Title and Authorship

Responses to Backward Masked Faces with and without Conscious Awareness

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Extended Abstract

Previous research has suggested that we can experience physiological arousal and emotional changes in response to emotional faces without conscious awareness. This line of research has also provided evidence to support that subordinate facial characteristics such as emotion, attractiveness and cultural background can be reported in the absence of conscious awareness. These traits are suggested to confer evolutionary important sociobiological value and therefore, the suggestion has been put through that they can be appraised automatically and involuntarily. The purpose of this mechanism is to enable us to respond to important environmental cues without relying on slow cortical systems for the initiation or inhibition of significant survival and social-related actions. Although a considerable number of publications support this notion, an equally substantial number of research papers has challenged the evidence that suggest that we can emotionally and physiologically respond to subliminal cues. The latter line of research suggests that the current experimental model for the assessment of subliminality includes important limitations relating to the implementation of subliminal presentations, the assessment of stimuli visibility and the statistical analysis of participant responses. In the current studies, we address these issues using a novel method for the assessment of subliminality. In the first three experimental chapters, we present a method for assessing skin conductance, heart rate, facial emotional responses and engagement task responses to backward masked emotional faces. This method includes defining individual thresholds for subliminal perception for each participant and for each facial expression using both hit rates and unbiased receiver operating characteristics. We also employ Bayesian analysis for the assessment of subliminal perception, trial-by-trial physiological assessment

of hits (correct detection/discrimination) and misses (incorrect detection/discrimination) for signal detection and discrimination performance, and trial-by-trial physiological assessment of confidence responses for hits and misses for awareness. In the final two experimental chapters, we use part of this assessment method to test whether facial characteristics, such as attractiveness and cultural background, can be appraised without conscious awareness. Our findings suggest that using the current assessment method, physiological and emotional changes, and the appraisal of facial characteristics, such as attractiveness and cultural background, can occur in response to brief masked faces only when the participants are able to report conscious face-detection meta-awareness. Our findings shed doubt on the "established" notion that we can be physiologically influenced by subliminal emotion, and counter-suggest that even though brief faces can influence our physiological and appraisal responses, this effect is accompanied by conscious awareness.

Introduction

The Story of an Idea

- *You are seriously unwell, Fräulein*
- *But I feel fine, Doctor*
- *Of course Fräulein, it is subconscious*

Mention of the possibility for a transcendental unconsciousness, as a part of the human psyche, was first made in religion-related texts by German philosophers Friedrich Schelling (1858) and Eduard von Hartmann (1869). The first, dedicated, philosophical analysis of unconsciousness as a phenomenological concept was made by German philosopher Friedrich Nietzsche (1876). In his book *Human, all too Human* Nietzsche adopted the style of romantic era writers, such as William Wordsworth, Samuel Taylor Coleridge and William Blake, and wrote, with poetical and philosophical eloquence, that "Dreams carry us back to the earlier stages of human culture and evolution… where everything is uncontrolled and entangled… they are a pilgrimage to the unconscious, to early mankind all over again… entire communities and even entire nations – as well as the artist and myth – labour simultaneously under them" (Nietzsche, 1876; p. 11-12).

Twenty-years after Nietzsche's *Human, all too Human*, the *Studies in Hysteria* (Breuer & Freud, 1895) were published. The concept of unconsciousness was applied in clinical premises. Sigmund Freud, living in what was possibly the most puritanical and religious era of continental philosophy (Smith, 1994), suggested that the human psyche was governed by a phylogenetically shaped topography (Freud, 1910; Figure 1). Freud's psychoanalytic theory outlined that we are driven by fierce instinctual and moral impulses (Freud, 1933), and of course, infamously, that neurosis is due to the repression of incestuous sexual desires to the unconscious (Freud, 1942). Freud expounded that the means to this

previously uncharted territory of the human psyche were, similarly to Plato's philosopher-king and the analogy of the cave (Edison, 1946), psychoanalysis and the psychoanalyst (Freud, 1921).

Psychoanalysis was applied in clinical-hospital settings for the better half of the previous century, despite ferocious and relentless clinical and philosophical antilogous (Wallace & Edwin, 1983), and intra-psychoanalytic dispute (Jung, 1928; Klein, 1946). In spite of these challenges, the psychoanalytic canon, that perhaps could not and should not be surmised as a singular approach (Meissner, 2003), did not suffer an irreparable and overthrowing clinical repudiation until the anti-psychiatry movement (Boyers & Orrill, 1971). As part of that movement, in one of the most infamous experiments in social psychology, David Rosenhan convinced several health professionals to visit U.S. hospitals and report that they experienced incoherent noise-like auditory hallucinations (Rosenhan, 1973; 1975). Based on the expert assessment of – reportedly (Spitzer, 1975) – psychoanalytically trained medical doctors, the entire "research team" was admitted to U.S. psychiatric wards (Millon, 1975). As soon as admitted, the researchers stopped reporting clinical symptoms. By

Figure 1: Psychoanalytic Topography

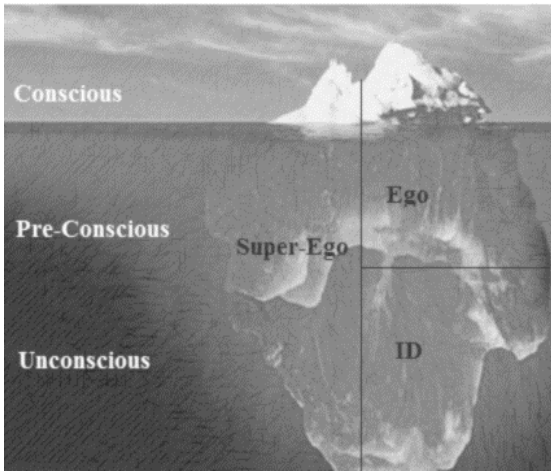


Figure 1: The Psychoanalytic model included the Ego, thoughts and perceptions, the Super-Ego, moral judgement, and the ID; including our instinctual impulses; such as Eros and Thanatos, and traumatic experiences, as well as irrational, unacceptable and violent sexual desires. The psychoanalytic topography included another three layers: the conscious, the part of the self that is currently subject to awareness, the pre-conscious, the part of the self that is not currently subject to awareness but is potentially accessible, and the unconscious, that is not accessible by awareness. Contrary to common belief, both the Super-Ego and the ID could be repressed and be part of the unconscious mind, and according to this model contribute to neurosis, the attempt of the Ego to defend against unwelcome internal impulses or traumatic experiences, or psychosis; the attempt of the Ego to defend against on-going external psychological harm (Freud, 1921).

that time – according to Rosenhan (1973; 1975) – it was too late because in the U.S. psychiatric system in the early 70's, an in-patient was either sick or in denial (Mullan, 1955). The research team reported that they were administered medication, held against their will and released only after acknowledging their medical diagnosis. Rosenhan also claimed that he was hospitalised and administered medication for two months, and released as a *schizophrenic in remission* (Rosenhan, 1975). Upon his release he composed a report named "Being Sane in Insane Places" (Rosenhan, 1973). His thesis was clear, provocative and blunt: "Madness is in the eye of the beholder…we cannot tell the sane from the insane". Rosenhan boldly advocated that the diagnostic system could be tricked, as in fact – we should not forget – any system can (Pessoa, 2005), and that it lacked an empirically confirmable method of diagnostic evaluation (Fisher, 1937; Popper, 1962; Kuhn, 1962; Williams, 1994).

Lessons for Contemporary Science

"An old Halloween tale", most readers might comment with a dismissive predisposition, and subsequently, treat these first pages as a playful and effusive re-iteration in the history of psychology and the social sciences; one perhaps, that, additionally, dismisses the notorious shortcomings and meretricious motivations of the Rosenhan report (Millon, 1975; Spitzer, 1975; 1976; Weiner, 1975), the impact of behaviouralist research during that era (Holland & Skinner, 1962), and the significant impact of many researchers and theorists that proposed models for the unconscious while psychoanalysis was still part of the psychological canon, such as Sidis (1898), Peirce (1906), Landis (1930), Papez (1937), MacLean (1955) and Bridgeman (1971), to name just a few (Morsella & Reyes, 2016; Bargh & Morsella, 2008). The reader might be right. The story of the "rise and fall" of the

subjective-expert assessment of subconsciousness is a noir-novel-styled historical episode; it resonates with an almost filmic and eerie atmosphere of pre-scientific ambience, and can, by no means, be solely attributed to a single – and no less scandalously debated – social experiment (Bowers & Meichenbaum, 1984).

The author would not like, or even dare, to make such claims; especially so, since it seems that anti-psychiatry and psychoanalysis are, for several contemporary psychologists, either vague concepts or, worse yet, unwelcome and excommunicated reminders of a taboo era of pre-scientific psychology. The intent of the current introduction is not to re-instate these. Instead, it is to explicitly acknowledge that the current area was always contentious. Consciousness, unconsciousness and emotion were always captivating themes for the general public and the scientific community, and were always quarrelsome (Morin, 2006). The author's perspective is that we should not – as is commonly the case in contemporary psychological settings (Hassin, Uleman & Bargh, 2004) – blatantly dismiss unconscious processing due to its historical stigmatization (Searle, 1989). We should explore it using coherent, revised, theoretically grounded and, at the same time, theoretically un-predisposed criteria (Brooks et al., 2012; van der Ploeg, Brosschot, Versluis & Verkuil, 2017). In other words, and as Erdelyi eloquently puts it, the reader should consider that to dismiss the exploration of unconscious processing, alongside the inability to provide an undisputed method for its assessment, entails the danger of "throwing away the baby with the bathwater" (Erdelyi, 2004; p.16-17).

Contemporary Models of Unconscious Processing

With these in mind, experimental psychologists and neuroscientists attempted to re-conceptualize the theoretical foundations of unconscious emotion (Dehaene, Changeux, Naccache, Sackur & Sergent, 2006). Joseph LeDoux (1989; 1992; 1993; 1994; 1995; 1998; 2000) was one of the first modern researchers to suggest a testable processing model for the unconscious mind, marking the paradigm passage from theoretical interpretation to empirical falsification (Popper, 1962), or – if you prefer – from the suppression of experiential trauma to the suppression of visual-emotional elicitors (Erdelyi, 2004). LeDoux's model suggested that a subcortical pathway from the visual thalamus to the amygdala regulates responses that require an imminent "fight-or-flight" response (Jansen et al., 1995). This subcortical pathway was suggested to bypass the occipital cortex and render higher cortical executive functions, in the pre-frontal cortex, unnecessary. The purpose of this pathway was to elicit survival-related responses, without relying on slow cortical systems for the initiation or inhibition of action and do so by triggering automatic and involuntary, peripheral, sympathetic and parasympathetic, nervous system arousal (Van der Ploeg et al., 2017). LeDoux's model reverberated, to some extent (Papez, 1937), particularly in relation to the temporal primacy of physiological arousal (Lange & James, 1922), with the early propositions of the James-Lange theory of emotion (James, 1894), and suggested that we can experience, particularly, fear without the need for conscious awareness because we require a mechanism for immediate responses to survival-related environmental cues.

Subsequent conceptual and experimental contributions to the study of unconscious emotion were, with some exceptions (Pessoa & Adolphs, 2010), unreceptive to the

consideration of parallel, central and peripheral nervous system, processing (Bard, 1934), the importance of context in the interpretation of physiological arousal (Schachter & Singer, 1962), and the distinction between subliminal processing – lack of conscious access – and pre-conscious processing (Dehaene et al., 2006) meaning potential for conscious accessibility (Bargh & Morsella, 2008). In their majority (Pessoa et al., 2005a; 2005b), publications in this area expanded monotonically the neurocircuitry and the evolutionary utility of the original model (Brooks et al., 2012). The locus-coeruleus and the brainstem were added to the neurocircuitry of subliminal pathways and were suggested as 'hubs' for the dissemination of peripheral nervous system arousal in response to subliminal emotional cues (Liddell et al., 2005). Numerous studies using backward masking, interocular rivalry and continuous flash suppression (see Figure 2), and recruiting healthy participants, and participants with visual scotomas[1] and amygdala-specific Kluver-Bucy syndrome[2], provided empirical support for physiological changes in response to subliminal emotional cues (Van der Ploeg et al., 2017). These studies presented masked emotional faces, emotional pictures, spiders, snakes and other evolutionary important stimuli (Williams, 2018), assessed neural (e.g. EEG, fMRI, and PET) and physiological responses (e.g. skin conductance, heart rate, and blood pressure), and suggested that we can experience neural activation and physiological arousal in response to subliminal emotional stimuli, meaning literally in Latin emotional stimuli that are below-the-threshold; implied here: *of conscious awareness* (Williams et al., 2005).

[1] An area of partial impairment in the field of vision consisting of a diminished or entirely degenerated visual acuity surrounded by a field of normal – or relatively well-preserved – vision. Patients with this conditions are, debatably, suggested to retain reactivity to overt and unconscious signals of fear (Naccache, 2015)

[2] A rare condition that can include calcification of the amygdala and extinction of fear responses. Patients with this condition show no fear responses to overt and unconscious signals of fear (Benarroch, 2015)

Figure 2: Contemporary Methods for the Presentation of Unconscious Stimuli

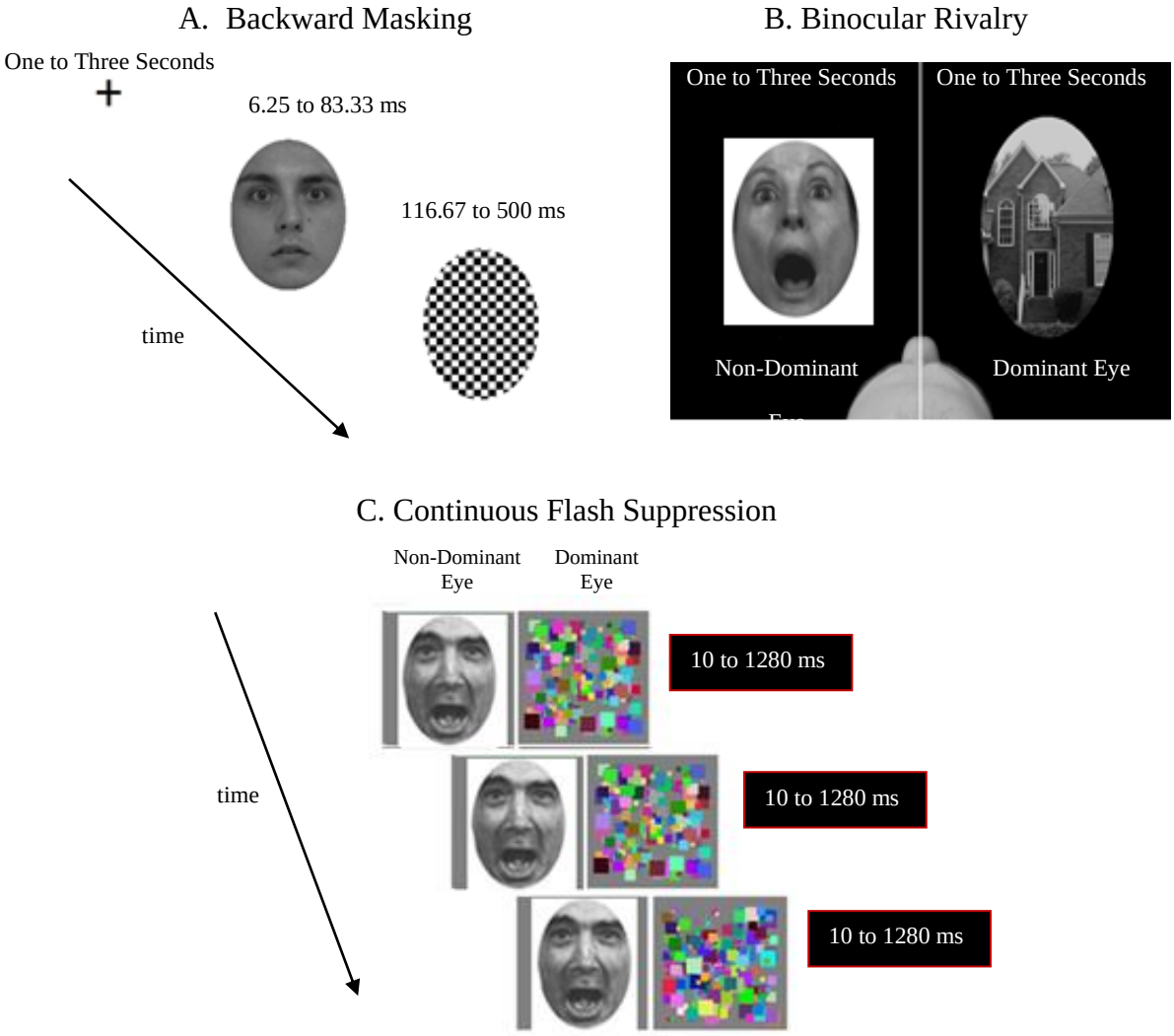


Figure 2: Examples of Backward masking (A.), Binocular Rivalry (B.) and Continuous Flash Suppression (C.), that are the most widely used methods for the exploration of neural and physiological responses to subliminal cues (Van der Ploeg et al., 2017; see also Table 1: Technical Terms).

Contemporary Controversy

Despite its conceptual appeal, this revised notion of subliminality (Dehaene et al., 2006), once more, divided psychology, and neuroscience (Pessoa, 2005). Erdelyi (2004) suggested that a substantial number of publications in the field of psychological research referred to some variation of subliminal processing and none of these agreed as to the

definition or the legitimacy of the concept (Pessoa & Adolphs, 2010). Consensus was eventually (Erdelyi, 2004) achieved in the area using a simple mathematical equation: for any type of participant response or informational availability defined as ε, and for conscious accessibility to the presented information defined as α, subliminal processing occurs when $\alpha = 0$ and $\varepsilon > \alpha$. Support for and against the validity of this proposition was provided in abundance by subsequent empirical research (Brooks et al., 2012) and the empirical diversity induced a rather polarizing effect; researchers were either firm supporters or firm sceptics of the idea that we can be influenced by subliminal cues.

Assessing the Controversy

Several fMRI studies (Brooks et al., 2012) were able to provide evidence supporting that we can experience emotion without conscious awareness of the eliciting stimuli. This line of research suggested that the neural correlates of emotion (e.g. the amygdala, the locus coeruleus, and the cingulate cortex) can be activated automatically and without conscious awareness via a subcortical collico-pulvinar pathway (Liddell et al., 2005). This subcortical pathway was suggested to elicit, via the brainstem, involuntary physiological arousal in response to subliminal emotional cues to enable us to automatically adapt to our environment. Several studies expanded on these neural findings and were able to report increased skin conductance (subcutaneous sweating) and HR (heart rate) responses during the presentation of subliminal emotion (Van der Ploeg et al., 2017). The argument raised by this line of research was that emotional cues can elicit physiological changes in the complete absence of awareness because they pose a demand for imminent, automatic and involuntary "fight-or-

flight" and social-adaptive responses to unconscious evolutionary important environmental cues that confer survival-related value (Meneguzzo, Tsakiris, Schioth & Brooks, 2014).

An equally substantial number of publications (Pessoa, 2017) suggested that brief emotional cues can indeed activate key limbic system structures. These structures included the amygdala (anger, fear and surprise), the insula (disgust) and the cingulate cortex (sadness and pain), enabled fast environmental adaptation to socio-biologically important environmental cues and induced physiological arousal. Nevertheless, this line of research suggested that physiological arousal in response to masked emotion recruits cortical and subcortical neural regions, including the prefrontal and primary visual cortex, that it is the result of conscious perception and occurs only in the subset of trials that participants are able to detect or discriminate the presented emotion (Pessoa, 2005). According to this line of research, the notion of subliminal emotional processing could not be supported by previous findings because of several major issues with the assessment of subliminality. These issues included the fixed duration of presentation for masked faces (Lähteenmäki, Hyönä, Koivisto & Nummenmaa, 2015), the assessment of subliminal perception using frequentist statistics (Dienes, 2015), the application of biased measures for the assessment of awareness (Stanislaw & Todorov, 1999) and the assessment of participant responses without trial-by-trial signal detection and discrimination (Pessoa et al., 2005a; 2005b), and confidence response analysis (Overgaard, Rote, Mouridsen & Ramsøy, 2006).

Understanding the Controversy

One of the most significant issues, that the latter line of research identified in previous methods, that provided evidence for subliminal responses, was that the

experimenters presented subliminal emotion for fixed durations of presentation (Lähteenmäki, Hyönä, Koivisto & Nummenmaa, 2015). For example, emotional and neutral faces were presented for durations ranging from 6.25 to 83.33 ms with backward masking to overt neutral faces and the assumption was made that these masked stimuli will be processed below the threshold of conscious awareness indiscriminately of within-participants and between-stimuli type differences (Brooks et al., 2012). The issue with this approach was that several studies (Pessoa, 2005) reported groups of under and over-achievers in respect to signal detection and discrimination performance, and also differences in detection and discrimination performance between different emotional types (Calvo & Lundqvist, 2008). For several researchers in the field, that meant that differences between participants due to, for example, differences in experiential sensitivity (Aru & Bachmann, 2007; Mather & Sutherland, 2011; Lundqvist, Juth, & Öhman, 2014) and attentional resources (Aru, Bachmann, Singer & Melloni, 2012), and differences between facial-emotional characteristics due to, for example, differences in emotional recognition reward value (Adolphs, 2002), emotional incongruence with the neutral mask (Kim et al., 2010) and higher perceptual acuity in response to pronounced facial features, such as valence, arousal, attractiveness and cultural background (Nummenmaa & Calvo, 2015), were sufficient to induce variations in face-detection and emotion-recognition performance, and lead to conscious awareness (Stanislaw & Todorov, 1999). Therefore, the studies that reported responses to subliminal cues were, according to subliminal sceptics, subject to a fundamental misinterpretation, i.e. that subliminal perception can be treated as a constant without adjusting for individual differences (Pessoa, 2005),

In addition to this limitation, the method of assessment and the statistical analysis for subliminality were subject to criticism. The vast majority of neuroimaging studies (Brooks et al., 2012) and physiological response studies (van der Ploeg et al., 2017) employed hit rates and frequentist analysis for the assessment of subliminality (Dienes, 2015). In this manner, experimenters would calculate the percentage of correct answers (hits or true positives) in a post-trial or post-experimental detection or discrimination task and compare these using a one sample t-test against chance-level performance (e.g. 50%). In case of non-significant results, the researchers would claim evidence for subliminal perception. The critical problem with this approach was that hit rates were subject to response strategies (Stanislaw & Todorov, 1999), such as replying consistently that a stimuli was – or was not – presented, due to having a very liberal – or respectively, a very conservative – response criterion for awareness (Overgaard et al., 2006). The limitation of using frequentist statistics for the assessment of subliminality was that "non-significantly different from chance" – lack of evidence for the alternative hypothesis - was misinterpreted as significantly at-chance and thus as evidence for the null (Dienes, 2015).

Table 1: Technical Terms

Backward masking	One of the masking methods for suppressing visual stimuli. It includes the presentation of a masked visual cue, such as a face, a picture or a shape presented for a brief duration; typically ranging from 6.25 to 83.33 ms. The masked cue is followed by a neutral stimulus, called a mask, such as a blur, a pattern or a neutral face (> 100 ms). The mask is suggested to render the masked cue imperceptible. Other similar methods include forward masking and sandwich masking (see van der Ploeg et al., 2017).
Bayesian Analysis	An inferential method of mathematical analysis. It can be statistically applied to explore whether the data report probabilistic significance for the alternate (or research) hypothesis (B > 3), whether the data report significance for the null hypothesis (B < .33); or whether the data are insensitive to both hypotheses (.33 > B < .3).
Binocular Rivalry	A method for suppressing visual stimuli. It includes the presentation of a target stimulus, such as a face, a picture or a shape to, typically, the non-dominant eye, and the parallel presentation of a neutral distractor, such as a blur, a pattern or a neutral stimulus, to the dominant eye. The simultaneous presentation of these stimuli is suggested to render the target stimulus imperceptible
Continuous Flash Suppression	A method for suppressing visual stimuli. It includes the presentation of a static target stimulus in, typically, the non- dominant eye, such as a face, a picture or a shape, and the parallel presentation of a series of distractors to the dominant eye. The presentation of a series of multiple distractors is suggested to render the static target stimulus imperceptible.
Detection (Threshold)	Most commonly referred to as the detection threshold. It indicates whether the participant was able to respond whether a visually suppressed stimulus was presented.
Discrimination (Threshold)	Most commonly referred to as the discrimination threshold. It indicates whether the participant was able to respond what type of visually suppressed stimulus was presented.
Meta-Awareness	The ability to report in a post-trial or post-experimental assessment task whether a target stimulus was presented. Originally considered synonymous to meta-cognition. In contemporary research, meta-cognition is considered a separate phenomenon relating to experiential awareness, such as subjective awareness of having a cognition or subjective ability to regulate a cognition.
Signal Detection Theory	A method for providing an unbiased ratio for participant response to an engagement task. It includes combining in a single ratio the correct (hits) and incorrect (misses) replies that a participant made.
Visual Staircase Reduction	A method for suppression of visual stimuli that can be used in addition to backward masking, binocular rivalry and continuous flash suppression. It includes a post-trial assessment task during which the participant is asked whether they were aware of the target stimuli. If the reply is “yes” the duration, pixelation or saturation of the target stimuli is adjusted to render it imperceptible.

Responding to the Controversy

Despite the contentious nature of the current topic, the studies that follow attempt to provide an answer to the controversy. The primary objective of our research was to provide a refined method for the assessment of subliminality and test whether our emotional, physiological and appraisal responses can be influenced by subliminal facial characteristics; meaning in this context processing without the ability to report conscious target meta-awareness (see Table 1). To achieve these goals we introduced several methodological changes in the assessment of subliminality. Our first step was the pre-experimental definition of subjective subliminal perception. We introduced a pre-main-experiment stage during which we presented several brief durations of presentation (e.g. 8.33, 16.67, and 25 ms) for each emotion, and used the participants' performance to individualise per emotional type the duration of presentation that was closest to chance; and that would suggest that individually each participants was *guessing*, or responded like a *blind person would*, concerning whether or what type of face was presented (Erdelyi, 2004). We tested signal detection performance using Bayesian analysis for chance-level significance ($B < .33$) that, unlike frequentist approaches to awareness, could provide direct evidence for the null; that the data are significantly at-chance (Dienes, 2015). We applied hit rates (percentage correct) and sensitivity index A (Zhang & Mueller, 2005) scores for this assessment to test whether potentially biased measures for the assessment of awareness, such as hit rates, would induce insufficient masking and lead to emotional and physiological changes (Stanislaw & Todorov, 1999), while faces that were masked using unbiased signal detection theory criteria would disallow conscious awareness and preclude physiological responses (Pessoa, 2005). Further

to these, we employed hits and miss analysis of participant responses to explore whether emotional, physiological and appraisal responses under conditions of backward masking were due to the subset of trials that included correct detection or correct discrimination of the presented faces (Pessoa et al., 2005). To avoid the categorization of awareness as a binary phenomenon (Morsella & Reyes, 2016; Bargh & Morsella, 2008) we included trial-by-trial analysis of confidence ratings for hits and miss responses for awareness and assessed miss responses for discrimination for conscious awareness of emotion eliciting facial sub-characteristics such as the valence and the emotional arousal of the presented stimuli that could lead to emotional change (Lohse & Overgaard, 2017). Using these criteria we explored whether emotional and physiological (Experimental Chapters One to Three), and appraisal responses (Experimental Chapters Four and Five) can be influenced by subliminal facial characteristics.

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Experimental Chapters

Skin Conductance Responses to Masked Emotional Faces Are Modulated by Hit Rate but Not Signal Detection Theory Adjustments for Subjective Differences in the Detection Threshold

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The published version of this study can be found in the Appendix.

Abstract

The biological preparedness model suggests that survival-related visual cues elicit physiological changes without awareness to enable us to respond to our environment. Previous studies have reported some evidence for this effect. In the current article, we argue that this evidence is subject to methodological confounds. These include the use of a universal masked presentation threshold, the employment of hit rates (HRs) to measure meta-awareness, and the assertion of overall guess-level target detection using nonsignificance. In the current report, we address these issues and test whether masked emotional faces can elicit changes in physiology. We present participants with subjectively adjusted masked angry, fearful, happy, and neutral faces using HRs and signal detection theory. We assess detection performance using a strict Bayesian criterion for meta-awareness. Our findings reveal that HRs adjustments in the detection threshold allow higher skin conductance responses to happy, fearful, and angry faces, but that this effect could not be reported by the same participants when the adjustments were made using signal detection measures. Combined these findings suggest that very brief biologically relevant stimuli can elicit physiological changes but cast doubt to the extent that this effect can occur in response to truly unconscious emotional faces.

Introduction

In the last 30 years, psychological research achieved technological and methodological advancements that enabled the scientific exploration of a very old and very interesting question (Freud, 1915): Can we *experience* unconscious emotion? Contemporary research in the area (Öhman & Soares, 1994) typically includes the presentation of very brief (6.25–83.33 ms) emotional stimuli (Van der Ploeg, Brosschot, Versluis, & Verkuil, 2017) that are masked by neutral stimuli to render the masked targets consciously imperceptible (Bachmann & Francis, 2013). Participant responses to these targets are considered evidence for unconscious processing (Axelrod, Bar, & Rees, 2015).

The theoretical foundation for this unconscious processing stems from what psychologists term the biological preparedness model (LeDoux, 2003; Mineka & Öhman, 2002). According to this model, when we encounter particularly threat-related cues such as a threatening animal or a fearful face (Brooks et al., 2012), we recruit a fast-subcortical processing pathway to the amygdala (Liddell et al., 2005) that disseminates autonomic nervous system arousal (Van der Ploeg et al., 2017). The purpose of this pathway is to allow us to *instinctively* adapt to important signals in our environment that require an imminent response by eliciting automatic and involuntary physiological changes (Van der Ploeg et al., 2017).

Previous research tested this theoretical model using a variety of masking techniques (Bachmann & Francis, 2013) and reported some evidence in support of this proposition (Van der Ploeg et al., 2017). Most previous studies (Esteves, Dimberg, & Öhman, 1994; Esteves, Parra, Dimberg, & Öhman, 1994; Lapate, Rokers, Li, & Davidson, 2014; Morris, Öhman, &

Dolan, 1998) employed skin conductance recordings (SCRs) to assess the effect because SCR is a measure of sympathetic autonomic nervous system arousal (Carlson, 1994) that can record physiological responses that are not under conscious regulation (Öhman, 2005) - such as fight-or-flight responses (Flykt, Esteves, & Öhman, 2007) - and is also relatively impenetrable to parasympathetic nervous system arousal artifacts (Cacioppo, Tassinary, & Bernston, 2007).

For example, Williams et al. (2006) reported a significance trend ($p = .08$) for higher SCR in response to backward-masked fearful faces compared with neutral faces when presented for 16.67 ms but several follow-up studies failed to replicate this trend (Codispoti, Mazzetti, & Bradley, 2009; Nielsen & Kaszniak, 2006). In more recent studies, Najström and Jansson (2007) reported that police officers (Correll, Urland, & Ito, 2006; Mann et al., 2004; McCaslin et al., 2006) experience higher SCR in response to backward-masked threatening pictures for 6 ms compared with neutral pictures for 6 ms, and Lapate et al. (2014) also reported significant findings for higher SCR and decreased liking ratings for subsequently presented neutral targets (see also Winkielman, Berridge, & Wilbarger, 2005) when participants were presented with fearful faces using dichoptic masking (Maehara & Goryo, 2005).

These findings provide support for unconscious emotional processing (LeDoux, 2003) but pose several possible limitations (Lähteenmäki, Hyönä, Koivisto, & Nummenmaa, 2015, pp. 2–5). The most important possible confound in previous research is the employment of a universal threshold for masked stimuli presentation (Pessoa, 2005; Pessoa, Japee, Sturman, & Ungerleider, 2006). Previous studies presented masked stimuli for 6.25 ms to 83.33 ms (Van

der Ploeg et al., 2017) relying on that other previous studies reported that overall target meta-awareness - the ability to respond if a target was presented in a post-experimental or post-trial task (Erdelyi, 2004) - was not significantly different than chance.

A possible issue with this approach is that previous research has also reported between stimuli types (Calvo & Lundqvist, 2008) and between participants (Pessoa, 2005; Pessoa et al., 2006) differences in the ability to detect masked stimuli. For example, the happy face superiority effect (Calvo & Lundqvist, 2008, pp. 113–115) posits that positively valanced masked faces such as happy faces are detected more accurately than other masked emotions because they portray more easily distinguishable facial characteristics. It is additionally possible that participants will report subjective differences in meta-awareness for the presented stimuli (Pessoa & Adolphs, 2010). Previous studies have reported substantial groups of *overachievers* - that could reliably discriminate the presence of a masked fearful face at 16.67 ms and 33.33 ms - and *underachievers* - that could not discriminate the presence of a masked fearful face even at 67 ms (Pessoa, 2005, 2017; Pessoa et al., 2005). This casts doubt to the extent that a universal threshold that is not adjusted for per participant and stimuli type differences in target meta-awareness is sufficient for unconscious stimuli presentation.

Another possible issue is that previous research has reached a consensus in respect to unconscious processing as the inability to perform different than chance in discriminating or detecting a masked target (Pessoa, 2005; Pessoa et al., 2006). In this context, chance-level performance indicates that participants were guessing - that they were in a sense performing "like a blind person would" (Erdelyi, 2004; p .79) - and were not aware whether a face was

presented or not (Stanislaw & Todorov, 1999). The main problem with this guess-level criterion is that it is commonly assessed using HRs (Brooks et al., 2012) and almost unanimously asserted using nonsignificance to chance-level detection performance (Dienes, 2015).

The possible limitation with using HRs is quite straightforward (Lähteenmäki et al., 2015). Participants can employ subjective strategies for replying for target meta-awareness. These strategies can be overly conservative - such as replying having seen a face only when they are beyond a shadow of a doubt certain a face was presented - or overly liberal - such as replying that they saw a face even when they are quite unsure if one was presented. This makes reporting chance-level performance using HRs possibly unrepresentative of realistic target meta-awareness and previous research has strongly recommended the employment of unbiased signal detection theory measures that can provide a ratio between correct (hits) and incorrect (misses) responses (Stanislaw & Todorov, 1999) for the assessment of detection and discrimination tasks (Pessoa, 2005; Pessoa et al., 2006).

The issue with nonsignificance is that - irrespectively of using HRs or signal detection theory - chance-level performance is asserted based on insufficient statistical analysis (Dienes, 2015). In simple terms, the methodological approach in previous research (Brooks et al., 2012) is the calculation of overall HR performance or signal detection theory performance (d', A', A'', A) and its comparison against absolute chance (HR = 50%, d' = .0, A' = .5). In case of nonsignificant findings, the researchers claim unconscious processing. The problem with this approach is that overall performance being not significantly different to chance - lack of evidence for the alternate hypothesis - is interpreted as significantly at-

chance - evidence for the null (Dienes, 2014, 2015). Further, Bonferonni-corrected pairwise comparisons are nonsensical because the alpha corrections operate in favour of unawareness (Overgaard et al., 2013). Previous research has suggested that Bayesian analysis should be undertaken to directly compare the null - evidence for chance level processing ($B < 1/3$) - to the alternate hypothesis - significantly different than chance ($B > 3$) in addition to frequentist approaches (Dienes, 2015) but research in the current field has not employed this method of assessment yet to assert unconscious processing (Van der Ploeg et al., 2017).

Given these possible limitations, the aim of the current study was to introduce the necessary methodological developments to establish unconscious presentation of emotional faces and test if unconscious emotional faces can elicit changes in physiology. To meet these objectives, we preexperimentally adjusted for subjective differences in the detection threshold (Pessoa, 2005; Pessoa et al., 2006) using HR and nonparametric signal detection theory measures (Van der Ploeg et al., 2017) and assessed detection performance using combined frequentist and Bayesian criteria for meta-awareness (Dienes, 2015). Then we used the preexperimentally defined thresholds for masked stimuli presentation and explored if masked angry, fearful, happy, and neutral faces can elicit changes in physiology using SCR.

Methods

Participants

In total, 25 (14 women) participants gave informed consent to participate in the current study. Mean age was 32.9 ($SD = 7.2$). The exclusion criteria for the current study were history of head trauma, current or previous psychiatric diagnosis (self-report), and current or previous diagnosis of drug or alcohol abuse (self-report). The participants were screened with the Sphere-12 mood questionnaire (Hickie et al., 2001). Participants with

scores at or below 1.0 were included. The participants were also screened using an online Alexithymia-Emotional Blindness questionnaire (Alexithymia, 2017) and participants with scores that indicated possible traits ($P > 94$) or diagnosis ($P > 112$) for alexithymia were excluded; data from a single participant were excluded from the study. We were able postexperimentally to contact several of the participants to acquire ethnic backward information via mail. Most of the participants that took part in the pilot (British: 70.59%; Greek: 17.64%; not responded: 11.76%) and main experimental (British: 79.17%; Italian: 12.5%; Greek: 8.33%) stages were White Caucasians recruited and were tested in the University of Nottingham. The experiment was approved by the University of Nottingham, School of Psychology Ethical Research Committee.

Facial Stimuli

The facial stimuli were taken from the facial set created by Gur et al. (2002). A total of 100 photos per emotional category (angry, fearful, happy, and neutral) were resized to a standard 1024×768 resolution, converted to grayscale and framed into pure white within a cropped circle (Height: 6 cm, Width: 4 cm). A total of 20 pattern blurs were also created, converted to grayscale, framed into pure white and framed within a cropped circle with the same dimensions using photoshop. Luminescence was averaged across all stimuli using MATLAB, SHINE.

Stimuli Preselection

The processed facial stimuli were preselected during a pilot pre-experimental stage. Processed faces were presented to a separate set of participants ($n = 17$) at fixation for 1 s preceded by a fixation cross for 3 s. Pretarget baseline and maximum deferral skin

conductance (1–3 s) were recorded during the presentation. Seven seconds after each trial participants were assigned a stimuli classification, a stimuli intensity, and a stimuli ambiguity engagement task. They were allowed 6 s to choose what emotion the presented face was expressing. They made this response using their keyboard, choosing from an onscreen list - angry (a), fearful (f), happy (h), surprised (s), neutral (n), or other (o). Subsequently, they were asked to rate from 1 (*not at all*) to 10 (*extremely*) the ambiguity and intensity of the presented faces. The order of stimuli was randomized, and participants were allowed 6 s to perform each task. An intertrial blank screen period of 8 s was used to allow skin conductance responses to return to baseline.

We ran two different stages of stimuli preselection. We selected angry, fearful, happy, and neutral stimuli that produced strict alpha significance criterion ($p \leq .01$) for correct classification of emotional valence. Surprised facial expressions (Tottenham et al., 2009) were initially intended to be part of this study (Duan, Dai, Gong, & Chen, 2010). These were not included because the stimuli number that produced a statistically significant emotional type recognition effect ($n = 14$) during the first stimuli preselection stage was smaller than the required number of stimuli ($n = 30$). We chose from the available subset the 30 angry, fearful, and happy stimuli that reported the highest scores in a self-developed percentage-based metric - Impact Factor, I.F. (%) - that took under equal consideration (50%) reports for stimuli ambiguity and intensity, and maximum deferral skin conductance arousal:

$$\text{I.F. (\%)} = \left(\left(\frac{(10 - Ambiguity) + Intensity}{2}\right) * 50\right) + \left(\left(\frac{Mean\ SCR\ Stimuli}{Max\ SCR\ Stimuli\ Type}\right) * 50\right)$$

The final stimuli set comprised 30 angry, fearful, and happy stimuli and a total of 60 neutral faces. The faces were from both male (52.67%) and female actors (47.33 %). The data set (Gur et al., 2002) did not contain ethnic and cultural origin labels. The selected stimuli were therefore, postexperimentally assessed using Noldus (2017), Face Reader 6.1. The facial set comprised Caucasian (58%), African (17.33%), and Asian (15.33%) actors. A small number of the stimuli (9.33%) were reported as unknown-other or did not provide a sufficient certainty report (≥ 85%) for ethnic origin. No further analysis was conducted to explore cultural and ethnic origins effects for the current study.

Equipment and Programming

Two computers were used during the experimental stages: one for stimuli presentation and one for recording physiological arousal. The two computers were connected using a PCI parallel port adapter (latency < .1 s). Stimuli presentation was coded using the builder and code components in Psychopy v1.83 (Peirce, 2007). Stimuli were presented on an HD LED LENOVO monitor with 120 Hz (8.33 ms) refresh rate. An IO platform transmitted 5 -V binary signals in five digital channels that distinguished stimuli type following signal onset.

Stimuli presentation validation testing

A 4.17-ms refresh rate CANON G16 camera recorded a pilot run of the experiment and the presentation content was assessed frame by frame. No instances of dropped frames were found. A dropped frame report script with one frame (8.33 ms) tolerance threshold was coded in Python and two pilot experimental diagnostic sessions were run. The presenting monitor reported no dropped frames and the prognostic dropped frame rate was 1 in 5,000 trials. Experimental stages were subsequently run using dropped frames diagnostics and

frame rate performance diagnostics of the stimuli presenting monitor. At no point during the running of the experiment were there any reports of dropped frames.

Skin conductance recording and analysis

Skin conductance responses were measured from the left hand (index/first and middle/second fingers; Banks, Bellerose, Douglas, & Jones-Gotman, 2012) of each participant using skin conductance electrodes with Biopac (Gel 101) skin conductance gel. The signals were received by a BIOPAC Systems, EDA100C preamplifier in units of microSiemens and recorded in *AcqKnowledge* (Braithwaite, Watson, Jones, & Rowe, 2013). We used the higher end of recommended specification for recording skin conductance (EDA channel sample rate: 2 KHz; acquisition rate: 2,000 samples/per second; gain: ×1,000).

To make our data comparable with previous research that reported trends for significance or significant results in response to masked emotional faces (Van der Ploeg et al., 2017), we used the exact same analysis parameters. The presence of a phasic skin conductance response was defined as an unambiguous increase (.01 μs) with respect to each pretarget baseline occurring 1 to 3 s post stimuli offset. The raw signal was processed using the Derive Phasic EDA from Tonic and Dirac Delta (δ) functions. The data did not require additional smoothing, filtering, or transformations (Braithwaite, 2013; pp. 1027–1029). Non-responders were included in the analysis.

Stage 1: Per participant and stimulus type detection threshold

Participants were invited in a laboratory space with controlled lighting and temperature. They were informed that they will be presented with brief emotional faces and they will be asked to decide how many faces were presented after each trial. During this

stage, we presented a fixation cross for 3 (±1) s in the middle of the screen. After the cross, an angry, fearful, happy, or neutral face or a matched for luminescence pattern blur was presented for 8.33 or 16.67 or 25 ms with backward masking to a 108.33-ms neutral face. In total, 20 emotional faces for each duration, 80 pattern blur trials, and 15 neutral masks showing actors who were not part of the masked stimuli subset were presented. All stimuli were presented in randomized order. Five seconds after each trial, an on-screen message asked participants to decide how many faces were presented on screen: "How many faces did you see? Please press 1 for one or 2 for two." Participants were asked to reply using the keyboard with their right hand. This stage was performed 7 days before and at the exact same time of day as Stage 2.

Stage 1: Data processing

The individual per stimulus type detection threshold was calculated separately using hit rates (percentage of true positives) and nonparametric signal detection theory (Zhang & Mueller, 2005). For each participant, the duration of presentation (8.33 or 16.67 or 25 ms) that produced the smallest negative or positive overall detection performance difference to chance per stimulus type was imported separately for HRs and signal detection theory measures to the main experiment—that is, the duration for which the value of $(0.5. - P_{\text{threshold}})$ was closest to .5. When participants reported an equal distance to chance between two thresholds (e.g., 16.67 ms: .45 and 35 ms: .55), the briefer duration was imported in the main stage.

Stage 2: Physiological Arousal in Response to Hit Rate and Sensitivity Index Adjusted Faces

Participants were invited to the same laboratory space under identical experimental conditions, including the same presenting monitor, response equipment, room temperature, and room luminance. They were informed that they will be presented with brief emotional faces while their physiology is measured. They were asked to complete two 15-min sessions with a 5-min interval break. In one of the sessions, participants watched masked emotional stimuli that were adjusted using HRs for the duration of the masked targets. In the other session, participants watched masked emotional stimuli that were adjusted using signal detection theory for the duration of the masked targets. Session order was randomized.

In both sessions, we presented a fixation cross for 3 (± 1) s in the middle of the screen. After the cross, an angry or fearful or happy or neutral face or a pattern blur was presented at fixation with backward masking to a 108.33-ms neutral face (Figure 1). Five novel stimuli per emotional category and 20 pattern-blur trials were presented in total. In total, 15 neutral masks were presented showing actors who were not part of the masked stimuli subset for either neutral or emotional masked faces for Stage 1 or 2 of the experimental process. All stimuli were presented in randomized order and skin conductance responses were measured during the presentation. The participants were not assigned with an engagement task during this stage. After each trial, an 8-s blank interval screen was presented to allow physiology to return to baseline.

