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Raising the Alarm: Individual Differences in the Perceptual Awareness of Masked Facial Expressions

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HIGHLIGHTS

- Backward masking effectiveness differs between subjective and objective measures.
- Participants can reliably access masked facial expressions of happiness.
- High trait anxiety enhances threat detection of masked facial expressions of anger.
- Low trait anxiety enhances perceptual access to masked happy facial expressions.

Abstract

A theoretical concern in addressing the unconscious perception of emotion is the extent to which participants can access experiential properties of masked facial stimuli. Performance on a two alternative forced choice (2AFC) task as a measure of objective awareness was compared with a new measure developed to access experiential phenomena of the target-mask transition, the perceptual contrast-change sensitivity (PCCS) measure in a backward-masking paradigm with angry, happy and neutral facial expressions. Whilst 2AFC performance indicated that the targets were successfully masked, PCCS values were significantly higher in the happy-neutral face condition than in the angry-neutral face and the neutral-neutral face conditions (Experiment 1). Furthermore, objective measures of awareness were more readily displayed by individuals with high trait anxiety, whereas individuals with low trait anxiety showed greater access to the experiential quality of happy faces (Experiment 2). These findings provide important insights into the methodological considerations involved in the study of non-conscious processing of emotions, both with respect to individual differences in anxiety and the extent to which certain expressions can be successfully masked relative to others. Furthermore, our results may be informative to work investigating the neural correlates of conscious versus unconscious perception of emotion.

Keywords: threat detection; emotion perception; backward-masking; face perception; amygdala; anxiety

1. Introduction

Ubiquitous in our daily lives, emotional experiences are ingrained in the evolutionary process (Al-Shawaf, Conroy-Beam, Asao, & Buss, 2016; Ekman & Cordaro, 2011; Ekman, 1992; Nesse & Ellsworth, 2009; Öhman, 2006). Thus firmly established in our neurobiological system, emotions are perceived automatically and unconsciously (Dimberg, Thunberg, & Elmehed, 2000; Dimberg, Thunberg, & Grunedal, 2002; Tamietto & de Gelder, 2010; Tracy & Robins, 2008). According to Tamietto and de Gelder (2010), the unconscious perception of emotion has been implicated in a multitude of subcortical brain regions, which can broadly be divided into a network involved in the visual processing of emotional cues and a network centered on non-visual emotion-oriented processes. The former network, as the authors note, includes the substantia innominate, the superior colliculus, the nucleus accumbens, the pulvinar and the amygdala, whereas the latter network involves the basal ganglia, the locus coeruleus, the hypothalamus, the periaqueductal grey, the hippocampus and the nucleus basalis of Meynert. Conscious perception of emotional cues, in turn, usually also extends across the cingulate, occipitotemporal and frontal areas, although such activity can sometimes be found in studies rendering emotional cues unconscious as well, possibly due to direct and indirect links between cortical and subcortical structures (Brooks et al., 2012; Tamietto & de Gelder, 2010). Not surprisingly then, there has been an avid debate concerned with the extent to which brain activation during conscious versus unconscious perception of emotion relies on common or distinct neural substrates (Balconi & Bortolotti, 2013; Jiang & He, 2006; Phillips et al., 2004; Tamietto & de Gelder, 2010; Tamietto et al., 2015; Yang, Cao, Xu, & Chen, 2012). Part of this debate rests on the crucial assumption that the paradigms used to test unconscious perception of emotion uniquely measure unconscious, but not conscious, perception of emotion.

1.1. The backward-masking paradigm in perceiving emotional expressions

One of the principal paradigms for the study of unconscious emotions in healthy individuals is the backward-masking procedure (Tamietto & de Gelder, 2010). The backward-masking procedure has made a significant contribution to the amygdala's status as the brain's silent 'alarm' system, alerting us to impending dangers, such as fearful and angry facial expressions, often with relatively little conscious appraisal on our part (Liddell et al., 2005; Öhman & Mineka, 2001). Procedurally, it entails the brief presentation of a visual stimulus, referred to as the *target*, followed by the subsequent presentation of another visual stimulus, in the same (or nearby) spatial location, referred to as the *mask.* Presentation rates of the target stimulus, which is usually a picture of an emotional face such as an angry or fearful expression, are very brief, usually in the order of 30msec or less. The masking stimulus, usually a picture of a neutral face has a slightly longer duration, typically 100msec or more. While participants are often able to report the presence of the mask, they are unable to identify or even detect the presence of the target. Thus, the participant is deemed to be *unaware* of the target, even though the physiological and neuroimaging changes are observed in the participant during the target's presentation in the backward-masking task (e.g., Dimberg, Thunberg & Elmehed, 2000; Whalen et al., 2004). Furthermore, manipulating the temporal interval between the presentation of the target and mask, most commonly expressed in terms of stimulus onset asynchrony (SOA), appears to play a key role in influencing the detection of emotional targets, with longer SOAs facilitating target detection performance (e.g., Esteves & Öhman, 1993).

