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Attentional bias to angry faces using the dot-probe task? It depends when you look for it.

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Abstract

A number of studies using the dot-probe task now report the existence of attentional biases to angry faces in participants who rate highly on scales of anxiety; however, no equivalent bias has been observed in non-anxious populations, despite evidence to the contrary from studies using other tasks. One reason for this discrepancy may be that researchers using the dot-probe task have rarely investigated any effects which might emerge earlier than 500 ms following presentation of the threat-related faces. Accordingly, in the current study we presented pairs of face stimuli with emotional and neutral expressions and probed the allocation of attention to these stimuli for presentation times of 100ms and 500ms. Results showed that at 100ms there was an attentional bias towards the location of the relatively threatening stimulus (the angry face in angry/neutral pairs and the neutral face in neutral/happy pairs) and this pattern reversed by 500ms. Comparisons of RT scores with an appropriate baseline suggested that the early bias toward threatening faces may actually arise through inhibition of the relatively least threatening member of a face pair rather than through facilitation of, or vigilance towards, the more threatening stimulus. However the mechanisms governing the observed biases are interpreted, these data provide evidence that probing for the location of spatial attention at 500ms is not necessarily indicative of the initial allocation of attention between competing emotional facial stimuli.

Keywords – Attention; Attentional Bias; Dot Probe; Threat; Face; Emotion.

1. Introduction

Recent studies using the dot-probe task (see below) have established that people who rate highly on scales of trait and state anxiety show an attentional bias towards threat-related stimuli and that control groups who have low scores on these measures do not show such a bias (e.g. Mogg & Bradley, 1999; Bradley et al, 1998). However, given the fact that an angry facial expression is an evolutionarily old and salient signal of threat it is somewhat surprising that the dot-probe task has failed to reveal an attentional bias in non-anxious individuals to threat related facial expressions (e.g. Bradley et al 1997). It is even more surprising given the wealth of evidence using a variety of other paradigms that angry faces do indeed capture attention in normal, non-anxious populations (Ohman, Lundqvist, & Esteves, 2001; Fox, Lester, Russo, Bowles, Pichler, & Dutton, 2000; Eastwood, Smilek, & Merikle, 2003; White, 1995).

In its most commonly used form the dot-probe task involves the presentation of a pair of stimuli for a fixed period of time (usually 500ms) followed by the appearance of a visual probe in one of the two stimulus locations. Participants then have to perform a task involving the probe (i.e. identification or localisation) and the distribution of spatial attention between the initially presented stimulus pair is inferred by comparing the speed of manual responses to the probe at each of the stimulus locations (following Posner, Snyder, & Davidson, 1980; Navon & Margalit, 1983). This procedure was initially developed to measure attentional biases to threat in clinically anxious populations (Macleod, Mathews, & Tata, 1986); however, its use has extended to many areas where attentional biases have been observed e.g. people with eating disorders (e.g. Ehrhardt, Weiss, Musial, Zimmanyi, Englert, Blanz, & Miltner, 2003), chronic pain sufferers (e.g. Dehghani, Sharpe, & Nicholas, 2003), smokers (e.g. Hogarth, Mogg, Bradley, Duka, & Dickinson, 2003) and various other clinical and non-clinical conditions (e.g. Townshend & Duka, 2001; Wenzel & Holt, 1999).