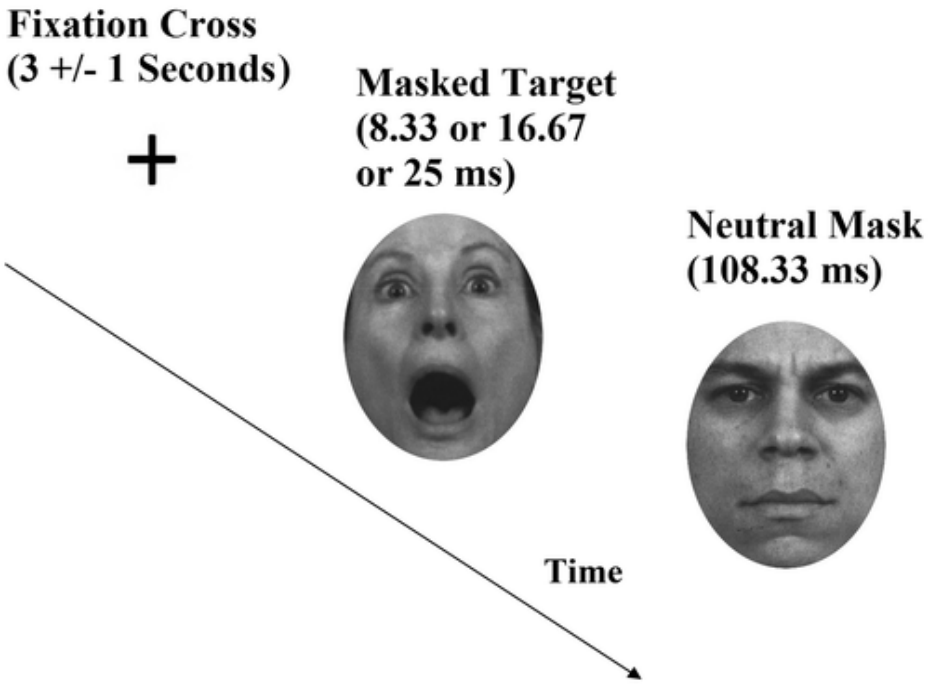


Figure 1. Example of stimuli sequence with fearful masked target. The participants watched angry, fearful, happy, and neutral faces and non-facial pattern blurs at fixation for 8.33 or 16.67 or 25 ms based on their subjective performance in a pre-experimental signal detection task. All stimuli were followed by a random neutral mask for 108.33 ms. Skin conductance was measured as the highest peak in electrodermal response 1 to 3 s post stimuli offset.

Results

Stage 1: Hit Rate Thresholds

To explore if masked faces using hit rates were not-significantly different to chance 309 we run one-sample t-tests against absolute chance-level performance (50%) for overall and 310 per stimuli type target meta-awareness. Overall hit rate adjusted emotional faces (M = 49.53 %, S.D. = 1.84 %) were not significantly different to chance (t (23) = 1.25; p = .22). The same effect was reported separately for angry (M = 48.96 %, S.D. = 4.89 %; t (23) = 1.05; p = .31), fearful (M = 49.58 %, S.D. = 3.88 %; t (23) = .53; p = .6), happy (M = 50.21 %, S.D. 314 = 4.29 %; t (23) = .29; p = .81) and neutral faces (M = 49.38 %, S.D. = 3.39 %; t (23) = .9; p = .38).

To further explore these results, a uniform Bayesian analysis corrected for degrees of freedom, $df < 30$; standard error $SE = (SE\ x\ \left(1 + \left(\frac{20}{df x df}\right)\right)$) (Berry, 1996) was run using the Dienes (2014, 2015) calculator. We set the higher and lower bounds for chance-level HR performance to a conservative −.5 (45%) and .5 (55%) criterion with 0 (50%) representing absolute chance-level performance. Overall HR performance ($SE = .37$; $B = .2$) was significantly at-chance. The same effect was reported for fearful faces ($SE = .79$; $B = .23$), happy faces ($SE = .89$; $B = .23$), neutral faces ($SE = .8$; $B = .26$), but not angry faces ($SE = 1$; $B = .43$), suggesting that the latter was the only type that was insensitive to both competing hypothesis (Figure 2; Individual Thresholds in Table B1).

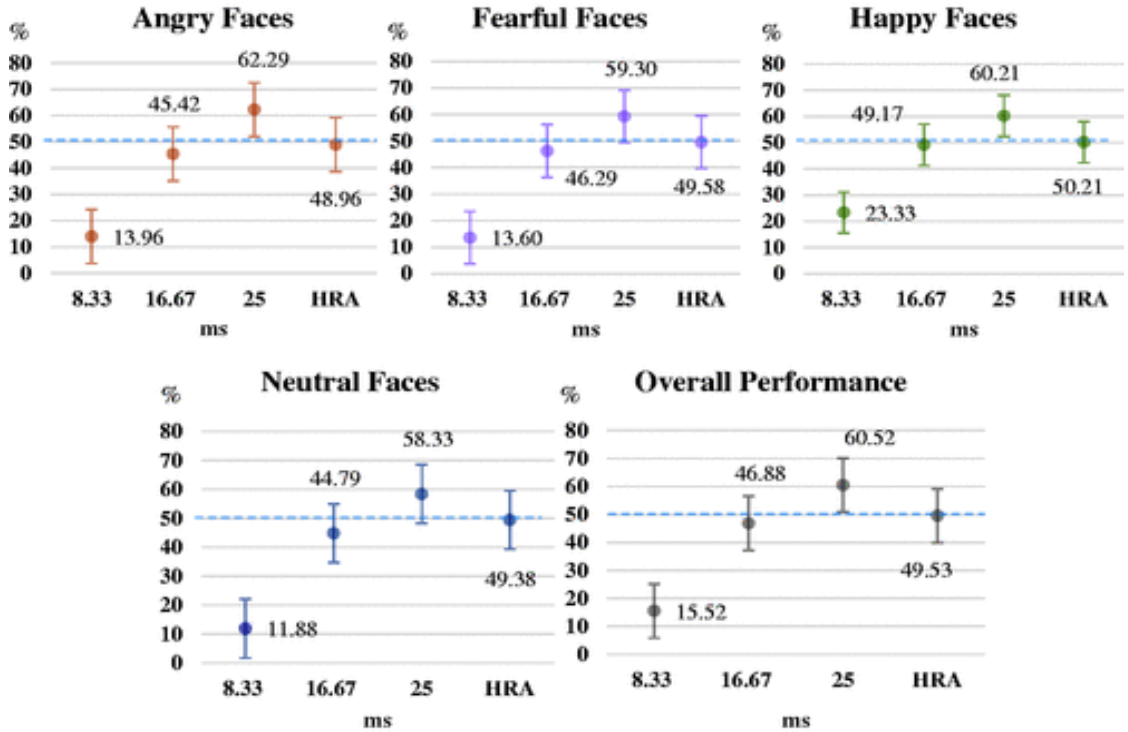


Figure 2. Overall, per threshold and per stimulus type detection performance for hit rates. Overall and per stimulus type hit rate percentage performance for 8.33, 16.67, 25 ms and hit rate adjusted faces (HRA). Midline indicates chance-level performance. Error bars for each score indicate Standard Error of the mean.

Stage 1: Signal Detection Theory Thresholds

To explore if masked faces using signal detection theory were not-significantly 338 different to chance we run one-sample t-tests against absolute chance-level performance (.5) 339 for overall and per stimuli type target meta-awareness. Overall signal detection theory 340 adjusted faces (M = .496, S.D. = .037) were not significantly different to chance (t (23) = .49; 341 p = .63). The same effect was reported for angry (M = .494, S.D. = .062; t (23) = .55; p = 342 .59), fearful (M = .494, S.D. = .061; t (23) = .53; p = .6), happy (M = .514, S.D. = .042; t (23) 343 = 1.62; p = .12) and neutral faces (M = .485, S.D. = .6; t (23) = 1.22; p = .24).

To further explore these results, a uniform Bayesian analysis corrected for degrees of freedom, $df < 30$; $SE = (SE\ x \left(1 + \left(\frac{20}{dfxdf}\right)\right)$) (Berry, 1996) was run using the Dienes (2014, 2015) calculator. We set the higher and lower bounds for chance-level signal detection theory performance to a conservative −.5 (.45) and .5 (.55) criterion with 0 (.5) representing absolute chance-level performance. Overall signal detection theory performance ($SE = .008$; $B = .22$) was significantly at-chance. Fearful faces ($SE = .013$; $B = .37$) and angry faces ($SE = .013$; $B = .38$) showed trends for at-chance level processing and happy faces ($SE = .009$; $B = .73$), and neutral faces ($SE = .013$; $B = .64$) were insensitive to both competing hypothesis (Figure 3).

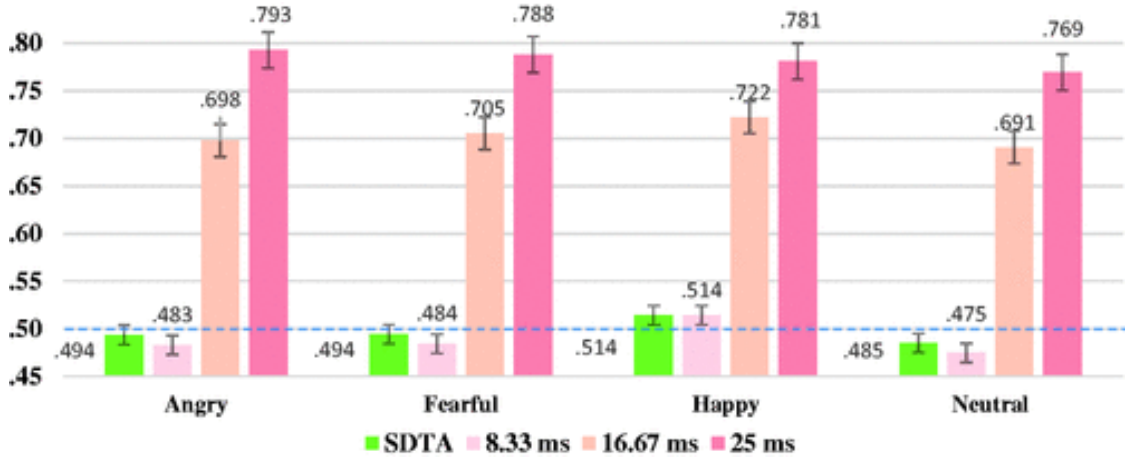


Figure 3. Signal detection theory performance per emotion and for adjusted faces. Participant threshold for each masked emotional stimulus for the signal detection theory session in stage two. SDTA refers to faces adjusted using signal detection theory (A) for the duration of masked stimuli presentation.

Stage 2: Skin Conductance Responses

To explore if hit rate adjusted emotional faces produced differences in skin conductance a one-way repeated measures ANOVA was run with independent variable Stimulus Type (angry, fearful, happy, neutral and pattern blur) and dependent variable maximum deferral (1-3 seconds) skin conductance (μS) for hit rate adjusted faces. effect of Stimulus Type was reported (F (1.64, 37.72) = 57.69 p <. 001; η^2 =.72; Greenhouse-Geiser corrected). Bonferroni adjusted pairwise comparisons reported that SCR scores were significantly higher for angry faces (M = .034, SD = .015) than for happy (M = .018, SD = .007; p < .001, d = 1.36) and neutral faces (M = .01, SD = .007; p < .001, d = 2.05) and for the pattern blur condition (M = .01, SD = .003; p < .001, d = 1.34).SCR scores were also significantly higher for fearful faces (M = .045, SD = .022) than for angry (p < .01, d = .58), happy (p < .001, d = 1.65), neutral faces (p < .001, d = 2.14) and for the pattern blur condition (p < .001, d = 2.22). Happy faces were also higher for SCR than neutral faces (p = .001, d = 1.14) and the patter blur condition (p < .001, d = 1.49). Skin conductance responses were not

significantly different between different stimulus types for signal detection theory adjusted emotional faces (F (2.47, 56.84) = 1.24, p = .3; η^2 = .05; Greenhouse-Geiser corrected) suggesting that only hit rate adjusted angry, fearful and happy faces elicited higher skin conductance scores in the current experimental setup.

Discussion

In the current experimental design, we tested if subjective adjustments in the threshold of presentation for masked emotional faces can elicit skin conductance responses. We used HR and signal detection theory adjustments in the threshold of presentation and we also implemented a combined frequentist and Bayesian assessment of chance-level detection performance. The frequentist analysis of detection performance showed that overall and per stimulus type masked faces were not processed significantly different to chance. Bayesian analysis of the same data revealed that both HR and signal detection theory adjusted faces were overall significantly at-chance. HR-adjusted angry faces and signal detection theory adjusted happy and neutral faces were insensitive to both competing hypotheses. For the physiological assessment, our analysis revealed evidence for higher skin conductance for masked angry, fearful, and happy faces that were adjusted using HRs. Masked targets that were adjusted using signal detection theory measures did not report significant differences in skin conductance between different emotional faces.

The biological preparedness theory (Mineka & Öhman, 2002) suggests that particularly fear is an evolutionary important, encapsulated module. Fear responses according to this model are elicited in response to preferentially pretechnological (Seligman, 1971) survival threats that have phylogenetic and neural evolutionary precedence and are therefore,

impenetrable to the more recent emergence of cognitive control (see also Lapate et al., 2014). These threats include angry faces—as a mean for ingroup social submission—and fearful faces—as an indication of unseen environmental danger (Öhman, 2009), and elicit automatic and involuntary physiological responses before cognitive analysis of the fear-related stimulus using a dedicated subcortical neural pathway (Brooks et al., 2012). Several previous studies (Van der Ploeg et al., 2017) have tested this model using masked emotional faces and suggested that physiological changes to biologically relevant stimuli can also occur without conscious target meta-awareness (Pessoa & Adolphs, 2010).

The current data support that at least the latter is not the case (Van der Ploeg et al., 2017). As mentioned in the Introduction section, in the current report, we addressed several possible confounds in previous research including subjective differences in the detection threshold (Pessoa, 2005; Pessoa et al., 2006) and per stimuli type differences in the detection threshold (Calvo & Lundqvist, 2008). We particularly noted that masked neutral faces for set presentation thresholds (8.33 or 16.67 or 25 ms) were detected less accurately than other stimuli types (Figure 2) possibly as a function of emotional congruence with the neutral mask (Kim et al., 2010). Irrespectively of stimulus type, post the adjustments in the detection threshold all masked targets were not significantly different to chance-level meta-awareness and most stimuli types were significantly at-chance (Figures 2 and 3). This means that in the current report, participants had approximately equal visual accessibility for different emotional stimuli and that this accessibility was as close to chance as the experimental parameters allowed using HRs and signal detection theory.

As Erdelyi (2004) posits unconscious or masked or implicit or subliminal processing (Dehaene, Changeux, Naccache, Sackur, & Sergent, 2006) is based on empirical evidence using a dissociation paradigm where availability (ε) exceeds accessibility (α) such as that for $\alpha = 0$, $\varepsilon > \alpha$. In the current context, our results suggest that when visual accessibility is equal to zero using HRs angry, fearful, and happy faces elicited higher skin conductance responses than neutral and non-facial pattern stimuli. When visual accessibility was equal to zero using unbiased signal detection theory measures, there were no significant differences in skin conductance responses between different emotions. In simple terms, when participants individually and objectively responded "like a blind person would" (Erdelyi, 2004; p. 79), we could not report evidence for *subliminal* or unconscious physiological responses.

In respect to the biological preparedness model, this suggests that—even if masked targets are physiologically processed before cognitive analysis (Mineka & Öhman, 2002)—they cannot be physiologically processed without conscious meta-awareness (Pessoa, 2005; Pessoa et al., 2006). These results also suggest that previous findings in the area (van der Ploeg et al., 2017) that have reported that target meta-awareness is not a necessary condition for physiological responses to masked emotional faces might have been the outcome of insufficient target masking (Kim et al., 2010) and that further methodological developments such as signal detection theory (Pessoa, 2005) subjective adjustments (Calvo & Lundqvist, 2008) and analysis for chance-level significance (Dienes, 2015) were required to properly assess and assert unconscious processing.

Our report also poses several additional limitations that should be further addressed (Tsikandilakis, Chapman, & Peirce, 2018). A basic limitation of the current design is that we

need to factor time as a possible variable in signal detection (Erdelyi, 2004). Preexperimentally defining chance-level processing is indicative for participant meta-awareness, but it does not imply that the implemented threshold might not vary from the threshold definition to the physiological assessment stages. Physiological correlates of awareness by condition such as further analysis of hits and misses (Pessoa, 2005; Pessoa et al., 2006) and subjective detection confidence reports (Overgaard et al., 2013) during the physiological assessment stage are needed to further assess unconscious processing (Lau, 2008). The current results are also limited by our method of assessment and cannot address whether further physiological measures such as heart rate or EMG, neural responses or behavioral responses will report the same effect when controlled for individual differences in signal detection (Brooks et al., 2012; Lapate et al., 2014; Van der Ploeg et al., 2017)

Conclusions

The current study is to our knowledge the first attempt in implementing subjective adjustments and Bayesian analysis for chance-level detection performance for the assessment of physiological responses to masked emotional faces. Our findings suggest that brief angry, fearful, and happy emotional faces can elicit changes in skin conductance but that when these emotional faces are adjusted for subjective differences in target detection using unbiased signal detection theory measures, there are no differences in skin conductance responses between different emotions. These findings cast doubt to the extent that we can physiologically respond to truly unconscious targets.

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Target meta-awareness is a necessary condition for physiological responses to masked emotional faces: Evidence from combined skin conductance and heart rate assessment

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The published version of this study can be found in the Appendix.

Abstract

Much heated debate surrounds the extent to which we can process emotional stimuli without awareness. In particular the extent to which masked emotional faces can elicit changes in physiology measurements, such as heart rate and skin conductance responses, has produced controversial findings. In the present study, we aimed to determine whether briefly presented faces can elicit physiological changes and, specifically, whether this is due to unconscious processing. We measured and adjusted for individual differences in the detection threshold using both receiver operating characteristics and hit rates. For this we also used a strict Bayesian assessment of participant thresholds. We then measured physiological responses to threshold adjusted emotional faces and for hits, misses and post-binary subdivisions of target meta-awareness. Our findings based on receiver operating characteristics revealed that, when faces were successfully masked there were no significant physiological differences in response to stimuli with different emotional connotations. In contrast, when targets were masked based on hit rates, we did find physiological responses to masked emotional faces. With further analysis we found that this effect was specific to correct detection of angry and fearful faces and that increases in experienced arousal were associated with higher confidence ratings for correct detection of these stimuli. Collectively, our results do not support the notion of unconscious processing when using markers of physiological processes. Rather they suggest that target meta-awareness is a necessary condition for – and possibly determined by – physiological changes in response to masked emotional faces.

Introduction

Can emotional responses be evoked without awareness? Is it possible that we can be scared, happy, sad, or simply aroused without being consciously aware of what has triggered this experience? These questions are as tantalizing in modern psychological research today (Pessoa, 2017) as they were in psychoanalytic theory almost one hundred years ago (Freud, 1923/1962). In the last thirty years, psychologists have devoted significant resources in providing an answer (Brooks et al., 2012). The method typically employed in the area (van der Ploeg, Brosschot, Versluis, & Verkuil, 2017) is to present very brief (6.25–83.33 ms) emotional stimuli preceded (forward masking) and/or followed (backward masking) by non-emotional stimuli used in order to mask - i.e., make invisible - the emotional targets (Bachmann & Francis, 2013). Neural, physiological or behavioural responses to these masked targets are suggested as evidence for unconscious processing (Pessoa & Adolphs, 2010).

This field of research has produced extensive (Brooks et al., 2012), though theoretically controversial, findings (Pessoa, 2005; Pessoa, Japee, Sturman, & Ungerleider, 2005). For example, fMRI activation in emotion processing areas such as the amygdala has been reported in response to masked angry (Nomura et al., 2004), fearful (Liddell et al., 2005) and happy faces (Duan, Dai, Gong, & Chen, 2010) among other masked stimuli types (Brooks et al., 2012). Masked emotional faces have also been shown to elicit specific markers of bioelectric activity recorded from cortical brain regions (Lu, Zhang, Hu, & Luo, 2011). They have been shown to induce liking and dislike to subsequently presented targets (Winkielman & Berridge, 2004; Winkielman, Berridge, & Wilbarger, 2005; Lapate, Rokers, Li, &

Davidson, 2014) and direct our attention as visual cues processed without explicit awareness (Yiend, 2010).

The biological preparedness model that has been put forth to explain these neural and behavioural responses suggests that unaware emotional targets can induce changes in physiological processes (van der Ploeg et al., 2017) that enable us to make automatic and involuntary responses to environmental stimuli (LeDoux, 2003). This model suggests that when stimuli confer survival value (Liddell et al., 2005) and social communication value (Hess & Fischer, 2013) and require an instant reaction they do not rely on slow-cortical pathways that enable awareness of the presented visual stimuli to produce a response. Instead they recruit a fast-subcortical pathway to the amygdala that disseminates automatic nervous system arousal and allows us to respond and adapt to our environment without conscious awareness (Pessoa & Adolphs, 2010).

When this theoretical notion was put to the test using physiological assessment such as sweating (skin conductance response) and cardiovascular changes (heart rate and blood pressure) there was evidence of an effect (van der Ploeg et al., 2017) such as higher physiological changes for masked fearful faces (Williams et al., 2004, 2006; Lapate et al., 2014) and threatening pictures (Najström & Jansson, 2007) compared to masked neutral stimuli. Nevertheless, the extent to which these findings represent unconscious processing has been extensively debated in the relevant literature. The main critical themes include the presentation of a set duration threshold for masked faces that is assumed "to remain consistently below the detection threshold on all trials and across all participants" (Lähteenmäki, Hyönä, Koivisto, & Nummenmaa, 2015; p. 341), the assessment of detection

performance using hit rates (Pessoa, 2005; Pessoa et al., 2005) and the assertion of unawareness using non-significance (Dienes, 2015).

For example, previous studies presented masked emotional faces for durations spanning from 6.25 to 83.33 ms and compared the concomitant physiological effects to the effects caused by masked neutral faces (presented for the same duration). Signal detection research has suggested that masked emotional faces are more clearly detected than masked neutral faces for set durations (e.g. 16.67 ms) because they confer emotional incongruence with the neutral mask (Calvo & Lundqvist, 2008; Kim et al., 2010). Previous research has also suggested that some participants are able to reliably discriminate what kind of face was presented at 16.67 and 33.33 ms (Pessoa, 2005; Pessoa et al., 2005). This casts doubt on whether previous studies reported results that were indeed indicative of the response to unseen stimuli and suggest that the duration of the masked targets should be adjusted both for per participant and stimuli type differences to ensure truly unconscious presentation.

Hit rates and non-significance for differences to chance-level meta-awareness have also been used in previous studies to assess and assert target awareness respectively (van der Ploeg et al., 2017). In this context, the consensus in previous research has been that if correct detection rate as assessed usually in a post-experimental task (Lähteenmäki et al., 2015) is not significantly different from chance this is evidence that the participants were guessing and were unaware of the presented target (Stanislaw & Todorov, 1999). The first problem with this approach is that hit rates are a possibly biased measure. It allows participants to reply using different subjective criteria. For example, chance-level performance can be the outcome of conservative or liberal detection strategies such as replying seeing a masked face

only when one is completely certain a face was presented or replying yes when one is quite unsure that a face was presented (Pessoa, 2005; Pessoa et al., 2005). The inclusion of unbiased signal detection measures such as d' and A' that produce a ratio between hits (correct answers) and false alarms (wrong answers) has been suggested as a more reliable alternative for assessing chance-level performance.

In respect to asserting chance-level awareness previous studies compared participant detection performance to absolute chance (e.g., 50%). If the analysis returned non-significant differences from chance the researchers claimed unconscious perception. The important problem with this approach is that "non-significantly different from chance" – lack of evidence for the alternative hypothesis - is misinterpreted as significantly at-chance and thus as evidence for the null (Overgaard et al., 2013). Previous research has suggested that instead of the traditional frequentist approach, Bayesian inference should be used to assert if performance is significantly at-chance ($B < 1/3$) and infer unconscious processing (Dienes, 2015).

These possible biases cast some doubt to the extent that emotional signals were adequately masked in previous studies. The primary aim of the current report was, therefore, to address these issues and provide necessary methodological conditions to answer whether we can evoke physiological changes in response to unconscious emotional faces. To achieve this goal, we pre-experimentally adjusted for per participant and stimuli type differences in detection performance using both hit rates and signal detection theory and we also assessed target meta-awareness using Bayesian significance for chance-level detection performance (Tsikandilakis & Chapman, 2017; in print); furthermore, we analysed separately correct and

incorrect responses and target detection confidence responses to masked angry, fearful, sad and neutral faces using combined skin conductance and heart rate recordings.

Methods

2.1. Participants

Twenty-four volunteers (thirteen females) participated in the current study. The mean age for the participants was 33.2 years (S.D. = 8.98). The exclusion criteria for the current study were history of head trauma, current medical treatment, current or previous DSM Axis I or II diagnosis and current or previous alcohol/drug abuse - assessed through self-report. Participants were screened before the experiment with the Somatic and Psychological Health Report Questionnaire; participants with scores at or below 1.0 were included. The experiment was approved by the Ethics Committee of the School of Psychology of the University of Nottingham.

2.2. Facial stimuli

The facial stimuli used were taken from the dataset created by Gur et al. (2002). They included faces with angry, fearful, sad and neutral facial expressions. The stimuli were adjusted for interpupillary distance, transformed to grey scale and resized to a standard 1024 × 768 pixels resolution. Their luminescence was averaged in SHINE, MATLAB Toolbox and Fourier Painter and finally they were spatially aligned and framed into pure white within a cropped circle (Height: 6 cm, Width: 4 cm).

2.3. Pilot stages: stimuli pre-selection

The processed faces were presented to a separate set of participants (n = 17). Stimuli were presented for one second preceded by a fixation cross for three seconds. Pre-target baseline

and maximum deferral skin conductance (3 s post stimuli offset; van der Ploeg et al., 2017) and heart rate (4 s post stimuli offset; Critchley, 2005) were recorded during the presentation. After each trial participants were assigned a stimuli classification, a stimuli intensity and a stimuli ambiguity task. A blank inter-screen interval for eight seconds was presented after the engagement tasks to allow skin conductance and heart rate responses to return to baseline.

After collecting the results for this pilot stage, we selected the angry, fearful, sad and neutral stimuli that produced a significant effect ($p \leq .01$) for correct classification of emotional valence. From this subset, we further chose as the most representative examples for their emotional valence thirty angry, fearful and sad stimuli that produced the highest scores in a self-developed percentage-based metric (Appendix A.1 and A.2):

$$\text{I.F. (\%)} = \left(\left(\frac{(10 - Ambiguity) + Intensity}{2}\right) * 50\right) + \left(\left(\frac{Mean\ SCR\ Stimuli}{Max\ SCR\ Stimuli\ Type}\right) * 25\right) + \left(\left(\frac{Mean\ HR\ Stimuli}{Max\ HR\ Stimuli\ Type}\right) * 25\right)$$

2.4. Pilot Stages: Visual contrast discrimination

The selected subset of processed faces and a total of forty non-facial blur patterns matched for cropped spatial alignment and luminance were presented to a different set of participants (n = 17). The stimuli were presented for 33.3 ms with backward masking produced by neutral faces presented for 116.67 ms. Participants were asked to rate their subjective experience of visual contrast after each presentation using ratings on a scale from one (not at all) to ten (intense). Subjective experience of contrast for the non-facial patterns (M = 2.19, S.D. = 1.08) was not rated higher than contrast in the face condition (M = 2.23, S.D. = 1.1; t (16) = 1.41, p =.17; d = .03; Appendix B.1) suggesting that differences of visual contrast between the non-facial patterns and the emotional faces, and the neutral masks would not artefactually

impact target detection (Bachmann & Francis, 2013) and physiological responses (Kim et al., 2010) in subsequent experimental stages.

2.5. Pilot stages: adaptation of the perceptual awareness scale

In a final pilot experimental stage, we implemented and tested an initial post-binary adaptation of the Perceptual Awareness Scale (PAS - Sandberg & Overgaard, 2015). We presented a different set of participants (n = 23) with hit rate threshold adjusted masked angry, sad, neutral and no facial stimuli for per participant and stimulus type durations. We assigned participants with a binary detection task (How many stimuli did you see? 1 or 2). Subsequently, for i being the reply to the binary task we asked them to rate their perceptual experience between unsure, possibly i, most likely i and definitely i. We measured skin conductance during the presentation.

We found that no differences in SCR changes were reported between possibly and most likely for any stimulus type and binary response type (hits, misses, correct rejects, false alarms; $p > .05$). On a follow-up stage, we could contact fifteen participants included in the original pilot and asked them to rate the ambiguity between each item on the four-point scale from one (not at all) to ten (intense). Ambiguity between possibly and most likely ($M = 6.8$, $S.D. = 0.94$) was rated significantly higher than any other category combination ($F (2.47, 34.51) = 28.63$. $p < .01$; $\eta^2 = .67$; Greenhouse-Geisser corrected; Appendix C.1; 3.2). Based on these findings and in order to avoid possible linguistic ambiguity between these categories we collapsed the four-point scale into a three-point scale including ‘unsure’, ‘possibly’ and ‘definitely’ as subjective measures.

2.6. Main experiment: physiological recording and analysis

During the main experiment skin conductance and heart rate were used to assess physiological responses. Skin conductance responses were measured from the non-dominant hand (index/first and middle/s fingers; Banks, Bellerose, Douglas, & Jones-Gotman, 2012) of each participant using disposable Ag/AgCl gelled electrodes. The signals were received by a BIOPAC System, EDA100C in units of microsiemens and recorded in AcqKnowledge (Braithwaite, Watson, Jones, & Rowe, 2013). Heart rate was measured via a double finger cuff from the non-dominant hand (ring/third and little/fourth finger) using an ambulatory CNAP™ MONITOR 500 and responses were recorded in beats per minute (bpm) also in AcqKnowledge.

To make our data comparable with previous research we used similar analysis parameters. The presence of a phasic skin conductance response was defined as an unambiguous increase (.01 μS) with respect to each pre-target baseline occurring 3 s post stimuli offset (van der Ploeg et al., 2017). The presence of a heart rate response was defined as an event-related heart rate peak in beats per minute with respect to each pre-target baseline occurring 4 s post stimuli offset (Critchley, 2005). The raw signals for both measures were processed using the Derive Phasic from Tonic and manual Dirac Delta (Δ) functions. The data did not require additional smoothing, filtering or transformations (Braithwaite et al., 2013; p. 10–12). Non-responders for physiological changes were included in the data analysis (Venables & Mitchell, 1996).

3. Main experiment: presentation testing

The stimuli were presented on a high frequency LED monitor set at 120 Hz (8.33 ms per frame). A Canon G16 camera with 240 Hz refresh rate (4.17 ms) recorded two pilot runs of the experiment and the stimuli presentation was assessed frame by frame; no instances of dropped frames were detected. A self-developed dropped frame report script with one frame (8.33 ms) tolerance threshold was coded in Python and two pilot experimental diagnostic sessions were run. The presenting monitor operated at 8.33 ms refresh rate for checking dropped framed diagnostics and reported no dropped frames; prognostic dropped frame rate was estimated at 1/5000 trials. Experimental stages were, subsequently, run using dropped frames diagnostics and per stimuli presentation frame rate performance of the stimuli presenting monitor; no instances of dropped frames were detected.

4. Main experiment: detection threshold

In the first part of the main experiment we defined the detection threshold individually per participant and stimulus type. We presented participants with a fixation cross for 3 (±1) seconds. After the fixation cross an angry or fearful or sad or neutral face or a non-facial blur pattern was presented for 8.33 or 16.67 or 25 ms with backward masking by a neutral face presented for 108.33 ms. Twenty angry, twenty sad, twenty neutral and twenty-six non-facial blur patterns were presented for each duration (8.33, 16.67, and 25 ms); presentation order was randomised. Five seconds after each presentation, an on-screen message asked participants to decide how many stimuli were presented during the trial. Participants were asked to press 1 if they saw one face or 2 if the saw two faces (using the keyboard).

To define the detection threshold per participant and stimulus type non-parametric receiver operating characteristics (Zhang & Mueller, 2005) and hit rate performance were calculated separately. The duration of presentation (8.33 or 16.67 or 25 ms) that marked the smallest negative or positive difference from chance per stimulus type was imported separately for ROC and hit rate performance to the main experiment; [0.5. - $P_{threshold}$] closest to 0.5 (Figs. 1 and 2). When participants reported equal differences from chance between two thresholds (e.g., 16 ms: 0.45; 25 ms: 0.55) the briefer duration was imported in the main stage. This stage was performed for each participant seven days before and at the same time slot as the skin conductance and heart rate responses stage below.

5. Main experiment: skin conductance and heart rate responses

In the second part of the main experimental stage we tested if, as assessed per participant and stimulus type, the threshold adjusted faces can elicit changes in physiological processes. Participants were invited to the same laboratory space under identical conditions. They took part in two 15-min experimental sessions separated by a 5 min long break; session order was randomised. In both sessions' participants were presented with a fixation cross for 3 (±1) seconds. After the fixation cross an angry or fearful or sad or neutral face or a non-facial blur pattern were presented. In one session, the faces were presented for hit rate adjusted durations and in the other session they were presented for ROC adjusted durations (Fig. 1). In both sessions, faces were backward-masked with a neutral face presented for 108.33 ms. Five different angry, sad, fearful, neutral and a total of twenty different non-facial blur patterns were presented in each session with order randomised.

Five seconds after each presentation an on-screen message asked participants to decide how many stimuli were presented during the trial. Participants were asked to press 1 if they saw one face or 2 if the saw two faces, using the keyboard. After this task, participants were asked to rate their confidence for their decision using the adjusted form of the PAS (Ramsøy & Overgaard, 2004). Using conditional branching for i being the participant response during the binary signal detection task participants were asked how they would rate their confidence for their reply between one (unsure), two (possibly i) and three (definitely i). Participants were allowed six seconds to complete each task. A blank screen for eight seconds was presented after the completion of the engagement tasks to allow physiological measures to return to baseline (Cacioppo, Tassinary, & Berntson, 2007).

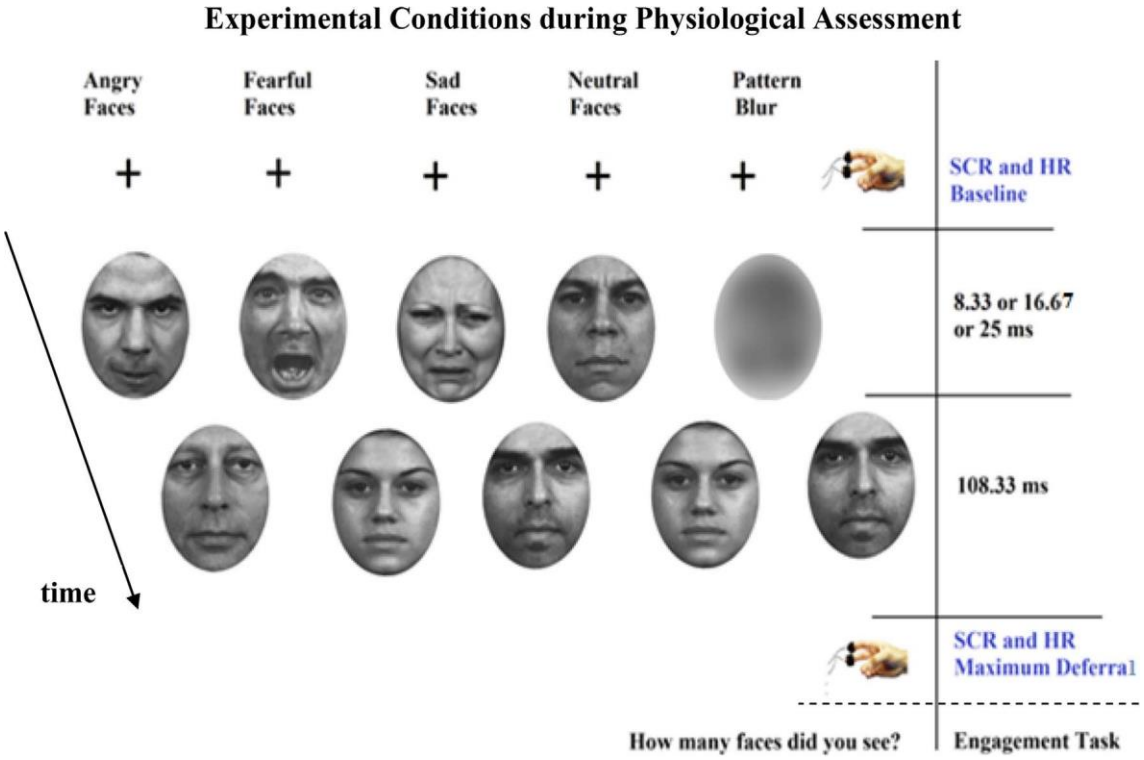


Fig. 1. Participants watched masked stimuli for ROC and Hit Rate adjusted durations (8.33 or 16.67 or 25 ms). The stimuli were backward-masked with neutral faces (108.33 ms). Heart rate and skin conductance responses were measured during the presentation

Results

6.1. ROC threshold adjusted faces

6.1.1. Signal detection

We wanted to explore if ROC threshold adjusted stimuli were processed significantly at-chance (A =0.5). A uniform Bayesian analysis with corrected degrees of freedom (df < 30; $SE = (SE\ x\ \left(1\ +\ \left(\frac{20}{df x df}\right)\right)$) (Berry, 1996) was run using the Dienes calculator (2014, 2015) to assess chance-level processing; B < 1/3. The credible intervals were defined at −.05 (lower bound) and .05 (higher bound) with 0 representing absolute chance-level performance. Detection performance using non-parametric receiver operating characteristics revealed significant evidence for overall chance-level processing (M = .49, S.D. = .03; S.E. = .01 (.01); B = 0.29). When tested separately, however, individual stimuli types indicated insensitivity to chance-level processing (1/ 3 > B < 3; Fig. 2).

6.1.2. Physiological responses

The ROC Threshold adjusted faces did not lead to significant differences between different emotions in terms of respective skin conductance (F (4, 92) = 1.51, p = 21; η^2 = .06) or heart rate responses (F (4, 92) = .34, p = .85; η^2 = .02). Angry (SCR: M = .01, S.D. = .01; HR: M = 0.37, S.D. = .64), fearful (SCR: M = .01, S.D. = .01; HR: M = 0.39, S.D. =0.63), sad (SCR: M = .01, S.D. = .01; HR: M = .36, S.D. = .55) and neutral faces (SCR: M = .01, S.D. = .01; HR: M = .36, S.D. = .51), and pattern blur stimuli (SCR: M = .01, S.D. = .01; HR: M = .53, S.D. = .65) were not processed differently in terms of physiological arousal.

6.2. Hit rate adjusted faces

6.2.1. Signal detection

To explore if hit rate adjusted faces were processed significantly at chance-level a uniform Bayesian analysis was run using the Dienes calculator and the exact same parameters used for ROC adjusted faces; credible intervals set at − 5% to 5% with standard error corrected for degrees of freedom (df < 30). Detection performance using hit rates showed insensitivity for chance-level processing (M = 49.01%, S.D. = 2.85%; S.E. = .1 (0.2); B = 0.55); sensitivity for individual stimuli can be seen in Fig. 2.

Detection Performance (A) and Thresholds (B) for Different Faces

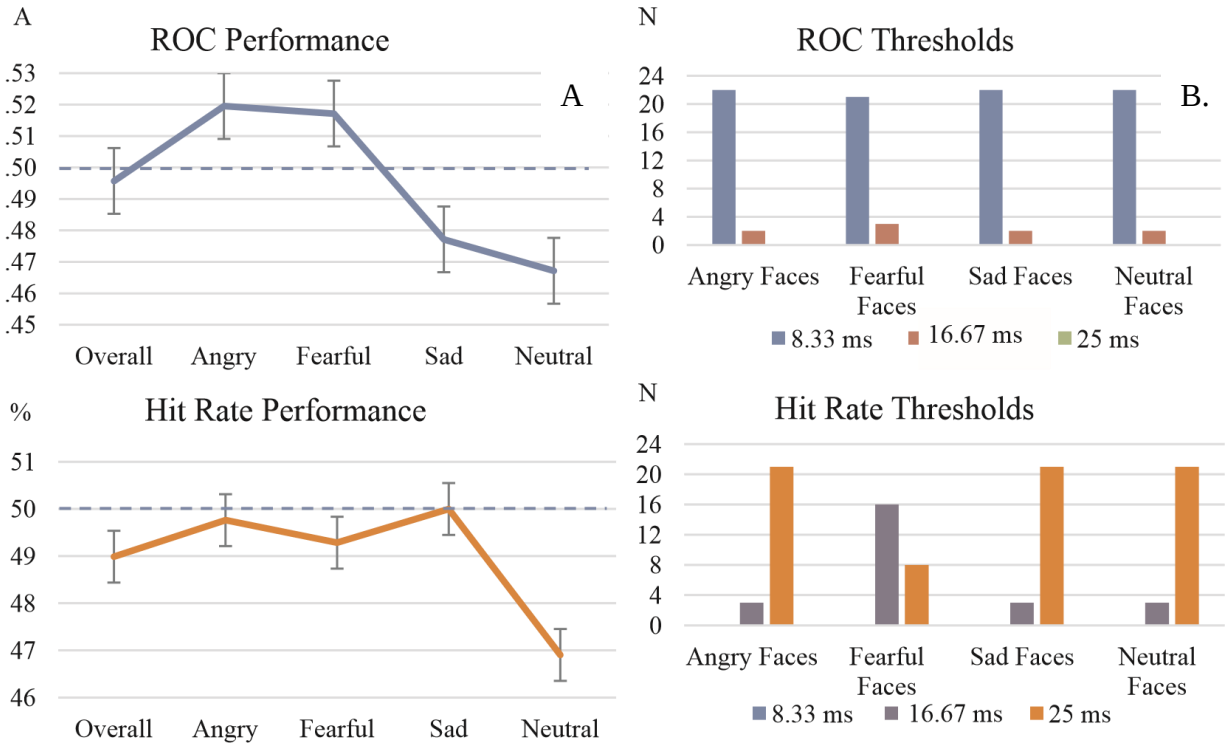


Fig. 2. Detection performance for ROC adjusted and Hit Rate adjusted faces and participant count (N) per assessed threshold of presentation (8.33, 16.67 or 25 ms) and stimuli type. Most of the participants were clustered (by ROC) across faces in the lowest available threshold condition (8.33 ms) where correct detection was lowest in comparison to other available durations. Bars indicate ±2 standard errors of the mean.

6.3. Overall physiological responses

The hit rate adjusted faces reported significant differences in SCR changes between different stimuli types (F (2.1, 48.32) = 25.16, $p < .01$; $\eta^2 = .52$; Greenhouse-Geisser corrected). When adjusted using Bonferroni corrections for multiple comparisons our findings revealed that the effect was specific to angry and fearful faces. Angry faces (M = .04, S.D. = .02) elicited higher SCR changes than sad (M = .01, S.D. = .01, $p < .01$; d = 1.21), neutral (M = .01, S.D. = .01, $p < .01$; d = 1.38) and pattern blur stimuli (M = .01, S.D. = .01, $p < .01$; d =1.37). Similarly, fearful faces (M = .04, S.D. = .02) also elicited higher scores for SCR changes than sad (M = .01, S.D. = .01, $p < .01$; d = 1.63), neutral (M = .01, S.D. = .01, $p < .01$; d = 1.83) and pattern blur stimuli (M = .01, S.D. = .01, $p < .01$; d = 1.76). Heart rate responses reported a similar effect (F (2.05, 47.09) = 10.09, $p < .01$; $\eta^2 = .31$). The effect was again specific to angry and fearful faces. Angry faces (M = 1.46, S.D. = 1.28) elicited higher heart rate changes than sad (M = .57, S.D. = .47, p =.04; d = .92), neutral (M = .5, S.D. = .34, p = .03; d = 1.02) and pattern blur stimuli (M = .63, S.D. = .61, $p < .01$; d = .82). Fearful faces (M =1.32, S.D. = .89) also elicited higher heart rate changes than sad (M = .57, S.D. = .47, p = .01; d = 1.05), neutral (M = .5, S.D. = .34, p = .01; d = 1.21) and pattern blur stimuli (M = .63, S.D. = .61, $p < .01$; d = .9).

6.4. Hits and misses

To further understand this effect, we compared SCR and HR changes per stimuli type (angry, fearful, sad, neutral and pattern blur) and detection response (hits, misses, correct rejects and false alarms). Our findings revealed that there were significant differences for SCR between stimuli (F (2.36, 54.34) = 20. 37, $p < .01$; $\eta^2 = .47$; Greenhouse-Geisser corrected). There

were also significant differences per detection response type ($F (1, 23) = 35.99$, $p < .01$; $\eta^2 = .61$) and a significant stimuli type by detection response interaction ($F (4, 92) = 19.65$, $p < .01$; $\eta^2 = .46$). When adjusted using Bonferroni corrections this effect revealed that hits for angry ($M = .05$, $S.D. = .04$) and fearful faces ($M = .06$, $S.D. = .04$) elicited significantly higher SCR than any other response combination and stimulus type ($p < .01$; Table 1). The same effect was reported for heart rate responses ($F (1.89, 43.57) = 5.93$, $p = .01$; $\eta^2 = .21$; Greenhouse-Geisser corrected). The effect was again specific to hits for angry ($M = 1.78$, $S.D. = 1.33$) and fearful faces ($M = 1.92$, $S.D. = 1.29$) in comparison to all other stimuli types ($p < .01$; Table 1) suggesting that the overall effect reported in the previous analysis was specific to correct detection for angry and fearful faces (Table 1; Appendix D.1).

Table 1: Hits and Misses SCR (μS) and HR (bpm) Changes for different Stimuli.