1.2. Emotion perception without awareness: the role of objective and subjective criteria

Outside of the neuroscientific investigation of the threat detecting capacities of the amygdala, cognitive psychologists have been concerned for quite some time as to whether participants are truly unaware of the masked threatening emotional expression (Pessoa, 2005; Pessoa, Japee & Ungerleider, 2005; Maxwell & Davidson, 2004; Milders, Sahraie & Logan, 2008). A particular problem in classifying whether or not a participant is unaware of the masked emotional expression partially derives from the criteria used in defining subjective vs objective levels of awareness. According to subjective criteria, awareness is assessed on the basis of participants' self-reports of their conscious experiences; if participants can report that they have 'seen' the target, it is assumed that the item was perceived with awareness, and if the participants report that they have not 'seen' the target, it is assumed that they are unaware of the critical (i.e., masked) item (e.g.,Dimberg, Thunberg & Elmehed; 2000; Morris, Öhman & Dolan, 1998; Merikle, 1992; Tsuchiya & Adolphs, 2007). A more sensitive approach over such binary responses (e.g., seen vs. not seen) involves the additional use of confidence ratings (e.g., Esteves & Öhman, 1993; Phillips et al., 2004) during the target/mask pairings to establish when participants become fully conscious or aware of the presence of the target (i.e., 'extremely confident').

According to objective criteria, awareness is assessed on the basis of setting performance thresholds, typically measured in a forced-choice decision task. Participants are deemed unaware of the target if they cannot discriminate the presence or absence of a stimulus or categorize the emotionality of the target (e.g., fear vs disgust) with above-chance accuracy (e.g., Liddell et al., 2005; Merikle, Smilek & Eastwood, 2001; Phillips et al., 2004). Objective perception of the target face is assessed using a signal detection framework in which the detection threshold of *d'* = 0 or its nonparametric analogue, *A'* = 0.50 is used as a measure of chance performance (e.g., Hanley & McNeil, 1982; Liddell et al., 2005; Macmillan & Creelman, 1991; Maxwell & Davidson, 2004; Milders et al., 2008; Szczepanowski & Pessoa, 2007). Studies that have utilized *A'* measures have reported above-chance detection even at 17msec target presentation times (e.g., Pessoa et al., 2005) thus contrasting with previous findings with longer, yet seemingly 'unconscious' thresholds (e.g., Morris et al., 1998; Whalen et al., 1998).

Self-report methodologies that focus on binary 'seen/unseen' responses or confidence ratings may not sensitively capture all relevant aspects of participants' conscious experiences of the backward-masking methodology (e.g., Maxwell & Davidson, 2004; Merikle et al., 2001). Usually, these experiences stem from the perceptual changes during the transition between target and mask, resulting in apparent motion phenomena which are likely to be intensified in some emotional expressions on account of the perceptual discrepancy in the localized facial features. For instance, happy facial expressions are reliably identified from neutral faces (i.e., 70% of raters agree) on the basis of the presence of the bags under eyes, cheeks raised, upper lip raised and exposure of the upper teeth, whilst angry facial expressions are reliably identified by the presence of a pronounced frown (Calvo & Marrero, 2008). Asking participants to explicitly report their experience of such phenomena through questionnaire formats and/or funnel interview techniques can yield important individual differences in detecting the emotionality of masked faces.

For example, Maxwell and Davidson (2004) divided their participant pool into those participants who could verbally report the presence of apparent motion (e.g., flickering and movement) in the backward-masking task (explicitly aware) and those who maintained, despite persistent prompting, not to have experienced any apparent motion phenomena (explicitly unaware). The two groups differed in performance in a target identification forced choice procedure, such that the explicitly aware group performed better than the unaware group in identifying happy and neutral targets, whereas the unaware group outperformed their explicitly aware counterparts in the identification of anger. Thus, the contrasting effects in setting subjective vs objective measures of awareness indicates how facial expressions of emotion perceived without awareness can both bias which stimuli are perceived with awareness and influence how stimuli are consciously experienced (e.g., Maxwell & Davidson, 2004).

1.3. The role of self-reported anxiety in emotion perception

The perceptual awareness of emotional stimuli may be further modulated by individual differences in trait levels of self-reported anxiety, which can affect an individual’s response to impending situational (i.e., state anxiety) stressors (Eysenck, 1992; Eysenck, Derakshan, Santos & Calvo, 2007; Spielberger, Gorsuch, Lushene, Vagg & Jacobs, 1983). Above threshold presentation of facial stimuli tends to trigger greater levels of visual spatial attention towards threatening facial expressions in individuals with high trait anxiety (Byrne & Eysenck, 1995; Mogg & Bradley, 1999). Anxiety-related difficulties also emerge when it comes to disengaging attention away from threat-relevant facial stimuli (Fox, Russo, Bowles & Dutton, 2001; Georgiou et al., 2005) and can also interfere in the processing of task-irrelevant threat distracters (e.g., Damjanovic, Pinkham, Clarke, Phillips, 2014).

Recent investigations with backwardly masked emotional expressions are also consistent with the view of a finely tuned threat detection mechanism in anxiety, such that high performing participants on fear detection trials are likely to belong to the high end of the trait anxiety continuum (Japee, Crocker, Carver, Pessoa & Ungerleider, 2009). This bias can emerge as early as 115-145 msec post-stimulus (Li, Zinbarg, Boehm & Paller, 2008), whilst spatial markers show increases in right amygdala activation which correlates strongly with symptom severity in individuals with generalized anxiety disorder (Monk et al., 2008).

