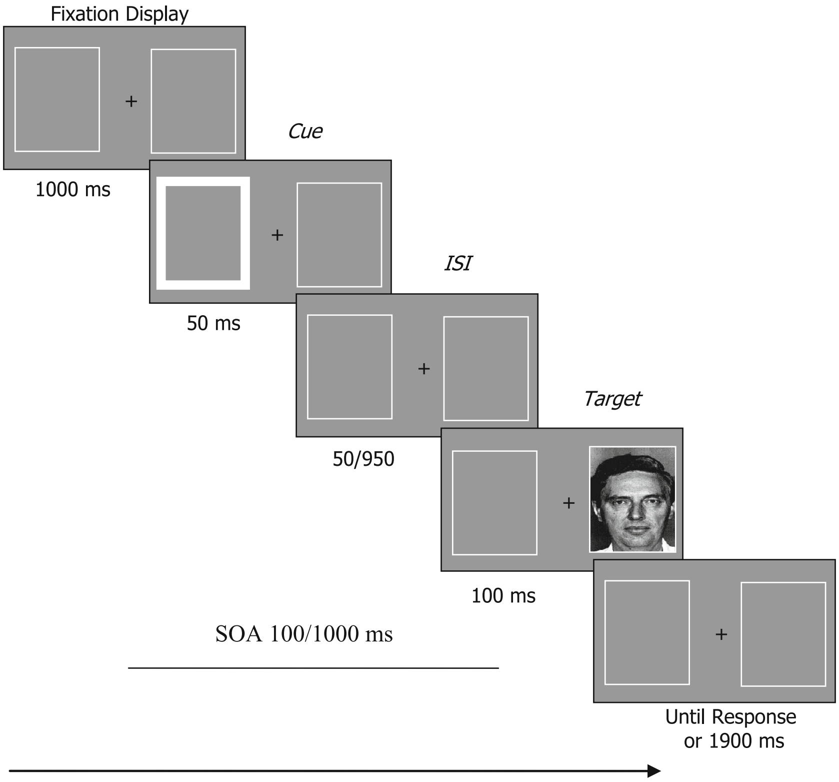

Fig. 1 Schematic procedure used in the spatial cueing task. Each trial begins with the fixation display and end with the response. The picture shows an example of an uncued trial with neutral target

Each experimental block was composed of 32 trials with neutral target (16 appearing at the cued location, and 16 at the uncued location), and 32 trials with emotional target, 16 with happy target and 16 with angry target (8 appearing at the cued location, and 8 at the uncued location). There were the same number of trials for each one of the eight photographs (40 trials for each face), for cues presented to the left or to the right (50 % right and 50 % left), for targets presented to the left or to the right (50 % right and 50 % left) and for each SOA (50 % 100 ms and 50 % 1,000 ms). The order of trials was randomized within each block.

Design

The experiment had a (2) anxiety (high- vs. low-trait anxiety) × (3) target valence (neutral vs. happy vs. angry faces) × (2) SOA (short vs. long) × (2) cueing (cued vs. uncued location) mixed design, with the first variable as a between-participants factor and the last three as within-participants factors.

Mean RT and percentage of errors were used as dependent variables. Trait anxiety was also analyzed according to anxiety level (high vs. low) to check that the sample had been appropriately selected.

Table 1 Mean trait anxiety scores for the high- and low-trait anxiety in Experiment 1 and mean state anxiety scores for the high- and low-state anxiety in Experiment 2 before and after the test

	Group	
	High anxiety	Low anxiety
Experiment 1		
Trait anxiety before	38.40 [89] (4.58)	8.80 [3] (4.04)
Trait anxiety after	34.26 [80] (7.40)	10.55 [4] (5.80)
Experiment 2		
State anxiety before	20.39 [45] (10.47)	14.29 [20] (6.78)
State anxiety after	35.48 [85] (9.90)	8.46 [5] (4.81)

Percentile data and standard deviation (SD) are presented in square brackets and brackets, respectively

Results

Trait anxiety

One way ANOVA revealed significant group differences before $F(1, 69) = 833.926$, $MS_e = 18.64$, $p < .001$ and after the test, $F(1, 69) = 226.31$, $MS_e = 44.05$, $p < .001$. The high-trait anxious group scored significantly higher on measures of trait anxiety compared to the low-trait anxiety group (see Table 1).