Stimulus Type	Detection Response	SCR Change (μS)	SCR S.D. (μS)	HR Change (bpm)	HR S.D. (bpm)
Angry	Hits*	.05	04	1.78	1.33
	Misses	.01	.02	.89	2.63
Fearful	Hits*	.06	.04	1.92	1.29
	Misses	.01	.01	.67	1.45
Sad	Hits	.02	.01	.72	.75
	Misses	.01	.02	.39	.47
Neutral	Hits	.01	.01	.5	.79
	Misses	.01	.01	.58	.68
Pattern Blur	Correct Rejects	.01	.01	.49	.49
	False Alarms**	.02	.02	.95	1.36

Table 1: SCR and HR per stimulus type and response for meta-awareness.* (Asterisk) signifies that the specific subdivision for meta-awareness for the specific stimuli type reported higher physiological changes (SCR and HR) than other stimuli types after adjusting for multiple Bonferroni comparisons.** Items that were associated with significance trends compared to other non-asterisk types after adjusting for multiple Bonferroni comparisons (Appendix D.1 and F.1).

6.5. Adjusted PAS scale

We further chased these significant results to explore if hits for angry and fearful faces could be associated with skin conductance and heart rate changes for different categories of the adjusted PAS scale (unsure, possibly and definitely). Our data showed two significant effects. Although there were no overall differences per adjusted PAS scale reply, hits for angry faces

demonstrated a significant linear trend for skin conductance ($F(2, 49) = 4.37$, $p = .02$) and heart rate responses ($F(2, 49) = 15.28$, $p < .01$). The same effect was revealed in response to hits for fearful faces for skin conductance ($F(2, 48) = 10$, $p < .01$) and heart rate changes ($F(2, 48) = 25.63$, $p < .01$) suggesting that physiological arousal interacted with confidence ratings for correct detection for angry and fearful faces (Fig. 3; Appendix E)

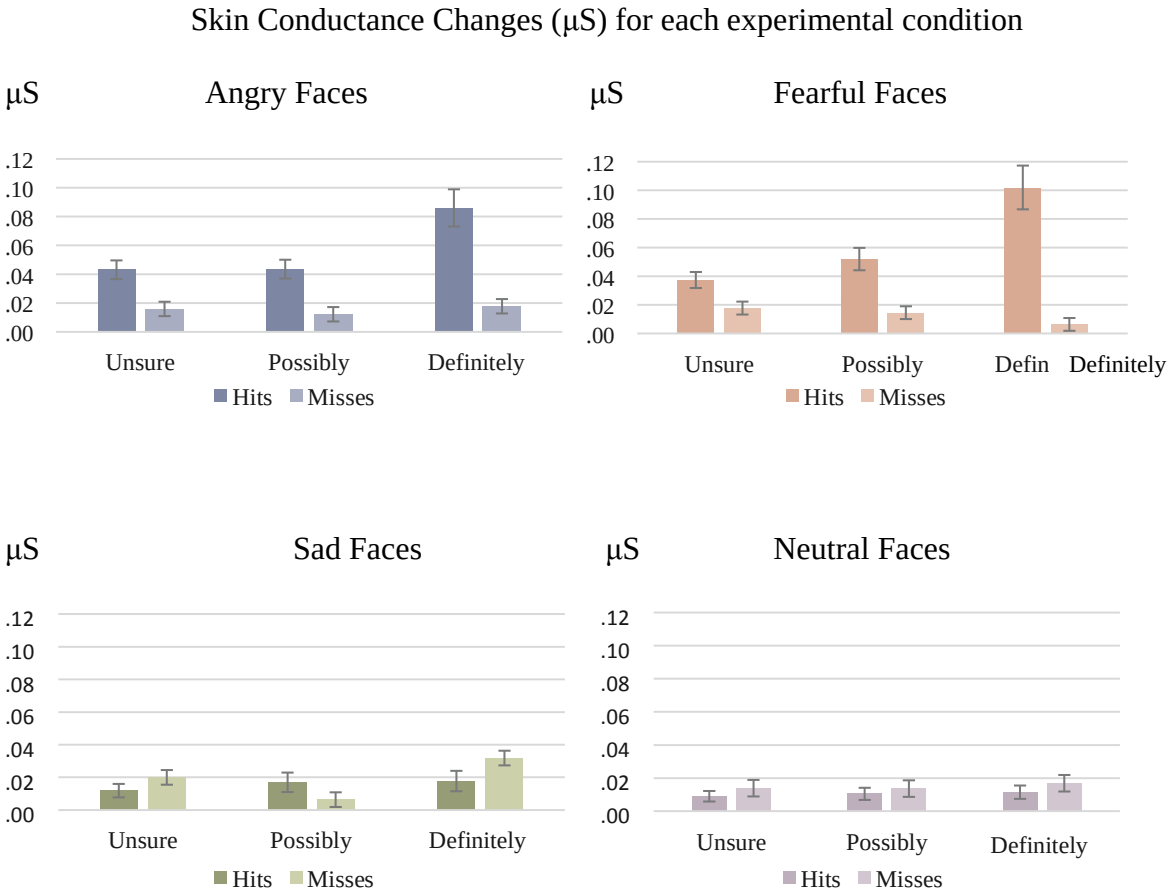


Fig. 3. Skin Conductance Changes (µS) for each experimental condition. Skin conductance changes for different stimuli types. SCR scores are arranged per signal detection response type (hits, misses) and detection confidence (unsure, possibly, definitely) ratings. Error bars show the standard error of the mean. A Linear trend was reported for skin conductance and detection confidence that suggested higher arousal interacted with confidence for target meta-awareness.

Discussion

In this experimental study, we examined if backward masked emotional faces can elicit physiological changes (Williams et al., 2004; Williams et al., 2006). We also examined

whether these changes can be due to unconscious processing (Pessoa, 2005; Pessoa et al., 2005). We implemented several methodological developments to explore this question such as separate ROC and hit rate adjustments in the detection threshold and Bayesian assessment of significance for chance-level detection performance. We found that ROC threshold adjusted faces did not elicit changes in physiological responses. Hit rate threshold adjusted faces elicited physiological changes that further analysis proved to be associated with correct detection for masked angry and fearful faces. We found a significant linear relationship between physiological arousal and detection confidence that was again specific to correct detection for angry and fearful faces.

Previous research has suggested that if a stimulus has biological relevance – such as survival value (Liddell et al., 2005) –, it can elicit automatic and involuntary changes in physiological processes irrespectively of whether it is consciously perceived (LeDoux, 2003). Our findings support the idea that biologically relevant stimuli can induce changes in skin conductance and heart rate (van der Ploeg et al., 2017) but suggest that target meta-awareness at some sufficient level of confidence is a necessary condition for these changes (Pessoa, 2005; Pessoa et al., 2005). In the current study, only angry and fearful faces produced an effect and only in trials that included correct detection of these stimuli. This result is partly counter to what prevails in topical publications (van der Ploeg et al., 2017). We could not provide evidence for unconscious processing of fully masked emotional faces that we had expected to be indicated using physiological assessment, and we could not support previous findings where fMRI, (Brooks et al., 2012), EEG (Zhang et al., 2011), behavioural responses (Winkielman & Berridge, 2004; Winkielman et al., 2005) or skin conductance (Lapate et al.,

2014) were used – all suggesting that emotional processing can occur without meta-awareness.

We suggest that this discrepancy is due to the substantial methodological differences between the current study and previous research (van der Ploeg et al., 2017). In the current investigation, we utilized previous signal detection findings (Calvo & Lundqvist, 2008; Lähteenmäki et al., 2015) and implemented subjective thresholds for detection performance. This could have been the catalyst for eliminating physiological differences using unbiased criteria for meta-awareness such as receiver operating characteristics (Stanislaw & Todorov, 1999). The alternative implementation of detection threshold durations using traditional detection criteria such as hit rates provided similar results to those obtained in previous studies and is the kind of evidence that has previously been used to conclude that masked angry and fearful faces induce changes in physiology (see also van der Ploeg et al., 2017). However, further analysis of the current data provided support for the Pessoa (2005), Pessoa (2017) and Pessoa et al. (2005), Pessoa, Japee, Sturman, and Ungerleider (2006) model that suggests that trial-by-trial response analysis reveals that the subset of trials that included correct detection modulates physiological changes to masked emotional content and creates the overall effect (Pessoa et al., 2005; p. 370). These findings cast doubt on the extent that physiological changes can be elicited without meta-awareness (Pessoa & Adolphs, 2010).

The critical question that the current study sets – and one that has also been raised by Pessoa (2005) and Pessoa et al. (2005) – is whether physiological changes influence correctness for target meta-awareness (Pessoa, 2017). Previous research has suggested that our behavioural responses to masked stimuli can be influenced by introspective cognitive and emotional

criteria (Kouider, De Gardelle, Sackur, & Dupoux, 2010; Aru, Bachmann, Singer, & Melloni, 2012). In relation to the current results, this suggests either that arousal could have been higher when target visibility was higher (Adolphs, 2008) or that arousal modulated target meta awareness and shaped the confidence of the perceptual experience (Anderson, 2005).

For example, Lapate et al. (2014) suggested that conscious processing has a regulatory role and disrupts the automatic associations between experienced arousal and evaluative judgement. Arousal elicited by unaware stimuli, on the other hand, decreases likeability for subsequent presented targets because the experience of affect is not subject to executive control (Pessoa & Adolphs, 2010). Evaluative judgement in relation to target presentation could also be regulated by experienced arousal by allowing participants to rely on the experience of affect to respond to the detection task. This would suggest that participant responses did not necessarily indicate whether a stimulus was consciously perceived but whether there was sufficient experienced affect and sufficient awareness of the experienced affect allowing to assume target presentation (Critchley, Wiens, Rotshtein, & Dolan, 2004; Critchley, 2005). In simpler terms, it is possible that participants could have responded in the laboratory in the same way that we respond in real-life when we experience physiological changes and environmental ambiguity: by inferring that "something must have happened".

This is a promising hypothesis that can nonetheless be quite controversial. Initially, the linear trend effect currently reported was significant only for correct detection of angry and fearful faces. This suggests that it is confidence for meta-awareness and not unawareness that is regulated by fluctuations in the experience of arousal for these faces. On the other hand, if we suggest that physiological changes can regulate meta-awareness and shape perceptual

experience this can be extended to posit that false alarms for either detection or discrimination performance would also be associated with physiological changes (Pessoa, 2005; Pessoa, 2017; Pessoa et al., 2005; Pessoa et al., 2006). This effect was not significant in the current research (Table 1; Appendix F.1), although there were trends in the predicted direction. This makes unclear whether it is only post-binary detection confidence or also binary target detection responses that are determined by the experience of arousal during the presentation (Pessoa, 2005; Pessoa et al., 2005).

Finally, a limitation of the current study must be noted. The reported effect was assessed using only measures of autonomic nervous system arousal such as skin conductance and heart rate responses. Our findings cannot answer whether emotional and behavioural reports, neural processing or different methods for the assessment of physiological changes will demonstrate the same linear trend between participants' responses and confidence for meta-awareness.

Conclusions

The current study suggests that successfully masked emotional faces do not elicit changes in physiological processes. Instead, the current results point to the possibility that autonomic nervous system arousal is specific to trials that include masked target meta awareness. The current findings allow the hypothesis that arousal could be a possible determinant for target meta-awareness by shaping perceptual experience and influencing confidence reports for the correct detection of angry and fearful faces.

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I can see you, I can feel it; and vice-versa: Physiological and Facial-Expressive Responses to Masked Emotional Faces

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An experimental replication of this chapter with increased statistical power and an additional author (Professor Jan Derrfuss) who contributed to the analysis and the writing of the manuscript can be found in the Appendix.

Abstract

In this paper, we explore if masked emotional faces can elicit changes in physiology without conscious awareness. We also explore whether emotional misclassification includes the physiological correlates associated with the perception of an emotion. We adjust the discrimination threshold of presentation per participant and stimulus type to the closest available duration to chance-level performance (20.83 or 27.78 or 34.72 or 41.67 ms) using hit-rates and receiver-operating-characteristics. We assess subliminality using an adjusted Bayesian criterion for awareness (A = .167) and measure skin-conductance, heart-rate, facial-emotional and engagement-task force-pressure responses to masked fearful, angry, happy, sad and neutral faces. We report that only hit-rate adjustments in the threshold of presentation were associated with physiological changes. These changes were reported for fearful, angry and happy faces for hits and misses for discrimination performance. For these faces, during misses for discrimination performance, participants could correctly appraise the valence and arousal of the presented face and intriguingly, participants also responded with false-positive miss-discrimination responses for seeing a fearful face when they experienced physiological arousal to innocuous masked stimuli types. These findings suggest that, upon explicit post-trial inquiry, if physiological arousal is elicited during the presentation of masked emotion, conscious assessment is involved in the evaluation of the elicited emotion and the emotional elicitor.

Introduction

More than one hundred years since the first approaches to the subconscious by Carl Gustav Carus (1851), Friedrich Nietzsche (1876) and Sigmund Freud (Breuer & Freud, 1895), experimental psychology and cognitive neuroscience still seek to answer whether we can be influenced by unconscious emotional cues (Brooks et al., 2012). In contemporary psychological research, the method for addressing this most interesting and enduring research question is commonly to present very brief (6.25 to 83.33 ms) emotional faces followed by clearly visible non-emotional masks that aim in rendering invisible the emotional targets (Bachmann & Francis, 2013). Physiological responses, such as skin-conductance (SCR) and heart-rate responses (HR), as well as neural responses, such as fMRI activation and cortical bioelectrical activity, to these brief emotional targets are interpreted as unconscious processing (Pessoa, 2005).

This technique for presenting emotional faces – termed backward masking – has produced an abundant array of findings. For example, several fMRI studies have reported limbic system activation in response to masked fearful, angry and happy faces, and the suggestion has been put forth that a dedicated subcortical neural pathway to the amygdala disseminates autonomic nervous system arousal in response to very brief stimuli when these confer evolutionary important survival and sociobiological value (Brooks et al., 2012). The purpose of this arousal pathway is to make us biologically prepared to adapt to environmental cues that require an imminent, automatic and involuntary response (Liddell et al., 2005).

When this theoretical notion was put to the test, several studies using skin-conductance and heart-rate responses were able to provide support that indeed very brief

(6.25 to 83.33 ms) masked emotional faces elicit higher autonomic nervous system arousal compared to non-emotional masked stimuli or masked neutral faces (van der Ploeg et al., 2017). Masked emotional stimuli were also suggested to emotionally *colour* our first impressions of clearly visible subsequently presented neutral targets (Lapate. Rokers & Davidson, 2014), affectively influence our perception of reality (Siegel, Wormwood, Quigley & Barrett, 2018) and even exert influence on how much we like, or dislike subsequently presented food and beverage (Winkielman & Gogolushko, 2018).

Although these findings are well-documented and partly replicated (Brooks et al., 2012), they have been extensively criticized. The main themes of criticism are the set duration of subconscious presentation (Lähteenmäki, Hyönä, Koivisto, & Nummenmaa, 2015), the assessment of detection or discrimination performance using hit rates (Pessoa, Japee, Sturman, & Ungerleider, 2005) and the assessment of awareness using non-significance (Dienes, 2015). For example, previous research presented masked emotional faces for 6.25 to 83.33 ms and assumed that the presented faces will remain below the threshold of conscious awareness irrespectively of individual differences, such as differences in attentional resources (Aru & Bachmann, 2017), and stimulus type differences, such as higher visibility of emotional faces due to emotional incongruence with the neutral mask (Calvo & Lundqvist, 2008; Kim et al., 2010). Additionally, according to the current paradigm, stimulus invisibility occurs when the participant detects or discriminates at chance what type of brief stimulus was presented in a post-trial or post-experimental task. In this manner, chance-level performance indicates that the participant responded randomly and in a sense *like a blind person would* when asked to identify a brief face (Erdelyi, 2004). The

assessment of this chance-level criterion is commonly done using hit rates and almost unanimously done using non-significance. The problem with hit rates is that the participants can apply individual conservative or liberal response strategies when responding for awareness, such as replying having seen a face only when they are certain beyond a shadow of a doubt that a face was presented or replying having seen a face when they are quite unsure if a face was presented (Stanislaw & Todorov, 1999). The problem with non-significance is that, to infer subconscious processing, detection or discrimination performance is compared against absolute chance (e.g. 50%) using a one-sample t-test, and "non-significantly different from chance", i.e. lack of evidence for the alternative hypothesis, is misinterpreted as significantly at-chance and thus as evidence for the null (Dienes, 2015).

In our previous work on consciousness and emotion, we attempted to address these issues (Tsikandilakis, Chapman & Peirce, 2018; Tsikandilakis & Chapman, 2018; Tsikandilakis, Bali & Chapman, 2018). We used per participant and stimuli type adjusted thresholds for the presentation of masked emotional faces, assessed awareness using both hit rates and non-parametric signal detection criteria (Zhang & Mueller, 2004), applied Bayesian analysis of chance-level significance for detection performance, and ran both post-binary response confidence and hits (correct detection/discrimination) and misses (incorrect detection/discrimination) analysis for participant responses. We reported that skin-conductance and heart-rate responses for angry, fearful and happy faces require a sufficient level of confidence for target-detection meta-awareness and, critically, that hits but not misses for detection confer these physiological changes. The questions that our previous work has, nevertheless, left unanswered are whether these findings apply for the detection as

well as for the discrimination of emotion, whether there are levels of emotional awareness between the detection and discrimination of emotional faces, and whether misclassification of a brief stimulus is sufficient to affectively impact our biological preparedness by driving our physiological responses.

In the current manuscript, we expand our model to address these questions. We test if emotional faces such as fearful, angry, happy, sad and neutral faces, and non-facial blurs that are adjusted per participant and stimuli type using both hit rates and receiver operating characteristics elicit physiological changes when presented for discrimination threshold durations. To implement an adjusted discrimination threshold criterion we set the chance-level threshold criterion at A = .167 and 16.67% when using hit rates, that would indicate chance-level performance given the available options for discrimination. We explore whether responses for hits and misses include correct appraisal of emotional information such as ratings for the type of emotional valence and the level of expressed arousal of the presented stimulus. Furthermore, we explore if brief stimuli that are not associated with physiological arousal such as sad and neutral faces and non-facial pattern blurs, induce physiological changes when misclassified as emotionally arousing stimuli, such as fearful faces.

Method

2.1. Participants

Forty-seven volunteers (twenty-four female) participated in the current study. The exclusion criteria were current or previous DSM Axis I or II diagnosis and current or previous alcohol/drug abuse through self-reports. The participants were screened with the Somatic and Psychological Health Report Questionnaire (Berryman, McAuley & Moseley,

2012) and participants with scores above 1.0 were excluded from the analysis; one participant was excluded. Participants were screened with an on-line Alexithymia questionnaire (Alexithymia, 2018) and participants with scores over 94 that indicated possible alexithymia traits were excluded from the analysis; one participant was excluded. Participants were also screened with a Hyperactivity-Impulsivity questionnaire (Kooij & Francken, 2010) and participants whose scores indicated a possible Hyperactivity-Impulsivity disorder were excluded from the analysis; two participants were excluded. The final sample consisted of forty-three (twenty-two female) participants with mean age 34.23 (S.D. = 8.38). The experiment was approved by the Ethics Committee of the School of Psychology of the University of Nottingham.

2.2. Facial stimuli

The facial stimuli used were taken from the dataset created by Gur and colleagues. (2002). They included faces with angry, fearful, happy, sad and neutral facial expressions. Non-facial blurs were generated from black and white pattern stimuli and scrambled using pseudo-randomised pixel permutation in MATLAB. All the stimuli were adjusted for interpupillary distance, transformed to grey scale and resized to a standard 1024 × 768 pixels resolution. Their luminescence was averaged in SHINE, MATLAB Toolbox and finally they were spatially aligned and framed into pure white within a cropped circle (Height: 6 cm, Width: 4 cm). The included stimuli were tested for physiological arousal during supraliminal presentations (one-second) and validated for emotional discrimination with Face-Reader software (Noldus, 2018) and participant assessment, they were controlled for low-level visual features, such as spatial frequency and gradient orientation differences, and the black and

white pattern mask was also separately contrasted and adjusted for luminance contrast with the presented faces (see Tsikandilakis & Chapman, 2018; Tsikandilakis, Peirce & Chapman, 2018; Tsikandilakis, Bali & Chapman, 2018).

2.3 Participant Assessment

2.3.1. Physiological recording and analysis

During the main experiment skin conductance and heart rate were used to assess physiological responses. Skin-conductance responses were measured from the left hand (index/first and middle/second fingers) of each participant using disposable Ag/AgCl gelled electrodes. The signals were received by a BIOPAC System, EDA100C in units of microsiemens and recorded in AcqKnowledge (Braithwaite, Watson, Jones, & Rowe, 2013). Heart rate was measured via a single finger sensor from the left hand (ring/third finger). The signal was received by a BIOPAC System, PPG100C in units of beats per minute (bpm) and recorded in AcqKnowledge. To make our data comparable with previous research we used similar analysis parameters. The presence of a phasic skin-conductance response was defined as an unambiguous increase with respect to each pre-target baseline occurring three seconds post stimulus offset. The presence of a heart-rate response was defined as an event-related heart-rate peak in beats per minute with respect to each pre-target baseline occurring five seconds post stimulus offset. The raw signals for both measures were processed using the Derive Phasic from Tonic and manual Dirac Delta (Δ) functions. The data did not require additional smoothing, filtering or transformations (Braithwaite et al., 2013).Non-responders for physiological changes were also included in the data analysis.

2.3.2. Analysis of Facial Responses

The analysis of facial expressions was conducted using Noldus 7.1 using an HD camera mounted on the bottom of the presenting screen and centred on the participant's face. The analysis was run using the maximum video capture frames per second allowed by the face-reader equipment (thirty fps). The analyses employed the Viola-Jones cascaded algorithm and an active appearance model (AAM) with a 500-point Euclidean transformation to eliminate static identification variability for image quality, lighting, background variation and orientation. The analysis included a custom template analysis and each participant was evaluated in respect to the expressed emotion after controlling for the influence of action units that were present in their own neutral expressions using the participant calibration module (Noldus, 2018). The General61 face module was used to assess European participants and the Asian and East Asian face modules were used to assess participants with an Asian ethnic background. Expression of an emotion was defined as a categorical recognition of an emotional expression up to five seconds post-stimuli offset. Participants were aware that their facial expressions were recorded.

2.3.3. Engagement Task Response Force Plate

To measure if participants had different patterns of response intensity and post-response task disengagement durations per stimuli type (angry, fearful, happy, sad and neutral), confidence (possibly, likely and definitely) and response type (hits and misses), we developed a mouse pad device that could measure mouse press force during the engagement tasks. The device included a working measurement area of 210 to 160 mm mechanically coupled to four 5kgf load cells. The signals from these cells were then amplified and

converted to a digital signal via a 24-bit ADCs that operated at 120 Hz with a minimum force accuracy of .01 grams (.00098 Newtons). The device operated using its own parallel port input and interfaced with the stimulus presenting computer using a USB 2.0 (Figure 1). The participant's right hand was rested upon a 45 by 20 by 3 cm forearm support and the device calculated mouse press pressure via drift filtering and mapping the location of the mouse to an on-screen visual matrix, and subsequently by subtracting the hand weight of the participant and the force applied after each bilateral movement from the force applied every time the participant replied using a mouse click. To avoid artifacts and outliers due to individual pressure strength, each participant was asked during a training session to press twenty times on one of six randomly positioned boxes on the screen and then confirm their choice by pressing a button labelled "OK" at the lower part of the screen. Z-scores for click pressure per participant were calculated and the force applied during the main experimental stage was measured in units of standard deviations from the performance in the training phase. In addition to force pressure, the Response Disengagement Residue (RDR) was also calculated as the time in milliseconds that each participant took to release the "OK" button after making an engagement task response. This was used as a measure of confidence/ambiguity response. Participants were aware that their engagement task responses were recorded.

Figure 1: Graphic Illustration of the Force Plate

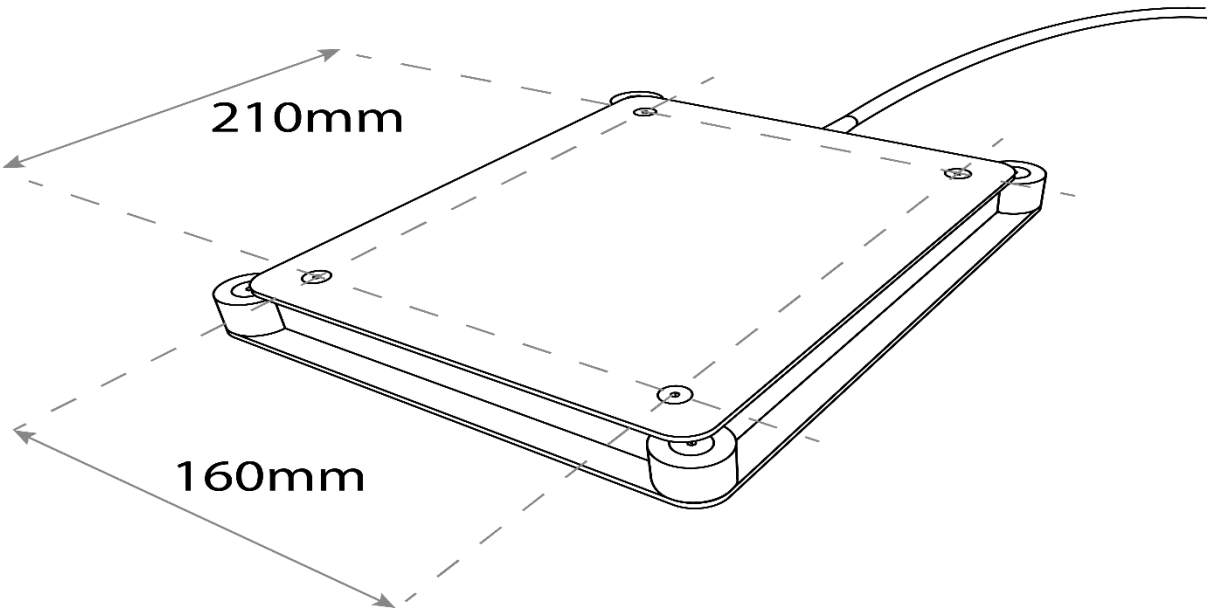


Fig. 1: A graphic illustration of the mouse pad force-plate device. The device was placed on a solid and even surface. The participants' hands were placed on a levelled wrist rest and the participants were asked to respond during the training and main experimental phases using the mouse.

2.4. Apparatus and Presentation-Testing

All stimuli were presented on a high frequency LED monitor set at 144 Hz (6.94 ms) and created in the Builder and Coder components of PsychoPy v.1.90.02 (Peirce, 2007). An IPAD PRO camera with 240 Hz refresh rate (4.17 ms) recorded two pilot runs of the experiment and the stimulus presentation was assessed frame by frame; no instances of dropped frames were detected. A self-developed dropped frame report script with one frame (6.94 ms) tolerance threshold was coded in Python and two pilot experimental diagnostic sessions were run. The presenting monitor reported no dropped frames; prognostic dropped frame rate was estimated at 1/5000 trials. Experimental stages were, subsequently, run using

dropped frames diagnostics and per stimuli presentation frame rate performance of the stimuli presenting monitor; no instances of dropped frames were reported.

2.5. Threshold Adjustment Experiment: Discrimination Phase

In the first part of the experiment we defined the discrimination threshold individually per participant and stimulus type. We presented participants with a fixation cross for 3 (±1) seconds. After the fixation cross an angry or fearful or happy or sad or neutral face or a non-facial blur pattern was presented for 20.83 or 27.78 or 34.72 or 41.67 ms with backward masking by a neutral black and white pattern for 125 ms. Ten different fearful, angry, happy, sad and neutral faces, and fifty non-facial blur patterns were presented for each duration; presentation order was randomised. Five seconds after each presentation, an on-screen message asked participants to decide what kind of stimulus was presented during the trial using their mouse. Participants were asked to press on one of six boxes labelled Angry, Fearful, Happy, Sad, Neutral or Non-Facial placed in random positions on the screen to indicate their choice. Then they were asked to press on a fixed position button in the lower part of the screen labelled "OK" to confirm their choice.

To define the discrimination threshold per participant and stimulus type, non-parametric receiver operating characteristics (ROC; Zhang & Mueller, 2005) and hit rate performance were calculated separately. The duration of presentation (20.83 or 27.78 or 34.72 or 41.67 ms) that marked the smallest absolute difference from chance per stimulus type was imported separately for ROC and hit rate performance to the main experiment; [.167. – $P_{Threshold}$] closest to .167 (Figs. 2 & 3). This stage was performed seven days before and at the same time slot as the Physiological Responses Phase.

2.6. Main Experiment: Physiological Responses Phase

In the main experiment, we tested if the threshold adjusted faces can elicit changes in physiological processes, facial responses and engagement task pressure responses. Participants were invited to the same laboratory space under identical conditions. They took part in two 15-min. experimental sessions separated by a 5 min. long break; session order was randomised. In both sessions participants were presented with a fixation cross for 3 (±1) seconds. After the fixation cross an angry or fearful or happy or sad or neutral face or a non-facial blur was presented. In one session, the faces were presented for hit-rate adjusted durations and in the other session they were presented for ROC adjusted durations (Fig. 2). In both sessions, faces were backward-masked with a neutral pattern mask presented for 125 ms. Ten different angry, sad, fearful, happy, neutral and a total of fifty different non-facial blur patterns were presented in each session with order randomised.

Seven seconds after each presentation, an on-screen message asked participants to choose what type of stimulus was presented. Participants were asked to choose using the mouse from randomly positioned on-screen boxes labelled Angry, Fearful, Happy, Sad, Neutral and Non-Facial. They were then asked to press on a fixed position button in the lower part of the screen labelled “OK” to confirm their choice. After this task, participants were asked to rate their confidence for their decision using the mouse between unsure, possibly and definitely and click “OK”. Participants were also asked to rate using the mouse the Emotional Valence of the presented stimuli from one (negative) to ten (positive) and click “OK”. They were also asked to rate using the mouse the Expressed Arousal of the presented stimuli from one (low arousal) to ten (high arousal) and click “OK”. The order of the three

tasks was randomised in each trial and participants were allowed six seconds to complete each task. A blank screen was presented for eight seconds after the completion of the engagement tasks to allow physiological measures to return to baseline.

Figure 2: Example Stimulus Sequence with Fearful Masked Target

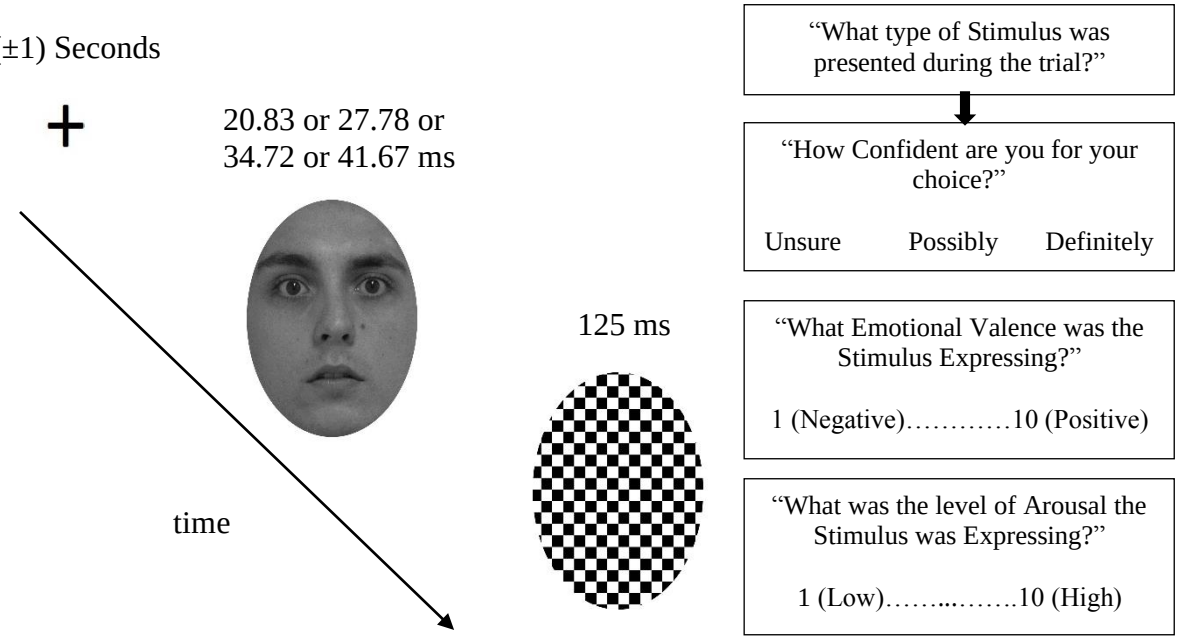


Fig. 2: Participants watched masked stimuli for ROC and hit-rate adjusted durations (20.83 or 27.78 or 34.72 or 41.67 ms). The stimuli were backward-masked with a black and white pattern mask (125 ms). Heart-rate, skin-conductance, facial and engagement task pressure responses were measured in each trial.

3. Results

3.1. Threshold Adjustment Experiment: Discrimination Phase

We wanted to explore if ROC adjustments in the threshold of presentation were associated with significance for chance-level performance. We defined the threshold for chance-level performance at A = .167 or 16.67% when using hit rates. A Bayesian analysis with uncorrected degrees of freedom was run using the Dienes calculator (2015) to assess chance-level processing (B < 1/3). The intervals were defined at - .1 (.067; lower bound) and .1 (.267; higher bound) with 0 (.167) representing absolute chance level performance.

Discrimination performance using non-parametric receiver operating characteristics was at chance (M. = .164; S.D. = .019; S.E. = .003; B = .06; Fig. 2).

To explore if hit-rate adjustments in the threshold of presentation faces were associated with significance for chance-level performance, a Bayesian analysis was run using the Dienes calculator and the exact same parameters used for ROC adjustments; intervals set at -10% (6.67%; lower bound) to 10% (26.67%; higher bound) with 0 (16.67%) representing absolute chance level performance and standard error uncorrected for degrees of freedom. Discrimination performance using hit rates was at chance (M. = 16.42; S.D. = 5.77; S.E. = .98; B = .12); Discrimination performance for individual stimuli can be seen in Fig. 3.

Figure 3: Discrimination Performance and n per Threshold for Different Faces

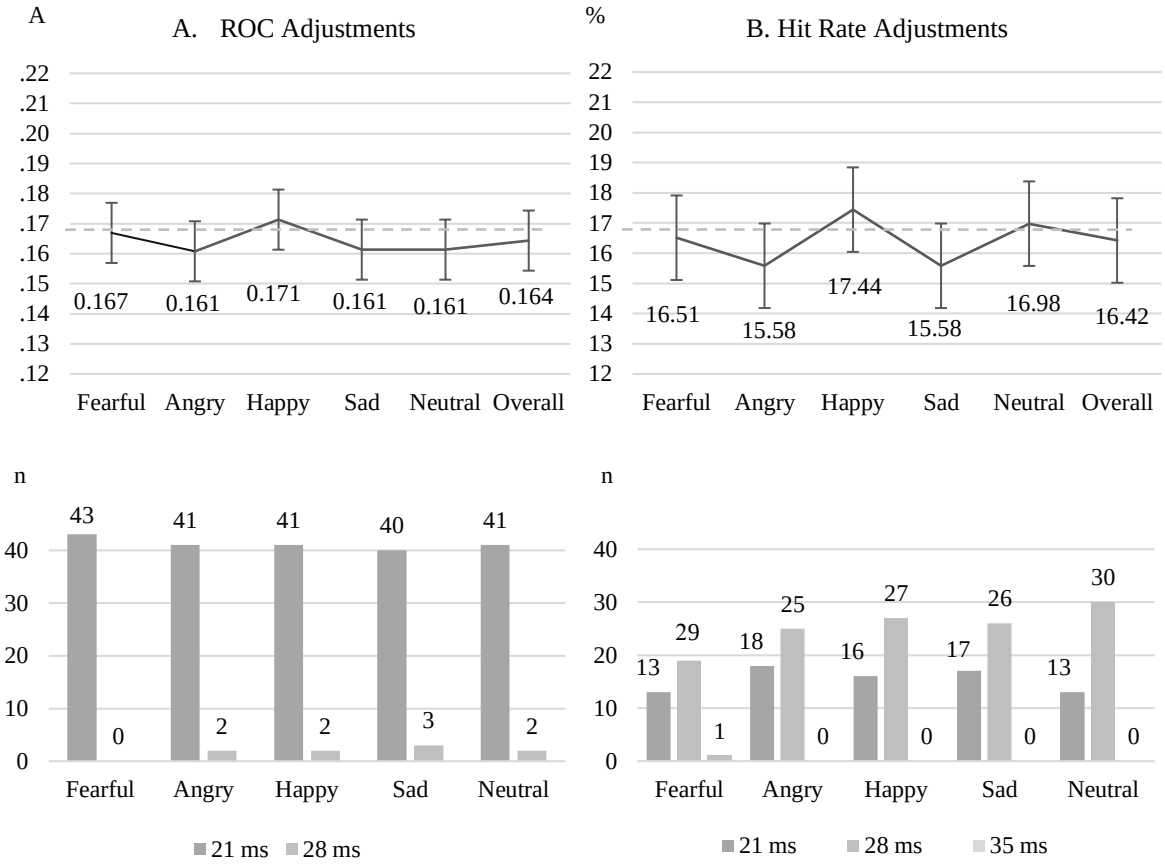


Fig. 3: Discrimination performance for ROC and hit-rate adjustments and participant count (N) per assessed threshold of presentation (20.83 or 27.78 or 34.72 or 41.67 ms) and stimulus type. Mid-line indicates absolute chance-level performance. Bars indicate ±2 standard errors of the mean.

4.1. Main Experiment: SCR and Heart-rate responses to Masked Faces

Adjustments using receiver operating characteristics did not lead to significant differences between different emotions in terms of skin-conductance ($F(4, 168) = 1.21$, $p = .31$; $\eta^2 = .03$) and heart-rate responses ($F(4, 168) = 1.92$, $p = .11$; $\eta^2 = .04$). Differences between stimuli types were also not found for ratings for valence ($F(4, 168) = 1.38$, $p = .24$; $\eta^2 = .03$) and arousal ($F(4, 168) = .63$, $p = .64$; $\eta^2 = .02$) suggesting that, using signal detection criteria, masked faces were not associated with significant differences in physiology and emotional ratings. Significant differences in SCR changes were found between different

stimulus types for adjustments using hit-rates (F (2.81, 118.2) = 588.05, p < .001; η^2 = .93; Huynh-Feldt corrected). A similar effect (F (3.12, 131.21) = 208.61, p < .001; η^2 = .83; Greenhouse-Geisser corrected) was revealed for heart-rate responses (Fig. 4).

Figure 4: Physiological Responses

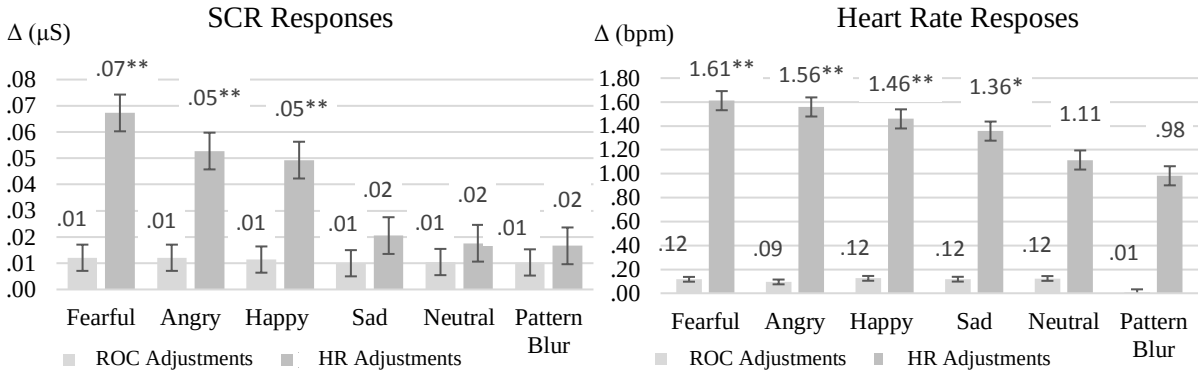


Fig. 4: Skin-conductance and heart-rate changes for ROC and hit-rate adjustments. * indicates significance at the < .01 level. ** indicates significance at < .001 level. Fearful faces reported high effect sizes for SCR compared to sad (d = 4.31), neutral faces (d = 4.88) and non- facial pattern blurs (d = 4.93). Bars indicate ±2 standard errors of the mean.

The effect for adjustments using hit-rates was significant both for hits (F (2.69, 113.08) = 1035.99, p < .001; η^2 = .96; Huynh-Feldt corrected) and misses (F (1.61, 67.55) = 57.95, p < .001; η^2 = .58; Huynh-Feldt corrected) for discrimination for SCR. For heart-rate changes, hits (F (3.44, 144.53) = 269.77, p < .001; η^2 = .87; Greenhouse-Geisser corrected) and misses (F (2.77, 116.35) = 36.91, p < .001; η^2 = .47; Huynh-Feldt corrected) also revealed significant differences between stimuli types. For both SCR and heart rate angry, fearful and happy faces were higher compared to other stimuli (Table 1). When we further explored these findings, our analysis revealed that for valence, overall ratings (F (3, 126) = 403.29, p < .001; η^2 = .91; Greenhouse-Geisser corrected) and ratings for hits (F (2.99, 125.48) = 361.36, p < .001; η^2 = .89; Greenhouse-Geisser corrected) and misses (F (4, 168) = 65.56, p < .001; η^2 = .61; Greenhouse-Geisser corrected) were significantly lower for angry and fearful faces and

significantly higher for happy faces compared to other categories (Table 1). A similar effect was revealed for overall ratings ($F (3.09, 130.01) = 386.65$, $p < .001$; $\eta^2 = .9$; Greenhouse-Geisser corrected), hits ($F (4, 168) = 409.96$, $p < .001$; $\eta^2 = .91$) and misses ($F (4, 168) = 362.91$, $p < .001$; $\eta^2 = .89$) for arousal, with fearful, angry and happy faces being rated higher than other stimuli types (Table 1). These results suggested that participants were able to correctly appraise the emotional valence and the level of arousal of the presented stimulus even for misses for discrimination.

Table 1: Hits and Miss Analysis for Responses for Adjustments using Hit-Rates

Stimuli Type	Discrimination Response	SCR Change (SD)	Heart-Rate Change (SD)	Valence Ratings (SD)	Arousal Ratings (SD)
Fearful	Hits**	.096 (.01)	1.973 (.13)	2.490 (.56)	6.638 (.64)
	Misses*	.039 (.01)	1.249 (.16)	4.833 (.18)	5.699 (.18)
Angry	Hits**	.064 (.01)	1.923 (.16)	2.205 (.66)	6.437 (.59)
	Misses*	.041 (.02)	1.195 (.14)	4.948 (.23)	5.403 (.23)
Happy	Hits**	.062 (.01)	1.832 (.13)	7.058 (.96)	6.375 (.54)
	Misses*	.037 (.01)	1.072 (.07)	5.576 (.31)	5.291 (.31)
Sad	Hits	.016 (.01)	1.735 (.09)*	2.709 (.88)*	4.179 (.61)*
	Misses	.025 (.01)*	.978 (.03)	5.085 (.22)	4.664 (.22)*
Neutral	Hits	.017 (.01)	1.189 (.12)	5.253 (.34)	2.345 (.55)
	Misses	.018 (.01)	1.041 (.14)	5.072 (.21)	3.989 (.22)
Pattern Blur	Hits	.016 (.01)	.983 (.09)	5.021 (.27)	2.214 (.2)
	False Alarms	.017 (.01)	.983 (.08)	5.003 (.19)	4.103 (.46)

Tab.1: Physiological and emotional responses for hits and misses for hit-rate adjustments. SCR change is described in μS. Heart-rate change is described in bpm. * indicates < .01 ** < .001. Arousal ratings for hits and misses for fearful faces reported high effect sizes compared to neutral hits ($d = 9.36$) and neutral misses ($d = 8.51$) and pattern blur hits ($d = 9.33$) and misses ($d = 4.57$) respectively.

An additional finding for adjustments using hit-rates was that as per our previous findings (Tsikandilakis, Peirce & Chapman, 2018) confidence reports for hits - but not misses - for angry (SCR: $F (1, 124) = 101.55$, $p < .01$, $\eta^2 = .99$; HR: $F (1, 124) = 55.59$, $p < .01$, $\eta^2 = .99$), fearful (SCR: $F (1, 125) = 87.39$, $p < .01$, $\eta^2 = .99$; HR: $F (1, 125) = 290.74$, $p < .01$, $\eta^2 =$

.99), and happy faces (SCR: $F(1, 125) = 6.93$, $p = .01$, $\eta^2 = .97$; HR: $F(1, 125) = 111.29$, $p < .01$, $\eta^2 = .99$) revealed significance for a linear trend for skin-conductance and heart-rate responses suggesting that higher confidence for the discrimination of a presented face was associated with higher physiological changes (Fig. 5).