1.4. Aims of the current study

Successful masking of facial expressions poses a complex challenge for researchers. The aim of the current study is to provide a detailed comparison between traditional approaches in determining successful masking, such as above-chance detection rates, and a less explored measure utilizing participants' subjective experiences of the target-mask transition process. In order not to prime the participants to the emotional content of the targets, we followed Dimberg et al's (2000) backward masking methodology whereby angry-neutral, happy-neutral and neutral-neutral, target-mask pairings were presented to participants in an independent groups design for 30msec followed by a 5 second neutral face mask. Priming was minimized in Dimberg et al's (2000) task by not instructing participants to decide whether an emotional target was presented to them during each target-mask trial. This is an important methodological detail to consider in order to arrive at a more accurate evaluation of the role of participant awareness (Pessoa et al., 2005) within the contextual demands of the testing protocol (i.e., instructions, participant's mode of responding, etc.,). Thus, a more robust argument in favour of an unconscious processing bias towards threat could be established under procedural requirements, which are designed to render participants consciously *unaware* (Pessoa et al., 2005) of the masked target. Previous research had overlooked this procedural requirement in their methodologies by explicitly priming participants to expect and categorize the emotional expressions of the targets, often on a trial-by-trial basis (e.g., Japee et al., 2009; Li et al., 2008; Maxwell & Davidson, 2004; Milders et al., 2008; Pessoa et al., 2005). We address this important methodological concern in the current study by focusing on the incidental processing of emotional expressions (e.g., Monroe et al., 2013) by concealing our backward-masking procedure within the context of a sex discrimination task. The success of this procedure will be assessed by a 2AFC task to establish an objective outcome measure of the degree of awareness of the masked target faces as indicated by significant levels of above-chance detection performance (e.g., Pessoa et al., 2005).

Experiment 1 reports the outcome of a new, sensitive measure developed in our laboratory, the perceptual contrast-change sensitivity (PCCS) measure, which aims to quantify for the first time participants' subjective awareness of perceptual phenomena (e.g., flickering and movement) for angry-neutral, happy-neutral and neutral-neutral, target-mask pairings. Earlier work limited participants' responses to such aspects of the target-mask transition to a yes/no response format (e.g., Dimberg et al., 2000; Maxwell & Davidson, 2004). We addressed this issue in our measure by asking participants to use a discrete response scale and to further quantify the frequency in which they experienced each phenomenon. These responses would then allow for a score to be calculated for each of the target-mask conditions, thus providing more detailed information about the perceptual transition process than that obtained in other studies. In Experiment 2, we apply these measures to an individual differences framework to assess how differences in self-reported trait anxiety (STAI-T) could modulate subjective and objective awareness of the target face.

Based on the perceptual saliency of the characteristics of happy and angry facial expressions and the magnitude of their perceptual differences compared to neutral faces, we hypothesized that the happy target condition would likely trigger greater perceptual phenomena, and in turn yield higher PCCS scores, than in the angry-neutral and neutral-neutral conditions (Maxwell & Davidson, 2004). This is because there are greater localized differences in the facial features between happy and neutral faces, than angry and neutral faces (e.g., Calvo & Marrero, 2008). Furthermore, the intensity of the eye region in negative facial expressions such as fear (Whalen et al., 2004) and anger (Fox & Damjanovic, 2006) may also trigger a perceptual discrepancy in the transition between the angry-neutral mask, which in turn would be higher than baseline levels, as represented by the neutral-neutral condition. This prediction is further supported by the automatic vigilance hypothesis (Pratto & John, 1991), which stipulates an attentional processing bias towards negative information, especially in situations where participants are unaware. We hypothesized that both the angry and happy targets would yield higher PCCS than the baseline condition, as represented by the neutral-neutral condition. Experiment 1 also provides participants with a two alternative forced choice (2AFC) task to establish whether sensitivity to such low-level information as measured by the PCCS is sufficient to lead to objective awareness of the expressive targets (e.g., Pessoa et al., 2005).

In Experiment 2, we assess whether the repeated exposure of angry facial expressions across experimental trials may tune the amygdala into ‘alarm’ mode (Etkin et al., 2004; Liddell et al., 2005) much more readily in high trait anxious participants due to their greater tendency to constantly scan their visual environment for threat (Blanchette & Richards, 2010; Laretzaki et al., 2011) coupled with an inability to incorporate positive feedback relative to low trait anxious participants (Moser, Huppert, Duval & Simons, 2008). As such, we hypothesized that this heightened threat priming in participants with high levels of self-reported trait anxiety in the current study may result in increased awareness of the angry target, coupled with a decrease awareness of the happy target, relative to the participants with low levels of self-reported trait anxiety. Whether these group differences are more pronounced under different measures of awareness (i.e., subjective vs objective) will be investigated systematically for the first time in the current study as previous attempts to link anxiety mechanisms to unconscious emotion processing have largely been explored on a post-hoc basis (Japee et al., 2009; Szczepanowski & Pessoa, 2007) or confined to ambiguous threat signals such a fearful expressions rather than direct threat signals such as angry expressions (Brosch, Sander, Pourtois & Scherer, 2008; Capitão et al., 2014; Ewbank et al., 2008; Japee et al., 2009; Li et al., 2008; Satterthwaite et al., 2011Whalen, 1998). Thus, it is unclear what role subjective and objective awareness measures play in the detection of other, more direct facial gestures of threat such as anger (Whalen, 1998) and how trait anxiety levels of the observer can impact on such measures.

Our methodological approach of embedding the backward-masking paradigm within a sex discrimination task in order to render the participants consciously *unaware* (Pessoa et al., 2005) of the target-mask is a step never before taken in cognitive studies of this kind, and should help meet the aims of subjective *unawareness* of the emotional targets and in doing so advance our understanding of the mechanisms that underpin facial expression processing, as well as the expression processing deficits in special populations where individuals may be particularly high or low in trait anxiety.