One reason for the lack of evidence for an attentional bias to threat in non-anxious individuals using the dot-probe task could be because, unlike the other paradigms used (e.g. the visual search task) the stimuli in the dot-probe paradigm are entirely irrelevant to the task the participant has to perform. This makes the dot-probe paradigm a relatively conservative test of whether or not a given stimulus is actually capturing attention (Driver et al, 1999). On the other hand, the failure to find effects in this paradigm could also be attributable to the fact that the dot-probe task, in its standard form, only measures a snapshot of attention, i.e. where attention is allocated when the probe appears. This allows no insight into where attention is allocated before or after the measured snapshot. However, by varying the time between the onset of the stimuli of interest and the appearance of the probe, one can assess the time-course of the deployment of attention over the stimulus pair. Studies using this approach have indicated different patterns of attentional allocation to valenced stimuli (emotional words and faces) at 500ms compared with longer latencies (Bradley, Mogg, Falla, & Hamilton, 1998; Mogg, Bradley, Miles, & Dixon, 2004). In these papers it is assumed that the probe's appearance at 500ms is a measure of the initial allocation of attention to the stimuli. This assumption is supported by evidence showing that the location of the first shift of attention, as assessed by manual key-press responses in the dot-probe task, is the same location as the initial eye movement made to the stimuli (Bradley, Mogg, & Millar, 2000). In line with this evidence most researchers probe for initial allocation of attention at 500ms (e.g. Macleod, Mathews, & Tata, 1986; Mogg & Bradley, 1999; Chen, Ehlers, Clark, & Mansell, 2002; Egloff & Hock, 2003). However, while sampling the allocation of attention at the 500ms time window may reflect the initial orienting of *overt* attention (i.e. where the eyes are directed), 500ms is sufficient time to allow more than one shift in *covert* attention (i.e. the shift of attention that precedes eye movements but can move independently of it) (Posner & Peterson, 1990). Indeed, measuring the initial allocation of covert attention may be crucial in the dot-probe task as Bradley et al (2000) reported that the attentional bias shown with RT data was not dependent on overt orienting: more than half of their participants made eye movements on less than 10% of all trials.

The aim of the current study is to establish whether the inability to find evidence for attentional capture by angry faces in the dot-probe task is due to the standard use of a 500ms presentation time. Research suggests that non-anxious individuals avoid angry faces when presented for 500ms (Bradley et al, 1997). However, only sampling attention at 500ms does not allow for the possibility that attention is initially captured by the angry face before being deployed elsewhere. As already mentioned, given the wealth of evidence showing the presence of attentional biases to angry expressions using other paradigms, it is important to examine whether the dot-probe task, as a relatively conservative test of attention, will reveal such a bias when the allocation of attention is measured at an earlier time-frame. A 100ms presentation time was chosen to contrast with the 500ms presentation time. While we cannot be sure that measuring the allocation of attention after this delay will be a true reflection of the initial allocation of attention between the competing stimuli other work has found different patterns of attentional effects when comparing 100ms and 500ms delays between stimulus and target onset (Langton & Bruce, 1999). It is predicted that if an angry face is paired with a neutral face and presented for 100ms, an attentional bias will be observed towards the location of the angry face.

Allied to this and of more general interest for researchers using the dot-probe task to study attention, we expect that the predicted bias at 100ms will be absent when attention is sampled again at 500ms. This follows from a number of studies that have found apparent avoidance of threat-related stimuli in normal controls with a 500ms presentation time (Macleod et al, 1986; Bradley et al, 1997). This outcome would mean that sampling attention at 500ms does not represent the initial allocation of attention to an item in a stimulus pair.

2. Method

2.1. Participants

60 undergraduate psychology students[1] (49 female, with a mean age of 20.5 years) from the University of Stirling took part for course credit. Participants' anxiety levels were not measured.

2.2. Materials

Thirty pictures were taken from the Ekman and Friesen (1976) set of emotional expressions. The photographs comprised ten individuals (six females) each posing neutral, happy, and angry expressions looking straight into the camera. Happy as well as angry expressions were used to ensure that if the predicted effects with angry faces were observed they could be attributed to the angry face specifically rather than emotional faces more generally. The external features of each of the faces were removed and the internal features were presented in a black rectangular frame. The image size (including the frame) measured 8.5cm x 3cm on the screen. An averted gaze version of each of the faces was created in Adobe Photoshop by moving the pupils laterally until they were at the corners of the eyes. Half of the gaze-averted faces were made to look to the left and the other half were made to look to the right. This gave a total of 60 photographs. Averted gaze faces were included because all previous research looking at attentional biases to emotional expressions has only used faces with gaze directed straight at the participant. Comparing responses in trials containing

[1] Allocation to the between subjects component of PT was not random. Initially 36 participants took part in the 500ms PT condition and one month later 24 participants took part in the 100ms PT condition.

direct gaze emotional faces with averted gaze emotional faces will allow us to see what impact (if any) gaze has on the orienting of attention to emotional facial expressions.