Figure 5: Skin-Conductance Changes (μS) for Response Confidence

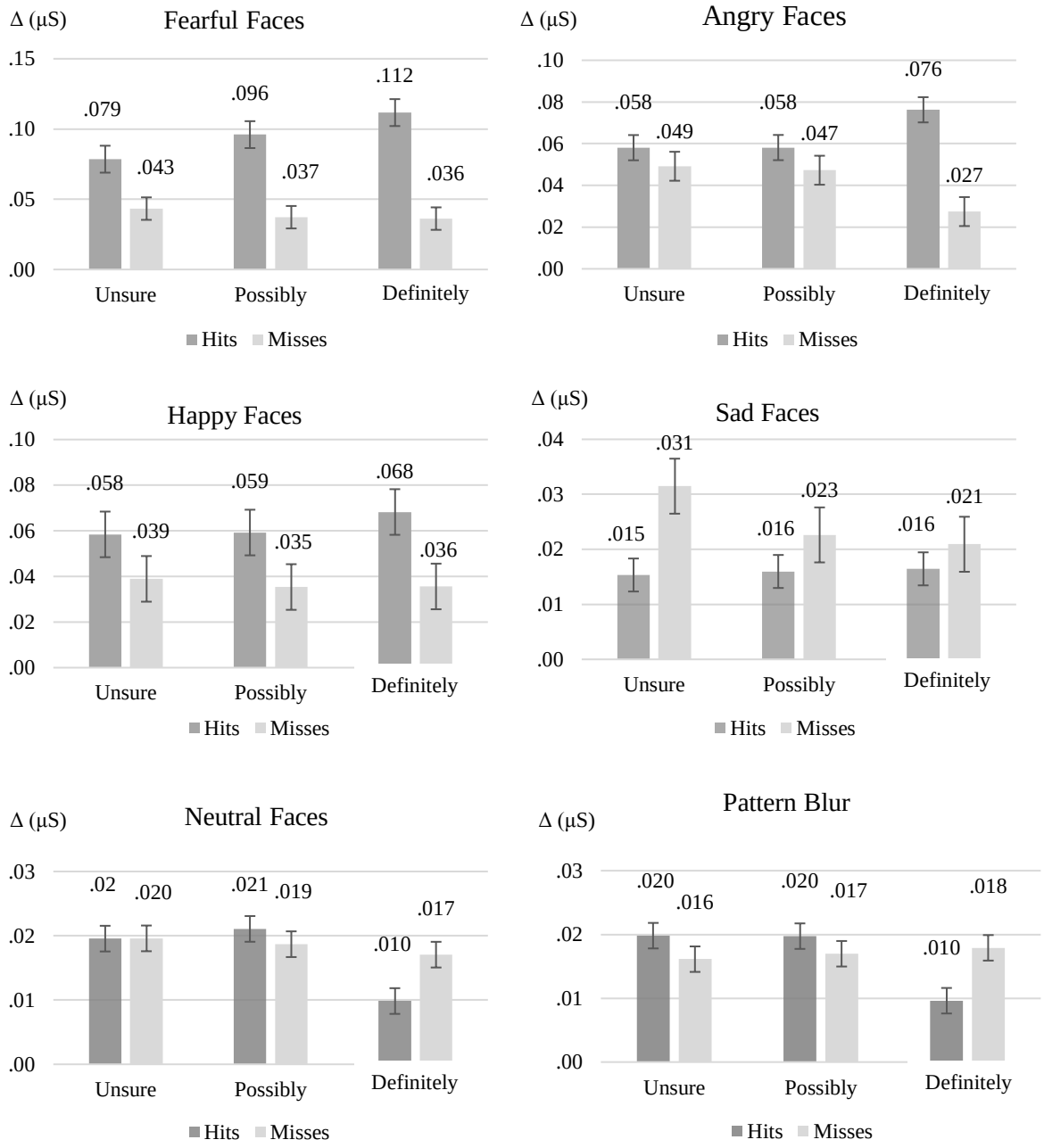


Fig. 5. Skin-conductance changes for different stimuli types. SCR scores are arranged per signal detection response type (hits, misses) and detection confidence (unsure, possibly, definitely) ratings. Error bars show the standard error of the mean. No individual comparisons survived the Bonferoni corrections. Bars indicate ±2 standard errors of the mean.

4.2. Main Experiment: SCR and Heart-rate responses for Emotional Misclassification

We wanted to explore if misclassification for hit-rate adjustments in the discrimination threshold can induce the physiological changes associated with the perception of an emotion. Because misclassification of an arousing emotional type (fear, anger and happiness) as another arousing type would be expected to induce physiological changes (Pessoa et al., 2005) independently of the discrimination response, we compared SCR and heart-rate changes for fearful, angry, happy, sad and neutral faces after excluding misclassification between fearful, angry and happy facial stimuli. An analysis of variance ($F(3.27, 127.68) = 17.43$. $p < .01$; $\eta^2 = .31$; Greenhouse-Geisser corrected) with further Bonferoni corrected pairwise comparisons revealed that misclassified fearful faces (M. = .04, S.D. = .01) were higher for SCR scores than angry (M. = .03, S.D. = .01, $p < .01$; $d = 1.59$), happy (M. = .03, S.D. = .01, $p < .01$; $d = 1.85$), sad (M. = .03, S.D. = .01, $p < .01$; $d = 1.6$) and neutral faces (M. = .03, S.D. = .01, $p < .01$; $d = 1.44$). A similar pattern was reported for heart-rate responses ($F(4, 152) = 5.61$, $p < .01$; $\eta^2 = .13$) with false positives for fearful faces (M. = 2, S.D. = .61) inducing higher responses than false positives for angry (M. = 1.49 S.D. = .49, $p < .01$; $d = .92$), sad (M. = 1.45.D. = .72, $p = .01$; $d = .82$) and neutral faces (M. = 1.46 S.D. = .67, $p = .01$; $d = .84$). These results suggested that, after removing the cross-misclassification between arousing emotional types, participants still experienced false positives for fearful face as more arousing compared to other stimuli types.

4.3. Main Experiment: Facial-emotional and Force-Plate Responses

ROC adjustments were not associated with significant differences between stimuli types for facial-emotional recognition ($F(2.55, 12.33) = .303$, $p = .82$; $\eta^2 = .01$; Greenhouse-

Geisser corrected), engagement task responses (F (3.2, 134.54) = .82, p = .51; η^2 = .02; Greenhouse-Geisser corrected) and RDR durations (F (4, 168) = .143, p = .23; η^2 = .03). For hit-rate adjustments, facial-emotional recognition revealed a significant effect for hits in discrimination only (F (2.18, 91.72) = 6.44, p < .01; η^2 = .13; Greenhouse-Geisser corrected). Further Bonferoni corrected pairwise comparisons revealed trends for significance for emotional recognition for happy expressions (M. = 5.58, S.D. = 7.34) compared to fearful (M. = 1.39, S.D. = 3.51, p = .02; d. = .73), angry (M. = 1.63, S.D. = 4.32, p = .02; d. = .66) and sad expressions (M. = 1.86, S.D. = 3.93, p = .04; d. = .63). These results suggested that participants were to some extend more likely to show happy-related facial expression characteristics in response to correctly discriminated happy faces but also that they could have possibly responded with a negative emotion regulation bias during the presentation (Garnefski & Kraaij, 2007). Differences for overall performance (F (2.96, 124.17) = 122.45, p < .001; η^2 = .75; Greenhouse-Geisser corrected), hits (F (3.26, 136.93) = 279.53 , p < .001; η^2 = .87) and misses (F (2.92, 122.45) = 11.91, p < .01; η^2 = .22) for hit-rate adjustments in the discrimination threshold were also recorded between different stimuli types for engagement task force responses. Angry, fearful and happy faces were higher than other stimuli types (Figure 6). No significant differences were reported between stimuli types for RDR (F (4, 168) = .92, p = 45; η^2 = .01). Although differences were not reported for reaction times between hits and misses (t (42) = .65, p = .52; d = .02), the RDR was higher for misses in discrimination (M. = .24, S.D. = .02) compared to hits (M. = .2, S.D. = .01; t (42) = 12.59, p < .01; d. = 2.74).

Figure 6: Mean Z-Scores for Engagment Task Force Pressure

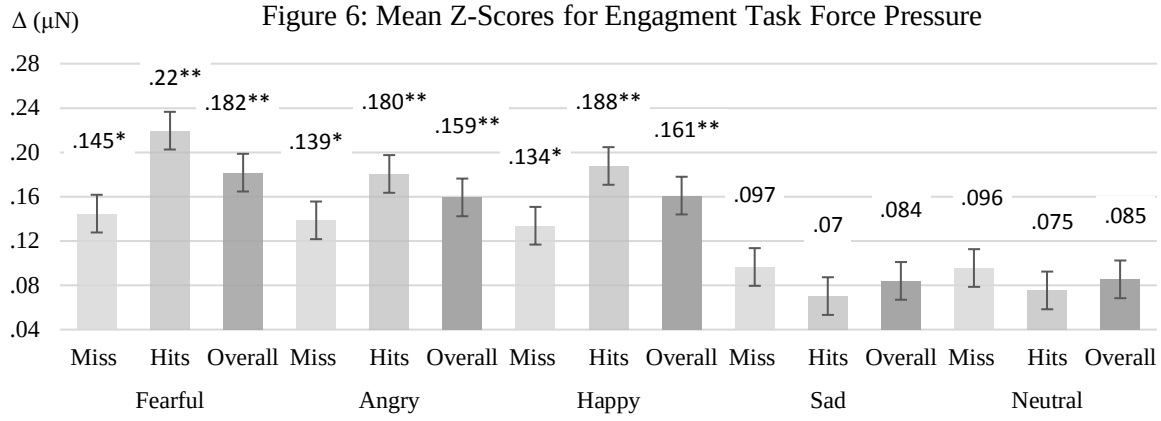


Fig. 6: Engagement task force pressure in standardized Z-scores units of pressure (micro-Newtons) based on the preliminary training task. Bars indicate ±2 standard errors of the mean. * indicates $p < .01$, ** indicates $p < .001$.

Discussion

In the current study, we explored whether brief emotional faces could elicit changes in physiological processes such as SCR and heart rate, as well as changes in facial-emotional expressions and engagement task responses. We also explored whether misclassification of an emotion can lead to the physiological correlates associated with that emotion. When faces were adjusted per participant and stimulus type to the closest available duration to chance-level discrimination performance using unbiased ROC criteria, we could not report significant differences in physiological processes or any differences in reports for emotional type or emotional subtype information such as emotional valence and the level of expressed arousal. When faces were adjusted using hit rates, we reported overall differences in physiological processes as well as differences between stimuli types for hits and misses in discrimination. These differences were recorded for fearful, angry and happy faces compared to other stimuli types.

Further analysis of hits, misses and overall performance for hit-rate adjustments in the discrimination threshold revealed that emotional subtype information, i.e. emotional valence

and level of arousal, were correctly appraised by the participants even during misses in discrimination. Interestingly, we also reported that misses – or more precisely false positives – for fearful faces revealed higher physiological arousal than false positives for other stimuli types. The application of face-reading software in the current study gave us limited findings, as only hits in discrimination conferred higher facial-expression recognition rates for happy faces compared to other stimuli types. This result suggests that participants might have experienced a negative emotion regulation bias (Garnefski & Kraaij, 2007), particularly since they were aware of the recording of their expressions. The application of the force plate revealed similar findings with SCR and heart-rate responses; angry, fearful and happy faces showed higher pressure responses for overall performance, and hits and misses responses compared to other stimuli types.

Previous research has suggested that evolutionary important survival-related and sociobiologically relevant facial stimuli can induce automatic and involuntary physiological responses without conscious awareness (van der Ploeg et al., 2017). The purpose of this arousal is to equip us with the ability to respond to environmental cues that require an imminent reaction without necessarily relying on *slow* cortical systems for initiating a course of action. This process is suggested to be *subliminal* in the sense that conscious awareness of the presented stimulus is not required to activate the neural substrates that are recruited for experiencing emotional changes and not required for the experience of physiological arousal (Brooks et al., 2012).

The current findings do not necessarily disagree with this concept, but they do suggest an additional and rather challenging consideration in relation to subliminality. We have

shown in the current manuscript that very brief emotional faces can elicit SCR, heart-rate and force-pressure responses. We have also shown that ROC adjustments in the duration of presentation were not associated with statistically significant differences for physiological responses. Hit-rate adjustments in the duration of presentation were associated with different physiological responses between different stimulus types but they were also associated both with a certain level of post-trial confidence for discrimination and correct appraisal of information such as the emotional valence and the level of expressed arousal of the presented faces.

These findings allow two possible interpretations. Firstly, the argument can be made that when we implemented hit-rate adjustments, the higher ratings for the levels of valence and arousal in response to fearful, angry and happy faces during misses for discrimination indicated that participants were aware of emotion-eliciting facial sub-characteristics. Therefore, the experience of physiological arousal could be due to conscious perception of emotion-eliciting facial features, and this interpretation is supported by the positive association between physiological arousal and confidence ratings for the discrimination of fearful, angry and happy faces. Another interpretation is that during misses for fearful, angry and happy faces, participants were making rating-guesses and not rating-assertion responses, i.e. the stimuli were presented at an appropriate signal-strength level (Rouder, Morrey, Speckman & Pratte, 2007; Morey, Rouder, Pratte & Speckman, 2017) to preclude correct discrimination but allow introspection or inference (Dehaene et al., 2006). This interpretation is not supported by the valence and arousal ratings during ROC adjusted presentations, but this finding could be due to the implementation of a corrected chance-level ROC criterion (A

= .167) that could have served to achieve the implementation of presentation durations that disallowed any – conscious or subconscious – processing of the presented faces (Pessoa, 2005).

These possibilities become further interesting when we consider that misclassification for fearful faces relied on joint physiological and conscious processes, even if these reflected seeing and feeling *what was not there* (Siegel et al., 2018). In simpler terms, when participants misclassified sad, neutral and non-facial stimuli as fearful, the physiological assessment revealed that they had experienced physiological arousal. This suggests that fearful faces were evaluated as the more likely presented stimuli post-hoc to physiological arousal during misses for discrimination and therefore, that participants possibly relied on intuitive and arousal-related criteria to respond to the discrimination task for false-positive responses for fearful faces.

These findings make the point that perception and consciousness, and emotional experience are not necessarily disconnected evolutionary encapsulated modules (van der Ploeg et al., 2017), that consciousness and perception influence and are influenced by emotional arousal in response to masked emotional faces and that physiological responses to masked emotional faces are therefore, not *subliminal* when the latter term is used to describe a state of conscious impenetrability (Brooks et al., 2012). The current data suggest that, as a function of meta-cognition – post-trial intuitive awareness of the experienced emotion – and/or meta-awareness – post-trial conscious awareness of the emotional type or emotional sub-type characteristics – if physiological arousal is elicited during the presentation of

masked emotion, conscious assessment is involved in the evaluation of the elicited emotion and the emotional elicitor.

Conclusions

In the current study, we adjusted the duration of presentation for masked emotional faces to the closest available duration to chance-level discrimination performance using receiver operating characteristics and hit-rate assessment. Only hit-rate adjustments in the threshold of presentation were associated with physiological changes – but not for facial-emotional responses – and these changes were reported both for hits and misses for discrimination performance. We found that when we implemented hit-rate adjustments in the threshold of presentation, for misses for discrimination, participants could correctly appraise the valence and arousal of the presented face and critically, that when participants were presented with sad, neutral and non-facial blur stimuli and experienced physiological arousal, they responded with false-positive miss-discrimination responses for seeing a fearful face. These findings suggest that, upon explicit post-trial inquiry, if physiological arousal is elicited during the presentation of masked emotion, conscious assessment is involved in the evaluation of the elicited emotion and the emotional elicitor.

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Beauty *is* in the eye of the Beholder: The Appraisal of Facial Attractiveness and its relation to Conscious Awareness

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The published version of this study can be found in the Appendix.

Abstract

Previous research suggests that facial attractiveness relies on features such as symmetry, averageness and above-average sexual dimorphic characteristics. Due to the evolutionary and sociobiological value of these characteristics, it has been suggested that attractiveness can be processed in the absence of conscious awareness. This raises the possibility that attractiveness can also be appraised without conscious awareness. In the present study, we addressed this hypothesis. We presented neutral and emotional faces that were rated high, medium and low for attractiveness during a pilot experimental stage. We presented these faces for 33.33 ms with backward masking to a black and white pattern for 116.67 ms and measured face-detection and emotion-discrimination performance, and attractiveness ratings. We found that high-attractiveness faces were detected and discriminated more accurately and rated higher for attractiveness compared to other appearance types. A Bayesian analysis of signal detection performance indicated that faces were not processed significantly at-chance. Further assessment revealed that correct detection (hits) of a presented face was a necessary condition for reporting higher ratings for high-attractiveness faces. These findings suggest that the appraisal of attractiveness requires conscious awareness.

Introduction

Attractiveness is considered a fundamental aspect of human interactions from infancy (Fisher & Ma, 2014; Thomas et al., 2007) to adulthood (Griffin & Langlois, 2006). It has been suggested to positively influence the quality of our peer relations, our behaviour and the behaviour of others towards us throughout our life (Langlois & Stephan, 1981), to influence and inform our mate choices (Saxton, Caryl & Roberts, 2006), and even exert influence in our professional development and income status (Frieze, Olson & Russell, 1991). In our modern society, where interpersonal communication, romantic-mate choice and even professional employability rely increasingly on on-line communication and posted photographic material (Hong, Tandoc Jr, Kim E., Kim B., & Wise, 2012), the perception of facial attractiveness has been re-approached as a highly relevant psychological research subject (Swami & Farnham, 2008).

Facial attractiveness has been associated with certain perceived characteristics; these include – among others (Little, Jones & DeBruine, 2011) – symmetry (Scheib, Gangestas & Thornhill, 1999), averageness (Grammer & Thornhill, 1994) and above-average sexually dimorphic characteristics (Barber, 1995). Bilateral facial symmetry, for example, is assumed to function as a cue for developmental health and ontogenetic resistance to parasites (Fink, Neave, Manning & Grammer, 2006). Facial averageness is also suggested to confer evolutionary important offspring-survival value due to indications of heterozygosity (Roberts et al., 2005) as well as a developmental propensity for familiarity due to average faces being overall more recognisable and prototypical exemplars of the *category* facial stimuli (Fink & Penton-Voak, 2002). Additionally, pronounced facial characteristics that signify sexually

dimorphic biological markers, such as testosterone in men and oestrogens in women, have been shown to increase gender-specific attractiveness ratings (Smith et al., 2006).

Although recent research has reported evidence that casts doubt on the role of attractiveness particularly as an indication of developmental health and immunocompetence (Scott, Clark, Boothroyd, & Penton-Voak, 2013; Foo, Simmons & Rhodes, 2017; Jones et al., 2017; Cai et al., 2018), the association of attractiveness with characteristics that could confer evolutionary important sociobiological value was sufficient to prompt researchers to explore whether attractiveness can be processed, reported and appraised under conditions that do not necessarily involve conscious awareness (Mineka & Öhman, 2002; Öhman, 2009). This line of research has suggested that attractiveness is a highly-salient visual characteristic (Barber, 1995) that can be appraised even from impoverished (pixelated) visual cues (Bachmann, 2007). Previous research has also suggested that – due to the evolutionary importance of high-attractiveness features – attractiveness can be processed and reported at a glance from faces, after only 13 ms of visual exposure to a high-attractiveness face (Olson & Marshuetz, 2005), and has reported evidence for inhibition of return to lateral Gabor patches preceded by high-attractiveness faces that were adjusted for visibility using staircase visual contrast manipulations (Hung, Nieh & Hsieh, 2016). Based on these findings, the argument has been raised that attractiveness "can be processed in the absence of conscious awareness" (Hung et al., 2016; p. 6) and that it can be appraised and reported without conscious awareness (Olson & Marshuetz, 2005).

In the current study, we explored whether particularly the appraisal of attractiveness requires conscious awareness. We presented emotional and neutral faces that were rated high,

medium and low in attractiveness. We presented these faces for 33.33 ms (Brooks et al., 2012) using backward masking to a black and white pattern for 116.67 ms. We measured face-detection and emotion-discrimination performance as well as attractiveness ratings in response to these faces. To accurately assess these responses, we used the paradigm we have developed for the assessment of subliminality described in detail in previous research (Tsikandilakis, Chapman & Peirce, 2017; Tsikandilakis & Chapman, 2018). This included response assessment using unbiased non-parametric signal detection theory criteria to measure face-detection and emotion-discrimination performance (Stanislaw & Todorov, 1999; Zhang & Mueller, 2005), Bayesian analysis (Dienes, 2015) for the assessment of chance-level significance (A = .5) that would indicate stimuli invisibility (Erdelyi, 2004), and hits (correct detection/discrimination) and misses (incorrect detection/discrimination) analysis of participant ratings (Fawcett, 2006).

The inclusion of neutral faces (Olson & Marshuetz, 2005; Hung et al., 2016) as well as emotional faces in the current study was necessitated by signal detection theory requirement for the exploration of different levels of conscious awareness (Stanislaw & Todorov, 1999). The inclusion of different emotions enabled us to explore whether the appraisal of attractiveness requires face detection as well as emotion discrimination of the presented face. This signal detection theory distinction could not have been performed without the inclusion of different emotions (Pessoa, 2005). This inclusion also meant that the current study would be the first to our knowledge study (Olson & Marshuetz, 2005; Hung et al., 2016; Ritchie, Palermo & Rhodes. 2017) that included assessment of different emotional

expressions and appearance types (high, medium and low-attractiveness faces) under conditions of backward masking.

This experimental condition allowed us to formulate a secondary and – in the absence of previous research in the area (Fink & Penton-Voak, 2002) – exploratory hypothesis. We explored whether the interaction between emotional expressions and appearance types can influence face detection, emotion discrimination, and attractiveness ratings under conditions of backward masking, in the same manner that previous research has reported that it influences participant responses during supraliminal presentations (O'Doherty et al., 2002; Calvo & Lundqvist, 2008; Lundqvist, Bruce & Öhman, 2015). The preliminary hypothesis for this exploratory objective was that faces that have high sociobiological value based on attractiveness ratings, i.e. high-attractiveness faces (Bachmann, 2007), would reveal higher face-detection and emotion-discrimination scores when they expressed emotions that also have high sociobiological and survival-related evolutionary value (Brooks et al., 2012), such as fearful (Pessoa, 2005) and angry faces (Lundqvist, Bruce & Öhman, 2015). We also explored whether higher attractiveness ratings would be reported for high-attractiveness faces that expressed highly-salient positive social signals, such as happy expressions, that have been associated with increased emotional-perceptual reward value in previous research (O'Doherty et al., 2002; Calvo & Lundqvist, 2008).

In the current research, it was extremely important that any potential influences of attractiveness could not be interpreted in terms of other evolutionarily relevant or low-level stimulus features. We thus included three pilot experimental stages (Study One) to ensure that the stimuli we used did not confound attractiveness with gender, emotional expression, or

detectability through contrast changes. In the first experimental stage, we validated the facial stimuli for gender and emotional characteristics and used strict attractiveness criteria to pre-select from an existing database (Gur et al., 2002) faces that were rated high, medium and low in attractiveness. In the second experimental stage, we assessed the pre-selected stimuli for emotionality to make sure that emotionality differences between appearance types would not bias signal detection performance in subsequent experimental stages (Calvo & Lundqvist, 2008). Finally, in stage three, we explored whether there were differences in visual contrast between the selected faces and their control condition during the main experiment (non-facial pattern stimuli) that could artefactually impact signal detection and discrimination responses when using backward masking (Bachmann & Francis, 2013).

Study One

Stage One: Stimuli Pre-Selection

Aims. The current stage had two aims. The first aim was to select from an existing database (Gur et al., 2002) the faces that were correctly recognised by participants and automatic facial recognition software (Noldus) for the emotion that they were expressing. The second aim was to select faces that were rated high, medium and low in attractiveness and test whether these faces produced significant differences in attractiveness that would make them appropriate stimuli for the inclusion in the following experimental stages.

Participants. A power calculation based on effect sizes (d = .81; f = .41) reported in previous research (Tsikandilakis et al., 2017) revealed that fifteen participants were required for $P_{(1-\beta)} \geq .8$ (Faul, Erdfelder, Buchner & Lang, 2009). Eighteen participants (nine females) volunteered to participate in this experiment. All participants reported normal or corrected-to-normal vision. Participants gave informed consent to participate in the current study prior to

the experiment. The participants were screened before the experiment with the Somatic and Psychological Health Report Questionnaire (Hickie et al., 2001); participants with scores at or below 1.0 were included. Participants were also screened using an online Alexithymia-Emotional Blindness questionnaire (Alexithymia, 2017) and participants with scores that indicated possible traits ($P > 94$) or diagnosis ($P > 112$) for alexithymia were excluded; data from a single participant were excluded from the study. Two participants were also excluded from the study due to neutral ratings on the attractiveness task (Olson & Marshuetz, 2005; Hung et al., 2016). The final population sample consisted of fifteen participants (eight females) with mean age 32.87 (S.D. = 6.12). The experiment was approved by the Ethics Committee of the School of Psychology of the University of Nottingham.

Stimuli and Procedures. The facial stimuli used were taken from the dataset created by Gur and colleagues (2002) and included faces with angry, happy, fearful, sad and neutral facial expressions. The stimuli were adjusted for interpupillary distance, transformed to grey scale and resized to a standard 1024x768 pixels resolution. Their luminescence was averaged in SHINE, MATLAB Toolbox and Fourier Painter and finally they were spatially aligned and framed into pure white within a cropped circle (Height: 6 cm, Width: 4 cm).

A total of three-hundred faces were presented from sixty different actors. Ninety cropped non-facial blurs patterns that were matched for luminescence (SHINE, MATLAB Toolbox) with the presented faces were also shown. The experimental trial started with a fixation cross for three seconds (± one second). After the fixation cross in random order a single face or non-facial pattern was presented at fixation for one second. After each target a black and white pattern mask was also presented for one second. A blank screen interval was

then presented for two seconds. After that participants were asked by an on-screen message to rate how attractive the presented stimulus was from one (not attractive at all) to ten (very attractive) using the keyboard. Participants were also asked to decide from an on-screen list what kind of stimulus was presented during the trial using the keyboard. The list included (a) angry, (f) fearful, (h) happy, (s) sad, (n) neutral, (o) other and (i) non-facial. The order of the two engagement tasks was randomised in each trial. A two-second blank screen interval was presented before the next trial.

Stimuli pre-selection. We selected from the presented faces the ones that reported 100% accuracy in correct discrimination of emotional expression (n = 248). These stimuli were further analysed using Noldus Face Reader 7.0 to validate their emotion. We used the participant calibration module for emotional recognition that controlled for the action units that were present in the neutral expressions of each actor to accurately assess emotional expressions. We also used the cultural-background recognition module and specific cultural-background emotional recognition modules (e.g. General6_1, Asian etc.) for each actor based on the cultural-background recognition assessment (Noldus, 2018). We set the emotional recognition certainty criteria for inclusion at > .99 for each facial stimulus; no stimuli were excluded (Appendix 1.1). From the resulting dataset we chose for each emotion (anger, fear, happiness, sadness and neutral) faces that were rated high, medium and low in attractiveness based on the following criteria. Six (three male and three female) high, medium and low-attractiveness faces were selected for each emotion. For high-attractiveness faces, the faces with a mean value that was more than seven were pre-selected. For medium-attractiveness faces we pre-selected faces that were rated between four and six on the attractiveness scale.

For low-attractiveness faces we pre-selected faces that were not rated higher than three on the attractiveness scale. Due to rating restrictions and to avoid identity priming due to uneven target repetition (Lander, Bruce & Hill, 2001), in subsequent stages actors that met the required attractiveness criteria per emotion were selected three times each, resulting in a final sample of thirty actors and ninety emotional expressions.

Results and Discussion: To confirm that attractiveness was different between different appearance types we ran a repeated measures ANOVA with independent variables Appearance Type (high, medium and low attractiveness) and Type of Emotion (anger, fear, happiness, sadness, neutral) and dependent variable attractiveness ratings. Appearance Type was significant ($F (2, 28) = 1739.43$, $p < .01$, $\eta^2 = .99$) confirming that high-attractiveness faces (M. = 7.8, S.D. = .23) were rated higher ($t (14) = 30.01$, $p < .01$; $d = 9.24$) than medium-attractiveness faces (M. = 5.17, S.D. = .33) and higher ($t (14) = 74.08$, $p < .01$; $d = 26.55$) than low-attractiveness faces (M. = 2.54, S.D. = .16) in attractiveness ratings. Medium-attractiveness faces were also rated higher than low-attractiveness faces ($t (14) = 46.29$, $p < .01$; $d = 10.14$) in attractiveness ratings. The findings suggested that appearance types (high, medium and low) were significantly different in attractiveness ratings and that they were appropriate stimuli for their inclusion in the following experimental stages.

In accordance with previous literature in the area (Olson & Marshuetz, 2005; Hung et al., 2016) we did not find any differences for actor gender attractiveness ratings ($F (1, 13) = .11$; $p = .75$; $\eta^2 = .01$) or with participant gender as a between-subjects variable ($F (1, 13) = .37$; $p = .56$; $\eta^2 = .03$). These findings were confirmed by a separate t-test analysis based on actor ($t (14) = - .473$; $p = .64$; $d = .13$) and participant gender attractiveness ratings ($t (13) =$

.407; p = .69; d = .18). These findings suggested that male and female participants did not differ in their ratings for attractiveness (see also Appendix 2.1 and 3.1; Figure 1).

Figure 1: Attractiveness Ratings per Appearance Type and Expressed Emotion

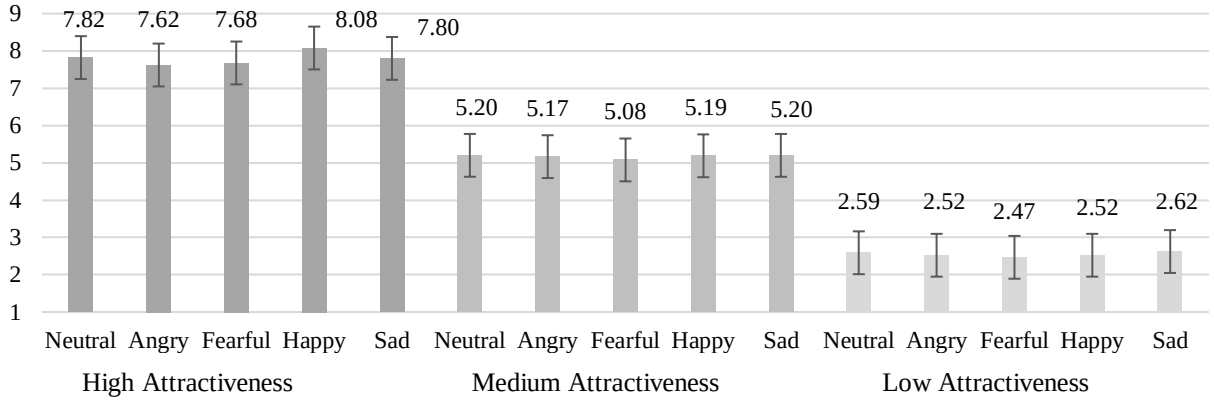


Figure 1: Mean attractiveness ratings (Y axis) per appearance type and expressed emotion (X Axis). Error bars indicate standard error of the mean (±2).

Stage Two: Emotionality Assessment

Aims. The aim of this stage was to assess the faces that were rated high, medium and low in attractiveness for emotionality differences to make sure that emotionality differences between appearance types would not bias signal detection performance in subsequent experimental stages.

Participants. A power calculation based on effect sizes (d = .86; f = .43) reported in previous research (Tsikandilakis et al., 2017) revealed that thirteen participants were required for $P_{(1-\beta)} \geq .8$. Fifteen participants (seven females) that were not part of stage one volunteered to participate in this stage. All participants reported normal or corrected-to-normal vision and gave informed consent to participate in the current study prior to the experiment. The participants were screened with the Somatic and Psychological Health Report Questionnaire and an online Alexithymia-Emotional Blindness questionnaire; no participants were

excluded. Data from two participants were excluded due to neutral ratings on the emotionality task (Olson & Marshuetz, 2005; Hung et al., 2016). The final population sample consisted of thirteen participants (eight females) with mean age 24.85 (S.D. = 3.95). This stage was approved by the Ethics Committee of the School of Psychology of the University of Nottingham.

Stimuli and Procedures. A total of ninety faces were shown during this stage from thirty actors. An equal number of female and male faces (n = 45) and actors (n = 15) were presented. Six faces (three male and three female) were shown per emotion (anger, fear, happiness, sadness and neutral) for each appearance type (high, medium and low attractiveness). The faces presented during this stage were the pre-selected stimuli from stage one. The ninety non-facial pattern blurs that were shown during stage one were also shown during this stage. The experimental trial started with a fixation cross for three seconds (± one second). After the fixation cross in random order a single face or non-facial pattern was presented at fixation for one second. After each target a black and white pattern mask was also presented for one second. A blank screen interval was then presented for two seconds. Participants were then asked by an on-screen message to rate how emotional the presented stimulus was from one (not emotional at all) to ten (very emotional) using the keyboard. A two-second blank screen interval was presented before the next trial.

Results and Discussion. A repeated measures analysis of variance tested the effects of Appearance Type (high, medium and low attractiveness) and Type of Emotion (angry, fearful, happy, sad and neutral) on emotional ratings. The analysis revealed that there were no significant differences in emotional ratings between high, medium and low-attractiveness

faces (F (2, 24) = 2.94, p = .12; η^2 = .16; see also Appendix 4.1). These findings suggested that high, medium and low-attractiveness faces were not overall different in emotional ratings and were appropriate stimuli for their inclusion in subsequent experimental stages.

An analysis of variance revealed that there were no differences for actor gender in emotionality ratings (F (1, 11) = .64; p = .44; η^2 = .06) or with participant gender as a between-subjects variable (F (1, 11) = .1; p = .75; η^2 = .01). This was confirmed by a separate t-test analysis based on actor (t (12) = - .77; p = .12; d = .05) and participant gender emotionality ratings (t (11) = 1.41; p = .19; d = .73). These findings suggested that male and female participants did not differ in their ratings for emotionality (see also Appendix 5.1; Figure 2).

Figure 2: Emotionality Ratings per Appearance Type and Expressed Emotion

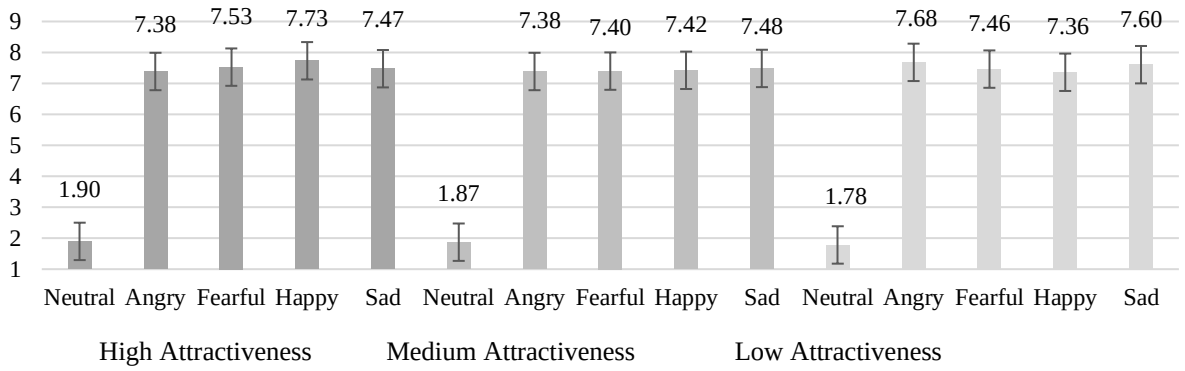


Figure 2: Mean emotionality ratings (Y axis) per appearance type and expressed emotion (X Axis). Error bars indicate standard error of the mean (±2).

Stage Three: Subjective Contrast Discrimination

Aims. Study two was designed to include a 116.67 ms black and white pattern mask and 33.33 ms non-facial blurs as a signal detection control condition for facial stimuli. For such a control condition to work it is important that low level changes in contrast cannot be used by

participants to detect the presence of faces. The aim of the current stage was to ensure that brief non-facial blurs did not have differences in visual contrast in respect to the black and white pattern mask when compared to the facial stimuli.

Participants: A power calculation based on effect sizes[3] (d = .05; f = .03) reported in previous research (Tsikandilakis et al., 2017) revealed that fourteen participants were required for $\beta < .2$ (Wesa, 2016; Soper, 2018). Fifteen participants (seven female) that were not part of experiment one or two volunteered to participate in this experimental stage. All participants reported normal or corrected-to-normal vision and provided informed consent prior to the study. The participants were screened with the Somatic and Psychological Health Report Questionnaire and an online Alexithymia-Emotional Blindness questionnaire; no participants were excluded based on this assessment. One participant was excluded due to non-compliance with the study procedures. The final population sample consisted of fourteen participants (seven female) with a mean age of 23.07 (S.D. = 2.70). Participants were briefed in writing concerning the experimental task and were asked to respond in the consent form whether they understood the instructions (yes or no). All participants responded positively. This stage was approved by the Ethics Committee of the School of Psychology of the University of Nottingham.

Stimuli and Procedures: Due to experimental time restrictions a subset of the selected faces including thirty faces and thirty non-facial blurs were presented during this stage. The presented faces were randomly chosen from the pre-selected stimuli in stages one and two. The selected set was assigned two faces per emotion (neutral, angry, fearful, happy and sad)

[3] See Schmider, Ziegler, Danay, Beyer and Bühner (2010)

for each appearance type (high, medium and low attractiveness). An equal number of male and female faces (n = 15) were presented to participants and no actor was repeated more than once at this stage. The experimental trial started with a fixation cross for three seconds (± one second). After the fixation cross in random order a single face or non-facial blur was presented for 33.33 ms followed by a black and white patterned mask for 116.67 ms. After the presentation of the black and white pattern mask, participants were shown a blank screen for two seconds and were then asked by an on-screen message to rate their subjective experience of visual contrast from one (not at all) to ten (intense). A two-second blank screen interval was presented before the next trial.

Results and Discussion. To test if the non-facial blurs had significantly different ratings for subjective experience of contrast compared to the presented faces in respect to the pattern mask a paired samples t-test was ran. Subjective experience of contrast for the non-facial blurs (M. = 4.95, S.D. = .49) was not rated higher than contrast in the face condition (M. = 4.96, S.D. = .21; t (13) = -.119, p = .907; d = .03; see also Appendix 6.1). These findings suggested that differences of visual contrast between the non-facial blurs and the presented faces, and the pattern mask would not artefactually impact signal detection and discrimination performance (Bachmann & Francis, 2013) in subsequent experimental stages.

Study Two

Aims. The primary aims of this study were twofold. Firstly, we wanted to test whether high-attractiveness faces would be detected and discriminated more accurately than other appearance types under conditions of backward masking. Secondly, we wanted to test whether the appraisal of attractiveness in high-attractiveness faces requires conscious

awareness. Finally an exploratory aim of the current study was to test if high, medium and low-attractiveness faces interact with different types of emotional expressions (fearful, angry, happy, sad and neutral) to influence face-detection and emotion-discrimination performance as well attractiveness ratings under conditions of backward masking.

Participants. A power calculation based on medium effect sizes ($\eta^2 = .06$; $f = .25$) revealed that twenty-three participants would be required for $P_{(1-\beta)} \geq .8$. Twenty-six participants (thirteen females) that were not part of Study One volunteered to participate in this experiment. All participants reported normal or corrected-to-normal vision and gave informed consent to participate in the current study prior to the experiment. The participants were screened with the Somatic and Psychological Health Report Questionnaire (Hickie et al., 2001) and an online Alexithymia-Emotional Blindness questionnaire (Alexithymia, 2017); data from one participant were excluded due to possible Alexithymia traits (> 94). Data from two additional participants were also excluded due to neutral ratings on the pre-experimental emotionality task and attractiveness tasks (Olson & Marshuetz, 2005; Hung et al., 2016; van der Ploeg et al., 2017). The final population sample consisted of twenty-three participants (thirteen females) with mean age 32.13 (S.D. = 7.47). This experiment was approved by the Ethics Committee of the School of Psychology of the University of Nottingham.

Stimuli and Procedures. The experiment involved two phases. In phase one participants were presented with twenty faces and twenty non-facial pattern blurs that were not part of the pre-selected stimuli. These stimuli were chosen based on discrimination, emotionality, intensity, expression-ambiguity ratings, and physiological responses (skin conductance and heart rate)

in a previous study (Tsikandilakis et al., 2017). These facial stimuli included four neutral, angry, happy, sad and fearful stimuli from different actors with an equal number (n = 10) of males and females. The experimental trial started with a fixation cross for three seconds (± one second). After the fixation cross in random order a single face or non-facial pattern was presented at fixation for one second. After each target a black and white pattern mask was also presented for one second. A blank screen interval was then presented for two seconds. After that participants were asked by an on-screen message to rate how emotional the presented stimulus was from one (not emotional at all) to ten (very emotional) using the keyboard. The participants were also asked by an on-screen message to rate how attractive the presented stimulus was from one (not attractive at all) to ten (very attractive) using the keyboard. The participants were also asked to decide from an on-screen list what kind of stimulus was presented during the trial using the keyboard. The list included (a) angry, (f) fearful, (h) happy, (s) sad, (n) neutral, (o) other and (i) non-facial. The order of the engagement tasks was randomised in each trial. A blank screen for two seconds was presented before each next trial. Phase one was conducted to ensure that participants were familiar with the tasks and stimuli under conditions in which the target stimuli were clearly visible for all participants. In phase two we used the same procedure with brief backwardly masked stimuli presented at durations where they would not necessarily be available to conscious awareness (Dehaene et al., 2006).

After phase one participants were allowed a five-minute break. After the break the participants were presented with the ninety pre-selected faces and ninety non-facial pattern blurs. The experimental trial started with a fixation cross for three seconds (± one second).

After the fixation cross in random order a single face or non-facial pattern was presented at fixation for 33.33 ms. After each target a black and white pattern mask was also presented for 116.67 ms. A blank screen interval was then presented for two seconds. After that participants were asked to reply to a set of engagement tasks with order randomised. They were asked by an on-screen message to press E if they saw a facial stimuli or W if the presented target was non-facial; the assignment of the keyboard responses was randomly counterbalanced in each trial. After this initial task we used conditional branching to present the participants with additional engagement tasks. If the participant responded having seen a facial stimulus, an on-screen message asked participants to decide from a list what kind of emotion the facial stimulus was expressing using the keyboard. The list included (a) angry, (f) fearful, (h) happy, (s) sad, (n) neutral and (o) other. If the participants replied not having seen facial stimulus, an on-screen message asked them to decide what kind of emotion best described their experience during the presentation using the keyboard. The list included (a) anger, (f) fear, (h) happiness, (s) sadness, (n) neutral and (o) other. Participants were also asked by an on-screen message to rate how attractive the presentation was from one (not attractive at all) to ten (very attractive) using the keyboard (Figure 3). A blank screen for two seconds was presented before the next trial.

Apparatus and Presentation Testing. All experiments were generated using the coder and builder components of Psychopy version 1.90d (Peirce, 2007). All stimuli for all experimental stages were presented on a standard 60 Hz Toshiba monitor in the same quiet laboratory space. To ensure that particularly brief stimuli (33.33 and 116.67 ms) were correctly presented, an IPAD PRO camera with 120 Hz refresh rate (8.33 ms) recorded two

pilot runs for Study One (Stage Three) and Study Two. The stimuli presentation was assessed frame by frame; no instances of dropped frames were detected. Subsequently, a self-developed dropped frame report script with one frame (16.67 ms) tolerance threshold was coded in Python and two pilot experimental diagnostic sessions were run. The presenting monitor reported no dropped frames; prognostic dropped frame rate was estimated at 1/5000 trials. Experimental stages were, subsequently, run using dropped frames diagnostics; no instances of dropped frames were reported.

Figure 3: Example Stimuli Sequence with High-Attractiveness Happy Masked Face

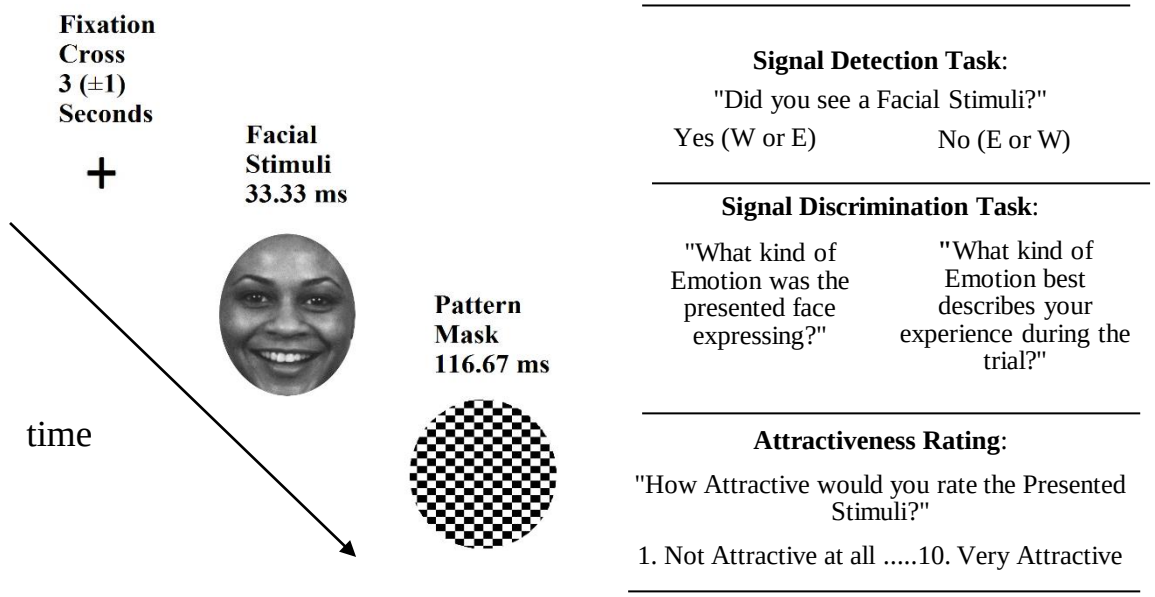


Figure 3: During the main experimental stage participants were presented with thirty high-attractiveness, thirty medium-attractiveness and thirty low-attractiveness emotional faces (angry, fearful, happy, sad and neutral) and ninety pattern blurs for 33.33 ms. Subsequently, they were asked to make face-detection and emotion-discrimination, and attractiveness-rating responses.