2. Experiment 1

2.1. Method

2.2. Participants

Fifty-four undergraduate and postgraduate students from the University of Essex took part in the study with a mean age of 25.1 years. The sample consisted of 37 females and 17 males. Participants received £6.00 for their participation. All participants had normal to normal-to-corrected vision. Informed consent was obtained from all participants.

2.3. Stimuli and Apparatus

Angry, happy and neutral expressions were selected from nine different posers from Ekman and Freisen’s (1976) database. Identity across all the target-mask pairings was kept constant. The stimuli were presented on a SVGA 17-inch monitor, connected to a Dell laptop. Supercard software controlled stimulus presentation. Each greyscale image subtended 7.15° horizontally and 10.0° vertically at a viewing distance of 122 cm and appeared in the centre of the screen against a grey background.

2.4. Procedure

Participants were randomly allocated to one of three target-mask conditions: angry-neutral, happy-neutral or neutral-neutral (baseline). The experiment consisted of the following three phases conducted in the following order: the backward-masking procedure, 2AFC task, and the completion of the PCCS.

2.4.1. Backward-masking procedure

Dimberg et al's (2000) backward-masking procedure was closely followed in this study. The target face (i.e, angry, happy or neutral) was presented for 30 msec immediately followed by the masking face (neutral) for 5 seconds. Target and mask poser identities were identical. There were nine different target-mask trials within each condition representing the nine individual posers selected from the facial database. These trials were randomly repeated 6 times, yielding 54 experimental trials per condition. The inter-trial interval between target-mask trials was set to 15 seconds.

A single-blind procedure was used to randomly allocate participants to the conditions. A cover story was used in which participants were instructed to verbally report the gender of the face presented on the monitor to the experimenter. Each target-mask trial was preceded with a 1 second low-intensity (<42 dBA) warning noise. This phase of the experiment lasted for approximately 20 minutes.

2.4.2. 2AFC task

Immediately upon completing the backward-masking phase of the study, participants were presented with nine face triads on paper. The top part of the triad always consisted of the neutral mask, which was surrounded by a grey border. Directly below the neutral mask, the two target emotions from the same poser were presented adjacently to each other. The order of the two bottom images in the triad was counterbalanced across participants. Participants were instructed that along with the neutral face (top image in triad) they were also presented with one of the two faces from the bottom pair of the triad during the gender judgment task. For each triad participants were asked to select one image from the bottom pair, which they most closely associated with the face at the top. Participants in the baseline (i.e., neutral-neutral) condition were also led to believe that they were presented with an emotional target. Their responses were recorded in terms of the number of angry faces selected, thus representing a bias towards threat in the absence of unconscious exposure to emotional stimuli. Overall, the 2AFC task constitutes an objective outcome measure of the degree of awareness of the masked target faces. In other words, it is an indicator of the success of the masking procedure. The 2AFC task also permits examination of the extent to which participants' sensitivity to low-level visual information, as indexed by the PCCS, predicts objective awareness of the expressive targets.

The 2AFC data represent the number of correct hits in selecting the target in our two experimental conditions. The 2AFC task consisted of nine triads, generating a minimum score of zero to a maximum of nine if the participant selected the emotional target corresponding to their allocated condition (angry or happy) for each pair. An incorrect response was coded if the participant selected an emotional target that did not correspond to their target-mask condition (e.g., selecting an angry face from the pair when exposed to the happy-neutral condition). In the baseline (i.e., neutral-neutral) condition, participants' responses were coded in terms of the number of angry faces they selected.

2.4.3. Perceptual Contrast-Change Sensitivity (PCCS)

The PCCS was developed to quantify participants' experiences of perceptual phenomena associated with the target-mask transition process. Odd numbered questions measured specific aspects of apparent motion, whereas even numbered questions instructed participants to rate the frequency with which they experienced each phenomenon. Question 1 measured awareness of flickering (*Did you ever think that you saw a flickering image just before a neutral face was displayed?*) and question 3 (*Did you ever think that you saw a neutral face image that was moving?*) measured awareness of movement (Dimberg et al., 2000; Li et al., 2008; Maxwell & Davidson, 2004; Szczepanowski & Pessoa, 2007). Response bias was addressed by including a reversed-phrased item for question 5 (*Did you ever think that the neutral face images were still, i.e., not moving?*). Here participants were required to rate their experience of viewing still images during the backward-mask pairing. Finally, question 7 *(Did you ever think that you saw a face image just before a neutral face was displayed?*) measured participants' awareness of a double image (Maxwell & Davidson, 2004).

Participants used a Likert type response scale for each question, ranging from, 0 (not at all) to 5 (definitely). Participants who reported noticing anything at all were asked to estimate the percentage of trials (questions 2, 4, 6 and 8) on which the target phenomena were experienced using the following percentage increments: 1-20%, 21-40%, 41-60%, 61-80% and 81-100%, which were subsequently coded 1-5 for analysis purposes. The participant's score on this measure is calculated by adding the points on questions 1 to 4, 7 and 8, and the reverse scores on questions 5 and 6. Scores on the PCCS range from zero representing no awareness of low level perceptual phenomena to 40 demonstrating that participants could perceive low level perceptual phenomena on all experimental trials. The measure yielded high reliability, Cronbach's $\alpha = .80$. Participants were instructed to base their responses on their experiences during the computer based phase of the study. Upon completion, participants were fully debriefed. As part of the debriefing process, none of the participants were able to identify the true nature of the backward-masking procedure nor did they notice the emotionality of the target.