Each one of the 60 photographs was paired in Photoshop with a neutral face of the same identity with averted gaze. It was assumed that a face with a neutral expression and averted gaze would be least likely to attract attention compared with the other emotion and gaze combinations. There is some evidence that direct gaze captures attention (von Grunau & Anston, 1995) and as such pairing each of the faces with one which has averted gaze should allow us to assess the role gaze plays in the allocation of attention to the facial stimuli. The photos were placed on a white background, one above the other, separated by 6 cm and were viewed by participants from a distance of approximately 60cm Two versions of each face pair were created with the relative positions switched so that each face could appear in both locations (either top or bottom). Stimuli were presented on an iMac using the experimental software SuperLab. Responses were collected using a Macintosh Keyboard.

2.3. Design and Procedure.

Participants saw a fixation cross for 750ms followed by a pair of faces for 100 or 500ms (depending on the group to which they were allocated) which were followed in turn by two dots. Participants' task was to identify whether the dots were horizontally or vertically oriented and that, as such, the faces had nothing to do with the task and so should be ignored. Participants had to press one key (z) when the dots were horizontal and another key (m) when the dots were vertical. The dots remained on the screen for two seconds or until a response was made, whichever came sooner. Participants were given ten practice trials to familiarise themselves with the procedure and then 240 test trials with a break in the middle. These comprised twenty trials in each of the eight conditions: two emotional expressions (angry or happy), two probe locations (the location of the emotional face or the neutral face), and two gaze directions (direct or averted). Of the remaining 80 trials, 40 contained face pairs where both faces were neutral but where the gaze direction differed (e.g. a neutral face with direct gaze paired with another neutral face of the same identity with averted gaze). These were included to examine any attentional effects arising from faces with direct compared to averted gaze. The other 40 trials comprised pairs of faces of the same identity, each with neutral expressions and averted gaze. These were included to act as a baseline in order to help determine which mechanisms (e.g. facilitation or inhibition) might be responsible for any observed attentional biases (Koster et al, 2004). Test trials were presented in a new random order for each participant.

3. Results

The data analysis for the dot-probe task was based on reaction times for correct responses[2]. Data from trials with errors were discarded (5% of data in both the two PT conditions) and not analysed further. Data from participants who made more errors than 2.5 standard deviations from the mean were discarded (Two participants, one from each of the between-subjects conditions, had an overall error rate of 24%). Median RTs were calculated for each of the experimental conditions for the 58 remaining participants. The interparticipant means of these medians are displayed in Table 1.

[2] There were no main effects of gaze nor did the gaze manipulation interact with any of the measures reflecting attentional bias. As such, all data are collapsed across this variable.

Table 1. Mean Reaction Times (ms) for Identifying Probes That Appear in a Location Previously Occupied by an Emotional (Happy or Angry) or Neutral Face, With a 100 or 500 ms Presentation Time (Mean ± Standard Error).

		Face Pair			
		Angry/Neutral		*Happy/Neutral*	
	Baseline	*Angry*	*Neutral*	*Happy*	*Neutral*
100ms	544 ± 14	552 ± 20	559* ± 20	559* ± 21	546 ± 23
500ms	610 ± 18	609 ± 16	598* ± 16	602 ± 16	618 ± 19