Response time

Mean response times (RT) and error rates were each analyzed with a mixed ANOVA with anxiety (high- vs. low-trait anxiety), as the between-participants factor, and target valence (neutral vs. happy vs. angry), SOA (short vs. long) and cueing (cued vs. uncued) as the within-participants factors. Responses faster than 200 ms were excluded from the analyses (2.55 % of the trials).

Results for the RT data revealed a significant main effect for target valence $F(2, 138) = 245.310$, $MS_e = 5{,}688$, $p < .001$, with participants being faster for happy (651 ms) than for angry (768 ms) and neutral faces (776 ms). Planned contrasts revealed differences between neutral and happy faces, $F(1, 69) = 458.08$, $MS_e = 4{,}840$, $p < .001$, and between angry and happy faces, $F(1, 69) = 247.58$, $MS_e = 7{,}922$, $p < .001$, with no difference between neutral and angry faces $F(1, 69) < 1$. There was also a significant SOA × cueing interaction $F(1, 69) = 28.95$, $MS_e = 2{,}075$, $p < .001$. Planned contrast revealed a significant main effect of cueing at the short SOA $F(1, 69) = 14.61$, $MS_e = 1{,}451.76$, $p < .001$, with participants being faster for cued (727 ms) than for uncued location trials (741 ms), showing a facilitation effect, and a main effect of cueing at the long SOA $F(1, 69) = 16.19$, $MS_e = 2{,}495.28$, $p < .001$, with participants being slower for cued (739 ms) than for uncued location trials (720 ms), showing an IOR effect.

There was a significant three-way interaction of target valence × SOA × cueing $F(2, 138) = 5.59$, $MS_e = 1{,}223$, $p < .01$. To examine this interaction, analyses were conducted for the short and long SOA separately.

Short SOA The 2 (anxiety) × 3 (target valence) × 2 (cueing) ANOVA revealed the already described main effects of target valence [$F(2, 138) = 197.53$, $MS_e = 3{,}468$, $p < .001$] and cueing ($F(1, 69) = 14.61$, $MS_e = 1{,}452$, $p < .001$), which did not interact with each other. Neither was significant any other interaction.

Long SOA Again, the 2 (anxiety) × 3 (target valence) × 2 (cueing) ANOVA revealed the above described main effects of target valence ($F(2, 138) = 196.25$, $MS_e = 3{,}624$, $p < .001$) and cueing ($F(1, 69) = 16.19$, $MS_e = 2{,}495$, $p < .001$).

Importantly, however, in this case there was also a significant target valence × cueing interaction $F(2, 138) = 3.1$, $MS_e = 1{,}177$, $p < .05$. Planned contrasts revealed significant effects of cueing with neutral faces $F(1, 69) = 19.57$, $MS_e = 1{,}693.12$, $p < .001$, (IOR, i.e., slower RT on cued location trials—788 ms—than on uncued location trials—758 ms), as well as with happy faces, $F(1, 69) = 8.51$, $MS_e = 1{,}166.73$, $p < .01$ (657 vs. 640 ms for cued vs. uncued location trials, respectively), revealing the IOR effect. However, according to our hypothesis, this effect disappeared with angry faces $F(1, 69) = 2.25$, $MS_e = 1{,}988.91$, $p = .14$ (see Fig. 2, left panel).

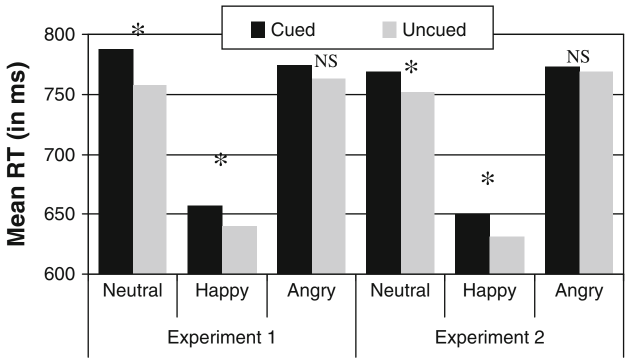

Fig. 2 Mean response times in ms (RT) as a function of target valence (neutral, happy and angry faces) and cueing (cued and uncued) in Experiment 1 (*left*) and in Experiment 2 (*right*)

There was no main effect of group, $F(1, 69) = 1.46$, $MS_e = 56{,}096$, $p = .23$. The target valence × cueing × anxiety group interaction was also non-significant, $F(2, 138) = 1.66$, $MS_e = 1{,}177$, $p = .19$. Therefore, trait anxiety level did not modulate our finding of reduced IOR for angry faces.