3. Results and Discussion

Mean performance on the objective (2AFC) and subjective measures (PCCS) for the three target-mask conditions are presented in Table 1. The alpha level for all statistical analyses was set at .05. For each participant the number of correct and incorrect responses were converted into proportions and treated as hits and false alarms for subsequent signal detection analysis (Macmillan & Creelman, 1991), thus generating an *A'* value for each participant as a measure of their sensitivity to the emotional targets. More conventional signal detection measures such as *d'* are estimated by the *z* score of the false alarm rate minus the *z* score of the hit rate and is considered to be a more suitable measure when hit and false alarm rates are not 1 or 0 (Snodgrass & Corwin, 1988). Because of the way *A'* is calculated, it allows data from participants who have hit or false alarm rates of 1 or 0, and it also does not require homogenous variance (Neath, 1998). The sensitivity index *A'* was calculated as follows (Donaldson, 1996):

$$A' = \frac{1}{2} + \frac{(\mathrm{HIT} - \mathrm{FA})(1 + \mathrm{HIT} - \mathrm{FA})}{4\mathrm{HIT}(1 - \mathrm{FA})}$$

The *A'* index, an indicator of discrimination of the correct emotional target, can vary between 0 and 1, with values of 1 indicating perfect discrimination of the correct target and values around 0.5 indicating chance performance. Participants are deemed to be aware of the masked target if *A'* values exceed chance levels, 0.50 (Hanley & McNeil, 1982; see also Japee et al., 2009). In the baseline condition (i.e., neutral-neutral), the higher the value the greater the bias towards selecting the angry target.

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INSERT TABLE 1 ABOUT HERE

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A' values for the 2AFC data for all three target-mask conditions were analyzed with a single factor independent groups ANOVA, which yielded no significant differences across conditions, F (2, 51) = 1.34, p = .271, η_p^2 = .05. Fifty-six per cent of participants (10 of 18) in the angry-neutral, and 44% of participants (8 of 18) in the happy neutral condition along with 44% of participants in the neutral-neutral condition (8 of 18) achieved detection scores that were above 0.50. However, three one sample t-tests failed to provide evidence in favor of significant levels of objective awareness across the three conditions, $p > .05$.

There was a significant effect of condition on PCCS scores, F (2, 51) = 46.46, $p < .001$, η_p^2 = 0.65, with higher levels of awareness in response to happy condition than in the angry, t (34) = 5.28, $p < .001$, r = .67 and baseline conditions, t (34) = 13.17, $p < .001$, r = .91. Perceptual awareness of the angry target was also significantly greater than in the baseline condition, t (34) = 3.30, p = .002, r = .49, which lacked perceptual transition after effects because of the identical nature of the target and mask. Thus, the PCCS demonstrates participants' awareness of perceptual changes that occur during the target-mask transition; with abrupt perceptual changes of local, high contrast features between the happy-neutral pairings creating more dramatic transition after effects than the angry-neutral pairings.

We also measured whether participants were able to use these subjective elements of the target-mask transition process in their recognition of the emotional expressions in the 2AFC task. Pearson's correlations revealed a significant relationship between PCCS scores and 2AFC performance only for the happy-neutral condition, such that greater access to perceptual properties of the happy target was associated with greater sensitivity in selecting the happy target in the 2AFC task, $r = .51$, $p = .031$. Experiment 2 examines to what extent the emotional state of the observer influences these objective and subjective measures of masked emotional targets.

4. Experiment 2

4.1. Method

4.2. Participants

One hundred and eight undergraduate and postgraduate students from the University of Essex took part in the study. As per Fox (2002) participants with STAI-T scores 35 (n = 54) or below were recruited for the low anxiety group and participants with STAI-T scores 45 (n = 54) or above were recruited for the high anxiety group. The age range of the entire sample was 20-59, with a mean age of 26.6 years. The sample consisted of 57 females and 51 males. STAI-T scores for the high trait anxiety group ($M = 49.85$, $SD = 8.36$) differed significantly from the low anxiety group ($M = 29.59$, $SD = 4.79$), $t(106) = 15.46$, $p < .001$, $r = .83$. Participants received

£6.00 for their participation. All participants had normal to normal-to-corrected vision. Informed consent was obtained from all participants.

4.3. *State-Trait Anxiety Inventory (STAI)*

We administered the trait subscale of the STAI (STAI-T; Spielberger et al., 1983), which constitutes a 20-item scale measuring trait anxiety. It assesses how participants generally feel (e.g., "I feel satisfied with myself" (reverse scored); "I get a state of tension or turmoil as I think over my recent concerns and interests"), on a 4-point rating scale (1 = "Almost never", 2 = "Sometimes", 3 = "Often", 4 = "Almost always"). All 20 items are summed to yield a total score of trait anxiety (maximum score: 80; minimum score: 20), with higher scores denoting higher levels of anxiety. Test-retest reliabilities for the trait scale are high, ranging from 0.73-0.86. Concurrent validity with other anxiety questionnaires ranges from 0.73-0.85 (Spielberger et al., 1983).

4.4. Procedure

Same as Experiment 1. Once participants completed all three phases they were required to complete the STAI-T component as a post-test reliability measure. The PCCS yielded high reliability, Cronbach's $\alpha = .78$. During debriefing, none of the participants were able to identify the true nature of the backward-masking procedure nor did they notice the emotionality of the target.