***Significantly different from baseline p<.05**

The data were entered into a 2 x 2 x 2 repeated measures ANOVA with two within-subjects factors of relative probe position (probe appears in location of emotional or neutral face) and type of emotional face (angry, happy), and a between-subjects factor of presentation time (100ms, 500ms). This revealed a significant effect of presentation time, $F(1, 56) = 4.110$, $p = .047$, reflecting the fact that average response time in the 100ms condition (554ms) was 53ms faster than the average response time in the 500ms condition (607ms). This effect was qualified by a three-way interaction between relative probe position, emotional face and presentation time $F(1,56) = 8.979$, $p=.004$. To simplify the three-way interaction a bias score was calculated for each type of emotional face pair, modifying the procedure of Macleod and Mathews (1988): Bias score = PN – PE where PN is the mean RT to probes which appeared in the location of the neutral face and PE is the mean RT to probes which appeared in the location of the emotional face. Positive values reflect attention towards the emotional face (vigilance) and negative values reflect attention away from the emotional face (avoidance). These bias scores are displayed in Figure 1. A 2 x 2 repeated measures ANOVA of the bias scores with emotional expression as a within-subjects factor and presentation time as a between-subjects factor yielded a significant emotional expression x presentation time interaction, $F(1,56) = 8.979$, $p = .004$. (This result is equivalent to the three-way interaction with RTs). Comparisons of the bias scores against zero (0 = no attentional bias) at 100ms showed significant avoidance of the happy face (bias score = -12, $t(22) = 2.636$, $p = .015$, two-tailed) but no significant vigilance of the angry face (bias score = 7, $p > .2$). At 500ms there was significant avoidance of the angry face (bias score = -11, $t(34) = 2.13$, $p = .041$, two-tailed) and a trend towards vigilance of the happy face (bias score = 16, $t(34) = 1.732$, $p=.092$, two-tailed).

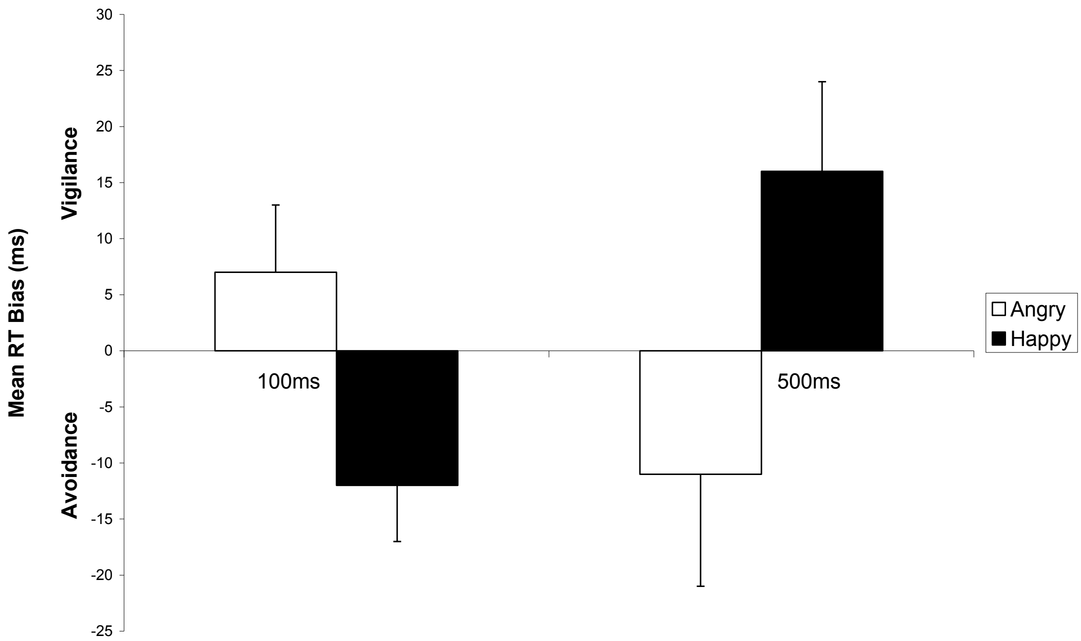

Figure 1. Mean attentional bias scores and standard errors for the angry and happy facial expressions in the 100ms and 500ms presentation times.