Errors

The analysis of accuracy data showed that participants made 14.17 % of errors and did not respond on 1.14 % of trials. There were no significant effects in the analysis of misses (no response trials). However, in the analysis of errors the main effect of target valence was again significant, $F(2, 138) = 113.96$, $MS_e = 0.02$, $p < .001$, showing that participants made less errors with happy faces (3.7 %) than with neutral (15.3 %) and angry (23.85 %) ones. Planned contrasts revealed differences between neutral and happy targets $F(1, 69) = 111.75$, $MS_e = 0.02$, $p < .001$, and between neutral and angry targets $F(1, 69) = 35.21$, $MS_e = 0.03$, $p < .001$.

There was also a significant SOA × cueing interaction $F(1, 69) = 5.25$, $MS_e = 0.0047$, $p < .05$. Participants made less errors on cued (13.67 %) than on uncued location trials (14.81 %) at the short SOA suggesting a facilitation effect, and more errors on cued (14.87 %) than on uncued trials (13.87 %) with long SOA suggesting an IOR effect. Although these differences were not significant (short SOA: $F(1, 69) = 2.64$, $MS_e = 0.005$, $p = .11$; long SOA: $F(1, 69) = 1.99$, $MS_e = 0.005$, $p = .16$), getting this pattern is important because these data reveal that participants are not faster at the expense of making more errors (a speed accuracy trade off).

Discussion

This experiment provides evidence that the IOR effect occurred in an emotional categorization task with real target faces. Participants were slower in categorizing a face that appeared in a cued location, relative to an uncued location. Although the IOR effect has been observed when faces have been used as targets, either when participants were to detect (Baijal & Srinivasan, 2011) or to discriminate them (Rutherford & Raymond, 2010), to our knowledge this is the first time that the IOR effect has been observed with emotional faces in an emotional categorization task. In addition, according to the literature, facilitation effect appeared only with short SOA between cue and target.

More importantly, the IOR effect was observed with long SOA only for happy and neutral faces independently of trait anxiety level, whereas it disappeared with angry faces. This pattern of results seems consistent with the previous findings observed in our lab with emotional words as target stimuli (Pérez-Dueñas et al., 2009). However, contrary to our previous finding in which only participants in the high-trait anxiety did not show the IOR effect for emotionally negative words, in the present experiment both groups failed to show IOR for angry faces, probably due to the evolutionary relevance of angry faces as compared to the meaning of words. This might be indicative of the social relevance of visual information present in angry faces, which might have a privileged capacity to capture attention in all individuals, independently of trait anxiety. These findings are in line with models of attention to threat (Mathews & Mackintosh, 1998; Mogg & Bradley, 1998) which postulate that all individuals attend to highly threatening information. A similar pattern has been consistently found in previous studies that also used facial stimuli with different paradigms, even in some of which trait anxiety was not manipulated (Eastwood, Smilek & Merikle, 2003; Fenske & Eastwood, 2003; Koster, Crombez, Verschuere, & De Houwer, 2004; Mogg et al., 2000; Öhman, Lundqvist, & Esteves, 2001; Wilson & MacLeod, 2003;Yiend & Mathews, 2001). In any case, the observed general attentional bias for angry faces in low- and high-trait anxiety groups provides converging evidence for the evolutionary function of attention to threat (e.g., Öhman, 1992).

In addition to these predicted findings, an unexpected effect was obtained regarding the valence factor where individuals were faster categorizing happy faces than angry faces. This finding contrasts with a number of previous studies indicating that threatening faces (angry) tend to attract attention more promptly than faces with different expressions including sad (Öhman et al., 2001), happy (Fox et al., 2000) and neutral (Eastwood, Smilek, & Merikle, 2001), using the face-in-the-crowd task or visual search tasks. It is noteworthy that participants in these previous studies had to detect or discriminate schematic faces embedded in an array of other faces.