5. Results and Discussion

The alpha level for statistical analyses was set at .05. For the assessment of above-chance detection performance, six separate one-sample t-tests were performed and are reported with a Bonferroni adjusted alpha level of $p < .008$. Post-test scores on the STAI-T for the high anxiety ($M = 53.52$, $SD = 6.57$) and low anxiety ($M = 30.89$, $SD = 3.63$) groups were significantly different, $t(106) = 22.15$, $p < .001$, $r = .91$. Mean *A'* performance on the 2AFC task for the two anxiety groups is displayed in Figure 1.

INSERT FIGURE 1 ABOUT HERE

A 2 (group: high vs low) x 3 (target: angry, happy or neutral) independent groups ANOVA was performed on the *A'* values for the 2AFC task. Higher scores were obtained in the low relative to the high anxiety group, F (1, 102) = 4.72, $p = .032$, $\eta_p^2 = .04$. The main effect of target was not significant, F (1, 102) = 1.29, $p = .279$, $\eta_p^2 = .03$, however it interacted significantly with the main effect of group, F (2, 102) = 21.16, $p < .001$, $\eta_p^2 = 0.29$. Greater levels of angry target detection was exhibited by the high than the low anxiety group, F (1, 102) = 6.21, $p < .014$, $\eta_p^2 = 0.06$. There were no significant group differences in the detection of happy targets, F (1, 102) = 0.02, $p = .894$, $\eta_p^2 = 0.00$. In the baseline condition, participants with high anxiety actively avoided selecting the angry target compared to individuals with low anxiety, F (1, 102) = 40.81, $p < .001$, $\eta_p^2 = 0.29$. Targets were differentially recognized both by the low anxiety, F (2, 102) = 11.66, $p < .001$, $\eta_p^2 = 0.19$ and the high anxiety groups, F (2, 102) = 10.80, $p < .001$, $\eta_p^2 = 0.17$, respectively. For the high anxiety group, both angry ($p < .001$) and happy ($p < .05$) target detection rates were higher than in the baseline condition, but detection between angry and happy targets was not significant ($p > .05$) In the low anxiety group, detection scores for both angry and happy targets were comparable ($p > .05$), with each condition producing considerably lower scores than in the baseline condition ($p < .001$).

Seventy-eight percent (14 of 18) of participants in the high trait anxious group showed above chance detection of the angry target compared to 50% (9 of 18) of participants in the low trait anxious group. For happy targets, 44% of the high trait (8 of 18) anxious group and 39% of the low trait anxious group (7 of 18) showed above chance detection. Whilst only 11% of high trait anxious participants (2 of 18) showed above chance bias towards the angry target in the 2AFC task in the baseline (i.e., neutral-neutral), all 18 participants in the low anxious group showed higher than chance values in selecting the angry target. Bonferroni ($p < .008$) corrected one-sample t-tests showed that the angry target detection rates exhibited by the high trait anxious group significantly exceeded chance levels, $t(17) = 3.29$, $p < .008$, $r = .62$ even though at baseline the high trait anxious group showed a significant bias away from threat, $t(17) = -7.19$, $p < .008$, $r = .87$. The low anxiety group showed a threat bias in the baseline condition that is greater to that expected by chance, $t(17) = 8.50$, $p < .008$, $r = .90$.

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INSERT FIGURE 2 ABOUT HERE

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There was no significant main effect of group for PCCS data, F (1, 102) = 0.05, $p = .818$, $\eta_p^2 = .00$, (see Figure 2). As per Experiment 1, a main effect of target was obtained, F (2, 102) = 38.05, $p < .05$, $\eta_p^2 = 0.43$, with happy target-to-mask transition generating higher perceptual awareness scores, followed by angry targets which differed significantly from the control condition ($p < .001$). However, there was also a significant group x target interaction, F (2, 102) = 13.87, $p < .001$, $\eta_p^2 = 0.21$. Higher levels of perceptual awareness were observed in the high anxiety than the low anxiety group for the angry target, F (1, 102) = 16.12, $p < .001$, $\eta_p^2 = 0.14$, but for happy targets there was greater perceptual awareness displayed in the low than the high anxiety group, F (1, 102) = 10.18, $p < .001$, $\eta_p^2 = 0.10$. There were no significant group differences in the neutral-neutral condition, F (1, 102) = 1.50, p = .224, $\eta_p^2 = .01$.

Perceptual awareness also differed significantly within the high F (2, 102) = 20.28, $p < .001$, $\eta_p^2 = 0.29$ and low F (2, 102) = 31.64, $p < .001$, $\eta_p^2 = 0.38$, anxiety groups, respectively. In the high anxiety group, perceptual awareness scores were higher than neutral for both angry and happy targets ($p < .001$), but did not differ significantly from each other ($p > .05$). In the low anxiety group, perceptual awareness scores for the happy target were significantly higher than for the angry and neutral conditions ($p < .001$), but the difference in perceptual awareness between the angry and neutral conditions was not significant ($p > .05$). Thus, angry masked targets break the threshold of awareness both in objective and subjective terms in individuals with high levels of self-reported anxiety.

We also measured how different subjective measures (i.e., mean trait anxiety, and PCCS) impact on participants' detection rates by correlating these subjective values with *A'* performance across the entire sample for the two experimental target mask conditions. Significant correlations emerged only for the angry-neutral condition, where an increase in a participant's level of trait anxiety correlated with improved detection performance, $r = .39$, $p = .018$ and with increased access to perceptual phenomena associated with angry faces, $r = .48$, $p = .003$, respectively.