Results and Discussion: Does Attractiveness influence Face Detection under conditions of Backward of Masking? To test whether high-attractiveness faces are detected and discriminated more accurately than other appearance types, the participants' face detection responses were transformed to non-parametric sensitivity index A (Zhang & Mueller, 2005).

An analysis of variance with independent variables Appearance Type (high, medium and low attractiveness) and Type of Emotion (angry, fearful, happy, sad, neutral) and dependent variable face-detection performance (A) was ran. The analysis revealed a significant effect of Appearance Type ($F (2, 44) = 9.49$, $p < .01$; $\eta^2 = .3$) and a significant effect of Type of Emotion ($F (2.81, 61.79) = 5.27$, $p < .01$; $\eta^2 = .19$; Greenhouse-Geisser corrected). Further Bonferonni corrected pairwise comparisons revealed that high-attractiveness faces (M. (A) = .797, S.D. (A) = .088; M. (H.R.[4]) = 74.07 % S.D. (H.R.) = 14.64 %) were detected more accurately than medium-attractiveness faces (M. (A) = .768, S.D. (A) = .093; M. (H.R.) = 69.72 % S.D. (H.R.) = 20.77 %; $p < .01$; $d = .32$.). We did not observe any gender effects ($F (2, 42) = .71$, $p = .49$; $\eta^2 = .03$).

Emotion discrimination was also calculated using non-parametric sensitivity index A (Zhang & Mueller, 2005). An analysis of variance was run to assess the effects of Appearance Type and Type of Emotion with dependent variable emotion-discrimination performance (A). The analysis revealed a significant effect of Appearance Type ($F (2, 44) = 4.97$, $p = .01$; $\eta^2 = .18$), a significant effect of Type of Emotion ($F (40.6, 2.57) = 12.58$, $p < .01$; $\eta^2 = .36$), and a significant interaction ($F (8, 176) = 10.81$, $p < .01$; $\eta^2 = .32$). Further Bonferonni corrected pairwise comparisons revealed that high-attractiveness faces (M. (A) = .756, S.D. (A) = .082; M. (H.R.) = 66.82 % S.D. (H.R.) = 20.37 %) were discriminated better than low-attractiveness faces (M. (A) = .734, S.D. (A) = .087; M. (H.R.) = 63.78 % S.D. (H.R.) = 20.51 %; $p < .01$; $d = .26$). We did not observe any gender effects ($F (2, 42) = 1.65$, $p = .2$; $\eta^2 = .07$). These results suggested that attractiveness influenced face detection and

[4] H.R.: Hit Rates

emotion discrimination under conditions of backward masking and more specifically that high-attractiveness faces were detected more accurately than medium-attractiveness faces and discriminated more acutely than low attractiveness-faces.

Exploratory Analysis. The exploratory analysis in the current stage tested whether appearance type and emotion interact under conditions of backward masking to influence face-detection and emotion-discrimination performance. The analysis revealed a significant interaction between Appearance Type and Emotion ($F (8, 176) = 10.81$, $p < .01$; $\eta^2 = .32$). Further Bonferonni corrected pairwise comparisons revealed that fearful ($p < .01$; $d = .36$) and sad ($p < .01$; $d = 42$) high-attractiveness faces were detected more accurately than other appearance type to emotion combinations, and that fearful ($p < .01$; $d = 36$) and angry ($p < .001$; $d = .65$) high-attractiveness faces, and also neutral low-attractiveness faces ($p < .001$; $d = .99$) were discriminated more accurately than other appearance type to emotion combinations. These results suggested that a significant interaction between attractiveness and emotion influenced face detection and emotion discrimination for the presented faces (Table 1).

Table 1: Detection and Discrimination Performance per Appearance Type and Emotion

Appearance Type	Emotion	Mean Detection (A)	S.D. Detection (A)	Mean Discrim. (A)	S.D. Discrim. (A)	Detection Standard. Cohen's d	Discrim. Standard. Cohen's d
High-Attractiveness	Fearful	.818	.132	.782	.101	.357*	.355*
	Angry	.798	.094	.815	.102	.161	.654**
	Happy	.752	.127	.687	.102	-.281	-.535**
	Sad	.825	.094	.747	.115	.416*	.026
	Neutral	.79	.08	.75	.09	.085	.05
Medium-Attractiveness	Fearful	.756	.112	.725	.11	-.242	-.184
	Angry	.788	.095	.76	.102	.067	.14
	Happy	.751	.113	.701	.098	-.287	-.409**
	Sad	.777	.139	.771	.11	-.044	.245
	Neutral	.766	.093	.716	.099	-.151	-.266
Low-Attractiveness	Fearful	.77	.098	.717	.128	-.108	-.256
	Angry	.809	.094	.734	.125	.267	-.099
	Happy	.742	.102	.683	.102	-.378*	-.576**
	Sad	.809	.1	.729	.139	.262	-.143
	Neutral	.768	.090	.851	.086	-.125	.996**

Table 1: Mean and S.D. (Standard Deviation) Detection and Discrimination Performance (A) per Appearance Type and Type of Emotion. In the two end-right columns the standardised effect size (Cohen's d) per stimuli type in units of standard deviations from the overall mean for detection (M. = .781, S.D. = .104) and discrimination performance (M. = .745, S.D. = .107). Asterisk (*) indicates significance at < .01 level. Double asterisk (**) indicates significance at < .001 level (see also Appendix 7.1),

Results and Discussion: Does the appraisal of Attractiveness require conscious awareness?

To test if high-attractiveness faces can be processed without conscious awareness, a Bayesian analysis (Dienes, 2015) with corrected degrees of freedom (df < 30; SE = (SE x ($\left(1+\frac{20}{dfxdf}\right)$)) (Berry, 1996) and higher and lower bounds set at .6 and .4 with .5 indicating absolute chance-level performance was run. The analysis revealed that face detection (A) for high-attractiveness (M. = .796, S.E. = .019; B > 3), medium-attractiveness (M. = .768, S.E. =

.017; B > 3) and low-attractiveness (M = .779, S.E. = .02; B > 3) faces, and emotion-discrimination performance for high-attractiveness (M = .756, S.E. = .018; B > 3), medium-attractiveness (M = .743, S.E. = .021; B > 3) and low-attractiveness (M =. 734, S.E. = .019; B > 3) faces were above chance-level (Dienes, 2015) that would indicate stimuli invisibility (Erdelyi, 2004). An analysis of overall attractiveness ratings was not appropriate for the exploration of whether the appraisal of attractiveness requires conscious awareness (Figure 5a and 5b).

To further explore whether attractiveness could influence ratings without conscious awareness, we ran an analysis of hits and misses per appearance type for face-detection and emotion-discrimination performance (Pessoa, 2005). For face-detection performance a factorial ANOVA with independent variables Appearance Type (high, medium and low attractiveness), Emotional Type (fearful, angry, happy, sad and neutral) and Detection Response (hits, misses) and dependent variable attractiveness ratings was performed. The analysis revealed a significant effect of Appearance Type ($F(2, 22) = 122.14$, $p < .01$; $\eta^2 = .92$), a significant effect of Emotion ($F(4, 44) = 3.37$, $p = .02$; $\eta^2 = .23$) and a significant effect of Detection Response ($F(1, 11) = 51.47$, $p < .01$; $\eta^2 = .63$). Critically, an Appearance Type by Detection Response interaction was reported ($F(2, 22) = 167.08$, $p < .01$; $\eta^2 = .94$), suggesting that there were attractiveness-rating differences between hits and misses for different appearance types.

To further explore these findings Bonferonni corrected pairwise comparisons were run. The comparisons revealed that for face detection high-attractiveness facial-hits (M. = 7.21, S.D. = .42) were rated higher than medium-attractiveness facial-hits (M. = 4.79, S.D. =

.24; t (22) = 30.55, p < .01; d = 7.07) and low-attractiveness facial-hits (M. = 3.78, S.D. = .54; t (22) = 22.29, p < .01; d = 7.09). No significant differences in attractiveness ratings were reported for misses for face detection (F (1.08, 20.5) = 1.10, p = .38; η^2 = .06; Greenhouse-Geisser corrected). For detection-misses, high-attractiveness faces were not significantly different than medium-attractiveness (p = 1; d = .22) and low-attractiveness faces (p = .96; d = .19) and medium-attractiveness faces were not significantly different than low-attractiveness faces (p = .85; d = .1).

A similar pattern was reported for emotion-discrimination responses. An analysis of variance was run with independent variables Appearance Type (high, medium and low attractiveness), Emotion (fearful, angry, happy, sad and neutral) and Discrimination Response (hits, misses) with attractiveness ratings as the dependent variable. The analysis revealed a significant effect of Appearance Type (F (2, 14) = 74.01, p < .01; η^2 = .91), a significant effect of Emotion (F (4, 28) = 2.98, p = .04; η^2 = .29) and a significant effect of Discrimination Response (F (1, 7) = 132.55, p < .01; η^2 = .95). Critically, a significant Appearance Type by Discrimination Response interaction was revealed (F (2, 14) = 39.78, p < .01; η^2 = .85).

To further explore these findings Bonferonni corrected pairwise comparisons were run. For emotion-discrimination performance, high-attractiveness facial-hits were rated higher (M. = 7.44, S.D. = .45) than medium-attractiveness facial-hits (M. = 4.83, S.D. = .25; t (22) = 26.46, p < .01; d = 7.17) and low-attractiveness facial-hits (M. = 3.58, S.D. = .53; t (22) = 23.12, p < .01; d = 7.85). Medium-attractiveness facial-hits were also rated higher for attractiveness ratings than low-attractiveness facial-hits (p < .01; d = 3.02). For emotion

discrimination, high-attractiveness facial-misses (M. = 6.23, S.D. = .68) reported significantly higher attractiveness ratings compared to medium-attractiveness facial-misses (M. = 4.23, S.D. = 1.14; t (15) = 4.91, p < .01; d = 2.13) and low-attractiveness facial-misses (M. = 4.59, S.D. = .49; t (11) = 9.44, p < .01; d = 2.77).

These results suggested that the appraisal of attractiveness could not be performed in the absence of conscious awareness (face-detection misses) and that correct face detection (hits) was a necessary condition for the appraisal of attractiveness (see Figure 4). Interestingly, although correct emotion discrimination (hits) enhanced the acuity of the appraisal for attractiveness, incorrect emotion discrimination (misses) reported significant differences between different appearance types, suggesting that emotion discrimination was not necessary for the appraisal of attractiveness from faces.

Figure 4: Attractiveness Ratings for Hits and Misses

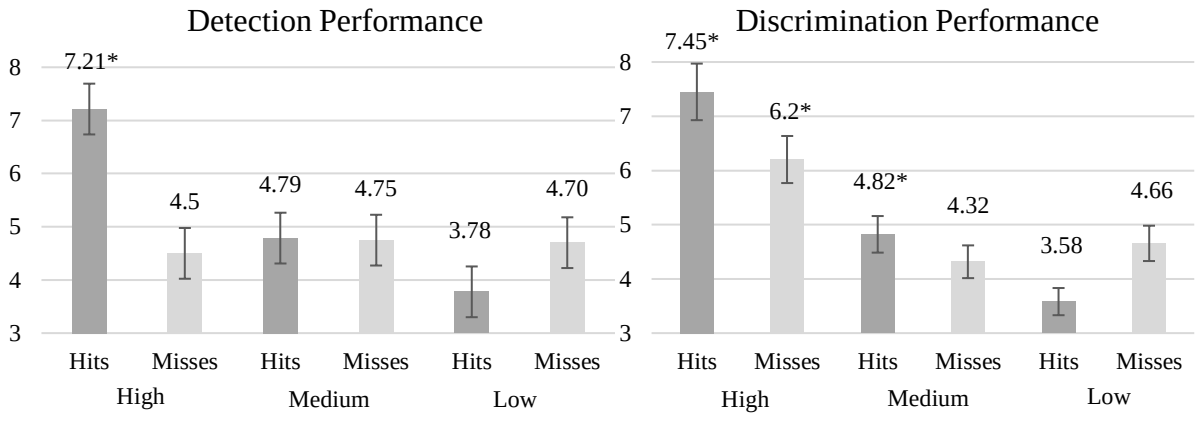


Figure 4: Mean Attractiveness ratings per Appearance Type (Y Axis) for Hits and Misses for face-detection and emotion-discrimination performance in Study Two. Error bars indicate standard error of the mean (±2). Asterisks (*) indicate significance at p < .01 level.

Exploratory Analysis. The exploratory analysis in the current stage tested whether appearance type and emotion interact under conditions of backward masking to influence attractiveness

ratings. The analysis revealed a trend for significance for an interaction between Appearance Type and Emotion ($F(4, 28) = 2.01$, $p = .06$; $\eta^2 = .22$); no pairwise comparisons survived the Bonferonni corrections (Figure 5). These findings suggested that the interaction between emotion and attractiveness was associated with minor differences in attractiveness ratings. Further hits and misses analysis for this interaction could not be performed because of insufficient face-detection and emotion-discrimination hits and misses responses for several appearance type and emotion combinations (e.g. high-attractiveness angry faces, low-attractiveness neutral faces) and because the available responses did not meet ($P_{(1-\beta)} = .34$) the minimum statistical power requirement criteria ($P_{(1-\beta)} \geq .8$).

Figure 5: Attractiveness and Emotion under Conditions of Backward masking

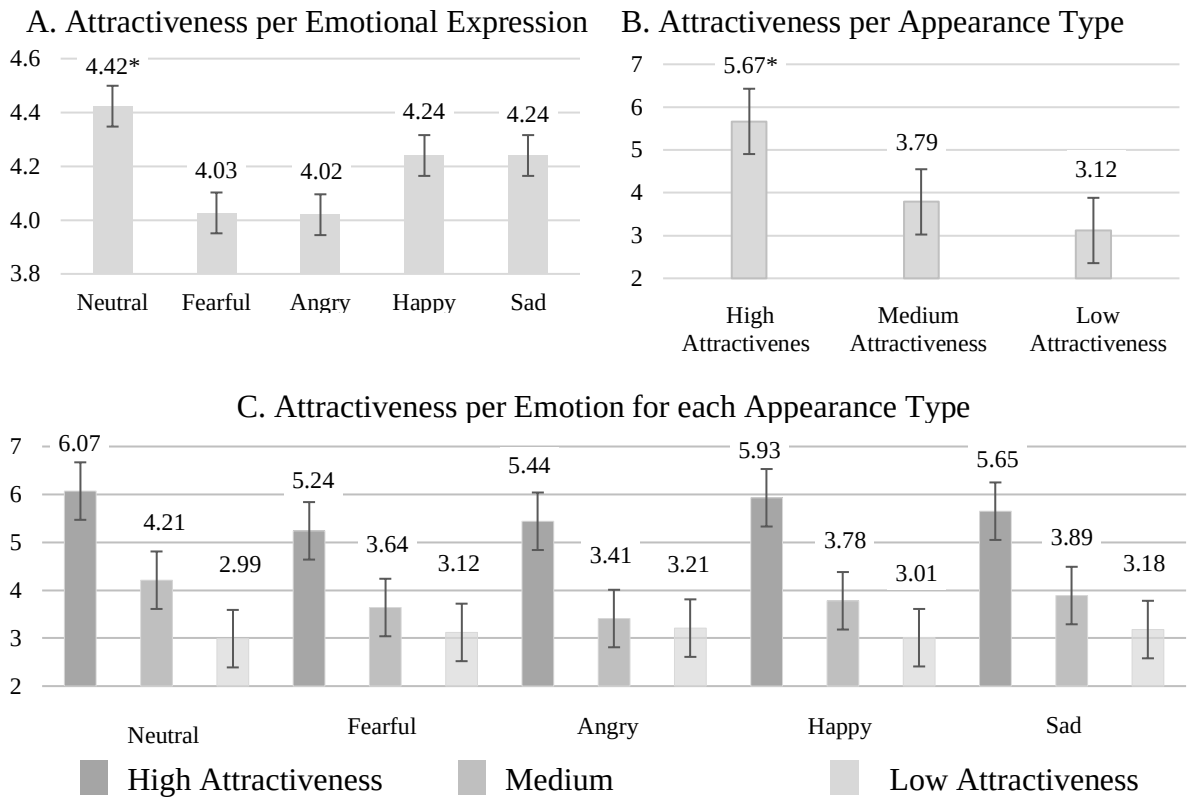


Figure 5: Attractiveness ratings for each Appearance type (high, medium and low attractiveness) for each Emotion (neutral, fearful, angry, happy and sad). A significance trend ($p = .06$) for an Appearance to Emotion Interaction was reported although no pairwise comparisons survived the Bonferonni corrections. Asterisks (*) indicate significance at $p < .01$ level.

Summary of Findings

The primary aims of the current manuscript was to explore whether attractiveness influences face-detection and emotion-discrimination performance and whether self-reports for the appraisal of facial attractiveness require conscious awareness. We implemented several methodological developments to explore these hypotheses such as extensive pilot experimental stimuli controls, signal detection analysis using sensitivity index A, Bayesian assessment for chance-level significance that would indicate stimuli invisibility, and analysis of hits and misses in face-detection and emotion-discrimination performance for

attractiveness-rating responses. We found that attractiveness influences face-detection and emotion-discrimination performance, and more specifically that high-attractiveness faces can be detected and discriminated more accurately than other appearance types. Our analysis also revealed that specific appearance type and emotion combinations such as high-attractiveness fearful, angry and sad faces, and low-attractiveness neutral faces were detected and discriminated more accurately than other appearance type to emotion combinations. Critically, we found that face detection (hits) was a necessary condition for the appraisal of attractiveness for high-attractiveness faces and that when participants had absence of conscious awareness of the presented face (face-detection misses) they did not rate high-attractiveness faces higher than other appearance types. Interestingly, although correct emotion discrimination (hits) enhanced the acuity of the appraisal for high-attractiveness faces, incorrect emotion discrimination (misses) also reported higher ratings for high-attractiveness faces compared to other appearance types, suggesting that emotion discrimination is not necessary for the appraisal of attractiveness from faces. Finally, our exploratory analysis revealed that the interaction of emotion and appearance type impacts face-detection and emotion-discrimination performance but has only a minor effect in ratings for attractiveness.

General Discussion

Previous research has reported that attractiveness can be appraised from minimal information, such as pixelated images (Bachmann, 2007) and brief presentations (Olson & Marshuetz, 2005), and processed despite interocular suppression (Hung et al., 2016). For example, Olson and Marshuetz (2005) reported that high-attractiveness faces presented for as

little as 13 ms, preceded by a high-frequency contour scrambled face mask for 39 ms and followed by a carton mask for 39 ms, were associated with higher attractiveness ratings than low-attractiveness faces presented under the same conditions. They also reported that 13 ms high-attractiveness faces elicited shorter reaction times for the appraisal of subsequently presented positively valanced words than low-attractiveness faces (Olson & Marshuetz, 2005; p. 500). Similarly, Hung, Nieh and Hsieh (2016) ran a series of experiments using interocular suppression (Sengpiel & Blakemore, 1995). They used staircase reduction of contrast visibility when bilaterally presenting high-attractiveness and low-attractiveness faces followed by Gabor patches. They reported a reduction in Gabor lines orientation discrimination performance for lateral high-attractiveness faces due to perceptual inhibition of return, suggesting that high-attractiveness faces were attended despite the staircase reduction in visual contrast (Klein, 2000). These findings have been used to propose that attractiveness can be appraised from minimal information and have also been used to suggest that attractiveness can be processed and reported in the absence of conscious awareness (see also Kleckner et al., 2018) .

The current findings refer to whether attractiveness can be appraised (Olson & Marshuetz, 2005) without conscious awareness. Our findings support previous research (Olson & Marshuetz, 2005; Bachmann, 2007; Hung et al., 2016) in that – like other evolutionary important stimuli (Mineka & Öhman, 2002; Öhman, 2009) that confer "sociobiological value" (Bachmann, 2007; p. 848) – high-attractiveness faces convey highly-salient cues (Fink & Penton-Voak, 2002) that render them more accurately detectable during brief presentations (Calvo & Lundqvist, 2008; Lähteenmäki, Hyönä, Koivisto &

Nummenmaa, 2015). The current findings also add to the existing literature by suggesting that high-attractiveness faces are discriminated more accurately (Adolphs, 2008) and that correct discrimination of the expressed emotion enhances the acuity but is not a necessary condition for the appraisal of the attractiveness from faces (Sergent & Dehaene, 2004).

Despite this partial consensus with previous research, the current manuscript employed different methodological assessment and statistical applications (Tsikandilakis et al., 2017; Tsikandilakis & Chapman, 2018) compared to previous publications. These included the application of signal detection theory (Zhang & Mueller, 2005), Bayesian analysis of chance-level significance (Dienes, 2015) that would indicate stimuli invisibility (Erdelyi, 2004), and separate analysis for hits and misses for attractiveness ratings (Pessoa, 2005). Based on the current methods, our results also partly disagree with previous findings and we propose that the appraisal of attractiveness does require conscious target-detection meta-awareness of facial characteristics (Tsikandilakis et al., 2017). This finding does not *per se* oppose previous findings that have suggested that attractiveness can be processed in the absence of awareness (Hung et al., 2016) because ratings for attractiveness were explicitly measured in the current study. Instead, the key finding of the current report is that the appraisal of attractiveness cannot be reported in the absence of awareness and that correct detection (hits) of a masked face was a required condition for the appraisal of attractiveness. Therefore, we suggest that to make conscious judgements (see also Lau, 2008) in relation to the attractiveness of a presented face, conscious detection of that face is a necessary condition.

Finally, in respect to our exploratory analysis we reported that high-attractiveness angry, fearful and sad faces as well as low-attractiveness neutral faces were detected and discriminated more accurately than other appearance type to emotion combinations. We also reported a trend for an interaction between emotion and appearance type in relation to attractiveness ratings under conditions of backward masking. These findings are a novel contribution to the field and support that high-attractiveness angry and fearful faces confer a face-detection superiority effect (Lundqvist, Bruce & Öhman, 2015) compared to other stimuli, possibly due to their high-salience and sociobiological value (Brooks et al., 2012). The finding that emotion and appearance type revealed only a trend for an interaction in relation to attractiveness ratings means that we could not provide solid support for the idea that particularly positive emotional expressions influence attractiveness ratings when these are presented under conditions of backward masking (O'Doherty et al., 2002). This could relate to low power in the current experiment and/or relate to participants' inability to process and integrate multiple informational input when the signal strength is reduced under conditions of backward masking (Baars, 2002).

Limitations

To our knowledge the current study is the first attempt to explore the appraisal of attractiveness using backward masking and angry, fearful, sad and happy faces in addition to neutral faces that have been employed in previous research (Olson & Marshuetz, 2005; Hung et al., 2016). Despite previous research suggesting a happy face detection superiority effect during low level visual processing (Miyazawa & Iwasaki, 2010) and higher attractiveness ratings for happy faces during supraliminal presentations (O'Doherty et al., 2003), we were

not able to find higher face-detection or emotion-discrimination responses for happy faces for any appearance type. Additionally, emotional expression and appearance type provided only an overall trend for an interaction with attractiveness ratings as the dependent variable. Future research could benefit from a dedicated and appropriately powered exploration of the interaction between emotional expressions and appearance types (Penton-Voak & Chang, 2008) under conditions of backward masking, and particularly the exploration of the possibility that different emotional type (fearful, angry, happy, sad and neutral) to appearance type (high, medium and low attractiveness) combinations could result in differentiating patterns of attractiveness reports (Rhodes, 2006). In the same context, it is possible, although outside the scope of the current manuscript, that low-attractiveness faces could also report face-detection and emotion-discrimination differences compared to other appearance types, such as mid-attractiveness faces, because they confer health and fitness related perceptual cues with avoidance response value (Pazda, Thorstenson, Elliot, & Perrett, 2016; Jaeger, Wagemans, Evans, & van Beest, 2018). This possibility is also supported by the data in the current manuscript (see Table 1), and future research could benefit from a dedicated exploration of face-detection and emotion-discrimination performance of low-attractiveness faces under conditions of backward masking.

Conclusions

The current study assessed whether attractiveness has an impact on face detection and emotion discrimination using backward masking, and whether attractiveness ratings require conscious awareness. Our results revealed that high-attractiveness faces were detected and discriminated more accurately than other appearance types but also that detection of a face

was a necessary condition for the appraisal of attractiveness. This is a novel contribution to the field and suggests that appraisal of attractiveness requires conscious awareness of a presented face.

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Responses to Cross-Cultural *Dialects* of Emotion with and without Conscious Awareness

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The published version of this study can be found in the Appendix.

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Abstract

The *dialects* theory of cross-cultural communication suggests that due to culture-specific characteristics in the expression of emotion we can recognise own-culture emotional expressions more accurately than other-culture emotional expressions. This effect is suggested to occur due to the non-convergent social evolution that takes place in different geographical regions. Based on the evolutionary value of own-culture social signals, previous research has suggested that own-culture emotional expressions can be appraised without conscious awareness. The current study tested this hypothesis. We developed, validated and made open access the first to our knowledge labelled, multi-cultural facial stimuli set, including freely-expressed and Facial Action Coding System (FACS) instructed emotional expressions. We assessed emotional recognition and cultural familiarity responses during brief backward-masked presentations in British participants. We found that emotional recognition and cultural familiarity were higher for own-culture faces. A Bayesian analysis of face-detection and emotional-recognition performance revealed that faces were not processed at chance. Further analysis of awareness, using hits (correct detection/recognition) and misses (incorrect detection/recognition), showed that face-detection hits were a necessary condition for reporting higher familiarity for own-culture faces. These findings suggest that the own-culture emotional recognition advantage is preserved under conditions of backward masking and that the appraisal of cultural familiarity involves conscious awareness.

Introduction

In the past fifteen years, we have been provided with an unprecedented access to cross-cultural communication. Not only are we now, more than ever, part of multi-cultural societies, but we can have face-to-face personal and professional contact with individuals from other nations without leaving the comfort of our living room or office. These contemporary privileges have yielded an increase in cross-cultural professional collaborations and have even influenced peer and romantic partner selection (Bochner, 2013). In our contemporary world, cross-cultural emotional recognition is vital and necessary on a social (Castells, 2004) and a professional level (Walker, Walker, Schmitz & Brake, 2003). But do we recognise emotion equally well in individuals from our own culture compared to other cultures, and do we recognise emotion equally well across other cultures indiscriminately?

Psychologists have spent considerable resources in the past decades exploring these questions. Cultural agreement in the expression of emotion was first addressed in the popularised studies conducted by Ekman and Friesen (1971) in indigenous tribal populations. These seminal, for social and cultural psychology, findings suggested that basic facial emotions such as fear, anger, surprise, happiness, sadness and disgust are universally recognised (Ekman, 2004). In more recent years, this concept has been expanded (Elfenbein & Ambady, 2003). Recent psychological research (Elfenbein, 2015) has adopted a linguistic metaphor (Tomkins & McCarter, 1964) for interpreting cross-cultural emotional communication. According to this approach, although basic emotional expressions are considered a universal language, there are culture-specific *dialects* that influence the expression and recognition of emotion (Elfenbein, Beaupré, Lévesque & Hess, 2007). These

dialects include display and de-coding rules. Display and de-coding rules refer to the particular way that a cultural group is allowed or encouraged or prohibited from expressing and interpreting emotion respectively (Matsumoto, Frank & Hwang, 2013).

Based on these concepts (Russell, Bachorowski & Fernández-Dols, 2003), researchers working in this field have suggested that there are discreet cross-cultural differences in the expression and recognition of emotion (Elfenbein, 2013). For example, Western individuals are more likely to express high-intensity emotional facial expressions (Marsh, Elfenbein & Ambady, 2003) and less likely to recognise low-intensity emotions, possibly because these lack in-group pro-social motivational value (Grant & Berg, 2012). On the other hand, Eastern individuals are more likely to express context-specific positive emotional expressions (Masuda, Gonzalez, Kwan & Nisbett, 2008) and less likely to express or acknowledge negative affect, possibly because it could signify an abrupt termination of the social transaction (Matsumoto, Frank & Hwang, 2013). These cultural *accents* are suggested to confer an in-group emotional recognition advantage for own-culture faces (Elfenbein & Ambady, 2003) and an out-group emotional recognition disadvantage for cultures that are distinctly different to our own (cross-cultural bias, see Elfenbein, 2017).

The interpretation of these findings includes that freely-expressed emotion is a possible cultural *mediator* and instructed emotion is a possible cultural *moderator* (Elfenbein & Ambady, 2003). In this context, freely-expressed emotion is suggested to act as a mediator because it allows culture-specific expressions that can be more accurately recognised by own-culture members due to their in-group pro-social motivational value. Instructed emotion, on the other hand, is suggested to act as a cultural moderator because it forces cross-cultural, and

possibly westernised, homogeneity in the expression of emotion and removes the in-group emotional recognition advantage (for a full and comprehensive review concerning the use of this particular terminology, see Elfenbein & Ambady, 2002a, 2002b; 2003). The suggestion that particularly freely-expressed culture-specific emotion induces a higher in-group emotional recognition accuracy (Haxby et al., 2002) has resulted in the hypothesis that own-culture emotional expressions have shared region-specific evolutionary and sociobiological value (Galscher, 2002), and that they can be appraised without conscious awareness (Chiao et al., 2008; Smith, Dijksterhuis & Chaiken, 2008).

In this context, Chiao and colleagues (2008) showed that both Japanese and Caucasian participants automatically responded with higher bilateral, and more pronounced right-lateral, BOLD activation in the amygdala, when presented with one-second own-culture instructed fearful faces compared to instructed fearful faces from other-cultures. Previous research (Eberhardt, Goff, Purdie & Davies, 2004; Smith, Dijksterhuis & Chaiken, 2008) also reported that different-culture and different-race neutral faces presented either for very brief durations (e.g. 33.33 ms) or suppressed by separately presenting colour patterns to the dominant or nondominant eye (Tong, Meng & Blake, 2008; Schlossmacher, Junghöfer, Straube & Bruchmann, 2017) decrease emotional recognition accuracy for subsequently presented supraliminal faces showing instructed own-culture emotion (Nosiek, Hawkings & Frasier, 2011)

Contrariwise, Pessoa and colleagues (2005) showed that bilateral BOLD activation in the amygdala during brief presentations (33.33 and 66.67 ms) occurs only when the participants correctly detected mixed-culture instructed fearful faces (hits), and not when

participants incorrectly did not detect mixed-culture instructed fearful faces (misses) in a post-trial signal detection assessment task. In a similar context, Amihai and colleagues (2011) used continuous-flash-suppression (Tsuchiya & Koch, 2004, 2005) and showed that exposure to racially ambiguous artificial faces (adaptors) biased recognition accuracy for subsequent supraliminal racially-unambiguous artificial faces in the opposite category of the adaptor only when the adaptors were not successfully suppressed; such as when participants responded with hits (correct detection) for seeing an artificial adaptor, but not when participants responded with misses (incorrect non-detection) for not seeing an artificial adaptor in a post-trial signal detection assessment task (Pessoa, 2005; Jiang & He, 2006; Gaillard et al., 2009; Pessoa & Adolphs, 2010; 2011).

The current study follows from these findings. Our first objective was to test if the own-group emotional recognition advantage – and/or the other-culture emotional recognition bias – can be preserved during visual suppression such as backward-masked presentations of faces for the durations for which they were presented in previous studies (e.g. 33.33 ms). We tested if these effects could occur in response to both freely-expressed and instructed, own and other-culture emotional expressions. Our second objective was to test whether cultural familiarity can be appraised without conscious awareness, such as for misses for face-detection and emotional-recognition responses in a post-trial signal detection assessment task, or whether the appraisal of cultural familiarity requires conscious awareness of the presented faces; such as hits for face-detection and emotional-recognition responses in a post-trial signal detection assessment task (Pessoa, 2005).

An important motivation for the current research was to provide ecological validity in the exploration of awareness and cross-cultural emotional communication. Hence, we included freely-expressed and instructed faces in our experimental design (Elfenbein & Ambady, 2002a; 2002b; 2003). Due to the lack of a labelled multi-cultural facial dataset in the area, we developed the first to our knowledge cross-cultural facial stimuli dataset that included freely-expressed and Facial Action Coding System (FACS) instructed facial expressions from different continental geographical regions based on U21 institutional availability (Britain, New Zealand, Chile and Singapore). We tested the dataset using cultural and emotional questionnaires, participant assessment and automatic emotional recognition software, to validate whether differences between cultures were due to cultural differences in the expression of emotion, and not random population sampling differences. The purpose of this assessment was to test whether the expressed emotional *dialects* conferred cross-cultural communication differences as opposed to differences due to sampling variables, such as occupational and life-style choices, that are not necessarily and uncontestedly related to emotional culturation (see Russell et al., 2003; p. 331-337).

We used this dataset to present British participants with backward-masked own-culture and other-culture FACS instructed and freely-expressed emotional faces, and assessed responses for face detection, emotional recognition and cultural familiarity. To implement a balanced design for the exploration of cross-cultural emotional differences, we treated each culture as a separate emotional elicitor and presented an equal number of repetitions per type of emotion and expression for each country of origin (see Elfenbein & Ambady, 2002b; p. 223-227). To accurately assess participant responses during the masking condition, we used

the method we developed for the assessment for conscious awareness described in detail in our previous research (Tsikandilakis, Chapman & Peirce., 2018; Tsikandilakis & Chapman, 2018; Tsikandilakis, Bali & Chapman, 2018). This method included unbiased non-parametric signal detection theory criteria to measure face-detection and emotional-recognition performance (Stansislaw & Todorov, 1999; Zhang & Mueller, 2005), Bayesian analysis for the assessment of chance-level signal detection performance (Dienes, 2015), that would indicate unawareness for the presentation of facial targets and/or their expressed emotional type (Erdelyi, 2004), and hits (correct detection/recognition) and misses (incorrect detection/recognition) analysis (Fawcett, 2006) for the assessment of cultural familiarity responses (Pessoa, 2005).

Using these criteria we tested whether the own-culture emotional-recognition advantage can be preserved under conditions of backward masking for freely-expressed and FACS instructed cross-cultural emotional expressions, and whether cultural familiarity can be appraised during backward masking with and without conscious awareness; such as for hits and misses for face-detection and emotional-recognition responses.

Study One

Stage One: Stimuli Development

Aims. The first objective of the current stage was to develop a multi-cultural facial dataset that would include non-professional actors from Britain, New Zealand, Chile and Singapore. The second objective of the current stage was to assess the actors that were part of the dataset using cultural and emotional questionnaires to explore if emotional differences between cultures were due to cultural – and not random population sampling – differences (Russell et al., 2003).

Participants. A total of one hundred and four non-professional actors (fifty-eight females) from Britain, New Zealand, Chile and Singapore volunteered to participate in this stage. All participants reported normal or corrected-to-normal vision. The inclusion criteria for the current stage were having been born in the country of interest, having attended primary, secondary and higher education in the country of interest, and in the language of the country of interest, having previously resided only and currently residing permanently in the country of interest, and characterising themselves as part of the culture of the country of interest (Yes/No). Participants were additionally screened with the Somatic and Psychological Health Report Questionnaire (SPHRQ; Hickie et al., 2001) and an online Alexithymia-Emotional Blindness questionnaire (Alexithymia, 2018). Two participants were excluded from the study due to having a joint nationality. Data from one participant were excluded from further analysis due to having a SPHRQ score that indicated a possible psychiatric diagnosis. Data from three participants were excluded due to scores that indicated possible alexithymic traits. Data from one participant were excluded due to lack of compliance with the experimental tasks. The final sample consisted of ninety-seven participants (fifty-six females) with mean age 24.19 (S.D. = 3.69) from Britain (n = 29; Mean Age = 22.93 (S.D. = 3.63); eighteen females), New Zealand (n = 22; Mean Age = 23.67 (S.D. = 4.27); fifteen females), Chile (n = 20; Mean Age = 22.47 (S.D. = 2.5); ten females) and Singapore (n = 26; Mean Age = 23.2 (S.D. = 2.2); thirteen females). All participants gave informed consent to participate in the study and for their data to be used for further research purposes. The experiment was approved separately by the Ethics Committee of the School or Department of Psychology or Medicine of each contributing institution.

Stimuli and Procedures. This stage took place at universities in Great Britain, New Zealand, Chile and Singapore. Questionnaires and instruction material were provided in the participants' native language. Participants in each contributing institution were invited into a brightly illuminated laboratory space. After the initial screening processes, they were asked to complete the Hofstede Cultural Dimensions Questionnaire (CDQ; Hofstede, 2003) and the Emotional Regulation Questionnaire (ERQ; Gross & John, 2003). Subsequently, they were asked to produce a set of expressions including fearful, angry, happy, sad, disgusted, neutral (Ekman, 1999) and calm (Tottenham et al., 2009) facial expressions in different conditions.

In the freely-expressed condition, photographs were taken while participants were asked to freely express basic emotions in three levels (mild, moderate and intense), and neutral and calm expressions (see also Appendix 1.1). Subsequently actors were asked to show instructed emotional expressions. In the instructed condition, photographs for each emotional expression were taken after the participants were trained and subsequently instructed on how to use specific facial action units (AU)[5] to portray basic emotions according to the Facial Action Coding System (FACS; Ekman & Friesen, 1978; Ekman, 1992a; 1992b; Ekman & Rosenberg, 1997; Figure 1). A minimum of three photos per condition and emotional expression were taken for each actor. The resulting stimuli were sorted and labelled. They were adjusted for interpupillary distance, transformed to grey scale and resized to a standard 1024x768 pixels resolution. Their luminescence was averaged in SHINE, MATLAB Toolbox and finally, the stimuli were spatially aligned and framed into pure white within a cropped circle with set dimensions (Height: 6 cm, Width: 4 cm).

[5] For specific training procedures see Ekman International PLC (2018); Appendix 2.1.

Analysis and Discussion. To explore whether cultural groups were characterised by cultural – and not random sampling – differences in the expression of emotion, the actors' scores in the ERQ and CDQ questionnaires were assessed (Russell et al., 2003; see also Appendix 3.1). An analysis of variance was ran with independent variable Country of Origin (Britain, New Zealand, Chile and Singapore) and dependent variable Cultural Dimensions Scores (power distance, individualism, masculinity, uncertainty-avoidance and long-term orientation). The analysis revealed a significant Country of Origin effect ($F(3, 42) = 4.92$, $p < .01$; $\eta^2 = .26$). Further Bonferonni corrected post-hoc comparisons revealed that uncertainty avoidance was higher for British actors (M. = 72.14, S.D. = 9.23) compared to actors from Singapore (M = 53.23, S.D. = 10.72; $p < .01$; $d = 1.89$). Actors from New Zealand (M. = 71.45, S.D. = 8.49; $p < .01$; $d = 1.88$) and Chile (M. = 67.6, S.D. = 9.53; $p < .01$; $d = 1.42$) also reported higher uncertainty-avoidance scores compared to actors from Singapore. No other comparisons survived the Bonferonni corrections. To further explore emotional differences between cultural groups an analysis of variance was ran with independent variable Country of Origin (Britain, New Zealand, Chile and Singapore) and dependent variable Emotional Expression Facets (Cognitive Re-appraisal and Emotional Suppression). The analysis revealed a significant effect of Country of Origin ($F(3, 51) = 4.5$, $p < .01$; $\eta^2 = .21$). Further Bonferonni corrected post-hoc comparisons revealed that Expressive Suppression was significantly lower for British actors (M. = 10.97, S.D. = 2.85) compared to Singaporean actors (M. = 16.11, S.D. = 3.56; $p < .01$; $d = 1.59$), and for Chilean actors (M. = 10.5, S.D. = 4.51), compared to Singaporean actors ($p < .01$; $d = 1.38$). No other comparisons survived the Bonferonni corrections.

Stage Two: Automatic Facial Recognition Software Assessment

Aims: The aims of this stage were to assess the dataset using automatic facial recognition software and use the output to select the stimuli that were validated for racial background, gender and expressed emotion.

Stimuli and Procedures. 2964 photographs from ninety-seven actors were assessed using Noldus Face-Reader 7.0 (Noldus, 2018). The analysis of the stimuli was run using the Viola-Jones cascaded algorithm (Viola & Jones, 2004) and an active appearance model (AAM) that employed a 500-point Euclidean transformation (Cootes, Edwards & Taylor, 2001) to eliminate static identification variability for image quality, lighting, background variation and orientation (Lewinski et al., 2014). The analysis was conducted using a custom template analysis, and each participant was evaluated in respect to the expressed emotion after controlling for the influence of action units that were present in their own neutral expressions using the participant calibration module (Noldus, 2018). The General6_1 face module was used to assess British, New Zealand and Chilean actors and the East Asian face module was used to assess actors from Singapore. Gender and cultural-background analysis was also conducted per participant and expressed emotion.

Output and Discussion. Stimuli that were not correctly identified in respect to gender and cultural background were excluded from further analysis; a total of forty-seven photographs were excluded. The remaining 2917 stimuli were further reduced to be able to meet the time restrictions for Study Two. The ethics approval for Study Two included a time-restriction for one hour of stimuli presentation. To provide sufficient trial repetitions to achieve the required power ($P_{(1-\beta)} \geq .8$) within the approved time-frame we chose, for further facial recognition

assessment and consideration for inclusion in the masking stage, the face types that reported a significant in-group advantage and a cross-cultural bias effects in previous research (Elfenbein et al., 2007). These included mid-intensity freely-expressed (Ekman & Rosenberg, 1997), and FACS-instructed (Bernstein, Young & Hugenberg, 2007) fearful (Chiao et al., 2008), sad (Elfenbein & Ambady, 2002a) and neutral (Marsh et al., 2003) faces for each culture. All mid-intensity freely-expressed faces that met the cultural-background and gender criteria (n = 291) were included for each culture. These could vary in emotion recognition and were not chosen based on Noldus scores (Tables 1 & 2). The FACS instructed faces that reported the highest emotional recognition, racial background and gender recognition criteria were selected (n = 291). The final subset consisted of freely-expressed and Facial Action Unit System instructed faces (n = 582) with the original sample demographic characteristics (stage one).

Table 1: Emotional Recognition Scores (%)

		Freely Expressed	FACS Instructed		
		Mean (S.D.)	Mean (S.D)	*p*	d
Brit.	Fear	85.07 (3.04)	91.18 (2.01)	.01	2.37
	Sad	86.41 (2.67)	92.45 (1.97)	.01	2.57
	Neutral	86.32 (2.81)			
N.Z.	Fear	85.12 (3.12)	90.84 (1.92)	.01	2.21
	Sad	86.19 (2.92)	92.1 (1.45)	.01	2.56
	Neutral	86.41 (2.44)			
Chile	Fear	85.92 (2.96)	91.18 (2.03)	.01	2.07
	Sad	86.15 (2.58)	93.45 (1.46)	.01	3.48
	Neutral	86.19 (2.45)			
Sing.	Fear	81.31 (4.23)	91.07 (2.93)	.01	2.68
	Sad	81.72 (3.91)	92.86 (2.84)	.01	3.26
	Neutral	89.43 (2.21)			

Table 1: Means and S.D. (%) certainty of emotional categorization (Noldus, 2017). Instructed faces were recognised more accurately than freely-expressed faces ($p < .01$; $\eta^2 = .49$). Significance values and Cohen's d, in far-right columns; see also Appendix 9.1.

Table 2: No. of Actors showing Key AUs for Instructed and Freely-Expressed Emotion

	FACS Instructed Fear (Freely-Expressed)					FACS Instructed Sadness (Freely-Expressed)				
	Brit.	N.Z.	Chile	Sing.	*p*	Brit.	N.Z.	Chile	Sing.	*p*
1. In Brow Raiser	24 (21)	23 (20)	24 (22)	22 (6*)	.01	21 (14)	19 (11)	21 (14)	18 (13)	.28
2. Out Brow Raiser	23 (20)	22 (20)	23 (21)	23 (7*)	.01	2 (3)	1 (2)	2 (2)	1 (5)	.32
4. Brow Lowerer	2 (7)	4 (8)	3 (6)	2 (2*)	.04	22 (11)	23 (13)	22 (12)	23 (12)	.81
5.Lid Raiser	23 (15)	23 (16)	24 (23)	22 (18)	.24	0 (2)	1 (2)	1 (9)	0 (7)	.19
7. Lid Tightener	0 (2)	0 (7)	0 (0*)	1 (9)	.01	2 (6)	2 (9)	0 (4)	2 (11)	.21
15. Lip Depressor	0 (1)	0 (0)	0 (0)	2 (12*)	.01	23 (16)	24 (15)	23 (17)	23 (16)	.82
20. Lip Stretcher	13 (12)	12 (12)	13 (14)	11 (18)	.27	2 (6)	1 (5)	1 (5)	0 (8)	.19
25. Lips Part	20 (21)	22 (23)	24 (24)	21 (7*)	.01	0 (3)	0 (3)	1 (7)	0 (2)	.17
27. Head Down	1 (5)	1 (3)	0 (4)	1 (12*)	.01	0 (2)	1 (3)	0 (1)	1 (9*)	.03
43. Eyes Closed	0 (0)	0 (1)	0 (0)	1 (4)	.21	0 (0)	0 (0)	0 (1)	0 (4)	.19

Table 2: Number of actors showing innervation of key action units per cultural background and emotion. Facial Coding System Instructed expressions are presented in each box with freely-expressed expressions per cultural background and emotion in brackets. Significance for each AU for freely-expressed emotion in *p* column, individual groups conferring significant differences marked with asterisk (*). Instructed emotion did not report significant differences or sensitivity for AUs ($p = .87$; $\eta^2 = .01$; $B = .07$); see also Appendix 9.1.