To clarify the interaction term further, t-tests were carried out on the differences in attentional bias scores between the two PTs. This revealed a significant decrease in bias score for the angry/neutral pair between the short and long PT (angry bias at 100ms PT = 7ms, angry bias at 500 ms PT = -11ms, $t(58) = 2.192$, $p = .033$, two-tailed) and a significant increase in the bias score for the happy/neutral pairs between the two PTs (happy bias at 100ms PT = -12ms, happy bias at 500ms PT = 16ms, $t(47) = -$

2.697, p = .01, two-tailed) face pairs. This indicates that the biases for each face pair are different at 100ms compared to 500ms.

Although the above analysis does illustrate the direction of attentional biases it does not make clear whether apparent vigilance - for example, to the happy face at 500ms - is a result of facilitation of attention at its location, inhibition of the neutral face location, or both. In order to establish which mechanisms are responsible for the observed attentional biases at both the 100ms and 500ms PTs we compared the mean RTs from the four experimental conditions to baseline RTs obtained from trials comprised of neutral-neutral face pairs. Responses faster than the baseline RT would indicate that facilitation (vigilance) was taking place at that location compared to baseline responding. Responses slower than the baseline would indicate inhibition (avoidance) at that location compared to baseline responding (Koster et al, 2004). In the 100ms condition the baseline was 544ms. In happy/neutral trials the mean RT to probes appearing in the location of the happy face (559 ms) was significantly slower than the baseline 544ms, $t(22) = 2.724$, $p=.012$ (two-tailed), whilst probes appearing in the location of the neutral face (546 ms) attracted equivalent RTs to baseline ($p > .8$). For angry/neutral trials the mean RT to probes appearing in the location of the angry face (552 ms) was no different from baseline ($p > .15$) but the mean RT to probes in the location of the neutral face (559 ms) was significantly slower than the baseline, $t(22) = 2.332$, $p=.03$ (two-tailed). To summarise, at the 100 ms PT the use of this baseline measure suggests that with angry/neutral pairs, participants inhibit the neutral face location but do not show vigilance to the angry face. For happy/neutral pairs, however, there is evidence for inhibition of the happy face location but no attentional bias for the neutral face.

In the 500ms condition baseline responding was 610ms. For angry/neutral pairs, responses to probes which appeared in the location of the neutral face (598 ms) were significantly faster than baseline (610 ms), t(35) = 3.018, p=.007 (two-tailed), but performance in all other conditions was equivalent to baseline(all p's > .14). At the longer PT there is therefore evidence for facilitation of attention to the neutral face location in angry/neutral pairs when comparing with the baseline, but no other attentional biases.

4. Discussion

In this study we were investigating whether previous attempts to observe an attentional bias towards angry faces in non-anxious participants using the dot-probe task had failed due to the standard use of a 500ms PT. Indeed, our data indicate that the initial deployment of attention occurs much earlier than 500 ms following presentation of a face pair. In fact, at 100 ms the pattern of deployment of attention is the opposite of that observed at 500 ms. More specifically, for the angry/neutral face pair at 100ms, there was a non-significant 7ms bias *towards* the angry face and by 500ms there was a significant 11ms bias *away* from the angry face. Although the initial bias was not significant this reflects the pattern of data that was predicted for attention to the angry face. For the happy/neutral face pair, at 100ms there was a significant 12ms bias *away* from the happy face and by 500ms there was a non-significant 16ms bias *towards* the happy face. Clearly a PT of 100 ms is sufficient for an analysis of the emotional valance of the competing face stimuli and a deployment of attention between the stimuli on the basis of this analysis; a presentation time of 500 ms does not, then, reflect the initial allocation of attention as has been assumed in previous research.