In contrast, however, when faces are presented alone, a growing body of evidence confirms that real happy faces are more efficiently detected relative to angry faces because the communicative intent of happiness is relatively straightforward and less ambiguous (Becker, Anderson, Mortensen, Neufeld, & Neel, 2011; Juth, Lundqvist, Karlsson, & Ohman, 2005; Mermillod, Vermeulen, Lundqvist, & Niedenthal, 2009; Williams, Moss, Bradshaw, & Mattingley, 2005). In fact, Calvo and Lundqvist (2008) found that happy faces were identified more accurately, earlier, and faster than other emotional faces where there were misclassifications between surprise and fear, and between anger and disgust. In the same way, neutral faces are ambiguous as they are perceived as mildly hostile (e.g., Öhman et al., 2001). Therefore, previous studies suggest that when the emotional meaning is processed and all potential confounds in the crowding or visual search tasks are removed or controlled for, happy faces are more efficiently detected because of their significance (Becker et al., 2011; Williams et al., 2005).

These facts do not inevitably conflict with the broader idea that facial threat may be easily detected when appears in a crowd where several stimuli are shown which is named in the literature as “anger superiority effect” (Eastwood et al., 2003; Horstmann and Bauland 2006; Öhman et al., 2001). The face-in-the-crowd studies reveal a more efficient search for angry than for happy faces probably because angry faces capture attention faster. This hypothesis has been recently supported by a larger and earlier N2pc for negative compared to happy faces (Feldmann-Wüstefeld, Schmidt-Daffy, & Schubö, 2011). The pattern of results observed in our first experiment goes in the same direction.

How can we then explain that happy faces were detected faster than neutral and angry faces, but angry faces seem to be more effective in capturing attention, as to override the IOR effect? Appraisals theories predict that attention is mainly oriented toward highly relevant stimuli to prepare the organism for adaptive behavioral responses (Sander, Grandjean, & Scherer, 2005). However, with happy faces we do not have to change our attention toward the stimuli as it happens with angry or fear faces to detect a threat, but simply have to perceive the signal as safe (Becker et al., 2011; Williams et al., 2005).

In this context, when angry faces are presented, in spite of participants being slower to overly discriminate them, they capture spatial attention more effectively given their biological relevance, even when appearing at a previously cued location, thus overriding the IOR effect (in our study), or when appearing in a crowd (in other studies).

On the other hand, in our experiment, the emotional meaning was relevant to categorize the target. Therefore, the emotion had to be processed to do correctly the task and participants were faster and more precise for happy faces because of their less ambiguous communicative intent (Becker et al., 2011; Juth et al., 2005; Mermillod et al., 2009; Williams et al., 2005).

Experiment 2

In our first experiment, we manipulated trait anxiety as previous research has shown that biases toward negative stimulus information can be observed in individuals with high-anxiety trait (e.g., Fox et al., 2002; Pérez-Dueñas et al., 2009; Yiend & Mathews, 2001). Nevertheless, we observed no differences as a function of anxiety trait. Some studies (e.g., Fox et al., 2001; Pacheco-Unguetti, Acosta, Callejas, & Lupiáñez, 2010) have found attentional orienting biases with high-state anxiety participants. We wondered whether state anxiety rather than trait would modulate the pattern of results.

If, as discussed above, angry faces are universally special in capturing attention, a similar absence of IOR might be observed in both high- and low-anxiety groups, especially given that the emotional categorization task emphasizes threat processing. To investigate this question, participants with high- and low-state anxiety performed the same task as in Experiment 1.

Method

Participants

Forty-eight University of Granada undergraduate students volunteered to participate in the 45-min experiment in exchange for course credit. Twenty-four participants were randomly assigned to the group with high-state anxiety, 20 females and 4 males (mean age 21.12 years, SD 4.37), and 24 to the group with low-state anxiety, 17 females and 7 males (mean age 22.16 years, SD 4.41). Data from one participant who did not respond on 55 % of the trials were eliminated from the analysis.