Figure 1: Cross-Cultural Faces of Emotion

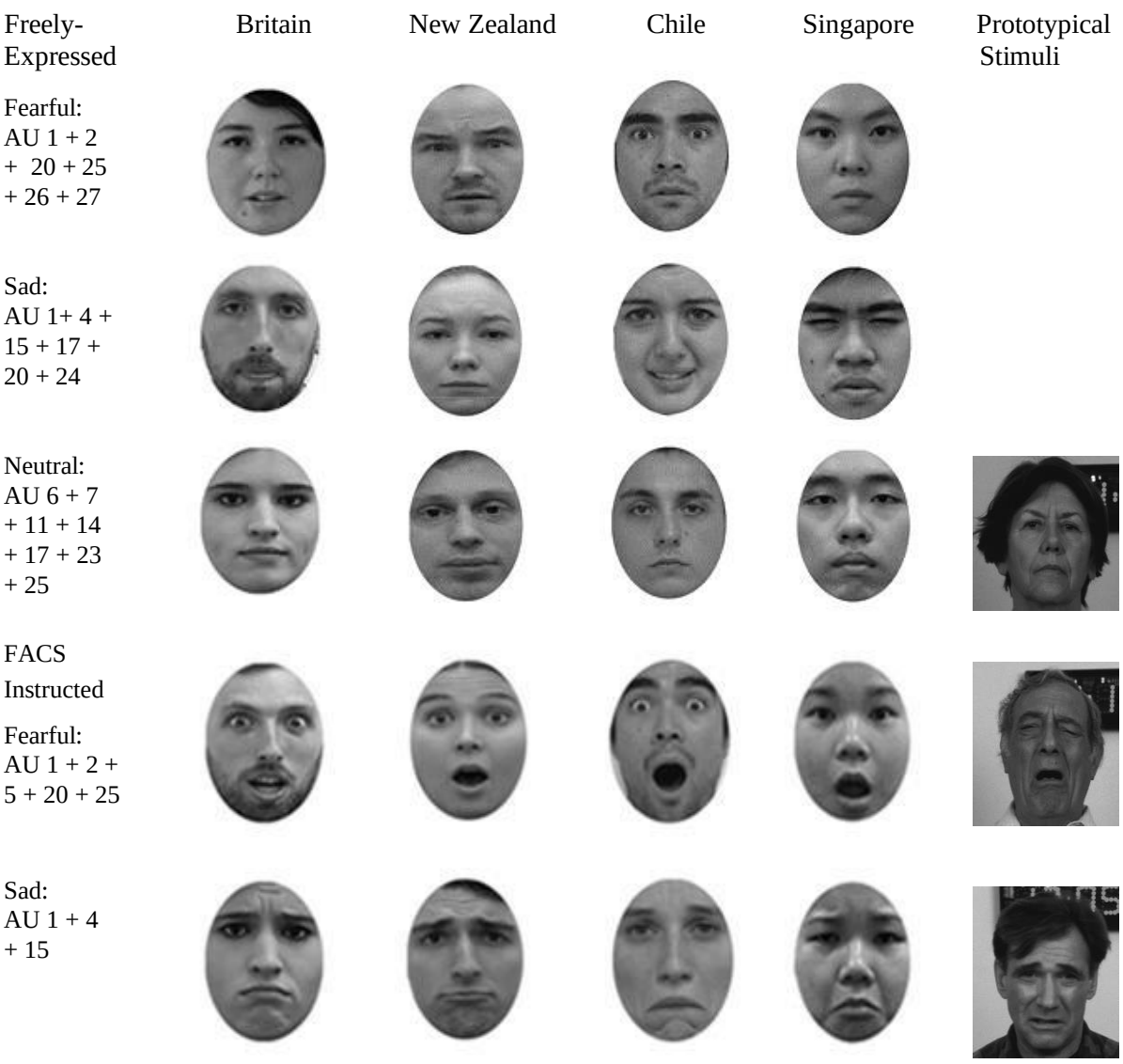


Figure 1: Example emotional expressions for each country. The most commonly shown AU items overall for freely expressed faces are listed per emotion in the left of the figure and the combinations used to produce fearful and sad expressions are listed beneath instructed labels. Prototypical stimuli were not part of any subsequent stage and are presented here for illustration purposes (Gur et al., 2002).

Stage Three: Overt Assessment

Aims. The aim in this stage was to assess participant responses for emotional recognition and cultural familiarity when the selected stimuli were presented for one second.

Participants. A power calculation based on medium effect sizes ($\eta^2 = .06$; $f = .25$) and within-subject experimental trial repetitions ($n = 582$) was performed. The result revealed that seventeen participants would be required for $P_{(1-\beta)} \geq .8$ (Faul et al., 2009). Nineteen participants (nine females) that were not part of stage one volunteered to participate in the experiment. All participants reported normal or corrected-to-normal vision. The inclusion criteria for the current study were having been born in the United Kingdom of Great Britain (U.K.)[6], having attended primary, secondary and higher education in English in the U.K., having previously resided only and currently residing permanently in the U.K., and characterising themselves as part of the culture of the U.K. (Yes/No). The participants were screened for psychiatric diagnosis (Hickie et al., 2001) and alexithymia (Alexithymia, 2018). Data for one participant were excluded due to possible Alexithymic traits. Data from one participant were excluded due to possible psychiatric diagnosis. The final population sample consisted of seventeen participants (nine females). The mean participant age was 27.48 (S.D. = 4.71). All participants gave informed consent to participate in the study. The experiment was approved by the local Ethics Committee of the School of Psychology.

Stimuli and Procedures. Participants were invited in a laboratory space in the local School of Psychology. Participants took part in two experimental runs scheduled one week apart at the same time-slot. Each run consisted of two hundred and ninety-one faces that were pseudo-

[6] Including the geographical areas of England, Scotland, Wales and Northern Ireland (see also Rhodes, 1997).

randomised using Python to include approximately equal (±1) numbers of faces for expression type, country of origin, emotional expression, and gender. The stimuli were presented in an HD Lenovo monitor adjusted at 60 Hz (16.67 ms per frame). The presentation was programmed in the coder and builder components of Psychopy version 1.85.3 (Peirce, 2007).

The experimental trial started with a fixation cross for three seconds (± one second). After the fixation cross a single freely-expressed or instructed face from Britain or New Zealand or Chile or Singapore showing a fearful or sad or neutral expression was presented at fixation for one second; order randomised. The face was immediately followed by a black and white pattern mask for one second (see also Figure 2). A blank screen interval was presented for two seconds before the rating tasks[7]. Participants were asked to respond to two on-screen stimuli-rating tasks using the keyboard; task order randomised. The participants were asked "What emotion best describes the emotion that the presented face was expressing? (fearful (f), sad (s), neutral (n) or other (o))" and "How culturally familiar was the presented face? (1: not familiar at all to 10: very familiar). After the engagement tasks a two-second blank screen interval was presented before the next trial.

Analysis and Discussion. Emotional Recognition: Emotional Recognition was transformed to non-parametric sensitivity index A. This measure was used for all subsequent analysis (Zhang & Mueller, 2005). Descriptive statistics for each condition can be seen in Table 3. An analysis of variance with independent variables Country of Origin (Britain, New Zealand, Chile and Singapore) and Type of Expression (freely-expressed and instructed), and

[7] Sequence adapted from previous research (Elfenbein & Ambady, 2002a).

dependent variable emotional recognition performance (A) was run. The analysis revealed a significant effect of Country of Origin (F 3, 48) = 968.06, $p < .001$; $\eta^2 = .99$), a significant effect of Type of Expression (F (1, 16) = 225.92, $p < .001$; $\eta^2 = .93$), and a significant interaction (F (1.68, 26.81) = 194.4, $p < .001$; $\eta^2 = .93$; Greenhouse-Geisser corrected). Further Bonferroni corrected pairwise comparisons revealed that British actors were emotionally recognised more accurately than actors from New Zealand ($p < .01$, $d = 1.55$), Chile ($p < .01$, $d = 1.55$) and Singapore ($p < .01$, $d = 8.52$) for the freely-expressed emotional condition. New Zealand ($p < .01$, $d = 1.28$) and Chilean ($p < .01$, $d = 1.43$) actors were emotionally recognised more accurately than actors from Singapore. No other comparisons survived the Bonferonni corrections. No significant differences were reported for instructed emotion (F (3, 48) = .3, $p = .82$; $\eta^2 = .02$; β[8] = .03).

Analysis and Discussion. Cultural Familiarity: An analysis of variance with independent variables Country of Origin (Britain, New Zealand, Chile and Singapore) and Type of Expression (freely-expressed and instructed), and dependent variable cultural familiarity ratings was run. The analysis revealed a significant effect of Country of Origin (F (3, 48) = 553.56, $p < .001$; $\eta^2 = .97$), a significant effect of Type of Expression (F (1, 16) = 119.05, $p < .001$; $\eta^2 = .88$) but not a significant interaction (F (3, 48) = 1.8, $p = .16$; $\eta^2 = .1$; $\beta = .09$). Further Bonferonni corrected pairwise comparisons revealed that British actors were rated higher for cultural familiarity than actors from New Zealand ($p < .001$; d (F.E[9].) = 2.47, d (I.[10]) = 2.12), Chile ($p < .01$; d (F.E.) = 1.62, d (I.) = 1.77) and Singapore ($p < .001$; d (F.E.) =

[8] Type II error (R, Chi Yau, 2018).
[9] Freely-Expressed Emotion.
[10] Instructed Emotion.

9.05, d (I.) = 8.23). Chilean actors were rated as more culturally familiar than actors from New Zealand ($p < .01$; d (F.E.) = .43, d (I.) = .33) and Singapore ($p < .001$; d (F.E.) = 6.29, d (I.) = 6.96). New Zealand actors were also rated higher for familiarity than actors from Singapore ($p < .001$; d (F.E.) = 5.59, d (I.) = 6.89).

Table 3: Emotional Recognition and Cultural Familiarity

	Freely-Expressed				Instructed			
	Mean (S.D.)				Mean (S.D.)			
	Britain	N.Z.	Chile	Sing.	Britain	N.Z.	Chile	Sing.
Emotional Recognition (%)	91.48 (3.59)	87.09 (1.94)	87.27 (2.19)	75.64 (2.65)	98.49 (1.37)	97.95 (1.49)	97.41 (1.65)	96.39 (1.9)
Emotional Recognition (A)	.95 (.01)	.93 (.01)	.94 (.01)	.85 (.01)	.98 (.01)	.98 (.01)	.98 (.01)	.98 (.01)
Cultural Familiarity	7.33 (.33)	6.27 (.51)	6.68 (.46)	3.39 (.52)	7.86 (.47)	6.95 (.38)	7.08 (.41)	4.19 (.42)

Table 3: Means and standard deviation for each condition for Stage Three. Emotional recognition and cultural recognition accuracy are presented here both in hit rates (percentage correct) and non-parametric sensitivity index A (Zhang & Mueller, 2005).

Study Two

Aims. The first objective of the current study was to test if the own-group emotional recognition advantage – and/or the other-culture emotional recognition bias – can be preserved during backward-masked presentations of brief faces for freely-expressed and instructed, own and other-culture emotional expressions. The second objective of the current study was to test whether cultural familiarity can be appraised from hits and miss responses for face detection and emotional recognition in a post-trial signal detection assessment task.

Participants. A power calculation based on medium effect sizes ($\eta^2 = .06$; $f = .25$) and within-subject experimental trial repetitions ($n = 480$) was performed. The result revealed that twenty-one participants would be required for $P_{(1-\beta)} \geq .8$ (Faul et al., 2009). Twenty-six

participants (thirteen females) that were not part of Study One volunteered to participate in the experiment. All participants reported normal or corrected-to-normal vision. The inclusion criteria for the current study were having been born in the U.K., having attended primary, secondary and higher education in English in the U.K., having previously resided only and currently residing permanently in the U.K., and characterising themselves as part of the culture of the U.K. (Yes/No). Participants were additionally screened with the Somatic and Psychological Health Report Questionnaire (Hickie et al., 2001) and an online Alexithymia Emotional Blindness questionnaire (Alexithymia, 2018). Three participants were excluded from the study due to joint nationality. Data from one participant were excluded from further analysis due to possible alexithymic traits and data from one participant were excluded due to possible psychiatric diagnosis. The final population sample consisted of twenty-one participants (ten females). The mean age for this stage was 30.21 (S.D. = 5.07). All participants gave informed consent to participate in the study. The experiment was approved by the local Ethics Committee of the School of Psychology.

Stimuli and Procedures. Participants were invited into a laboratory space at the local School of Psychology. After the initial screening processes, they were administered the ERQ and CDQ[11]. They were then allowed a small break. The main experiment started with a five-minute response training task and participants were then asked to indicate when they were ready to start the stimuli presentation using the keyboard. Previous research (Elfenbein & Ambady, 2002a, 2002b; p. 243-247) suggests that to accomplish a balanced design when a single cultural group is exposed to cross-cultural stimuli an equal number of stimuli from

[11] For cultural distance analysis (Russell et al., 2003) see Appendix 5.1 and 5.2.

each selected culture should be presented to the participants including equal emotional expression and type, and gender distributions per cultural group during the presentation. In this study, we followed these experimental guidelines to attain a balanced cross-cultural emotional recognition design. Two hundred and forty faces and an equal number of randomly generated non-facial pattern blurs were shown (see Appendix 4.1). Each presentation run was pseudorandomised for the face condition and assigned one hundred and twenty faces per type, eighty faces per emotion and sixty faces per nationality. Each actor identity was repeated three times to attain an equal number of male and female faces (n = 120).

The experimental trial started with a fixation cross for three seconds (± one second). After the fixation cross a non-facial blur or a single freely-expressed or instructed face from Britain or New Zealand or Chile or Singapore showing a fearful or sad or neutral expression was presented at fixation for 33.33 ms; order randomised (see also Appendix 11.1). The target was immediately followed by a black and white pattern mask for 116.67 ms. After the mask a blank screen interval was presented for two seconds. After the presentation, participants were asked to reply to three on-screen questions using the keyboard. First they were asked “Did you see a face? (Y/N)”. After this task we used conditional branching. If the response was “Yes”, an on-screen message asked participants “What kind of emotion was the face expressing? (fear (f), sad (s), neutral (n) or other (o))”. To balance the task length when using conditional branching, if the participants’ response was ”No”, an on-screen message asked participants “What kind of emotion best describes your experience during the presentation? (fear (f), sadness (s), neutral (n) or other (o))”. This task was included to disallow participants to make their choice based on shorter engagement task length criteria.

After this task, participants were asked by an on-screen message “How culturally familiar was the presentation? (1: not familiar at all to 10: very familiar)”. A blank screen interval was presented for two seconds before the next trial (Figure 2).

Figure 2: Stimuli Sequence

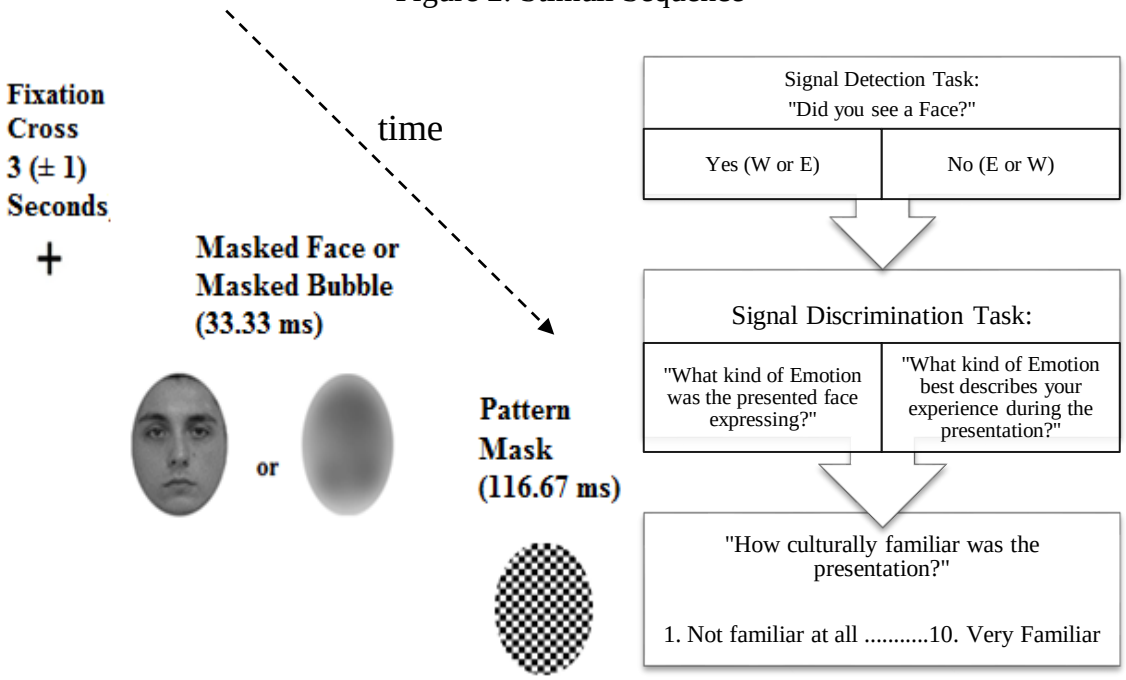


Figure 2: Example stimuli sequences including a neutral Chilean face or a non-facial blur. Participants were presented with brief culturally diverse faces. They were asked to reply if they saw a face using the keyboard by pressing W or E; key order randomised. They were then assigned with either an emotional recognition or emotional self-assessment task. Finally, they were asked to rate cultural familiarity for the presentation.

Apparatus and Presentation Testing. The stimuli were presented in an HD Lenovo monitor adjusted at 60 Hz. The presentation was programmed in the coder and builder components of Psychopy version 1.85.3. To ensure that brief stimuli were correctly presented, an IPAD PRO camera with 120 Hz refresh rate (8.33 ms) recorded two pilot runs. The stimuli presentation was assessed frame by frame; no instances of dropped frames were detected. A self-developed dropped frames script report with one frame (16.67 ms) tolerance threshold was coded in Python and two pilot experimental diagnostic sessions were run. The presenting

monitor reported no dropped frames; prognostic estimate 1/5000 trials. Experimental stages were subsequently run using dropped frames diagnostics; no instances of dropped frames were reported.

Analysis and Discussion: In-group advantage and Cross-Cultural Bias for Emotional Recognition under Conditions of Backward masking. Descriptive statistics for signal detection performance can be seen in Table 4. Emotional Recognition was transformed to non-parametric sensitivity index A. This measure was used for all subsequent analysis (Zhang & Mueller, 2005). An analysis of variance with independent variables Type of Expression (freely-expressed and instructed), Country of Origin (Britain, New Zealand, Chile and Singapore) and Type of Emotion (fear, sadness and neutral), and dependent variable emotional recognition performance (A) was run. The analysis revealed significant effect only for Country of Origin (F (2.01, 40.11) = 33.55, $p < .001$; $\eta^2 = .63$). Further Bonferroni corrected pairwise comparisons revealed that actors from Britain (M. = .64, S.D. = .11) were recognised more accurately than actors from Singapore (M. = .43, S.D. = .11; $p < .001$; $d = 1.82$). Significance trends were revealed for higher recognition to actors from Britain in comparison to actors from New Zealand (M. = .58, S.D. = .13; $p = .02$; $d = .5$) and Chile (M. = .58, S.D. = .14; $p = .04$; $d = .48$).

Actors from New Zealand ($p < .001$; $d = 1.25$) and Chile ($p < .001$; $d = 1.19$) were recognised significantly more accurately in respect to what emotion they were expressing compared to actors from Singapore. This finding indicated that emotional recognition for actors from Singapore was subject to a cross-cultural emotional-recognition bias. Therefore, we tested the exploratory hypothesis that, due to higher emotional suppression scores

reported during Study One, the current results could have occurred because actors from Singapore could have been most commonly miss-recognised as expressing emotional neutrality. This hypothesis was investigated further using confusion matrix analysis (Fawcett, 2006). Sensitivity index A was calculated for hits and misses for neutral faces for each country of origin and an analysis of variance was run with independent variable Country of Origin (Britain, Chile, New Zealand, Singapore) and dependent variable emotional recognition (A) for neutral faces, to test if particularly miss (false positive) responses for emotional neutrality were higher for participants from Singapore. A significant effect was reported (F (2.05, 40.89) = 30.15, $p < .001$; $\eta^2 = .6$). Further Bonferonni corrected pairwise comparisons revealed higher sensitivity index A scores for false positives for neutral faces in response to actors from Singapore (M. = .39, S.D. = .02) compared to actors from Britain (M. = .67, S.D. = .03; $p < .001$; $d = 11.51$), New Zealand (M. = .59, S.D. = .03; $p < .001$; $d = 7.74$) and Chile (M. = .59, S.D. = .04; $p < .001$; $d = 6.57$).

Analysis and Discussion. Does appraisal of cultural familiarity require conscious awareness? Descriptive statistics can be seen in Tables 4 and 5. A one-sample t-test against chance-level performance (A) revealed that masked faces were detected significantly better than chance ($p < .01$) but they were not recognised significantly different than chance ($p = .67$; see also Appendix 6.1, 6.2 and 7.1). A Bayesian analysis (Dienes, 2015) with corrected degrees of freedom (df < 30; $SE = (SE\ x \left(1 + \left(\frac{20}{df x df}\right)\right)$) (Berry, 1996) and higher and lower bounds set at -.1 (.4) and .1 (.6), with 0 (.5) representing absolute chance level performance, revealed that face-detection for British (S.E. = .02; B > 3), New Zealand (S.E. =

.02; B > 3), Chilean (S.E. = .02; B > 3) and Singaporean (S.E. = .02; B > 3) faces was significantly higher than chance (Dienes, 2015). A Bayesian analysis (Dienes, 2015) with corrected degrees of freedom and higher and lower bounds set at -.1 (.15) and .1 (.35), with 0 (.25) representing absolute chance-level performance, revealed that emotional-recognition for British (S.E. = .03; B > 3), New Zealand (S.E. = .03; B > 3), Chilean (S.E. = .03; B > 3) and Singaporean (S.E. = .03; B > 3) faces was significantly higher than chance (see also Appendix 8.1).

Table 4: Hit Rates (A.) and Sensitivity Index A (B.) for Signal Detection Performance

	Freely-Expressed Condition				Instructed Condition			
A.	Detection		Recognition		Detection		Recognition	
	Mean (%)	S.D. (%)	Mean (%)	S.D. (%)	Mean (%)	S.D. (%)	Mean (%)	S.D. (%)
Britain	62.22	15.79	53.02	17.33	76.51	13.35	67.62	17.12
New Zealand	64.44	13.44	53.65	17.15	72.38	13.23	57.78	18.07
Chile	66.67	14.39	54.6	18.57	66.35	13.91	54.29	20.73
Singapore	68.25	13.23	34.29	18.26	75.56	14.01	33.02	19.02
B.	Detection		Recognition		Detection		Recognition	
	Mean (A)	S.D. (A)	Mean (A)	S.D. (A)	Mean (A)	S.D. (A)	Mean (A)	S.D. (A)
Britain	.606	.131	.534	.148	.713	.101	.644	.138
New Zealand	.623	.113	.535	.145	.68	.106	.571	.15
Chile	.64	.114	.546	.155	.637	.111	.543	.165
Singapore	.652	.106	.399	.144	.7	.101	.393	.155

Table 4: In A. mean and standard deviation percentage of correct detection (hit rates) and in B. mean and standard deviation sensitivity index A per type of expression (freely-expressed and instructed) and per country of origin for detection and recognition performance.

To explore if cultural familiarity can be appraised without conscious awareness, we ran an analysis of cultural familiarity scores for hits and misses for detection and recognition performance (Pessoa, 2005). The analysis revealed that hits for face-detection performance were associated with significant differences between cultures ($F(2.33, 46.65) = 68.98$, $p <$

.001; $\eta^2 = .44$) while misses were not significantly different between cultures ($F(15, 210) = 1.19$, $p = .28$; $\eta^2 = .08$; $\beta = .07$). Further Bonferonni corrected pairwise comparisons revealed that correctly detected British faces (M. = 6.59, S.D.= .86) were rated higher in cultural familiarity than correctly detected faces from New Zealand (M. = 4.8, S.D. = .39; $p < .001$; $d = 2.68$), Chile (M. = 4.91, S.D. = .44; $p < .001$; $d = 2.46$) and Singapore (M. = 3.48, S.D. = .52; $p < .001$; $d = 4.38$). A different pattern was found for recognition performance. Hits ($F(2.34, 41.13) = 62.78$; $p < .001$; $\eta^2 = .78$) and misses ($F(15, 120) = 14.21$; $p < .001$; $\eta^2 = .64$) in emotional-recognition revealed significant differences in familiarity ratings between different cultures (Figure 3). Further Bonferonni corrected comparisons revealed that for recognition hits British actors (M. = 6.72, S.D. = .93) were rated higher for cultural familiarity than actors from New Zealand (M. = 4.89, S.D. = .37; $p < .001$; $d = 2.59$), Chile (M. = 4.98, S.D. = .46; $p < .001$; $d = 2.37$) and Singapore (M. = 3.33, S.D. = .64; $p < .001$; $d = 4.25$). For misses in recognition, British actors (M. = 6.33, S.D. = .68) were also rated higher than actors from New Zealand (M. = 4.84, S.D. = .88; $p < .001$; $d = 1.89$), Chile (M. = 4.9, S.D. = .82; $p < .001$; $d = 1.89$) and Singapore (M. = 3.67, S.D. = .98; $p < .001$; $d = 3.15$).

Table 5: Hits and Miss Cultural Familiarity Responses within Cultures

	Detection						Recognition					
	Freely-Expressed			Instructed			Freely-Expressed			Instructed		
	Mean (S.D.)			Mean (S.D.)			Mean (S.D.)			Mean (S.D.)		
	Hits	Miss	Sig.	Hits	Miss	Sig.	Hits	Miss	Sig.	Hits	Miss	Sig.
Brit.	5.92 (.63)	4.79 (.38)	.001 2.17	6.82 (.99)	4.81 (.14)	.001 2.93	5.99 (.7)	5.73 (.8)	.05 .35	7.13 (.93)	6.73 (.67)	.04 .49
N.Z.	4.86 (.46)	4.72 (.45)	.29 .31	4.79 (.38)	4.81 (.42)	.87 -.05	4.84 (.54)	4.88 (.49)	.68 .04	4.83 (.42)	4.71 (.41)	.05 .32
Chile	4.91 (.44)	4.83 (.37)	.4 .19	4.81 (.53)	4.88 (.38)	.64 .06	4.97 (.49)	4.98 (.59)	.94 -.01	4.87 (.52)	4.46 (.65)	.03 .69
Sing.	3.39 (.6)	4.63 (.21)	.001 -2.76	3.61 (.68)	4.84 (.79)	.001 -1.81	3.31 (.72)	3.49 (.71)	.09 .25	3.46 (.82)	3.64 (.76)	.2 -.23

Table 5: Mean and standard deviation for each condition for hits and misses in Study Two. In Sig., Bonferonni corrected α values (≤ .001) for each comparison and effect size Cohen's d.

Figure 3: Hits and Miss Cultural Familiarity Responses between Cultures

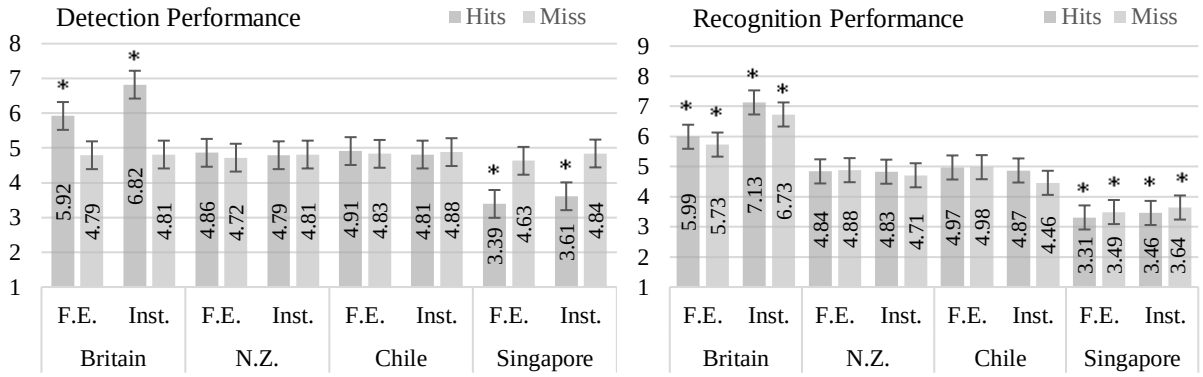


Figure 3: Mean cultural familiarity ratings (Y axis) per Country of Origin for Hits and Misses in detection and recognition performance for freely-expressed (F.E) and FACS instructed (Inst.) faces for Study Two. Error bars indicate standard error of the mean (±2). Asterisks indicate Bonferonni corrected significance between different cultures ($p \leq .001$).

General Discussion

Summary of Research

In Study One, we developed a cross-cultural facial stimuli dataset including non-professional actors from Britain, Chile, Singapore and New Zealand showing freely-expressed and FACS instructed emotional expressions. We assessed and validated the dataset

using standard cultural dimensions and emotional expression questionnaires, automatic facial recognition software and participant assessment. In Study Two, we used the developed dataset to explore whether the own-culture emotional recognition advantage can be preserved under conditions of backward masking and whether the appraisal of cultural familiarity from faces requires conscious awareness. We reported significant findings for an own-group emotional recognition advantage and that face-detection was a necessary condition for the appraisal of cultural familiarity. No effects were reported for misses for face detection between different cultural groups. Correct emotional recognition of own-culture faces increased ratings for cultural familiarity but was not a necessary condition for significant differences between cultures.

The Dialects Theory of Emotion and Conscious Awareness

Previous research has reported extended evidence for a regional in-group advantage in emotional recognition (Elfenbein & Ambady, 2002a). Higher accuracy for emotional recognition for own-culture compared to other-culture faces has been reported by African-American (Wickline et al., 2009), Canadian (Beaupré & Hess, 2005), American-U.S. (Soto & Levenson, 2009), European (Sauter et al., 2010), Chinese (Han & Northoff, 2008), Australian (Elfenbein, 2006) and Japanese (Chiao et al., 2008) participants, and has been used to shape contemporary cross-cultural psychological theories (Elfenbein & Ambady, 2002b; Matsumoto, 2002). This in-group advantage is suggested to rely on culture-specific ways of expressing emotion, i.e. display rules, and culture specific ways of responding to emotion, i.e. de-coding rules (Matsumoto & Hwang, 2013).

Contemporary cross-cultural psychologists suggest that the expression of basic emotions such as anger, fear, sadness, happiness, surprise and disgust are considered a universal language, but they are *pronounced* in different ways due to the non-convergent social evolution that takes place in different geographical regions (Elfenbein et al., 2007). This non-convergent evolution has been suggested to confer culture-specific sociobiological value (Adolphs, 2003). Based on this hypothesis the argument has also been raised that culture specific emotional expressions are recognised more accurately because they are appraised without conscious awareness (Eberhardt et al., 2004; Smith et al., 2008; Gifford, 2008). Previous research has provided support for the notion of automatic appraisal of own-culture emotional faces (Chiao et al., 2008) and the notion that other-culture and own-culture faces, that are visually suppressed using either backward masking or dichoptic rivalry, can influence our subsequent responses to supraliminal cues (Smith, Dijksterhuis & Chaiken, 2008). This line of research has been challenged by findings from other research groups that suggest that, although it is possible that facial characteristics can influence participant responses during visual suppression, these effects could be due to inadequate masking of the presented stimuli and conscious awareness (Pessoa et al., 2005; Amihai et al., 2012; Tsikandilakis, Chapman & Peirce, 2018).

In the current study, we followed from these findings. We tested whether the effects of cross-cultural dialects in the expression of emotion can be preserved under conditions of backward masking and whether the appraisal of cultural familiarity requires conscious awareness; such as hits and miss responses for face detection and emotional recognition in a post-trial signal detection assessment task. We found that participants could emotionally

recognize own-culture emotional faces more accurately than other-culture faces under conditions of backward masking irrespective of type of expression (freely-expressed and FACS instructed) and despite the brief duration of presentation (i.e. 33.33 ms). The participants in the current study were, furthermore, able to accurately rate and recognise own-culture masked negative emotions and masked negative emotions expressed by actors from Chile and New Zealand. However, they responded with a cross-cultural miss-recognition bias (emotional neutrality) and the lowest familiarity ratings for masked faces from Singapore. These findings suggest that the participants in the current study employed cultural and emotional display rules for emotional recognition and they did not experience a negative emotion de-coding bias (Phaf & Roteveel, 2005).

The finding that the own-culture emotional recognition advantage was preserved under conditions of backward masking, for the duration for which faces were presented in previous research, is not surprising. Using the current method for the assessment of subliminality the presented faces did not report significant evidence for subliminal perception (Tsikandilakis & Chapman, 2018; Tsikandilakis, Chapman & Peirce, 2018; Tsikandilakis, Bali & Chapman, 2018). Further analysis of awareness revealed that higher in-group cultural familiarity ratings were specific to the subset of trials that included hits for face-detection of the presented stimuli. Emotional recognition enhanced this effect while misses for face detection did not reveal significant differences between cultural groups. During the masking study, British participants reported an own-group emotional recognition advantage for both freely-expressed and FACS instructed faces, but this finding did not extend to higher familiarity and emotion recognition for other-culture FACS instructed faces as compared to

other-culture freely-expressed faces. This suggests that under conditions of backward masking the most pronounced emotional differences survive the reduction in signal strength (Aru et al., 2012), and that the presentation of unfamiliar physiognomic characteristics (Amihai et al., 2012) in combination with the challenging task of appraising brief expressions (Gaillard et al., 2009) resulted in the extinction of the other-culture FACS instructed emotion recognition-superiority effect (Bochner, 2013).

In relation to the dialects theory of emotion, this suggests that culture-specific emotional characteristics have an impact on emotional recognition and the appraisal of cultural familiarity during very brief presentations of facial stimuli. Nevertheless, from a psychophysics perspective, it also indicates that fixed durations of masked presentations might not be sufficient to induce subliminal visual suppression (Tsikandilakis & Chapman, 2018), particularly for own-culture emotional faces (Schlossmacher et al., 2017), and that, when using further hits (correct detection/recognition) and miss (incorrect detection/recognition) analysis of participant responses, the appraisal of cultural familiarity from emotional faces involves, and possibly relies on, conscious awareness as reported in a post-trial signal detection assessment task (Erdelyi, 2004; Pessoa, 2005; Pessoa & Adolphs, 2010; Etkin, Büchel & Gross, 2015; Tsikandilakis, Chapman & Peirce, 2018). In simpler terms, the current data point towards that the appraisal of cultural familiarity from faces involves conscious awareness (Jiang & He, 2006; Gaillard et al., 2009; Amihai et al., 2012; Schlossmacher et al., 2017).

Limitations

To attain a balanced cross-cultural experimental design (Elfenbein, 2002b), given the institutional availability for the current study, the stimuli set included three Caucasian and one Asian physiognomic group. The current study included British participants in the masking stage, due to restrictions relating to the funding scheme that supported the current research. Further cross-cultural replication has been approved and initial raw data can be found at https://osf.io/7mkgu/.

Conclusions

The current studies suggest that we can recognise freely-expressed and instructed emotional faces from our own-culture more accurately than faces from other cultures during backward-masked presentations. Our findings suggest that the appraisal of cultural familiarity involves, and possibly relies on, conscious awareness (face-detection hits responses), and that it could not be reported in the absence of conscious awareness (face-detection miss responses). These findings suggest that a brief, yet conscious, exposure to one's own cultural-emotional characteristics is sufficient to elicit emotional recognition and the appraisal of cultural familiarity.

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and have equal contribution and co-authorship status for the current manuscript. All measures, manipulations, and exclusions in the study were disclosed, and no data were collected after the initial analysis. Raw data for the current report and examples of the photographic material have been made open access at https://osf.io/3z97s/. The entire dataset is available, subject to proof of concept of ethically approved institutional research, from the primary author. Many thanks go to our families, friends and academic colleagues that supported us during this project. The primary author would like to thank Jan Derrfuss, Talis Bachmann, Harry Purser, Alison, Martyn, Maria-Dolores and the Takimi Team.

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Discussion

Summary of the Current Research

In the current thesis we presented experimental research associated with one of the most controversial areas in traditional (Dixon, 1971) and contemporary (Brooks et al., 2012) psychological science. In the current thesis we addressed whether participants could experience physiological changes and make correct self-report responses to unconscious emotional faces. Our research consisted of five experimental chapters. The first three experimental chapters included the assessment of physiological responses, such as skin conductance (SCR), heart rate (HR), force pressure assessment and facial emotional expressions assessment, as well as self-reports for detection, discrimination and the experience of emotion, to backward masked emotional faces. The subsequent and final two experimental chapters included the assessment of self-reports for the evaluation of facial characteristics, such as attractiveness and cultural familiarity, in response to backward masked faces.

In the first experimental chapter (p. 25-50) we used backward masking to neutral faces to make the presentation of emotional faces covert. In this chapter we implemented the first to our knowledge definition of subjective thresholds for unconscious presentation using unbiased non-parametric receiver operating characteristics (A; Zhang & Mueller, 2005) and hit rates, and Bayesian analysis (Dienes, 2016) for assessing chance-level detection performance (Hit Rates = 50% or A = .5). In this chapter the duration of the masked emotional faces (8.33 or 16.67 or 25 ms) was defined individually for each participant for each stimulus type (angry, fearful, happy and neutral faces) as the duration that was closest to

chance for detecting whether a facial stimulus was presented. The result of this implementation was that stimulus perception was approximate to chance when applying Bayesian analysis for the null hypothesis for detection performance for both adjustments. When participants were presented with individually adjusted faces using hit rates the durations of presentation that reported Bayesian evidence for chance-level performance were for most participants at three frames of a 120 Hz monitor (25 ms), and fearful, angry and happy faces were higher for SCR compared to neutral faces. When the adjustments were made using unbiased receiver operating characteristics the duration of presentation that provided Bayesian evidence for chance-level performance was most commonly a single frame (8.33 ms) and the same participants did not experience physiological changes.

In the second experimental chapter (p. 51-76) we replicated our previous design and introduced several methodological improvements. Firstly, we included sad masked faces in the presentation. This inclusion was introduced as a control condition because previous research has suggested that sad facial stimuli do not elicit physiological arousal (Killgore & Yurgelun-Todd, 2004). Therefore, we included sad faces to ensure that our previous findings for differences in SCR between angry, fearful and happy faces, and neutral faces were not due to mismatch with the neutral mask, such as startle responses due to the presentation of two different types of emotional expressions during the same trial (see Kim et al., 2010). Secondly, we included HR assessment in the analysis of physiological responses as an additional measure of physiological arousal (see van der Ploeg et al., 2017). Thirdly, we included a post-trial confidence scale for binary detection responses and separate hits (correct responses for seeing a presented faces) and miss (incorrect responses for not seeing a

presented face) responses in the analysis. We found that when the analysis showed Bayesian evidence for chance-level performance using hit-rates, angry and fearful faces elicited higher SCR and HR responses compared to sad and neutral faces. We also found an ascending linear trend between SCR and HR responses and confidence for correct discrimination of an emotional face. Further hits and miss responses analysis revealed that the reported differences were specific to correct detection of a presented face. The receiver operating characteristics adjustments in the duration of presentation replicated our previous findings. When emotional faces were presented using unbiased metrics for chance-level detection performance there were no differences in physiological arousal between different stimuli.

In the third experimental chapter (p. 77-106) we further developed our previous methodology. We adjusted signal detection theory to multiple answers for the discrimination of backward masked angry, fearful, happy, sad and neutral faces using a corrected criterion for chance level awareness (Hit Rates = 16.67% or A = .167). We utilized state-of-the-art refresh rate monitor technology to individually define per participant and stimulus type chance-level discrimination performance between the smallest intervals that have been to our acknowledge applied for presenting masked faces in the current area (6.94 ms; i.e. 20.83 or 27.78 or 34.72 or 41.67 ms; see van der Ploeg et al., 2017). We added facial recognition analysis and developed and added our own prototype for force pressure responses to SCR and HR for assessing the physiological impact of these emotional faces. We additionally, added continuous valence (1: Negative to 10: Positive) and arousal (1: Low to 10: High) self-report ratings in our post-trial assessment. Our findings revealed that when discrimination performance was at chance using an adjusted criterion (16.67%) for hit-rates angry, fearful

and happy faces were higher for SCR, HR and force pressure responses compared to sad and neutral faces. Facial recognition provided trends for differences between different stimuli in the hit-rate adjustments condition suggesting that the application of masking possibly resulted in reduced signal strength and disallowed us to replicate previous significant findings for facial responses as reported in studies that presented overt emotional faces (Lewinski, den Uyl & Butler, 2014). We further replicated and elaborated on this finding in a post-thesis publication (see Tsikandilakis, Bali, Derrfuss & Chapman, 2019a). Unbiased receiver operating characteristics adjustments in the discrimination threshold replicated our previous findings and we found that there were no significant differences in response to different emotional faces in this condition. The current chapter offered what was possibly the most seminal finding of the current thesis. We found that when participants were presented, during the hit-rate adjustments condition, with innocuous stimuli, such as sad and neutral faces, and pattern blurs, and experienced physiological arousal they misclassified the presented stimuli as expressing negative valence and high arousal and made false positive discrimination responses for seeing a fearful face. This finding suggested that physiological meta-cognition, such as post-trial self-assessment of the experienced emotional arousal (see Tsikandilakis, Bali, Derrfuss & Chapman, 2019b), influenced the experience of perception of the presented stimuli (see also Pessoa & Adolphs, 2010).

In the final two experimental chapters of the current thesis we applied our model for the assessment of unconscious processing to explore whether facial characteristics such as attractiveness (p. 107-144) and cultural familiarity (p. 145-185) can be evaluated from masked faces. In these studies we presented masked faces for durations that in previous

research have – debatably (Pessoa et al., 2005) – been suggested to result in subliminal processing (i.e. 33.33 ms; see Brooks et al., 2012). When applying transformations of hit rates to non-parametric receiver operating characteristics (Stanislaw & Todorov, 1999; Zhang & Mueller, 2005) and Bayesian analysis (Dienes, 2016) for chance-level performance we found that faces were processed above the chance-level perceptual threshold (A = .5; Zhang & Mueller, 2005; p. 205) required for inferring subliminality (see also Erdelyi. 2004). The participants were also able to make accurate evaluations in the form of self-reports for the attractiveness and cultural familiarity of pre-labelled during pilot stages faces only for hits for detection performance as predicted by the application of our model in the previous chapters.

The Theoretical and Methodological Lineage of the Current Research

The fundamental philosophical opinion of the current work was that perceptual sensitivity is not an interpersonal constant (Pessoa et al., 2005; Pessoa & Adolphs, 2010; Lähteenmäki et al., 2015). This argument was influenced by a seminal finding (Pessoa et al., 2005) that perhaps has received less attention than it deserves in the area of unconscious processing. Pessoa and colleagues (2005) tested a group of thirty-seven participants for perceptual sensitivity to backward masked fearful faces presented for 33.33 and 66.67 ms and associated their perceptual sensitivity with fMRI findings for amygdala activation. They found that a group of – as the authors described them – *overachievers* (n = 10) were able to discriminate fearful faces significantly above chance (A' = .5) at 33.33 ms. Conversely, another group of participants (n = 5) could not reliably discriminate fearful faces at 66.67 ms. Their results also revealed that the amygdala was activated for the participants who were conscious of the presentation. Although, Pessoa and his research group continued to replicate

this finding for diversion in perceptual sensitivity and also provided evidence for diversity in perceptual sensitivity between different types of stimuli (Pessoa, 2018), experimental research in the current area did not take the next step to developing a method for subjective thresholds for unconscious processing. Research in this field continued to use fixed durations of presentation (16.67 to 83.33 ms; Brooks et al., 2012; van der Ploeg et al., 2017) to infer that both fMRI and SCR responses at these durations illustrated *subliminal processing*. This methodological shortcoming – as well as the philosophical axiom that perception is an interpersonal and interstimulus constant (see Lähteenmäki et al., 2015) – was the basis for the implementation of varying per participant and stimulus type subjective thresholds in the current research as described in the experimental chapters of this thesis. This implementation resulted in a rebuttal and not a validation of subliminal processing. The implementation of *subjective unconsciousness* did not provide evidence for physiological responses to masked emotional faces (Chapters One, Two and Three) or evidence for the correct evaluation of facial characteristics in response to masked faces (Chapters Four and Five).

An important factor for understanding the reasons for which subliminality is so widely contested in contemporary psychological science is its lineage to older and formative debates. One important and often understated such debate related to the validity of self-reports as a reliable metric for conscious awareness and the definition of an objective threshold for subliminal processing (Dixon, 1971; 1981; Merikle. 1983; 1984; Holender, 1986; Merikle & Cheesman, 1987). In contemporary psychophysics, Stanislaw and Todorov (1999) were one of the first researchers to provide an overview concerning why self-reports, such as percentage of correct answers (i.e. hit rates), for stimuli

detection or discrimination are an insufficient metric for awareness. Stanislaw and Todorov suggested that hit rates can be biased metrics for awareness because they are subject to conservative (replying that a stimulus was presented only when a participant is absolutely sure that it was presented) or liberal (replying that a stimulus was presented when a participant is quite unsure concerning whether it was presented) criteria for detection or discrimination. Therefore, their suggestion was that a metric that would take into account both hits and miss responses should be implemented for the definition of unbiased awareness (Macmillan & Creelman, 2004). Erdelyi (2004) added to these that, when it comes to defining subliminality, this unbiased metric should indicate that a participant responded at chance for detecting or discriminating a presented stimulus. This assertion was made on the grounds that if a stimulus is presented below the threshold of conscious awareness, a participant should respond "like a blind person would" (Erdelyi, 2004; p .79) to a detection or discrimination task: *by guessing*. Despite the simplicity with which these definitions were presented in 1999 and 2004, this argument was, in fact, at a certain time in this area, the subject of polemic debate. It predates our *reliable* contemporary definitions of subliminality (Pessoa & Adolphs, 2010) and could be, in fact, as old as the current area of experimental research itself (see for example, Sidis, 1983/1898).