Traditionally, biases towards and away from stimuli in a pair in the dot-probe task have been termed, respectively, vigilance and avoidance (e.g. Bradley et al, 1998, Mogg et al, 2000). For the angry/neutral face pair the pattern of results just described would be interpreted as initial vigilance to the angry face at 100ms (albeit only a weak trend) followed by avoidance of the stimulus at 500ms. Indeed, the current results showing apparent avoidance of the angry face at 500ms replicate the findings of Bradley et al (1997) with non-anxious individuals and are consistent with Mogg and Bradley's (1998) vigilance/avoidance model of attention to threat with initial vigilance being followed by avoidance. For the happy/neutral face pair the data are suggestive of initial avoidance of the happy face at 100ms followed by vigilance at 500ms. However, these data can be interpreted in another way if we assume that on each trial attention is initially allocated to the most threatening face on the screen. In angry/neutral trials this would be the angry face but on happy/neutral trials this would be the neutral face. An expressionless face with gaze directed straight at the viewer could be considered neutral in terms of the emotion that is displayed but the signal that this conveys could be considered hostile or, at the very least, ambiguous. If this assumption is made then the pattern of data is identical in both the angry/neutral and happy/neutral trials with attention being initially allocated to the relatively threatening face at 100ms and then shifting to the other face by 500ms.

Thus, there are at least three ways of interpreting the advantage in RTs to probes appearing in the location of the neutral face in a neutral/happy pair over RTs to probes appearing in the location of the happy face in the same type of pair: avoidance of the happy face or vigilance to the neutral face (perhaps because it is relatively more threatening), or both. In standard forms of the dot-probe task there would be no-way of choosing between these interpretations. All other studies assume that the neutral face (or neutral scene or word) plays an entirely passive role and that attention is either allocated to, or away from, the valenced stimulus. As the current study illustrates, it is not clear if differences in attentional bias are as a result of vigilance to one particular stimulus, avoidance of another, or both. One method that has been recently employed to try and tease these issues apart is the introduction of baseline trials which are comprised of neutral/neutral stimulus pairs (Koster et al, 2004, Koster et al, in press). Response times in experimental conditions are then compared with the baseline response times. If, in a particular condition, responses to identify the target are faster than the baseline, this implies that these responses are facilitated by a mechanism allocating attention to the region. If, however, response times are slower than the baseline, this implies that attention serves to inhibit processing at the location of the probe.

Using the baseline to interpret the nature of the observed biases in the current study radically alters their interpretation. For example, with the angry/neutral stimuli in the 100 ms condition, the traditional method of computing attentional bias reveals a bias towards the angry face location (and hence away from the neutral face location) that would normally be interpreted as vigilance to the angry face. However, if the RT scores from these conditions are compared against the neutral/neutral baseline the data suggests that differences in responses to probes following angry/neutral trials are due to inhibition of the neutral face rather than facilitation of the angry face. This pattern is mirrored in the happy/neutral face trials with the apparent vigilance to the angrier face (neutral) being due to inhibition of the happy face location. Our data therefore suggest that an early attentional bias towards threat may actually arise through the inhibition of the relatively least threatening stimulus rather than through the facilitation of the more threatening member of a stimulus pair. This highlights the problem of interpreting data in this paradigm (see Koster et al, 2004 for a more detailed exploration of these ideas). What is clear is that results that would traditionally have been taken as evidence of avoidance or vigilance have to be reinterpreted when a baseline condition is employed. As such we echo the sentiments of Koster et al (2004) when they state that without a baseline measure from which comparisons can be made, inferences concerning attentional mechanisms in the dot-probe task are problematic.

Independent of the mechanism responsible for the effects observed in the current study the data show a pattern that is consistent with other studies looking at attention to emotional faces in 'normal' populations; namely facilitated processing of threat related stimuli (Ohman et al, 2001, Fox et al, 2000). This is in line with recent models of attention to threat which have suggested an attentional bias towards threat is a universal feature of human cognitive processing (Mathews & Mackintosh, 1998; Mogg & Bradley, 1998) and not just present in anxious individuals as was suggested previously (Eysenck, 1992).