Apparatus and stimuli

The apparatus and stimuli were the same as in Experiment 1, with the following exceptions. Pictures to induce high and low anxiety were selected from the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 2005). To induce state anxiety we use negative stimuli, ten slides about war, danger, etc. (pictures number 3000, 3071, 3080, 3150, 3170, 3350, 3550, 6312, 9040 and 9410), which were presented accompanied by a related text emphasizing the lack of control, meant to help participants to get involved theMS_elves with each negative unexpected event (e.g., Nobody knows whether we will suffer an attack. We cannot control crime). As a control induction procedure, positive stimuli were used (ten slides about happy partners, babies, nature, etc.; pictures number 2040, 2091, 2340, 2501, 2540, 4599, 5260, 5830, 8540 and 8600), which were presented accompanied by a text emphasizing the great joy of live (e.g., We can enjoy contemplating Nature. We are part of this).

Procedure

The procedure was the same as the Experiment 1, except that before performing the experimental task participants filled in the Spielberger state anxiety scale (STAI state; Spielberger et al., 1994). After this they underwent the induction procedure. The high-state group underwent the anxiety induction procedure, whereas the low-state group underwent the positive mood induction procedure. All participants filled in again the STAI state after the induction, and then performed the experimental task.

Design

Experimental data for the measures of interest, response times (RTs) and percentages of error, were each analyzed with a mixed ANOVA with anxiety (high- vs. low-state anxiety) as the between-group factor and target valence (neutral vs. angry vs. happy), SOA (shot vs. long) and cueing (cued vs. uncued location) as the within-participants factors. State anxiety was analyzed according to the experimentally induced anxiety state level (high and low).

Results

State anxiety

One-way ANOVA showed significant differences between the high-state anxiety group and the low-state anxiety group in the measures taken after the state induction $F(1, 45) = 143.46$, $\mathrm{MS}_e = 59.77$, $p < .001$. Although, as can be seen in Table 1, the groups also differed in the measure taken before the induction, $F(1, 45) = 143.46$, $\mathrm{MS}_e = 5.66$, $p < .05$, these differences were much smaller, and all participants' scores felt in a normal range. Importantly, more specific analyses with t tests revealed that the high-state anxiety group scored significantly higher on measures of anxiety state after than before the mood induction, t (44) $= -5.02$ $p < .001$, and low-state anxiety group scored significantly lower on measures of anxiety state after than before the mood induction, t (46) $= 3.48$ $p < .01$.

Response time

There were no responses faster than 200 ms, so that only trials with erroneous responses were excluded from the RT analyses. The analysis of the RT data again revealed a significant main effect for target valence F(2, 90) = 126.78, $MS_e = 7{,}621$, $p < .001$, as participants were faster for happy (641 ms) than for neutral (762 ms) and angry faces (768 ms). Planned contrasts revealed differences between neutral and happy targets F(1, 45) = 226.71, $MS_e = 6{,}085$, $p < .001$ and between angry and happy targets F(1, 45) = 139.75, $MS_e = 10{,}849$, $p < .001$, with no difference between the neutral and angry targets F(1, 45) < 1. The analysis also revealed a significant SOA × cueing interaction $F(1, 45) = 17.44$, $MS_e = 1{,}541$, $p < .001$. Planned contrast revealed a significant main effect of cueing at the short SOA $F(1, 45) = 6.92$, $MS_e = 2007.39$, $p < .01$, with participants being faster for cued (717 ms) than for uncued location trials (731 ms), showing a facilitation effect, and a significant main effect of cueing at the long SOA $F(1, 45) = 6.79$, $MS_e = 1{,}913.73$, $p < .01$, with participants being slower on cued (731 ms) than on uncued location trials (717 ms). Thus, a significant IOR effect was observed again. To examine our main hypothesis concerning the modulation of the IOR effect by emotionality of the target, separate analyses were conducted for the short and long SOA.

Short SOA The 2 (anxiety) × 3 (target valence) × 2 (cueing) ANOVA revealed the already described main effects of target valence [$F(2, 90) = 111.165$, $MS_e = 4{,}266$, $p < .001$] and cueing [$F(1,45) = 6.92$, $MS_e = 2{,}007$, $p < .01$], which did not interact with each other. Neither was significant any other interaction.