6. General Discussion

Whilst both objective and subjective measures have been used in the past to determine participants' levels of awareness of masked facial expressions, these have largely been based on binary yes/no responses from tasks in which participants have been primed to expect or to categorize facial expressions of emotion (e.g., Japee et al., 2009; Li et al., 2008; Maxwell & Davidson, 2004; Milders et al, 2008; Pessoa et al., 2005). This raises the important consideration of whether participants continue to demonstrate non-conscious awareness of the masked target with task instructions which render the participants subjectively *unaware* of the task demands (Pessoa et al., 2005). This was achieved in the present study by concealing the backward-masking procedure within a sex discrimination task, and in doing so yields the following key findings: (i) some facial expressions are masked more successfully than others, and, crucially, (ii) their detection varies greatly across individual levels of self-reported anxiety.

Providing a more detailed description of the subjective phenomena participants experience during the backward-masking transition than that obtained in other studies, our PSSC measure indicated that participants were able to detect some perceptual qualities of the target, even though objective measures of performance on the 2AFC task were at chance. Specifically, for the most salient emotional expression, happiness, participants' subjective experiences were moderately related to their emotion detection performance (Experiment 1). As previously noted, happy facial expressions have a number of uniquely defining facial features that differentiates them perceptually from neutral faces (e.g., Calvo & Marrero, 2008). The characteristic toothy smile of happy faces (Calvo & Marrero, 2008; Juth, Lundqvist, Karlsson & Öhman, 2005; Lipp, Price & Tellegen, 2009) is likely to trigger greater perceptual phenomena, and in turn yield higher PCCS scores, than in the angry-neutral and neutral-neutral conditions. This may have been underpinned by activity in the brain's reward system in response to masked positive cues, including the ventral striatum, the anterior cingulate gyrus, the amygdala, the left anterior insula as well as the sublenticular substantia innominate (Juruena et al., 2010; Killgore & Yurgelun-Todd, 2004; Wetherill et al., 2014; Whalen et al., 1998). Thus, the processing of seemingly unconscious positive facial expressions may be achieved via the detection of the presence of low-level perceptual cues located around the mouth region. In terms of understanding unconscious emotion processing more broadly, objective measures alones are not sufficient in establishing whether the participant is unconsciously aware of the target, but rather subjective measures of awareness should be more readily integrated into backward-masking designs to establish potential cut-offs when these features may eventually be deemed inaccessible, and thus not further susceptible to conscious awareness.

Previous research investigating the impact of the emotional state of the observer on the perception of masked facial expressions has revealed several important findings in terms of objective levels of awareness and temporal characteristics of unconscious threat processing. For instance, STAI-T scores are higher in participants who show above-chance detection of fearful masked targets than those participants whose *A'* scores do not differ from chance (Japee et al., 2009). Alternative measures to STAI-T scores derived from composite measures, such as the Behavioural Inhibition Scale (BIS: Carver & White, 1994) and the Social Phobia Scale (SPS: Mattick & Clarke, 1998), have also been shown to impact on the affective judgment of faces previously primed with fearful but not happy facial expressions, triggering early visual processing indexed by brain potentials at about 150 ms after target onset – an effect which was stronger in individuals with high trait anxiety (Li et al., 2008).

The discrepancy in angry detection for high-anxious individuals between the PCCS and 2AFC measures obtained in the current study extends this important individual differences framework in several ways (Experiment 2). Although both angry and happy targets are detected to the same degree in both low and high anxious groups, it is only the high anxiety group that displays objective levels of awareness for the angry target, as indicated by above-chance detection, mirroring previous behavioural findings with fearful targets (e.g., Japee et al., 2009), and highlighting a heightened 'alarm' system in anxiety that is also potentially responsive to angry facial expressions (i.e., Etkin et al., 2004; Liddell et al., 2005). Finally, mean trait anxiety was correlated with *A'* and PCCS scores for participants exposed to angry targets, but not happy targets, replicating similar results obtained with the unconscious processing of fearful expressions (Li et al., 2008).

Perceptual sensitivity (i.e., PCCS scores) is greater in participants with high-trait anxiety than participants with low-trait anxiety in response to viewing angry targets, although this does not appear to be threat-specific as indicated by comparable levels of perceptual sensitivity between angry and happy targets displayed by the highly anxious individuals. Even though happy faces are likely to trigger greater perceptual phenomena than angry faces in the target mask transition (Experiment 1), it appears that the perceptual qualities of the two facial expressions are experienced in the same way, at least for participants with high trait anxiety, who also display significantly lower levels of perceptual sensitivity to happy targets than their low trait counterparts, thus indicating an overall reduced responsiveness to positive material. Moreover, some evidence suggests that the STAI-T measures negative affect, including features of anxiety and depression (Bados, Gómez-Benito, & Balaguer, 2010; Balsamo et al., 2013; Bieling, Antony & Swinson, 1998). It may therefore be that participants with high trait anxiety ratings in our study were also depressed. Depressed individuals are particularly known for emotional blunting to positive material (Bylsma, Morris, & Rottenberg, 2008; Joormann & Gotlib, 2007; Leppänen, 2006), which could also account for the reduced awareness of happy targets in high trait individuals.

In contrast, our finding that low trait anxious participants have greater access to the perceptual properties of happy faces than high trait anxious participants and also show greater perceptual sensitivity to happy than angry faces is consistent with a face processing bias favoring positive facial expressions at early stages of visual attention in low anxious participants (Moser, Huppert, Duval & Simons, 2008). This is also in line with findings from several studies showing that healthy individuals (versus patients with affective disorders) exhibit increased amygdala responsiveness to masked happy stimuli (Suslow et al., 2010; Victor, Furey, Fromm, Öhman, & Drevets, 2010).