For example, Dixon, in his early (1971) and his subsequent works (1981), was one of the first researchers to challenge the extent to which we can apprehend *subliminal perception* and therefore, the extent to which self-reports for awareness, without the imposition of further requirements for unawareness, were sufficient criteria for inferring unconscious processing. Dixon (1971) provided a set of criteria for subliminality. He suggested that a

stimulus should be presented below the lowest threshold that a participant had previously reported conscious perception for that stimulus. The participant should also be unable to identify the below-threshold presented stimulus in a post-trial and/or post-experimental recognition task as having been presented during the experimental trial(s). Finally, Dixon proposed that the subliminal and conscious processing of a stimulus must result in different responses, such as inducing different effects for reaction times and human performance metrics, semantic and higher executive processing and priming, and physiological responses. These criteria became themselves a source of diversity as regards their experimental implementation (see Merikle, 1983) and resulted in further conceptual debates as to the validity of experimental outcomes that suggested evidence for unconscious processing at that time (see Holender, 1986).

Dixon's argument led to a series of published correspondences between authors supporting, contesting and – if the reader can excuse the euphemism – *struggling* with these propositions (Marcel 1983a, 1983b; Merikle 1983, 1984; Henley, 1984; Holender, 1986). Conceptually, the antilogous to Dixon's thesis of "subliminal perception" was relatively simple: perception by definition implies the involvement of conscious awareness unless a model that distinguishes perception from conscious awareness can be provided and defended (Merikle & Cheesman, 1987). In response, Dixon revised the term "subliminal perception" to "preconscious processing" (1981) and although, the debate was not methodologically resolved, and conflicting publications from both sides *continued as normal* (Nolan & Karamazza, 1982; Zimba & Blake, 1982; Underwood, Rusted & Thwaites, 1983; Groeger, 1984; see also Kouider & Dupoux, 2004), a less contentious thesis was adopted. Dixon

(1981) suggested that higher order semantic and executive processing can be influenced by preconscious signals because memory and sensation are cognitive faculties that have a wide range of processing capacity, only a portion of which enters the more limited channelling of conscious awareness.

This argument reverberated with Hegel's notion of the *Phenomenology of Mind* (2012/1807) in the sense that it proposed that the cognitive faculties that underlie the experience of consciousness and the perceptions of conscious awareness – to which the former result – are distinct phenomena. This point was also supported by Marcel (1983b) who proposed that, outside the area of semantic processing, the experience of emotion and the perception of an emotional elicitor are not equivalent. He suggested that the former is comprised of an intricate network of bodily processes and self-assessments, the effects of memory systems in the processing of emotion and it is influenced by whether there is need for action or reflection in response to an elicitor. Marcel (1983b) also suggested that perception is depended on the awareness or unawareness of a condition or elicitor to which the emotional experience could be associated with. This seminal argument would later develop to what Bargh and Morsella (2008), and Dehaene and colleagues (2006) termed preconscious processing in contemporary psychological research; meaning in this context the automatic processing of cues that can lead to cognitions and behaviours that are potentially accessible by consciousness but remain latent until the need for conscious recall is either requested or necessitated.

The *transubstantiation* of subliminal perception – a term that could be considered an *ad absurdum* proposition by many contemporary psychological researchers (see for example

Bachmann & Francis, 2013) – to preconscious processing illustrated conceptual progress. Nevertheless, as Holender (1986) explicitly highlighted, during this past debate, this approach – possibly correctly (Merikle & Cheesman, 1987) – compartmentalised the underlying mechanisms of consciousness and the awareness of perceiving an elicitor but it did not offer a remedy for the subjectivity and unreliability of self-reports as the means for assessing conscious perception, and it did not resolve whether conscious perception was involved in the reported effects that supported subliminal or unconscious or preconscious processing in psychological science at the time (Dixon & Henley, 1980).

Eventually, it would be mathematical psychology that would provide a solution to this polemic. As early as 1964 Pollack and Norman had provided a method for assessing the reliability of self-reports in psychological research but it would not be until the beginning of the 21st century that their method would be made widely accessible (Stanislaw & Todorov, 1999), algorithmically revised (see Zhang & Mueller, 2005) and applied in the current area (Pessoa et al., 2005). Many psychologists would be familiar with this method today as *signal detection theory* (Macmillan & Creelman, 2004). Signal detection theory was used to provide a reliable metric for self-reports for conscious awareness. The basic principle of this approach was that, given a binary task for detecting or discriminating a stimulus, a participant could provide four different types of responses. These responses were true positives (TP), seeing a stimulus that was presented, true negatives (TN), not seeing a stimulus that was not presented, false positives (FP), seeing a stimulus that was not presented, and false negatives (FN), not seeing a stimulus that was presented. By combining these responses in a single metric – i.e. $\left(\frac{TP+TN}{TP+TN+FP+FN}\right)$ (for a comprehensive review see Krupinski, 2017) – self-report

errors, biases and response strategies were moderated to a reliable index that could arguably (Yonelinas, 1994) be applied to explore whether detection or discrimination performance were at-chance (e.g. d' = 0; A = .5); meaning in this context that the stimuli were processed subliminally (Erdelyi, 2004). Signal detection theory offered a more reliable alternative to hit rates and a possibly unbiased metric for inferring the unconscious presentation of stimuli; although it must be noted that it did not, by any means, fully resolve the debate for many of the involved parties (see for example, Henley, 1984)[12].

The implementation of unbiased self-report metrics for perception was a first step. Another challenge that the aforementioned debate raised for contemporary psychology was of statistical nature. It was true that mathematical psychology had achieved the provision of a reliable metric for self-reports for assessing with an objective criterion (Erdelyi, 2004) the threshold for chance-level performance and subliminality but the statistical process which was applied for this inference was of debatable validity (Dienes, 2016). The majority of relevant research used (Brooks et al., 20120) – and surprisingly is still to a large extent using (see van der Ploeg et al., 2017) – a one-sample t-test methodology for inferring subliminality. According to this model the reported detection or discrimination performance is compared to absolute chance (e.g. d' = 0; A = .5). In case of non-significant findings, the researchers claim that the reported detection or discrimination performance was not significantly different to

[12] The interested reader can study these further in Dixon and Henley (1980), Ratner (1994) and Erdelyi (2004); among other publications (see van der Ploeg et al., 2017). A series of arguments are presented in these publications. These include the exploration of unconscious processing using an aggregate continuous index (i.e. d', A', A'', A) thar is derived from categorical responses (Yes/No) and results in a categorical distinction; consciousness or unconsciousness (see also Seth et al., 2010). These also include Erdelyi's *paradox of the Goldilocks' interval*; meaning in this context that preconsciousness – if it is indeed a condition that can influence human cognition and behaviour – could only influence our cognition and behaviour so far as a participant is not explicitly asked to report whether they can be conscious of a semantic cue or emotional elicitor (Erdelyi, 2004; p. 75-79).

chance and therefore, that this was evidence for unconscious processing. The problem with this approach is that not significantly different to chance - lack of evidence for the alternate hypothesis - is interpreted as significantly at-chance - evidence for the null. This hurdle can be addressed using Bayesian inference (Dienes, 2016)[13]. Bayesian inference could be used to define the lower and upper bounds for chance-level performance (e.g. Lower Bound = .45 and Higher Bound = .55) and provide a Bayesian factor that would indicate at $B < .33$ that detection performance provided evidence for being within these a-priori criteria (see also Dienes, 2019) to assert subliminality during a presentation.

Contemporary psychological science responded to the aforementioned debate by providing unbiased – or possibly, should we desire to be more accurate, less biased (Tuzlukov, 2013) – self-report metrics for detection and discrimination performance (see Zhang & Mueller, 2005), an objective threshold for inferring unconscious processing (Pessoa et al., 2005) and at-least one reliable method for statistically inferring subliminality (Dienes, 2016; Overgaard, 2017). To these the current thesis contributed the subjective definition of unconsciousness (Chapters One, Two and Three). Using these methods we were able to define with some extent of reliability whether a stimulus was unconscious, and we were able to present truly unconscious stimuli. The subsequent questions are possibly the most important: What happens when a stimulus is truly unconscious and what does the answer mean?

[13] Here it must be noted that an adaptation of the traditional Pearson and Neymar model for p-value significance using two one-tailed t-tests that would compare detection or discrimination performance for being respectively not above and not below chance-level was proposed by Overgaard (2017) to resolve this issue and, therefore, that – against relevant claims (Rescorla, 2015; Wagenmakers et al., 2017) – Bayesian statistics are not the only reliable assessment of chance-level detection and discrimination performance.

The Contribution of the Current Research

In the current research after implementing unbiased metrics for self-reports, Bayesian analysis for subliminality and subjective thresholds for unconscious processing our findings suggested that truly unconscious faces do not elicit changes in physiology and that during the presentation of unconscious faces participants cannot correctly evaluate facial characteristics, such as the valence and the arousal of an emotional face, and also attractiveness and cultural familiarity. We presented two different conditions to illustrate this phenomenon in the first three chapters of the current thesis. The first condition included subjective adjustments per participant and per stimulus type using non-parametric receiver operating characteristics. This condition replicated previous findings that there are interpersonal (Pessoa et al., 2005) and interstimulus (Lähteenmäki et al., 2015) differences in perceptual sensitivity but this is possibly of secondary importance for the current thesis. What is possibly more important is that during this condition in all three experiments that we implemented our methodology we could not report evidence for physiological responses. This finding is important because it is not a Type II error. During a second condition we implemented subjective adjustments per participant and stimulus type using hit-rates. During this condition the same participants responded with higher SCR, HR and force pressure responses to angry, fearful and happy faces as compared to neutral and sad faces. In simple terms, we introduced a method for biased unconsciousness that could be better described as the presentation of brief (typically 25 ms) backward emotional masked faces. In this condition the participants responded in the same way they did in the majority of previous publications in this area (van der Ploeg et al., 2017): with physiological arousal. We also introduced a method for unbiased

unconsciousness and in this condition the same participants did not experience the same effects. In summary, if the reader can excuse the affirmatory tone of the current statement, the contribution of the current research is that we provided evidence that truly unconscious emotional faces do not elicit changes in physiological responses as suggested by the vast majority of previous research in this area (see van der Ploeg et al., 2017), that, therefore, it is unlikely that we possess a subcortical system for the dissemination of peripheral nervous system arousal for the processing of emotion that does not involve or require conscious awareness as suggested by previous reviews (Brooks et al., 2012) and that consciousness can be extended to at-least retrieve preconsciously processed information (Dehaene et al., 2006).

Conclusions

In the current thesis we explored whether unconscious emotional faces could elicit physiological responses and whether facial characteristics, such as attractiveness and cultural familiarity, can be evaluated from masked emotional faces. We included unbiased metrics for detection and discrimination performance, Bayesian analysis for assessing chance-level detection and discrimination performance, separate hits versus miss response analysis for physiological arousal and self-report ratings and introduced a method for subjective per participant and stimulus type adjustments for the presentation of unconscious faces in our research. Our results, throughout the five experimental chapters in the current thesis, suggested that truly unconscious faces do not elicit physiological responses. Additionally, participants could not correctly evaluate facial characteristics, such as attractiveness and cultural familiarity, when they were presented with truly unconscious faces.

A promising result of the current thesis is that, even when the presented stimulus is not a physiological elicitor, if a participant experiences physiological changes during an experimental trial, they report false positives for the conscious experience of a physiologically arousing stimulus. Based on this novel and seminal finding we suggest that emotional consciousness and conscious perception are not equivalent phenomena and that the experience of emotion can influence conscious perception under conditions of visual uncertainty and ambiguity. We emphasize that the experience of consciousness is influenced by physiological meta-cognition, such as post-trial self-assessment of the experienced emotional arousal, and that this mechanism can result in affective miss-perception. This phenomenon should be explored further, particularly in relation to its real-life applications and the extend to which our consciousness of experiencing an emotion can result in the experience of the subject of our conscious perception as an emotional elicitor.

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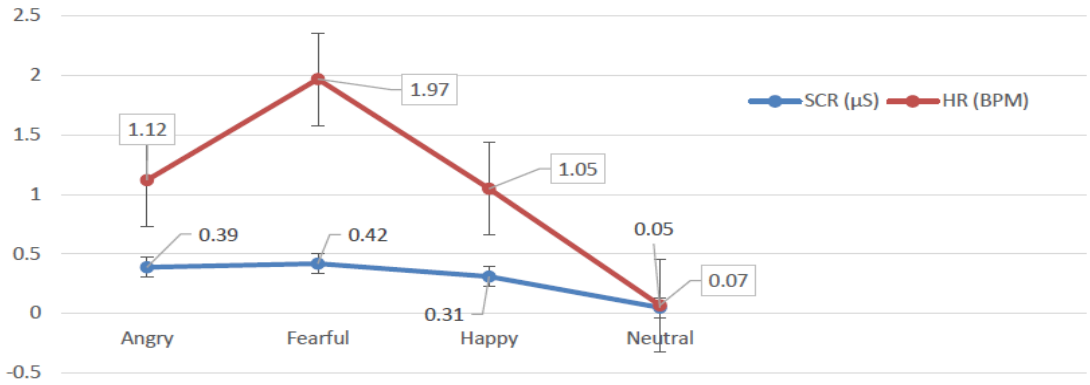
Appendices

Skin Conductance Responses to Masked Emotional Faces Are Modulated by Hit Rate but Not Signal Detection Theory Adjustments for Subjective Differences in the Detection Threshold

Angry (M: 87.82, S.D.: 1.97), fearful (M: 87.91, S.D.: 1.92) and happy (M: 86.61, S.D.: 1.97) that were included in the final selection were not significantly different ($F = 1.41$, $p = .19$) in I.F. (%) scores.

Stimuli Type	Accuracy (%)	Stimuli Type	Intensity (1 - 10)	Stimuli Type	Ambiguity (1 - 10)
Angry	78.67 (8.49)	Angry	6.68 (1.15)	Angry	5.12 (.99)
Fearful	79.74 (8.38)	Fearful	6.89 (1.13)	Fearful	5.45 (.92)
Happy	82.67 (8.66)	Happy	5.91 (1.19)	Happy	5.14 (1)
Neutral	89.05 (8.19)			Neutral	3.55 (1.42)

To explore the effect of emotional stimuli on skin conductance a repeated measures ANOVA was run with independent variable Stimuli Type (angry, fearful, happy and neutral) and dependent variable SCR (maximum deferral). The model reported a significant effect of Stimuli Type ($p < .01$; $\eta^2 = .56$) An additional repeated measures ANOVA was run with independent variable Stimuli Type (angry, fearful, happy and neutral) and dependent variable HR[5] (maximum deferral BPM) scores. The model reported a significant effect of Stimuli Type ($p < .01$; $\eta^2 = .67$).


2.5
2
1.5
1
0.5
0
-0.5
1.12
1.97
1.05
0.07
0.39
0.42
0.31
0.05
Angry
Fearful
Happy
Neutral
SCR (µS)
HR (BPM)

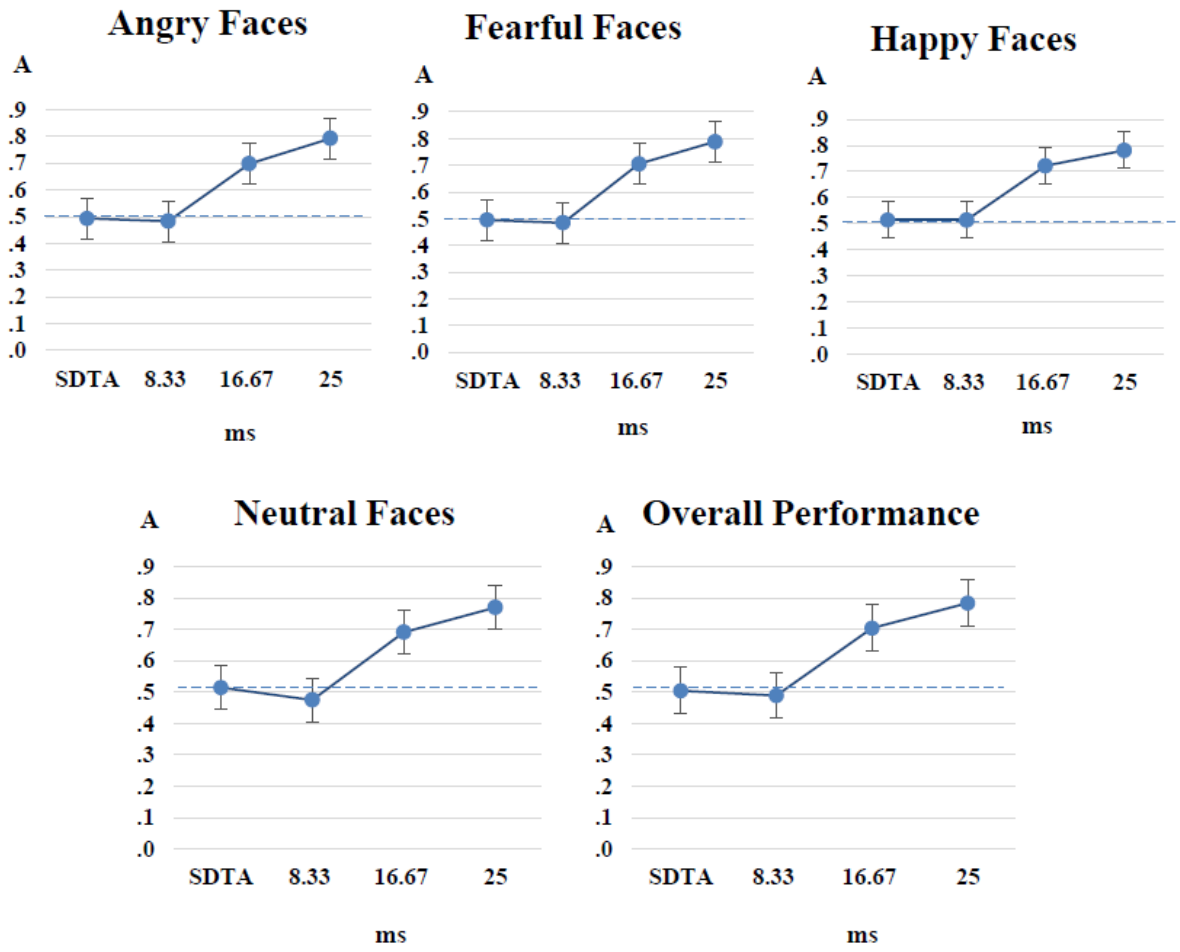
2.1:

Thresholds Hit Rates

Column1	Angry	Column 2	Fearful	Column 5	Happy	Column 8	Neutral	Column 11
	HR Threshold	Performance	HR Threshold	Performance	HR Threshold	Performance	HR Threshold	Performance
1	16	45	16	50	16	55	25	50
2	16	45	16	45	16	50	25	50
3	16	50	16	50	16	50	16	45
4	16	40	16	45	16	55	16	55
5	16	45	16	50	16	50	16	45
6	25	55	16	40	16	45	25	50
7	16	50	16	50	16	50	25	50
8	25	55	25	50	16	55	25	55
9	25	60	16	50	16	55	16	45
10	16	45	16	55	16	40	16	45
11	16	40	16	55	25	50	16	50
12	16	50	16	50	16	50	16	50
13	16	55	16	45	16	45	16	45
14	16	55	16	50	16	55	16	45
15	16	50	16	55	16	45	25	50
16	16	50	16	45	16	45	25	55
17	16	45	16	50	16	50	25	50
18	16	50	16	50	16	55	25	55
19	16	45	16	45	16	55	16	50
20	16	50	16	55	16	50	16	50
21	16	45	16	50	16	50	16	50
22	16	50	16	50	16	50	16	50
23	16	50	16	55	16	45	16	45

2.2:

	Angry		Fearful		Happy		Neutral	
	Threshold (ms)	A	Threshold (ms)	A	Threshold (ms)	A	Threshold (ms)	A
1	8.33 ms	.40	8.33 ms	.44	8.33 ms	.44	8.33 ms	.40
2	8.33 ms	.42	8.33 ms	.45	8.33 ms	.53	8.33 ms	.49
3	8.33 ms	.52	8.33 ms	.52	8.33 ms	.52	8.33 ms	.48
4	8.33 ms	.56	8.33 ms	.53	8.33 ms	.56	8.33 ms	.53
5	8.33 ms	.47	8.33 ms	.44	8.33 ms	.47	8.33 ms	.44
6	8.33 ms	.46	8.33 ms	.46	8.33 ms	.50	8.33 ms	.46
7	8.33 ms	.52	8.33 ms	.45	8.33 ms	.52	8.33 ms	.45
8	8.33 ms	.42	8.33 ms	.45	8.33 ms	.49	8.33 ms	.42
9	8.33 ms	.46	8.33 ms	.46	8.33 ms	.54	8.33 ms	.46
10	8.33 ms	.44	8.33 ms	.47	8.33 ms	.51	8.33 ms	.51
11	16.67 ms	.66	8.33 ms	.45	8.33 ms	.48	8.33 ms	.48
12	8.33 ms	.53	8.33 ms	.53	8.33 ms	.56	8.33 ms	.49
13	8.33 ms	.57	8.33 ms	.50	8.33 ms	.57	8.33 ms	.54
14	8.33 ms	.53	8.33 ms	.53	8.33 ms	.53	8.33 ms	.49
15	8.33 ms	.50	8.33 ms	.50	8.33 ms	.57	8.33 ms	.54
16	8.33 ms	.53	8.33 ms	.53	8.33 ms	.56	8.33 ms	.49
17	8.33 ms	.50	8.33 ms	.57	8.33 ms	.54	8.33 ms	.50
18	8.33 ms	.53	8.33 ms	.53	8.33 ms	.56	8.33 ms	.53
19	8.33 ms	.54	8.33 ms	.46	8.33 ms	.54	8.33 ms	.50
20	8.33 ms	.44	8.33 ms	.44	8.33 ms	.44	8.33 ms	.44
21	8.33 ms	.42	8.33 ms	.49	8.33 ms	.49	8.33 ms	.42
22	8.33 ms	.54	8.33 ms	.46	8.33 ms	.46	16.67 ms	.70
23	8.33 ms	.41	16.67 ms	.72	8.33 ms	.45	8.33 ms	.45
24	8.33 ms	.46	8.33 ms	.46	8.33 ms	.50	8.33 ms	.43


Angry Faces
Fearful Faces
Happy Faces
Neutral Faces
Overall Performance
A
.9
.8
.7
.6
.5
.4
.3
.2
.1
.0
SDTA
8.33
16.67
25
ms

3.1 Factorial ANOVA Analysis

Descriptive Statistics

	Mean	Std. Deviation	N
Angry	.0336	.01508	24
Fear	.0448	.02161	24
Happy	.0177	.00738	24
Neutral	.0104	.00675	24
Bubble	.0085	.00316	24
AngryA	.0056	.00517	24
FearA	.0055	.00518	24
HappyA	.0046	.00182	24
NeutralA	.0036	.00257	24
BubbleA	.0050	.00253	24

Mauchly's Test of Sphericity[a]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
Adjustment	1.000	.000	0	.	1.000	1.000	1.000
Stimuli_Type	.071	56.714	9	.000	.483	.527	.250
Adjustment * Stimuli_Type	.061	59.812	9	.000	.411	.438	.250

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. Design: Intercept

Within Subjects Design: Adjustment + Stimuli_Type + Adjustment * Stimuli_Type

b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Adjustment	Sphericity Assumed	.020	1	.020	98.611	.000	.811
	Greenhouse-Geisser	.020	1.000	.020	98.611	.000	.811
	Huynh-Feldt	.020	1.000	.020	98.611	.000	.811
	Lower-bound	.020	1.000	.020	98.611	.000	.811
Error(Adjustment)	Sphericity Assumed	.005	23	.000			
	Greenhouse-Geisser	.005	23.000	.000			
	Huynh-Feldt	.005	23.000	.000			
	Lower-bound	.005	23.000	.000			
Stimuli_Type	Sphericity Assumed	.013	4	.003	50.613	.000	.688
	Greenhouse-Geisser	.013	1.933	.007	50.613	.000	.688
	Huynh-Feldt	.013	2.107	.006	50.613	.000	.688
	Lower-bound	.013	1.000	.013	50.613	.000	.688

Error(Stimuli_Type)	Sphericity Assumed	.006	92	6.313E-005			
	Greenhouse-Geisser	.006	44.453	.000			
	Huynh-Feldt	.006	48.457	.000			
	Lower-bound	.006	23.000	.000			
Adjustment * Stimuli_Type	Sphericity Assumed	.011	4	.003	52.407	.000	.695
	Greenhouse-Geisser	.011	1.643	.007	52.407	.000	.695
	Huynh-Feldt	.011	1.753	.006	52.407	.000	.695
	Lower-bound	.011	1.000	.011	52.407	.000	.695
Error(Adjustment*Stimuli_Type)	Sphericity Assumed	.005	92	5.233E-005			
	Greenhouse-Geisser	.005	37.792	.000			
	Huynh-Feldt	.005	40.315	.000			
	Lower-bound	.005	23.000	.000			

Pairwise Comparisons

Measure: MEASURE_1

(I) Adjustment	(J) Adjustment	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
1	2	.018*	.002	.000	.014	.022
2	1	-.018*	.002	.000	-.022	-.014

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Bonferroni.

Target meta-awareness is a necessary condition for physiological responses to masked emotional faces: Evidence from combined skin conductance and heart rate assessment

Appendix A

A.1. Stimuli pre-selection

See Fig. 4.

	Session					
	A (type): Mean (S.D.)		B (experience) Mean (S.D.)			
Accuracy (%)	Group AB	Group BA	Group AB	Group BA	Overall Session A	Overall Session B
Angry*	71.97 (9.97)	80.55 (5.27)	46.35 (11.25)	44.44 (8.07)	76.47 (8.79)	45 .29 (9.43)
Fearful	75 (8.01)	77.22 (6.66)	53.12 (7.98)	57.22 (11.48)	76.17 (7.18)	55.29 (9.91)
Disgusted	73.12 (10.66)	67.77 (8.7)	45 (8.45)	40.55 (7.26)	70.29 (9.75)	42.64 (7.92)
Happy	81.25 (9.54)	81.11 (10.24)	60 (11.95)	66.66 (12.74)	81.17 (9.6)	63.52 (12.47)
Sad	85.62 (5.62)	80 (9.35)	54.37 (8.63)	57.55 (7.94)	82.64 (8.12)	56.17 (8.2)
Neutral	88.75 (4.43)	85.55 (8.45)	66.9 (4.58)	70 (16.95)	87.05 (6.85)	68.52 (12.47)
Intensity (1 - 10)						
Angry	6.3 (.89)	6.02 (1.32)	7.35 (1.09)	7.13 (1.69)	6.15 (1.11)	7.23 (1.4)
Fearful	5.91 (.46)	5.48 (,63)	7.06 (.35)	6.71 (1.14)	5.68 (.58)	6.88 (.86)
Disgusted	5.46 (.34)	5.88 (.67)	6.43 (.26)	6.92 (1.01)	5.68 (.56)	6.69 (.77)
Happy	5.96 (.59)	5.87 (.45)	7.51 (1.01)	7.42 (.64)	5.91 (.5)	7.46 (.81)
Sad	4.88 (,48)	4.81 (.59)	5.06 (1.15)	5.26 (.77)	4.84 (.52)	5.16 (.94)
Ambiguity (1 - 10)**						
Angry	5.62 (1.02)	5.66 (1.34)	4.63 (1.29)	3.5 (1.07)	5.64 (1.16)	4.03 (1.28)
Fearful	5.24 (1.13)	5.16 (.81)	4.19 (.73)	4.05 (1)	5.19 (.94)	4.12 (.86)
Disgusted	6.23 (.58)	5.29 (.51)	4.98 (.85)	4.49 (.32)	5.74 (.71)	4.72 (.65)
Happy	5.28 (.48)	5.2 (.56)	3.69 (.66)	3.61 (.55)	5.24 (.51)	3.64 (.59)
Sad	5.61 (.58)	5.52 (.48)	3.79 (.75)	3.96 (.65)	5.56 (.51)	3.88 (.68)
Neutral	4.38 (.6)	4.93 (.84)	2.93 (.96)	3.26 (.96)	4.67 (.77)	3.1 (.94)
Accuracy Analysis (p values)						
	(AT Task)					
(AE Task)	Angry	Fearful	Disgusted	Happy	Sad	Neutral
Angry*	.00***	.138	.365	.016	.005	.00
Fearful	.	.00***	.003	.65	1	.007
Disgusted		.	.00***	.003	.00	.00
Happy		.	.	.00***	1	1
Sad	.				.00***	.001
Neutral		.	.		.	.00***

Fig. 4. Accuracy, Intensity and Ambiguity Ratings in respect to emotional category for session A (stimuli type) and B (current mood) per participant group; AB (type first), BA (experience first) and overall. In the bottom part Bonferonni **adjusted** ($p \leq .05$) Post Hoc analysis for overall accuracy. Green items signify higher scores for left column; red items for top row. *BA > AB, AE order effect; **AB > BA, AT order effect. ***Same stimuli are compared between tasks (task/type interaction); Bonferonni **corrected** ($p \leq .01$) paired samples *t*-test. Left column refers to **AE task**, top row refers to **AT task**. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

A.2. Percentage metric

$$IF\ (\%) = \left(\left(\frac{(10-\text{Amb.}) + (\text{Int.})}{2}\right)*50\right) + \left(\left(\frac{\text{SCR Maximum Deferral}}{\text{Max}\{\text{SCR Maximum Deferral Stimuli Type}\}}\right)*25\right) + \left(\left(\frac{\text{HR Maximum Deferral}}{\text{Max}\{\text{HR Maximum Deferral Stimuli Type}\}}\right)*25\right)$$

Ambiguity using a one (not at all) to ten (extremely) scale. This item is reversed (10 – x).

Intensity using a one (not at all) to ten (extremely) scale.

Highest unambiguous increase of a phasic skin conductance response three seconds post stimulus offset with respect to pretarget baseline for the specific stimuli.

The score for the stimuli with the highest unambiguous increase in phasic skin conductance response three seconds post stimulus offset with respect to pretarget baseline for the specific emotional stimuli category.

Highest unambiguous increase of a phasic heart rate response four seconds post stimulus offset with respect to pretarget baseline for the specific stimuli.

The score for the stimuli with the highest unambiguous increase in phasic heart rate four seconds post stimulus offset with respect to pretarget baseline for the specific emotional stimuli category.

Appendix B

B.1. Visual contrast

Gender

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Male	8	47.1	47.1	47.1
	Female	9	52.9	52.9	100.0
	Total	17	100.0	100.0	

Descriptive Statistics

	N	Range	Minimum	Maximum	Sum	Mean		Std. Deviation	Variance
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Statistic
Face	17	3.75	1.10	4.85	38.05	22382	0.26725	1.10192	1.214
NoFace	17	3.80	1.15	4.95	37.35	21971	0.26211	1.08072	1.168
Angry	17	4.00	1.20	5.20	38.40	22588	0.28787	1.18694	1.409
Fear	17	4.00	1.20	5.20	40.40	23765	0.30384	1.25276	1.569
Sad	17	3.80	1.00	4.80	37.80	22235	0.26172	1.07908	1.164
Neutral	17	3.20	1.00	4.20	35.00	20588	0.23374	0.96375	0.929
Valid N (listwise)	17								

Appendix C

C.1. Ambiguity descriptives

Descriptive Statistics

	Mean	Std. Deviation	N
Unsure_vs_Possibly	3.8000	1.52128	15
Unsure_vs_Most_Likely	2.4667	0.74322	15
Unsure_vs_Definetely	2.4000	0.82808	15

Possibly_vs_Most_Likely	6.8000	0.94112	15
Possibly_vs_Definetely	3.6000	1.63881	15
Definetely_vs_Most_Likely	4.2000	1.08233	15

.2. Ambiguity pairwise comparisons

Pairwise Comparisons

Measure: MEASURE_1

(I) factor1	(J) factor1	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
1	2	1.333*	0.333	0.020	0.157	2.510
	3	1.400	0.423	0.078	−0.094	2.894
	4	−3.000*	0.338	0.000	−4.193	−1.807
	5	0.200	0.698	1.000	−2.265	2.665
	6	−0.400	0.423	1.000	−1.894	1.094
2	1	−1.333*	0.333	0.020	−2.510	−0.157
	3	0.067	0.284	1.000	−0.936	1.069
	4	−4.333*	0.252	0.000	−5.223	−3.444
	5	−1.133	0.477	0.484	−2.816	0.549
	6	−1.733*	0.316	0.001	−2.848	−0.619
3	1	−1.400	0.423	0.078	−2.894	0.094
	2	−.067	0.284	1.000	−1.069	0.936
	4	−4.400*	0.289	0.000	−5.422	−3.378
	5	−1.200	0.509	0.502	−2.996	0.596
	6	−1.800*	0.312	0.001	−2.900	−0.700
4	1	3.000*	0.338	0.000	1.807	4.193
	2	4.333*	0.252	0.000	3.444	5.223
	3	4.400*	0.289	0.000	3.378	5.422
	5	3.200*	0.595	0.001	1.099	5.301
	6	2.600*	0.335	0.000	1.417	3.783
5	1	−0.200	0.698	1.000	−2.665	2.265
	2	1.133	0.477	0.484	−0.549	2.816
	3	1.200	0.509	0.502	−0.596	2.996
	4	−3.200*	0.595	0.001	−5.301	−1.099
	6	−0.600	0.505	1.000	−2.383	1.183
6	1	0.400	0.423	1.000	−1.094	1.894
	2	1.733*	0.316	0.001	0.619	2.848
	3	1.800*	0.312	0.001	0.700	2.900
	4	−2.600*	0.335	0.000	−3.783	−1.417
	5	0.600	0.505	1.000	−1.183	2.383

ppendix D

.1. Comparison between hits and misses per stimuli type

Descriptive Statistics

	Mean	Std. Deviation	N
TPAngry	0.0527	0.04005	24
FNAngry	0.0124	0.01632	24
TPFear	0.0641	0.03669	24

FNFear	0.0094	0.01443	24
TPSad	0.0154	0.01368	24
FNSad	0.0109	0.01929	24
TPNeutral	0.0093	0.01359	24
FNNeutral	0.0120	0.01444	24
TNNoFace	0.0094	0.00673	24
FPNoFace	0.0159	0.01576	24

Pairwise Comparisons

Measure: MEASURE_1

(I) Stimuli_Type	(J) Stimuli_Type	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
1	2	−0.004	0.004	1.000	−0.016	0.008
	3	0.019*	0.005	0.009	0.004	0.035
	4	0.022*	0.005	0.002	0.007	0.037
	5	0.020*	0.005	0.003	0.005	0.035
2	1	0.004	0.004	1.000	−0.008	0.016
	3	0.024*	0.004	0.000	0.011	0.036
	4	0.026*	0.004	0.000	0.013	0.040
	5	0.024*	0.004	0.000	0.013	0.035
3	1	−0.019*	0.005	0.009	−0.035	−0.004
	2	−0.024*	0.004	0.000	−0.036	−0.011
	4	0.003	0.002	1.000	−0.004	0.009
	5	0.001	0.003	1.000	−0.009	0.010
4	1	−0.022*	0.005	0.002	−0.037	−0.007
	2	−0.026*	0.004	0.000	−0.040	−0.013
	3	−0.003	0.002	1.000	−0.009	0.004
	5	−0.002	0.002	1.000	−0.009	0.005
5	1	−0.020*	0.005	0.003	−0.035	−0.005
	2	−0.024*	0.004	0.000	−0.035	−0.013
	3	−0.001	0.003	1.000	−0.010	0.009
	4	0.002	0.002	1.000	−0.005	0.009

Based on estimated marginal means

* The mean difference is significant at the 0.05 level.

[b] Adjustment for multiple comparisons: Bonferroni.

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	TPAngry - TPSad	0.03731	0.04129	0.00843	0.01987	0.05474	4.427	23	0.000
Pair 2	TPAngry - TPNeutral	0.04345	0.03826	0.00781	0.02730	0.05961	5.564	23	0.000
Pair 3	TPAngry - TNNoFace	0.04336	0.04021	0.00821	0.02638	0.06034	5.283	23	0.000
Pair 4	TPFear - TPSad	0.04872	0.03821	0.00780	0.03258	0.06485	6.246	23	0.000
Pair 5	TPFear - TPNeutral	0.05486	0.03604	0.00736	0.03964	0.07008	7.457	23	0.000
Pair 6	TPFear - TNNoFace	0.05477	0.03843	0.00784	0.03855	0.07100	6.983	23	0.000

Appendix E

See Fig. 5.

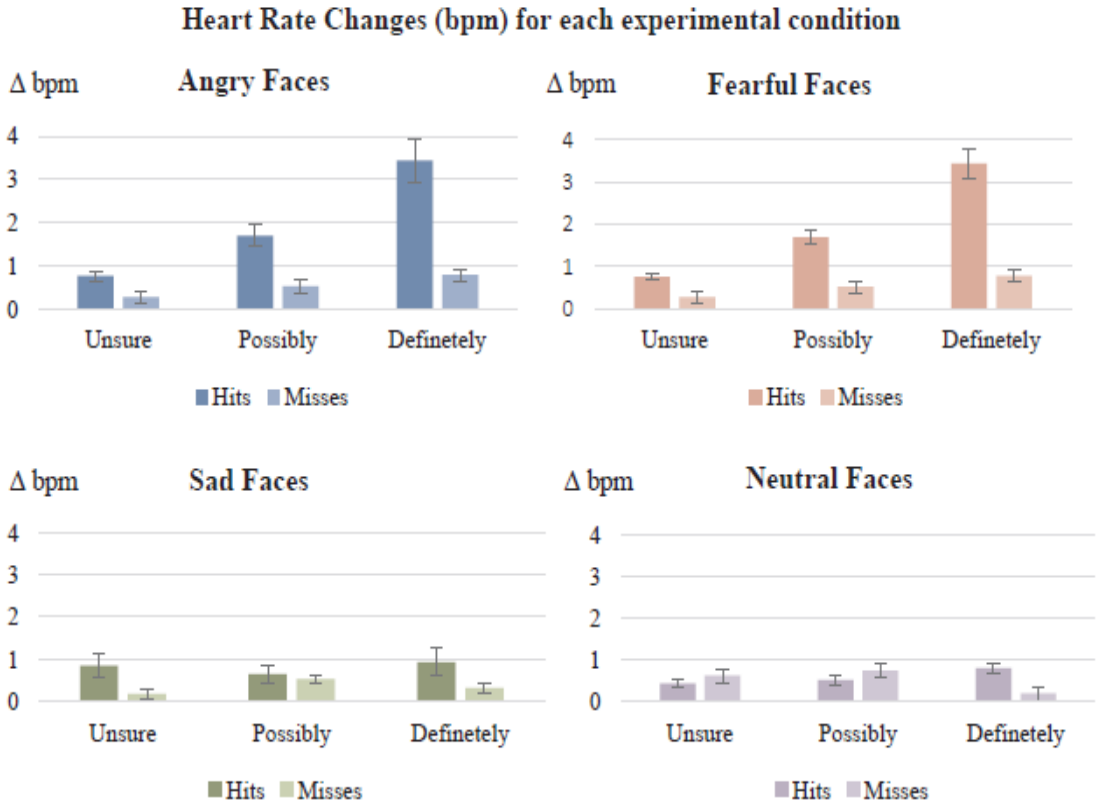


Fig. 5. Heart rate changes in beats per minute for different stimuli types arranged for signal detection (hits, misses, correct rejects, false alarms) and detection confidence replies (unsure, possibly, definitely). Error bars how ± 1 standard error of the mean.

Appendix F

F.1. Trends for false alarms

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	TNNoFaceHR	0.4988	24	0.49545	0.10113
	FPNoFaceHR	0.9478	24	1.36430	0.27849
Pair 2	TNNoFace	0.0094	24	0.00673	0.00137
	FPNoFace	0.0159	24	0.01576	0.00322

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	TNNoFaceHR - FPNoFaceHR	−0.44897	1.14660	0.23405	−0.93313	0.03520	−1.918	23	0.068
Pair 2	TNNoFace - FPNoFace	−0.00654	0.01772	0.00362	−0.01402	0.00094	−1.808	23	0.084

Appendix G. Supplementary material

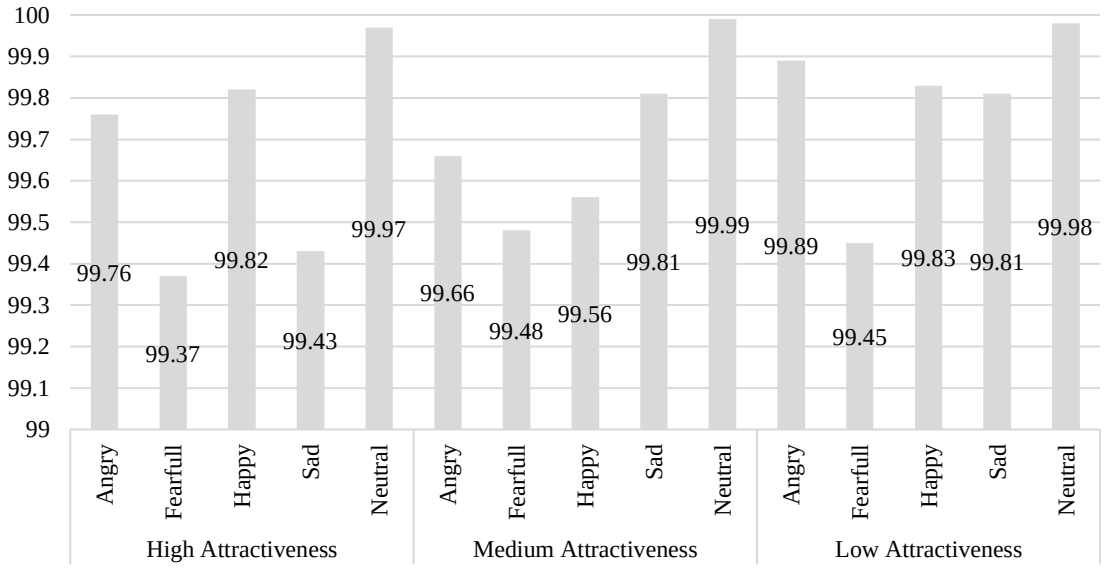
Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.concog.2017.10.013.

I can see you, I can feel it; and vice-versa: Physiological and Facial-Expressive Responses to Masked Faces Subjectively Adjusted for Emotional Discrimination

Appendices online at https://osf.io/xdjy8/

Beauty *is* in the eye of the Beholder: The Appraisal of Facial Attractiveness requires Conscious Awareness

1.1: Noldus Emotional Recognition Certainty Scores (%)



2.1: Gender Effects

In accordance with previous research that used frequentist statistics (Olson & Marshuetz, 2005) we were not able to report actor or participant related gender effects in our analysis. This is a counter-intuitive and yet recurrently reported finding in the current research area (Little et al., 2011). Future research could benefit from an assessment of the possible effects of facial cropping techniques (Lyons et al., 2000) and the possible role of bodily characteristics (Barber, 2005; Winkler & Rhodes, 2005) in exploring gender-specific differences in attractiveness ratings.

3.1: Bayesian Analysis for Attractiveness in Stage one for Gender

A Bayesian analysis (Dienes, 2015) with corrected degrees of freedom (df < 30; $SE = (SE\ x\ \left(1\ +\ \left(\frac{20}{dfxdf}\right)\right)$) (Berry, 1996) revealed that for attractiveness ratings in stage one male (S.E. = .07; B = .09) and female (S.E. = .07; B = .09) participant responses were significantly within the predefined uniform credible intervals (4 < M. > 6).

4.1 Bayesian Analysis of Emotionality in Stage Two between Appearance Types

A Bayesian analysis (Dienes, 2015) with corrected degrees of freedom (df < 30; $SE = (SE\ x\ \left(1\ +\ \left(\frac{20}{dfxdf}\right)\right)$) (Berry, 1996) revealed that in stage two emotionality ratings for high-attractiveness faces (S.E. = .05; B = .08), medium-attractiveness faces (S.E. = .04; B = .06) and low-attractiveness faces (S.E. = .04; B = .07) were significantly within the predefined uniform credible intervals (5 > M. < 7).

5.1: Bayesian analysis for Emotionality in Stage Two for Gender

A Bayesian analysis (Dienes, 2015) with corrected degrees of freedom (df < 30; $SE = (SE\ x\ \left(1\ +\ \left(\frac{20}{dfxdf}\right)\right)$) (Berry, 1996) revealed that in stage two emotionality ratings for male (S.E. = .03; B = .07) and female (S.E. = .03; B = .07) were significantly within the predefined credible intervals (5 > M. < 7).

6.1: Bayesian Analysis in Stage Three for Visual Contrast

A Bayesian analysis (Dienes, 2015) with corrected degrees of freedom (df < 30; $SE = (SE\ x\ \left(1\ +\ \left(\frac{20}{dfxdf}\right)\right)$) (Berry, 1996) revealed that non-facial blurs (S.E. = .13; B =

.16) and facial stimuli (S.E. = .06; B = .08) were significantly within the predefined uniform credible intervals (4 > M. < 6).