Long SOA Again, the 2 (anxiety) × 3 (target valence) × 2 (cueing) ANOVA revealed the above described main effects of target valence [$F(2, 90) = 97.18$, $MS_e = 5{,}071$, $p < .001$] and cueing [$F(1, 45) = 6.79$, $MS_e = 1{,}914$, $p < .01$].

To further test our specific hypothesis that the IOR effect would be reduced for angry faces, and to see whether data from Experiment 1 are replicated, three different 2 (anxiety) × 2 (cueing) mixed ANOVAS were conducted, one for each type of target. The analysis of neutral target trials revealed a significant main effect of cueing $F(1, 45) = 4.48$, $MS_e = 1{,}417$, $p < .05$, where RTs were slower on cued (769 ms) than on uncued location trials (752 ms), independently of group, $F(1, 45) = 1.52$, $MS_e = 1{,}417$, $p = .22$. Similarly, the effect of cueing was significant in the analysis of happy targets, $F(1, 45) = 8.70$, $MS_e = 1{,}038$, $p < .01$ (650 vs. 631 ms for cued and uncued location trials, respectively), also independently of group, $F(1, 45) = 1.55$, $MS_e = 1{,}038$, $p = .22$. These results show IOR effect for neutral and happy faces. However, supporting our hypothesis, the cueing effect disappeared with angry faces $F(1, 45) < 1$, revealing more effective attentional capture by angry faces as to override the IOR effect. Again this effect was independent of anxiety level, $F(1, 45) = 1.44$, $MS_e = 2{,}498$, $p = .24$. As it can be seen in the Fig. 2 (right panel) these results are very similar to those observed in Experiment 1.

Errors

The analysis of accuracy data showed that participants made errors on 15.65 % of the trials and did not respond on 0.69 % of the trials. There was no significant effect or interaction in the analysis of misses. In the analyses of error percentages, however, there was a significant main effect for target valence $F(2, 90) = 108.91$, $MS_e = 0.02$, $p < .001$ with participants making less errors for happy (3.73 %) than for neutral (13.36 %) and angry faces (26.52 %). Planned contrasts revealed differences between neutral and happy targets $F(1, 45) = 106.69$, $MS_e = 0.008$, $p < .001$, and between neutral and angry targets $F(1, 45) = 78.65$, $MS_e = 0.02$, $p < .001$.

The analysis also revealed a significant SOA × cueing interaction $F(1, 45) = 5.36$, $MS_e = 0.0048$, $p < .05$, where participants had less errors on cued (14.51 %) than on uncued trials (15.18 %) at the short SOA (although these differences were not significant, $F(1, 45) < 1$), and more errors on cued (15.25 %) than on uncued trials (13.2 %) at the long SOA, $F(1, 45) = 5.68$, $MS_e = 0.005$, $p < .05$. These results confirm again that participants are not faster at the expense of making more errors (a speed accuracy trade off).

Discussion

Once again a significant IOR effect was observed with neutral and happy faces in an emotional categorization task, which disappeared with angry faces. Importantly, there were again no significant differences between groups. These data support once more that angry faces capture participants' attention as to eliminate the IOR effect.

These results are in line with an evolutionary viewpoint that the efficient detection of threatening stimuli confers obvious survival value, so that the hypothesis of preferential automatic attentional capture by threatening stimuli can be considered applicable to all individuals in the population. These results are in line with experiments studying the deployment of attention toward relevant phylogenetic stimulus (Brosh, Sander, & Scherer, 2007; Brosh, Sander, Pourtois, & Scherer, 2008) where attention is allocated to highly biologically relevant stimulus for members of a species.

It is important to highlight once again that attentional capture by angry faces was strong enough as to overcome the IOR effect, which is considered a highly automatic, almost hardwired mechanism (Stoyanova, et al., 2007; Taylor & Therrien, 2005, 2008).

This experiment also shows that participants were again faster categorizing happy than angry faces, even if the IOR effect was only overridden by angry faces. This might indicate that even if happy faces are more efficiently discriminated from other emotional faces because their communicative intent is relatively more straightforward and less ambiguous (Becker et al., 2011; Juth et al., 2005; Mermillod et al., 2009; Williams et al., 2005), angry faces are more effectively detected and more effective in capturing attention, supporting the hypothesis of spatial attentional biases toward angry faces outlined by appraisal theories (Ellsworth & Scherer, 2003; Sander et al., 2005). The results also support the proposal that IOR mainly index a detection cost, a cost in detecting or encoding new information at a location or object where attention was recently captured (Lupiáñez et al., 2013).