We consider these distinctions between the two anxiety groups as reflecting different patterns of social interpretation biases in response to processing facial expressions. These social interpretation biases include negative social appraisals for even seemingly neutral expressions by individuals with high levels of anxiety, likely involving a hyper-responsitivity of the amygdala coupled with hypo-activity of the prefrontal system (e.g., Bishop, 2007; Blanchette & Richards, 2010; Lapointe et al., 2013; Yoon & Zinbarg, 2007). This may be amplified further when the facial signal's threat value is unambiguous, as conveyed by an angry facial expression.

The prolonged exposure to the angry face over the course of the backward-masking phase and then during the 2AFC phase may have resulted in attentional orienting towards the angry target triggering a stronger negative interpretation of the angry face in the high trait than the low trait anxious group (Mogg, Bradley, Miles, & Dixon, 2004). The fact that both subjective and objective scores did not differ between angry and happy targets in participants with high levels of anxiety suggests that the above-chance detection shown by this group is likely to be inflated by a heightened interpretation bias towards negative information. The finding that trait anxiety correlated with both *A'* and PCCS scores for angry targets, but not with happy targets, is consistent with this view.

Group differences in the neutral-neutral condition may help shed further light on the role of social interpretation biases on the perception of facial expressions. The pattern of selecting the angry target at above chance levels coupled with actively avoiding the angry face target in the baseline condition in our high anxious group may be tentatively linked with the vigilance-avoidance model of anxiety at short vs long presentation intervals, respectively (Mogg et al., 2004). After the exposure to the neutral-neutral condition, the unexpected presentation of angry faces at the 2AFC stage may have been particularly discomforting for individuals with high trait anxiety, who may have tried alleviating their anxious mood by actively avoiding the aversive threat stimulus (Mogg et al., 2004), thus displaying an attentional shift away from threat at postawareness stimulus levels (Amir, Foa & Coles, 1998; Eastwood et al., 2005).

In contrast, participants with low levels of anxiety were more likely to associate neutral masks with angry faces in the 2AFC task. One possibility for this pattern of responding is that participants may have selected the angry face based on perceptual factors, matching the angry face to the neutral face based on greater perceptual similarity in local features shared by angry and neutral faces than happy and neutral faces (e.g., Calvo & Marrero, 2008; Damjanovic, Roberson, Athanasopoulos, Kasai & Dyson, 2010). Although alternative interpretations based on affective factors, such as the net affective value of the triads in 2AFC task (Haberman & Whitney, 2010) or other latent facial signals of aggressive potential based on craniofacial attributes should not be ruled out (e.g., Shasteen, Sasson & Pinkham, 2015). Future research that varies the type of distractor in the 2AFC task in terms of its perceptual saliency and net affective value may help to establish some of the characteristics that underpin social interpretation biases in anxiety in the absence of previous exposure to emotional stimuli.

Although this study extends the existing literature on individual differences in emotion perception, some limitations must be considered. First, participants' endorsement of the PCCS items may have been influenced by the prior experience of completing the 2AFC task where they had been made explicitly aware that multiple images were being shown. Furthermore, participants tended to endorse perceptual anomalies in the neutral-neutral condition where nothing actually changed between the target and mask. These concerns are somewhat mitigated by the fact that participants performed differently on the angry and happy conditions, suggesting some true sensitivity to the motion phenomena and also the effective use of deception in our neutral-neutral condition where participants were led to believe that they were presented with an emotional target. Nevertheless, future research should systematically counterbalance the order of the 2AFC and PCCS measures in order to minimize the possibility of recall bias in the endorsement of perceptual phenomena.

Second, although the STAI is a popular measure of self-reported anxiety, factor analytic methods indicate that the trait scale assesses depression, as well as anxiety, with some items assessing anxiety and worry, whilst others assess sadness and self-deprecation (e.g., Bieling et al.,1998). Given the likelihood that our high and low trait anxious participants may have also differed on these and along many other emotional dimensions, further work is needed to assess the relative contributions of these dimensions on objective and subjective measures of emotion perception, especially in relation to the processing of happy facial expressions.

7. *Conclusions.*

In conclusion, our study highlights the importance of taking into consideration the experiential properties of the backward-masking procedure, and proposes that subjective measures as revealed by the PCCS should be used in conjunction with objective measures when drawing conclusions about the ‘silent’ threat detecting capacities of the amygdala and other subcortical regions. Crucially, such a combination of objective and subjective outcome measures can usefully contribute to resolving the debate of the neural mechanisms underlying conscious versus unconscious perception of emotion (Tamietto & de Gelder, 2010). Moreover, combining such measures within an individual differences framework will most certainly provide a fruitful avenue for future research by aiding our understanding of the brain’s ‘alarm’ system and its role in vigilance-avoidance across the anxiety continuum.

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Figure Captions

Figure 1. Mean target detection in the 2AFC task measured by *A'* for high and low anxious groups in Experiment 2. Performance in the neutral condition represents a bias towards selecting the angry target. Chance performance is denoted by the dashed line. Error bars correspond to the standard errors of each condition individually. Asterisks indicate statistically significant effects (* $p < .05$; *** $p < .001$).

Figure 2. Mean perceptual awareness score on the Perceptual Contrast-Change Sensitivity (PCCS) measure for the high and low anxious groups across the different target-mask pairings in Experiment 2. Error bars correspond to the standard errors of each condition individually. Asterisks indicate statistically significant effects (*** $p < .001$).