It is interesting to note that the allocation of attention in the dot-probe task was unaffected by the direction of gaze adopted by the face stimuli. This is somewhat surprising given that a number of recent studies have found that the processing of emotional expressions is modulated by gaze direction (Adams, Gordon, Baird, Ambady, & Kleck, 2003; Adams & Kleck, 2003; Wicker, Perrett, Baron-Cohen, & Decety, 2003). However, the critical difference between the current study and the previous work is that the current study was assessing which attributes of a face attract attention whereas the previous work was measuring how the processing of the face occurs once the face has been attended. These are two entirely different levels of analysis. The current results suggest that attention to competing facial stimuli is allocated on the basis of their emotional expression but not their gaze direction. It is possible that differences in facial expression might be more salient than differences in gaze direction because they occupy a larger surface area of the face. It is also possible that emotional expressions are intrinsically more likely to draw visual attention than gaze direction not because of this saliency explanation but because of the evolutionary importance of the emotional signal. Further research is needed to address this issue.

In more general terms, the results clearly demonstrate different patterns of attentional deployment at 100ms compared to 500ms. Far from representing the initial allocation of attention the results at the 500ms PT are significantly different to those observed at the100ms PT. This difference cannot be accounted for by assuming that no bias is present at 100ms and that one emerges by 500ms. At the 100ms PT a significant bias away from the location of the happy face and towards the location of the neutral face was recorded which did not remain at the 500ms PT. This means that a different pattern of bias was observed at the two presentation times. These results undermine the widely held assumption in the dot-probe literature that sampling attention at 500ms is a reflection of the initial orienting of attention towards the stimulus (e.g. Macleod, Mathews, & Tata, 1986; Mogg & Bradley, 1999; Chen, Ehlers, Clark, & Mansell, 2002; Egloff & Hock, 2003). This, combined with recent work showing different patterns of attentional deployment at 100ms compared to 500ms, and 500ms compared to 1250ms for threat-related pictures (Koster et al, in press), suggests that researchers looking to investigate attentional biases in both clinical and non-clinical populations should use a number of presentation times, including one shorter than the standard 500ms condition (e.g. 100ms). Measuring the initial allocation of spatial attention earlier than 500ms would be in line with much research using other paradigms to study spatial attention (e.g. Posner, 1980; Langton & Bruce, 1999; Friesen & Kingstone, 1998).

A limitation of the current study is that the variable presentation time (100ms or 500ms) was between-subjects and the allocation of participants to the two presentation times was not done randomly. The experiments were conducted one after the other with a gap of approximately 4 weeks in between. While this does not represent the ideal scenario for looking at differences in the allocation of attention there is no reason to suspect (although no way of knowing for sure) that the two groups differed from one another on any variable that might be influential on the results of the current experiment (e.g. anxiety).

A further possible limitation of the current study is that the participants were primarily female. This is a limitation in the sense that there is recent evidence that females show greater visual cortical activity to negatively valenced pictures suggesting that females may be particularly sensitive to such information (Sabatinelli, Flaisch, Bradley, Fitzsimmons, & Lang, 2004). While the link between this evidence and the allocation of visual attention to threat-related stimuli is not clear it seems appropriate to take this into account in the design of future studies.

In sum, interpretation of observed attentional bias is ambiguous in the standard version of the dot-probe task. The use of baseline trials in the current experiment suggests bias to initial threat arises from inhibition of the least threatening stimulus rather than vigilance to the threat. Thus the inclusion of baseline trials is one way of elucidating the attentional mechanisms that are responsible for any observed biases. Furthermore, sampling attention to facial expressions at 100ms in the dot-probe task can reveal a different pattern of attentional allocation than is observed at 500ms. More generally, this is good evidence that sampling the location of attention at 500ms in the dot-probe task does not necessarily represent its deployment at 100ms. As such, researchers wishing to sample the initial allocation of attention to competing stimuli using this paradigm should take this into account in the design of their experiments.

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