General discussion

In this research, we wanted to explore whether real angry faces do capture attention to the extent of overcoming the IOR effect and whether the anxiety level of participants modulates this effect. Thus, on the one hand, we investigated whether the emotional nature of target stimuli would affect attentional capture of targets appearing at locations subjected to reduced attentional capture (i.e., where attentional capture is hindered so that an IOR effect is observed) and, on the other hand, we investigated whether angry faces show an enhanced capacity to attract attention in people with high compared to low trait and state anxiety in conditions in which attentional capture is cognitively hindered.

According to the recent frameworks, the IOR effect is due to reduced attentional capture at the cued location, either due to the habituation of the orienting response (Dukewich, 2009), or to a lost of novelty which hinder detection processes (Lupiáñez, 2010). To the extent that, biologically relevant, threatening targets (like angry faces) might be resistant to these processes, and therefore might be especially good in capturing attention (for a review, see Yiend, 2010), IOR should be reduced or absent for angry faces, as shown in our two experiments.

Classically, the IOR effect has been thought to reflect a bias against returning attention to previously explored locations (Klein, 2000; Posner et al., 1985). However, as highlighted in the introduction, there is a growing evidence that disengaging attention is neither necessary nor sufficient for the IOR effect to be observed (for a review, see Lupiáñez, 2010) and IOR effect operates independent of the orienting of attention no matter whether it is endogenous (Berger et al., 2005; Chica & Lupiáñez, 2009; Chica et al., 2006) or exogenous (Martín-Arévalo et al., 2013). Therefore, the IOR effect should be related to attentional capture rather than to orienting of attention. In this sense, when the unpredictive cue is presented, the peripheral onset captures the attention (bottom-up) and attention is engaged to this location (top-down) thus leading to a facilitatory effect in discriminating the target, to the extent that cue and target are treated by the perceptual system as the same object or event (Lupiáñez, 2010; Lupiáñez et al., 2013). Short cue-target intervals and sharing location on cued location trials benefit the object integration processes that underlie the attentional benefits in discriminating the target.

However, after a few hundred milliseconds between the cue and the target, the integration of the cue and target representations within the same object file is disrupted, thus reducing the attentional benefits in target discrimination (Lupiáñez et al., 2013). Furthermore, saliency-driven attentional capture habituates shortly after attention is captured (Donk and van Zoest 2008; Dukewich, 2009; Hu et al., 2010). This will make it more difficult for a new object to capture attention again when it appears in a nearby or the same location as the previous attention-capturing object (i.e., the cue). After all, it will be more difficult for the perceptual system to detect the appearance of the new object as it will be less new if it appears at the same location as the previous one. However, if stimuli as angry faces, which are especially effective in capturing the attention, are presented at the cued location, no cost in detecting them will be observed, as indexed by the absence of any IOR effect.

Different studies have previously manipulated the emotional valence of the cue and the target in cuing procedures with detection, localization or categorization tasks, with manipulations suitable to observe IOR (Bertels et al., 2011; Baijal & Srinivasan, 2011; Fox et al., 2002, Experiments 2 and 3; Lange et al., 2008; Pérez-Dueñas et al., 2009, Rutherford & Raymond, 2010, Stoyanova et al., 2007). In some of them, IOR was not modulated by threatening cues (Lange et al., 2008; Stoyanova et al., 2007). In other experiments, IOR was observed with negative stimuli except in those participants with high anxiety, no matter whether they were specifically selected by their trait or state anxiety (Fox et al., 2002, Experiment 3; Pérez-Dueñas et al., 2009), or the mood state was induced in them by the context (Rutherford & Raymond, 2010). Finally, other researchers found abolished IOR in all participants with schematic faces (Fox et al., 2002, Experiment 2) and spoken word (Bertels et al., 2011) as cues and schematic sad faces as target (Baijal & Srinivasan, 2011).

It is important to highlight the differences between the studies reported in the current paper and previous studies: (1) the emotional stimuli were used as targets in our experiments rather than as cues (as in Bertels et al., 2011; Fox et al., 2002, Lange et al., 2008 and Stoyanova et al., 2007). This manipulation makes it possible to study the habituation or detection cost hypothesis, with the observed results supporting it, as no IOR effect was observed with angry face targets. As aforementioned, in our experiments the target valence was manipulated within blocks of trials, so that it could not be anticipated until the target was presented. Therefore, any process occurring before the target was presented should be equated for all trials and independent of target valence (Lupiáñez et al., 2007), and therefore theories explaining IOR entirely due to processes related to disengaging of attention should predict no effect of valence (attention should be either disengaged or engaged to the cued location equally for all target types); (2) the emotional stimuli were naturalistic and ecologically valid in the present experiments rather than symbolic (as in Pérez-Dueñas et al., 2009). Whereas words might be relevant for individual with specific anxiety worries, angry faces would represent a more universal threat, for which all individuals might show a bias. In line with evolutionary theories and habituation hypotheses, the IOR effect disappeared for angry faces in all participants (i.e., individuals with high- vs. low-anxiety trait and state); and (3) the task used in the current experiments made the emotional valence of the targets somehow relevant by having participants to categorize, rather than to localize them (as in Rutherford & Raymond, 2010) or detect them (Baijal & Srinivasan, 2011). The fact that emotionality of faces was task relevant might have also increased the saliency of angry faces as to intensely capture attention (Pashler et al., 2001), thus overriding the IOR effect.

Supporting the habituation hypothesis of IOR, the effect only disappeared in an emotional categorization task for threatening words targets, and not with neutral or positive ones, in high-trait anxious participants (Pérez-Dueñas et al., 2009), or when the valence was presented in blocks, probably inducing social anxiety due to the threatening context with angry faces (Rutherford & Raymond, 2010). Many theories and research support that attention is biased toward potentially threatening information in people with high anxiety because they are hypersensitive to threatening information and do not habituate to such stimuli (Eysenck, 1992; Mathews & MacLeod, 1994; Williams et al., 1997). It makes then perfect sense that reduced habituation to negative words was shown only by the participants with high anxiety.

Similar results were observed with sad faces as target in previous studies but the anxiety level was not measured (Baijal & Srinivasan, 2011). Perhaps, if groups differed in specific social anxiety instead of general trait or state anxiety, differences between groups might come to surface, as current accounts of social anxiety suggest that it is characterized by abnormal processing of social threat information, such as negative facial expressions (e.g., see Heinrichs & Hofmann, 2001, for a review). Some studies including other experimental methods as dot probe and face-in-the-crowd paradigms have reported that people with social anxiety show greater attentional biases for angry faces compared to controls (e.g., Gilboa-Schechtman, Foa, & Amir, 1999; Juth et al., 2005; Mogg & Bradley, 2002).

Literature about anxiety disorders evidences that while attentional biases are common to all anxious people, the precise content of the bias tends to be related to unique features that are significant to specific anxiety disorders (Craske & Waters, 2005; Williams et al., 1997). In this line, Amir, Elias, Klumpp, and Przeworski (2003), by manipulating the emotional valence of the cue in a cuing paradigm, found attentional biases in social phobics due to a difficulty in disengaging attention from specific social threat word.

In any case, the social anxiety level, other anxiety disorders or even other traits as anger (van Honk et al., 2001) has not been manipulated in an exogenous cuing paradigm with emotional targets as to measure specifically facilitated attentional capture and reduced habituation toward angry faces. Future research with different type of anxiety disorders is necessary considering that different attentional bias patterns could be related to the diverse symptoms of each disorder (Ashwin et al., 2012).

Therefore, to conclude, future studies will need to establish whether participant's level in social phobia can modulate these results as well as other anxious populations. It will be very interesting to investigate whether relevancy can be specifically created for each specific individual, so that each individual show less IOR (i.e., show less habituation) for specific stimuli for which they experimentally develop a trend, or for which they are more motivated.

In the same way, it should be investigated whether non-threatening stimuli that are nonetheless biologically relevant for members of a species, such as babies (Brosh et al., 2007, 2008), can abolish the IOR effect.

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