7.1: Happy Faces and Emotional Recognition Performance

The current study includes a counter-literature and confounding finding that in light of the complexity and exploratory nature of the current manuscript – and in communication with the editorship and the allocated reviewers – was not included in the final version of the manuscript. The primary author felt that even as an addendum or an appendix note – and against journal feedback – this findings should be at-least acknowledged. Happy low, medium and high attractiveness faces were discriminated less accurately than other attractiveness to emotional types. This finding could be due to the valence imbalance in the design that included three negative-valence expressions and one positive-valence expression; possibly resulting in higher within-negative valence recognition acuity via stimuli repetition. It is further possible that in order to make accurate judgements concerning both the attractiveness and the emotional expression of the presented faces the participants addressed them as separate characteristics and the argument could be made that only happiness and high attractiveness were registered within a single cognitive framework of positive valence and processed less distinctly than incongruent, negative emotional and positive-high attractiveness, social signals; this finding, nevertheless, would not explain why low and mid attractiveness happy faces were also discriminated less accurately and the author would suggest that from an Occam's razor perspective the valence imbalance would be a more likely cause of this counter-literature effect. In light of these, this finding should be further

explored by subsequent research and once more – despite the provided feedback – the author considers that it is a possibly important and a worth-exploring aspect of the current study.

Responses to Cross-Cultural Dialects of Emotion with and without Conscious Awareness

1.1: Photo stage

Participants were asked to come to the session without make-up, remove facial items (e.g. earrings, piercings, glasses etc.) and pull their hair back using pins provided by the researchers. Participants were asked to sit on a chair, keeping a straight posture and upright head position and facing the camera. The cameras used were subject to the availability of each institution with the restriction of at least 1080 pixels. To be consistent with prior research (Gur et al., 2002), the cameras –with flash deactivated – were set two meters away from the actors. Photos were taken with similar backgrounds (i.e., white walls) and similar light conditions across the involved institutions. All experimenters were trained to watch out for shadows from around the actor's nose and shadows on the background from the actor's head. Highlights from participants' forehead and reflections in their eyes were also prevented. Several photos for each expression (> 3) were taken for each trial to ensure that onset, offset and holding of an emotion would not influence expressiveness. For the freely-expressed condition participants could take as much time as they wanted to prepare the emotion and then indicate when they were ready to express the emotion as freely as in a social interaction with someone from their own cultural background (Elfenbein et al., 2007).

2.1: Action Units

https://www.paulekman.com/product-category/facs/

3.1: Descriptive Statistics for CDQ and ERQ facets in Stage One

	Mean				S.D.			
	Britain	N.Z.	Chile	Singapore	Britain	N.Z.	Chile	Singapore
Power Distance	48.41	47.64	48.2	46.92	10.44	13.69	11.93	7.72
Individualism	62.76	66.91	65.4	59.08	11.47	11.72	6.9	15.36
Masculinity	46.48	44	41.2	52	8.65	9.72	9.09	18.03
Uncertainty-Avoidance	72.14	71.45	67.6	53.23	9.23	8.49	9.53	10.72
Long-Term Orientation	50.21	50.73	51.6	52.46	5.19	10.57	11.31	8.26
Cognitive Re-appraisal	28.38	31.55	31.6	32.11	4.08	7.26	5.63	5.18
Emotional Suppression	10.97	13.55	10.5	16.11	2.85	5.35	4.51	3.56

Descriptive Statistics for Stage One. Cultural dimensions are adapted in percentage units.

4.1: Non-Facial Blurs

Aims. Study Two was designed to include a 116.67 ms black and white pattern mask and 33.33 ms non-facial blurs as a signal detection control condition for cross-cultural faces (Bachmann & Francis, 2013). The aim of the current stage was to test if brief non-facial blurs had different visual contrast in respect to the back and white pattern mask when compared to the facial stimuli (Gorea & Tyler, 1986).

Participants: Fifteen participants (eight females) that were not part of the other experimental stages volunteered to participate in the experiment. All participants reported normal or corrected-to-normal vision. Participants were subject to the same inclusion criteria and questionnaire assessment as Study One: Stage Two. No participants were excluded. The mean age for this stage was 32.73 (S.D. = 7.37). All participants gave informed consent to participate in the study. The experiment was approved by the local Ethics Committee of the School of Psychology.

Stimuli and Procedures: Due to ethics approval time-restrictions a total of one hundred and eight faces were presented during this stage. The presented faces were selected from Stage two. Each presentation run was pseudorandomised in Python and assigned fifty-four faces per duration and emotional type, thirty-six faces per emotion (fearful, sad and neutral) and twenty-seven faces per nationality (Britain, New Zealand, Chile and Singapore). Each actor identity was repeated three times during each run to attain an equal number of male and female faces (n = 54). One hundred and eight non-facial blurs that were generated from black and white pattern stimuli, scrambled using pseudo-randomised pixel permutation and averaged for luminescence (SHINE, MATLAB Toolbox) were also presented. Participants were informed in writing prior to the experiment that a brief facial or non-facial stimulus was going to be presented in each trial followed by a black and white pattern. Participants were asked to decide whether the stimulus and the pattern differed significantly in luminescence and rate this contrast from one (not intense at all) to ten (very intense). Participants were asked to respond in the consent form whether they understood the instructions (yes or no). All participants responded positively.

The experimental trial started with a fixation cross for three seconds (± one second). After the fixation cross, a single non-facial blur or a single freely-expressed or instructed face from Britain or New Zealand or Chile or Singapore showing a fearful or sad or neutral expression was presented at fixation for 33.33 ms; order randomised. The target was immediately followed by a black and white pattern mask for 116.67 ms. After the presentation of the black and white pattern mask, participants were shown a blank screen for two seconds. After the blank screen, participants were asked by an on-screen message “How

would you rate your experience of subjective visual contrast during the presentation? (1: not intense at all to 10: very intense)". A two second blank screen interval was presented before the next trial.

Apparatus and Presentation Testing. The stimuli were presented in an HD Lenovo monitor adjusted at 60 Hz. The presentation was programmed in the coder and builder components of Psychopy version 1.85.3. Brief stimuli (33.33 ms) were assessed using camera recoding and a Python developed dropped-frames script report. No instances of dropped frames were reported.

Analysis and Discussion. To test if the non-facial blurs had significantly different ratings for subjective experience of contrast than the presented faces in respect to the pattern mask a paired samples t-test was run. Subjective experience of contrast for the non-facial blurs (M. = 5.13, S.D. = .19) was not rated significantly higher than contrast in the face condition (M. = 5.11, S.D. = .23; t (14) = .44, p = .66; d = .01; β = .03) suggesting that differences of visual contrast between the non-facial blurs and the presented faces, and the pattern mask would not artefactually impact signal detection performance (Bachmann & Francis, 2013) in subsequent experimental stages

5.1: Distance Analysis Overall CDQ Scores

Post-Hoc Comparisons

Measure: MEASURE_1

(I) Country_of_Origin	(J) Country_of_Origin	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
British Actors	N.Z. Actors	-3.240*	.369	.000	-4.412	-2.068
	Chilean Actors	.380	.254	1.000	-.427	1.187
	Singapore Actors	-3.930*	.313	.000	-4.922	-2.938
	British Participants	-1.000	.372	.145	-2.180	.180
N.Z Actors	British Actors	3.240*	.369	.000	2.068	4.412
	Chilean Actors	3.620*	.413	.000	2.309	4.931
	Singapore Actors	-.690	.293	.292	-1.618	.238
	British Participants	2.240*	.372	.000	1.060	3.420
Chilean Actors	British Actors	-.380	.254	1.000	-1.187	.427
	N.Z Actors	-3.620*	.413	.000	-4.931	-2.309
	Singapore Actors	-4.310*	.367	.000	-5.475	-3.145
	British Participants	-1.380*	.284	.001	-2.282	-.478
Singapore Actors	British Actors	3.930*	.313	.000	2.938	4.922
	N.Z Actors	.690	.293	.292	-.238	1.618
	Chilean Actors	4.310*	.367	.000	3.145	5.475
	British Participants	2.930*	.333	.000	1.874	3.986
British Participants	British Actors	1.000	.372	.145	-.180	2.180
	N.Z Actors	-2.240*	.372	.000	-3.420	-1.060
	Chilean Actors	1.380*	.284	.001	.478	2.282
	Singapore Actors	-2.930*	.333	.000	-3.986	-1.874

5.2 Distance Analysis Emotional Suppression Facet; ERQ

Post-Hoc Comparisons

Measure: MEASURE_1

(I) Country_of_Origin	(J) Country_of_Origin	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
British Actors	N.Z Actors	-3.278	1.762	.802	-8.955	2.399

N.Z Actors	Chilean Actors	.167	1.422	1.000	-4.415	4.748
	Singapore Actors	-5.167*	1.094	.002	-8.693	-1.640
	British Participants	.222	.945	1.000	-2.822	3.267
	British Actors	3.278	1.762	.802	-2.399	8.955
	Chilean Actors	3.444	1.530	.379	-1.486	8.375
	Singapore Actors	-1.889	1.590	1.000	-7.013	3.235
	British Participants	3.500	1.344	.185	-.830	7.830
Chilean Actors	British Actors	-.167	1.422	1.000	-4.748	4.415
	N.Z Actors	-3.444	1.530	.379	-8.375	1.486
	Singapore Actors	-5.333*	1.160	.003	-9.072	-1.594
	British Participants	.056	1.277	1.000	-4.059	4.170
Singapore Actors	British Actors	5.167*	1.094	.002	1.640	8.693
	N.Z Actors	1.889	1.590	1.000	-3.235	7.013
	Chilean Actors	5.333*	1.160	.003	1.594	9.072
	British Participants	5.389*	1.029	.001	2.072	8.706
British Participants	British Actors	-.222	.945	1.000	-3.267	2.822
	N.Z Actors	-3.500	1.344	.185	-7.830	.830
	Chilean Actors	-.056	1.277	1.000	-4.170	4.059
	Singapore Actors	-5.389*	1.029	.001	-8.706	-2.072

6.1 Analysis of subliminal perception for study two using previous methods

To test the hypothesis that cultural familiarity can be processed even in briefly presented and masked stimuli, we ran a one-sample t-test against absolute chance (50%) for recognition performance (hit rates) 33.33 ms faces. Faces presented for 33.33 ms (M. = 50.67%, S.D. = 10.49%) were not significantly different to chance (t (20) = .29, p = .77; d = .06), although they did not report significance for chance level processing for signal detection theory measures (M. (Di) = .66, S.E. (Di) = .02; M. (De) = .59, S.E. (De) = .03; B > 3). An analysis of variance was run for 33.33 ms faces with independent variable Country of Origin (Britain, New Zealand, Chile and Singapore) and dependent variable cultural ratings. The analysis was significant (F (1.389, 27.74) = 91.17, p < .001; η^2 = .82; Greenhouse- Geisser

corrected; $P_{(1-\beta)}$ = .99) suggesting that there were significant differences between different cultures. Further Bonferonni corrected pairwise comparisons revealed that British faces were rated higher for familiarity (M. = 6.04, S.D. = .62) than faces from New Zealand (M. = 4.88, S.D. = .31; p < .001; d = 2.37), Chile (M. = 4.34, S.D. = .23; p < .001; d = 3.58) and Singapore (M. = 4.01, S.D. = .4; p < .001; d = 3.89). The results would initially suggest that cultural familiarity was processed subliminally.

6.2 Cultural Familiarity Ratings per Experimental Condition

		Mean				S.D.			
		Britain	N.Z.	Chile	Singapore	Britain	N.Z.	Chile	Singapore
Freely-Expressed	Fear	5.61	4.81	5.04	3.86	.65	.45	.39	.71
	Sadness	5.66	4.81	4.93	3.9	.54	.52	.63	.55
	Neutral	5.36	4.89	4.83	3.59	.8	.57	.47	.66
Instructed	Fear	6.5	4.78	5	3.79	.85	.58	.52	.73
	Sadness	6.22	4.75	4.86	3.74	.92	.74	.61	.67
	Neutral	6.54	4.84	4.79	3.57	.92	.34	.64	.97

Mean and standard deviation for each condition during Study Two.

7.1: The assessment of Subliminality

Previous research has suggested that facial characteristics such as emotion (Adolphs, 2002), racial background (Eberhardt et al., 2004; Smith, Dijksterhuis & Chaiken, 2008), attractiveness (Olson & Marshuetz, 2005; Hung, Nieh & Hsieh, 2016) and sexual cues (Gillath et al., 2008) can be processed automatically and without conscious awareness. These characteristics are suggested to elicit automatic processing because they confer evolutionary important survival (Liddell et al., 2005) and sociobiological value (Glascher & Adolps,

2003). Subsequent research (Pessoa & Adolphs, 2010; Lähteenmäki, Koivisto & Nummenmaa, 2015; Pessoa, 2017) has suggested that the application of unbiased signal detection theory measures for the assessment of detection and recognition performance (Zhang & Mueller, 2005), Bayesian analysis of chance-level significance (Dienes, 2015), and separate analysis for hits and misses for detection and recognition responses (Pessoa, 2005) should be implemented to assess these effects. In the current study we used this paradigm for the assessment of subliminality.

8.1 Sensitivity Index A adapted for multiple forced choice comparisons

$$\frac{\sum_{i=1}^{n} xi(\text{hits}+.001)}{\sum_{i=1}^{n} xi\left(\frac{\text{miss}+.001}{(\text{fixed choices}-1)}\right)} = x, \text{if } x > 1 \Rightarrow \text{A} = \left(.5 - \left(\frac{.5}{x}\right)\right) + .5; \text{if } x < 1 > .5 \Rightarrow \text{A} = (.5 - (.5 \text{ x } x) - .5; \text{ if x} < .5 \Rightarrow y = (.5 + x), \text{A} = (.5 - (.5 \text{ x } y)) - .5)$$

=IF(AND(AN3<=0.5,AO3>=0.5),3/4+(AO3-AN3)/4AN3*(1AO3),IF(AND(AN3<=AO3,AO3<0.5),3/4+(AO3-AN3)/4-AN3/(4*AO3),IF(AND(AN3>0.5,AO3>AN3),3/4+(AO3-AN3)/4-(1-AO3)/(4*(1-AN3)),0)))

9.1: Mean and S.D. Action Unit Recognition Scores in Freely-Expressed Faces (%)

	Britain		New Zealand		Chile		Singapore	
	Fear	Sad	Fear	Sad	Fear	Sad	Fear	Sad
1.Inner Brow Raiser	82.67 (8.91)	25.26 (11.17)	65.56 (17.81)	17.65 (2.48)	89.12 (2.21)	18.23 (6.21)	28.76* (17.13)	14.55 (4.51)
2. Outer Brow Raiser	79.43 (11.35)	4.56 (1.12)	84.58 (7.12)	5.18 (2.34)	91.13* (4.56)	11.41 (4.56)	92.15 (11.22)	19.26 (7.23)
4.Brow Lowerer	17.56 (5.04)	29.48 (7.66)	29.45 (4.32)	34.56 (5.55)	11.56 (6.67)	38.41 (5.56)	9.51* (1.79)	67.44* (19.21)
5. Lid	58.46*	3.46	28.46	5.56	92.25*	22.24*	27.67	12.45

Raiser	(7.32)	(1.43)	(16.52)	(2.33)	(11.6)	(7.28)	(8.76)	(5.71)
7.Lid	32.56*	28.67	68.45	69.71*	22.31	12.53*	58.26	66.87*
Tightener	(4.13)	(5.45)	(5.49)	(8.34)	(3.45)	(7.45)	(8.11)	(17.81)
15.Lip	2.34	56.68	4.56	68.92	8.17	34.56*	22.17*	45.55
Depressor	(5.17)	(11.54)	(3.71)	(11.12)	(4.56)	(13.99)	(9.16)	(17.84)
17.Chin	3.45	5.56	4.48	11.45	3.31	9.48	3.67	18.76*
Raiser	(2.76)	(1.12)	(3.17)	(5.67)	(1.76)	(4.21)	(1.15)	(5.52)
20.Lip	12.68	4.48	13.66	5.12	12.98	6.78	14.15	5.77
stretcher	(3.23)	(2.45)	(2.12)	(3.01)	(2.42)	(4.21)	(1.17)	(2.01)
24.Lip	13.22	54.66*	6.56	12.46	13.55	9.21	33.45*	21.52
Pressor	(3.12)	(4.55)	(2.31)	(9.12)	(4.28)	(2.36)	(6.22)	(8.93)
25. Lips	68.46	5.76	69.71	3.44	70.98	31.21*	34.41*	9.04
Part	(8.72)	(2.11)	(5.26)	(1.07)	(4.15)	(18.47)	(14.56)	(4.55)
26.Jaw	.69	37.46	1.12	45.54	2.45	21.23	1.91	58.84*
Drop	(.31)	(12.22)	(.91)	(13.42)	(1.16)	(11.16)	(.87)	(18.41)
27.Head	3.21	2.45	4.76	5.71	3.11	4.07	17.76*	29.42*
Down	(1.72)	(1.1)	(2.32)	(1.24)	(1.55)	(2.02)	(3.45)	(11.36)
43.Eyes	2.31	3.17	2.91	2.87	3.01	2.04	2.86	9.86*
Closed	(1.11)	(1.07)	(1.45)	(1.06)	(.66)	(.72)	(1.07)	(2.45)

FACS-instructed faces were recognised significantly better than freely-expressed emotions ($p < .01$; $\eta^2 = .49$). No significant differences were reported for country of origin ($p = .77$; $\eta2 = .01$) and expressed emotion ($p = .41$; $\eta2 = .03$). Mean and standard deviation (%) certainty recognition categorization for freely-expressed photos can be seen in the table above. A significant effect of Country of Origin ($p < .01$; $\eta^2 = .41$), a significant effect of

Type of Expression ($p < .01$; $\eta^2 = .78$) and a significant interaction ($p < .01$; $\eta^2 = .47$) were reported. Asterisks indicate significance for Bonferonni corrected differences in AU scores ($p \leq .001$).

10.1: Further Possible Limitations of the Current Study

Time-allowances in the current design enabled us to assess and control for in-group culturation and acculturation, and personal outgroup contact but not for social media cross-cultural familiarity (Elfenbein & Ambady, 2003). It is possible that the participants responded with a cross-cultural bias due to more limited social media exposure to Singaporean faces as opposed to faces from New Zealand and Chile. Conversely, the participants' life-choices for culturation could confer partial generalization to individuals with increased cross-cultural experience. Finally, the current study included three freely-expressed and FACS-instructed emotional expressions for a total of one hour of masked presentation. The aim of reducing the type and range of the emotional expressions and for presenting masked stimuli for a prolonged period of time was to present sufficient stimuli repetitions to achieve the necessary power ($P_{(1-\beta)} \geq .8$) to conduct an analysis by condition (hits and misses). This approach could have progressively depleted the required cognitive reserve for cross-cultural emotional recognition and future research could benefit from arranging multiple and smaller in length sections to explore additional emotional types.

11.1 Original Study Design

The original study design (2016) included mimicked facial expressions (Gur et al., 2002), emotional stimuli presented for 66.67 ms and participant assessment of subordinate facial characteristics, such as naturalness of expression and emotional intensity. These assessments

were excluded from the current study due to study-duration restrictions. The raw data for these conditions are available on request from the primary author.

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Skin Conductance Responses to Masked Emotional Faces Are Modulated by Hit Rate but Not Signal Detection Theory Adjustments for Subjective Differences in the Detection Threshold

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Abstract
The biological preparedness model suggests that survival-related visual cues elicit physiological changes without awareness to enable us to respond to our environment. Previous studies have reported some evidence for this effect. In the current article, we argue that this evidence is subject to methodological confounds. These include the use of a universal masked presentation threshold, the employment of hit rates (HRs) to measure meta-awareness, and the assertion of overall guess-level target detection using nonsignificance. In the current report, we address these issues and test whether masked emotional faces can elicit changes in physiology. We present participants with subjectively adjusted masked angry, fearful, happy, and neutral faces using HRs and signal detection theory. We assess detection performance using a strict Bayesian criterion for meta-awareness. Our findings reveal that HR adjustments in the detection threshold allow higher skin conductance responses to happy, fearful, and angry faces, but that this effect could not be reported by the same participants when the adjustments were made using signal detection measures. Combined these findings suggest that very brief biologically relevant stimuli can elicit physiological changes but cast doubt to the extent that this effect can occur in response to truly unconscious emotional faces.

Keywords
masked, emotion, skin conductance

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Introduction

In the last 30 years, psychological research achieved technological and methodological advancements that enabled the scientific exploration of a very old and very interesting question (Freud, 1915): Can we *experience* unconscious emotion? Contemporary research in the area (Öhman & Soares, 1994) typically includes the presentation of very brief (6.25–83.33 ms) emotional stimuli (Van der Ploeg, Brosschot, Versluis, & Verkuil, 2017) that are masked by neutral stimuli to render the masked targets consciously imperceptible (Bachmann & Francis, 2013). Participant responses to these targets are considered evidence for unconscious processing (Axelrod, Bar, & Rees, 2015).

The theoretical foundation for this unconscious processing stems from what psychologists term the biological preparedness model (LeDoux, 2003; Mineka & Öhman, 2002). According to this model, when we encounter particularly threat-related cues such as a threatening animal or a fearful face (Brooks et al., 2012), we recruit a fast-subcortical processing pathway to the amygdala (Liddell et al., 2005) that disseminates autonomic nervous system arousal (Van der Ploeg et al., 2017). The purpose of this pathway is to allow us to *instinctively* adapt to important signals in our environment that require an imminent response by eliciting automatic and involuntary physiological changes (Van der Ploeg et al., 2017).

Previous research tested this theoretical model using a variety of masking techniques (Bachmann & Francis, 2013) and reported some evidence in support of this proposition (Van der Ploeg et al., 2017). Most previous studies (Esteves, Dimberg, & Öhman, 1994; Esteves, Parra, Dimberg, & Öhman, 1994; Lapate, Rokers, Li, & Davidson, 2014; Morris, Öhman, & Dolan, 1998) employed skin conductance recordings (SCRs) to assess the effect because SCR is a measure of sympathetic autonomic nervous system arousal (Carlson, 1994) that can record physiological responses that are not under conscious regulation (Öhman, 2005)—such as fight or flight responses (Flykt, Esteves, & Öhman, 2007)—and is also relatively impenetrable to parasympathetic nervous system arousal artifacts (Cacioppo, Tassinary, & Bernston, 2007).

For example, Williams et al. (2006) reported a significance trend ($p = .08$) for higher SCR in response to backward-masked fearful faces compared with neutral faces when presented for 16.67 ms but several follow-up studies failed to replicate this trend (Codispoti, Mazzetti, & Bradley, 2009; Nielsen & Kaszniak, 2006). In more recent studies, Najström and Jansson (2007) reported that police officers (Correll, Urland, & Ito, 2006; Mann et al., 2004; McCaslin et al., 2006) experience higher SCR in response to backward-masked threatening pictures for 6 ms compared with neutral pictures for 6 ms, and Lapate et al. (2014) also reported significant findings for higher SCR and decreased liking ratings for subsequently presented neutral targets (see also Winkielman, Berridge, & Wilbarger, 2005) when participants were presented with fearful faces using dichoptic masking (Maehara & Goryo, 2005).

These findings provide support for unconscious emotional processing (LeDoux, 2003) but pose several possible limitations (Lähteenmäki, Hyönä, Koivisto, & Nummenmaa, 2015, pp. 2–5). The most important possible confound in previous research is the employment of a universal threshold for masked stimuli presentation (Pessoa, 2005; Pessoa, Japee, Sturman, & Ungerleider, 2006). Previous studies presented masked stimuli for 6.25 ms to 83.33 ms (Van der Ploeg et al., 2017) relying on that other previous studies reported that overall target meta-awareness—the ability to respond if a target was presented in a post-experimental or post-trial task (Erdelyi, 2004)—was not significantly different than chance.

A possible issue with this approach is that previous research has also reported between stimuli types (Calvo & Lundqvist, 2008) and between participants (Pessoa, 2005; Pessoa

et al., 2006) differences in the ability to detect masked stimuli. For example, the happy face superiority effect (Calvo & Lundqvist, 2008, pp. 113–115) posits that positively valanced masked faces such as happy faces are detected more accurately than other masked emotions because they portray more easily distinguishable facial characteristics. It is additionally possible that participants will report subjective differences in meta-awareness for the presented stimuli (Pessoa & Adolphs, 2010). Previous studies have reported substantial groups of *overachievers*—that could reliably discriminate the presence of a masked fearful face at 16.67 ms and 33.33 ms—and *underachievers*—that could not discriminate the presence of a masked fearful face even at 67 ms (Pessoa, 2005, 2017; Pessoa et al., 2005). This casts doubt to the extent that a universal threshold that is not adjusted for per participant and stimuli type differences in target meta-awareness is sufficient for unconscious stimuli presentation.

Another possible issue is that previous research has reached a consensus in respect to unconscious processing as the inability to perform different than chance in discriminating or detecting a masked target (Pessoa, 2005; Pessoa et al., 2006). In this context, chance-level performance indicates that participants were guessing—that they were in a sense performing "like a blind person would" (Erdelyi, 2004; p .79)—and were not aware whether a face was presented or not (Stanislaw & Todorov, 1999). The main problem with this guess-level criterion is that it is commonly assessed using HRs (Brooks et al., 2012) and almost unanimously asserted using nonsignificance to chance-level detection performance (Dienes, 2015).

The possible limitation with using HRs is quite straightforward (Lähteenmäki et al., 2015). Participants can employ subjective strategies for replying for target meta-awareness. These strategies can be overly conservative—such as replying having seen a face only when they are beyond a shadow of a doubt certain a face was presented—or overly liberal—such as replying that they saw a face even when they are quite unsure if one was presented. This makes reporting chance-level performance using HRs possibly unrepresentative of realistic target meta-awareness and previous research has strongly recommended the employment of unbiased signal detection theory measures that can provide a ratio between correct (hits) and incorrect (misses) responses (Stanislaw & Todorov, 1999) for the assessment of detection and discrimination tasks (Pessoa, 2005; Pessoa et al., 2006).

The issue with nonsignificance is that—irrespectively of using HRs or signal detection theory—chance-level performance is asserted based on insufficient statistical analysis (Dienes, 2015). In simple terms, the methodological approach in previous research (Brooks et al., 2012) is the calculation of overall HR performance or signal detection theory performance (d', A', A'', A) and its comparison against absolute chance (HR = 50%, d' = .0, A' = .5). In case of nonsignificant findings, the researchers claim unconscious processing. The problem with this approach is that overall performance being not significantly different to chance—lack of evidence for the alternate hypothesis—is interpreted as significantly at-chance—evidence for the null (Dienes, 2014, 2015). Further, Bonferonni-corrected pairwise comparisons are nonsensical because the alpha corrections operate in favor of unawareness (Overgaard et al., 2013). Previous research has suggested that Bayesian analysis should be undertaken to directly compare the null—evidence for chance level processing ($B < 1/3$)—to the alternate hypothesis—significantly different than chance ($B > 3$) in addition to frequentist approaches (Dienes, 2015) but research in the current field has not employed this method of assessment yet to assert unconscious processing (Van der Ploeg et al., 2017).

Given these possible limitations, the aim of the current study was to introduce the necessary methodological developments to establish unconscious presentation of emotional

faces and test if unconscious emotional faces can elicit changes in physiology. To meet these objectives, we preexperimentally adjusted for subjective differences in the detection threshold (Pessoa, 2005; Pessoa et al., 2006) using HR and nonparametric signal detection theory measures (Van der Ploeg et al., 2017) and assessed detection performance using combined frequentist and Bayesian criteria for meta-awareness (Dienes, 2015). Then we used the preexperimentally defined thresholds for masked stimuli presentation and explored if masked angry, fearful, happy, and neutral faces can elicit changes in physiology using SCR.

Methods

Participants

In total, 25 (14 women) participants gave informed consent to participate in the current study. Mean age was 32.9 ($SD = 7.2$). The exclusion criteria for the current study were history of head trauma, current or previous psychiatric diagnosis (self-report), and current or previous diagnosis of drug or alcohol abuse (self-report). The participants were screened with the Sphere-12 mood questionnaire (Hickie et al., 2001). Participants with scores at or below 1.0 were included. The participants were also screened using an online Alexithymia-Emotional Blindness questionnaire (Alexithymia, 2017) and participants with scores that indicated possible traits ($P > 94$) or diagnosis ($P > 112$) for alexithymia were excluded; data from a single participant were excluded from the study. We were able postexperimentally to contact several of the participants to acquire ethnic backward information via mail. Most of the participants that took part in the pilot (British: 70.59%; Greek: 17.64%; not responded: 11.76%) and main experimental (British: 79.17%; Italian: 12.5%; Greek: 8.33%) stages were White Caucasians recruited and were tested in the University of Nottingham. The experiment was approved by the University of Nottingham, School of Psychology Ethical Research Committee.

Facial Stimuli

The facial stimuli were taken from the facial set created by Gur et al. (2002). A total of 100 photos per emotional category (angry, fearful, happy, and neutral) were resized to a standard 1024×768 resolution, converted to grayscale and framed into pure white within a cropped circle (Height: 6 cm, Width: 4 cm). A total of 20 pattern blurs were also created, converted to grayscale, framed into pure white and framed within a cropped circle with the same dimensions using photoshop. Luminescence was averaged across all stimuli using Matlab SHINE.

Stimuli Preselection. The processed facial stimuli were preselected during a pilot preexperimental stage. Processed faces were presented to a separate set of participants ($n = 17$) at fixation for 1 s preceded by a fixation cross for 3 s. Pretarget baseline and maximum deferral skin conductance (1–3 s) were recorded during the presentation. Seven seconds after each trial participants were assigned a stimuli classification, a stimuli intensity, and a stimuli ambiguity engagement task. They were allowed 6 s to choose what emotion the presented face was expressing. They made this response using their keyboard, choosing from an onscreen list—angry (a), fearful (f), happy (h), surprised (s), neutral (n), or other (o). Subsequently, they were asked to rate from 1 (*not at all*) to 10 (*extremely*) the ambiguity and intensity of the presented faces. The order of stimuli was randomized, and participants were allowed 6 s to perform each task. An intertrial blank screen period of 8 s was used to allow skin conductance responses to return to baseline.

We ran two different stages of stimuli preselection. We selected angry, fearful, happy, and neutral stimuli that produced strict alpha significance criterion ($p \leq .01$) for correct classification of emotional valence. Surprised facial expressions (Tottenham et al., 2009) were initially intended to be part of this study (Duan, Dai, Gong, & Chen, 2010). These were not included because the stimuli number that produced a statistically significant emotional type recognition effect ($n = 14$) during the first stimuli preselection stage was smaller than the required number of stimuli ($n = 30$). We chose from the available subset the 30 angry, fearful, and happy stimuli that reported the highest scores in a self-developed percentage-based metric—Impact Factor, I.F. (%)—that took under equal consideration (50%) reports for stimuli ambiguity and intensity, and maximum deferral skin conductance arousal (Appendix A):

$$\begin{aligned}\text{I.F.}(\%) = (((10 - \text{Amb.}) + (\text{Int.}))/2) * 50) + (((\text{SCRMaximumDeferral}) \\ /(\text{Max}\{\text{SCRMaximumDeferralforStimuliType}\})) * 50)\end{aligned}$$

The final stimuli set comprised 30 angry, fearful, and happy stimuli and a total of 60 neutral faces. The faces were from both male (52.67%) and female actors (47.33 %). The data set (Gur et al., 2002) did not contain ethnic and cultural origin labels. The selected stimuli were therefore, postexperimentally assessed using Noldus (2017), Face Reader 6.1. The facial set comprised Caucasian (58%), African (17.33%), and Asian (15.33%) actors. A small number of the stimuli (9.33%) were reported as unknown-other or did not provide a sufficient certainty report ($\geq$ 85%) for ethnic origin. No further analysis was conducted to explore cultural and ethnic origins effects for the current study (Tsikandilakis et al., 2018).

Equipment and Programming

Two computers were used during the experimental stages: one for stimuli presentation and one for recording physiological arousal. The two computers were connected using a PCI parallel port adapter (latency < .1 s). Stimuli presentation was coded using the builder and code components in Psychopy v1.83 (Peirce, 2007). Stimuli were presented on an HD LED LENOVO monitor with 120 Hz (8.33 ms) refresh rate. An IO platform transmitted 5-V binary signals in five digital channels that distinguished stimuli type following signal onset.

Stimuli presentation validation testing. A 4.17-ms refresh rate CANON G16 camera recorded a pilot run of the experiment and the presentation content was assessed frame by frame. No instances of dropped frames were found. A dropped frame report script with one frame (8.33 ms) tolerance threshold was coded in Python and two pilot experimental diagnostic sessions were run. The presenting monitor reported no dropped frames and the prognostic dropped frame rate was 1 in 5,000 trials. Experimental stages were subsequently run using dropped frames diagnostics and frame rate performance diagnostics of the stimuli presenting monitor. At no point during the running of the experiment were there any reports of dropped frames.

Skin conductance recording and analysis. Skin conductance responses were measured from the left hand (index/first and middle/second fingers; Banks, Bellerose, Douglas, & Jones-Gotman, 2012) of each participant using skin conductance electrodes with Biopac (Gel 101) skin conductance gel. The signals were received by a BIOPAC Systems, EDA100C preamplifier in units of microSiemens and recorded in *AcqKnowledge* (Braithwaite, Watson, Jones, & Rowe, 2013). We used the higher end of recommended specification for

recording skin conductance (EDA channel sample rate: 2 KHz; acquisition rate: 2,000 samples/per second; gain: ×1,000).

To make our data comparable with previous research that reported trends for significance or significant results in response to masked emotional faces (Van der Ploeg et al., 2017), we used the exact same analysis parameters. The presence of a phasic skin conductance response was defined as an unambiguous increase (.01 μs) with respect to each pretarget baseline occurring 1 to 3 s post stimuli offset. The raw signal was processed using the Derive Phasic EDA from Tonic and Dirac Delta (δ) functions. The data did not require additional smoothing, filtering, or transformations (Braithwaite, 2013; pp. 1027–1029). Nonresponders were included in the analysis.

Stage 1: Per participant and stimulus type detection threshold

Participants were invited in a laboratory space with controlled lighting and temperature. They were informed that they will be presented with brief emotional faces and they will be asked to decide how many faces were presented after each trial. During this stage, we presented a fixation cross for 3 (±1) s in the middle of the screen. After the cross, an angry, fearful, happy, or neutral face or a matched for luminescence pattern blur was presented for 8.33 or 16.67 or 25 ms with backward masking to a 108.33-ms neutral face. In total, 20 emotional faces for each duration, 80 pattern blur trials, and 15 neutral masks showing actors who were not part of the masked stimuli subset were presented. All stimuli were presented in randomized order. Five seconds after each trial, an on-screen message asked participants to decide how many faces were presented on screen: ''How many faces did you see? Please press 1 for one or 2 for two.'' Participants were asked to reply using the keyboard with their right hand. This stage was performed 7 days before and at the exact same time of day as Stage 2.

Stage 1: Data processing. The individual per stimulus type detection threshold was calculated separately using hit rates (percentage of true positives) and nonparametric signal detection theory (Zhang & Mueller, 2005). For each participant, the duration of presentation (8.33 or 16.67 or 25 ms) that produced the smallest negative or positive overall detection performance difference to chance per stimulus type was imported separately for HRs and signal detection theory measures to the main experiment—that is, the duration for which the value of $(0.5. - P_{\text{threshold}})$ was closest to .5. When participants reported an equal distance to chance between two thresholds (e.g., 16.67 ms: .45 and 35 ms: .55), the briefer duration was imported in the main stage.

Stage 2: Physiological Arousal in Response to Hit Rate and Sensitivity Index Adjusted Faces

Participants were invited to the same laboratory space under identical experimental conditions, including the same presenting monitor, response equipment, room temperature, and room luminance. They were informed that they will be presented with brief emotional faces while their physiology is measured. They were asked to complete two 15-min sessions with a 5-min interval break. In one of the sessions, participants watched masked emotional stimuli that were adjusted using HRs for the duration of the masked targets. In the other session, participants watched masked emotional stimuli that were adjusted using signal detection theory for the duration of the masked targets. Session order was randomized.

In both sessions, we presented a fixation cross for 3 (± 1) s in the middle of the screen. After the cross, an angry or fearful or happy or neutral face or a pattern blur was presented at fixation with backward masking to a 108.33-ms neutral face (Figure 1). Five novel stimuli per emotional category and 20 pattern-blur trials were presented in total. In total, 15 neutral masks were presented showing actors who were not part of the masked stimuli subset for either neutral or emotional masked faces for Stage 1 or 2 of the experimental process. All stimuli were presented in randomized order and skin conductance responses were measured during the presentation. The participants were not assigned with an engagement task during this stage. After each trial, an 8-s blank interval screen was presented to allow physiology to return to baseline.

Results

Stage 1: Hit Rate Thresholds

To explore if masked faces using HRs were not significantly different to chance we run one-sample *t* tests against absolute chance-level performance (50%) for overall and per stimuli type target meta-awareness. Overall HR adjusted emotional faces ($M = 49.53\%$, $SD = 1.84\%$) were not significantly different to chance: $t(23) = 1.25$; $p = .22$. The same effect was reported separately for angry, $M = 48.96\%$, $SD = 4.89\%$; $t(23) = 1.05$; $p = .31$; fearful, $M = 49.58\%$, $SD = 3.88\ \%$; $t(23) = .53$; $p = .6$; happy $M = 50.21\%$, $SD = 4.29\%$; $t(23) = .29$; $p = .81$;; and neutral faces, $M = 49.38\%$, $SD = 3.39\%$; $t(23) = .9$; $p = .38$.

To further explore these results, a uniform Bayesian analysis corrected for degrees of freedom, $df < 30$; standard error $(SE) = (SE \times (1 + \frac{20}{df \times df}))$; (Berry, 1996) was run using the Dienes (2014, 2015) calculator. We set the higher and lower bounds for chance-level HR performance to a conservative −.5 (45%) and .5 (55%) criterion with 0 representing absolute chance-level performance. Overall HR performance ($SE = .37$; $B = .2$) was significantly at-chance. The same effect was reported for fearful faces ($SE = .79$; $B = .23$), happy faces

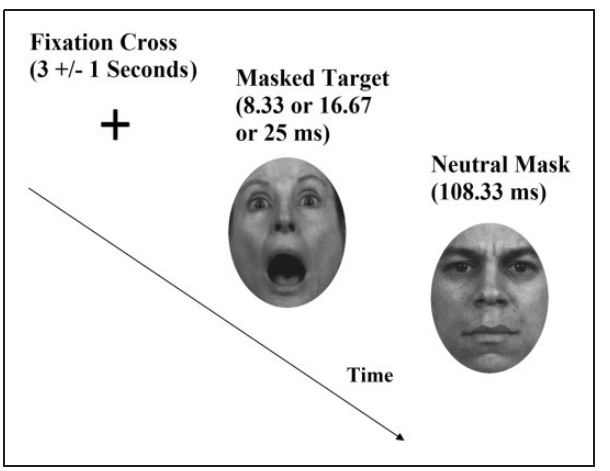


Figure 1. Example of stimuli sequence with fearful masked target. The participants watched angry, fearful, happy, and neutral faces and nonfacial pattern blurs at fixation for 8.33 or 16.67 or 25 ms based on their subjective performance in a preexperimental signal detection task. All stimuli were followed by a random neutral mask for 108.33 ms. Skin conductance was measured as the highest peak in electrodermal response 1 to 3 s post stimuli offset.

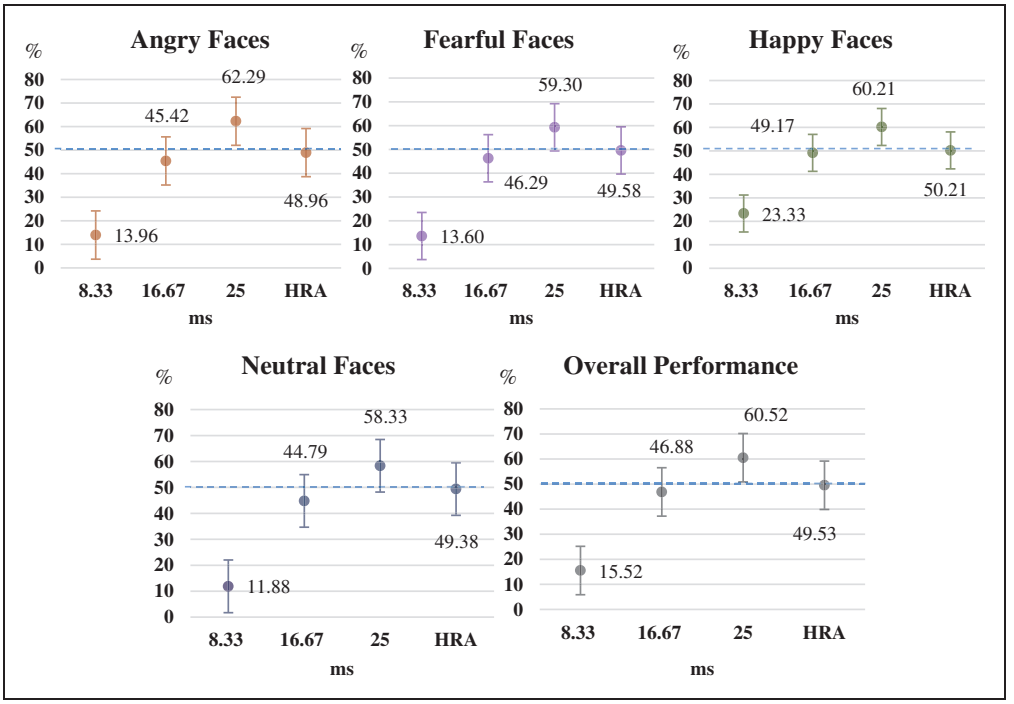


Figure 2. Overall, per threshold and per stimulus type detection performance for hit rates. Overall and per stimulus type hit rate percentage performance for 8.33, 16.67, 25 ms and hit rate adjusted faces (HRA). Midline indicates chance-level performance. Error bars for each score indicate Standard Error of the mean.

($SE = .89$; $B = .23$), neutral faces ($SE = .8$; $B = .26$), but not angry faces ($SE = 1$; $B = .43$), suggesting that the latter was the only type that was insensitive to both competing hypothesis (Figure 2; Individual Thresholds in Table B1).

Stage 1: Signal Detection Theory Thresholds

To explore if masked faces using signal detection theory were not significantly different to chance, we run one-sample t tests against absolute chance-level performance (.5) for overall and per stimuli type target meta-awareness. Overall signal detection theory adjusted faces ($M = .496$, $SD = .037$) were not significantly different to chance: $t(23) = .49$; $p = .63$. The same effect was reported for angry, $M = .494$, $SD = .062$; $t(23) = .55$; $p = .59$; fearful, $M = .494$, $SD = .061$; $t(23) = .53$; $p = .6$; happy, $M = .514$, $SD = .042$; $t(23) = 1.62$; $p = .12$; and neutral faces, $M = .485$, $SD = .6$; $t(23) = 1.22$; $p = .24$.

To further explore these results, a uniform Bayesian analysis corrected for degrees of freedom, $df < 30$; $SE = (SE \times \left(1 + \frac{20}{dfxdf}\right))$; (Berry, 1996) was run using the Dienes (2014, 2015) calculator. We set the higher and lower bounds for chance-level signal detection theory performance to a conservative −.5 and .5 criterion with 0 representing absolute chance-level performance. Overall signal detection theory performance ($SE = .008$; $B = .22$) was significantly at-chance. Fearful faces ($SE = .013$; $B = .37$) and angry faces ($SE = .013$; $B = .38$) showed trends for at-chance level processing and happy faces ($SE = .009$; $B = .73$), and neutral faces ($SE = .013$; $B = .64$) were insensitive to both competing hypothesis (Figure 3; Individual Thresholds in Table B2).

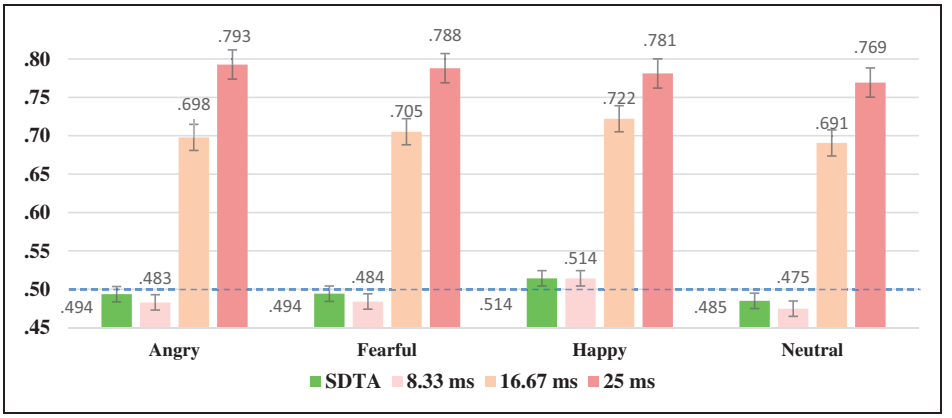


Figure 3. Signal detection theory performance per emotion and for adjusted faces. Participant threshold for each masked emotional stimulus for the signal detection theory session in stage two. SDTA refers to faces adjusted using signal detection theory (A) for the duration of masked stimuli presentation.

Stage 2: Skin Conductance Responses

To explore if HR-adjusted emotional faces produced differences in skin conductance a one-way repeated measures analysis of variance (ANOVA) was run with independent variable Stimulus Type (angry, fearful, happy, neutral, and pattern blur) and dependent variable maximum deferral (1–3 s) skin conductance (μS) for HR adjusted faces. A main effect of Stimulus Type was reported: $F(1.64, 37.72) = 57.69$, $p < .001$; $\eta^2 = .72$; Greenhouse–Geiser corrected. Bonferroni adjusted pairwise comparisons reported that SCR scores were significantly higher for angry faces ($M = .034$, $SD = .015$) than for happy ($M = .018$, $SD = .007$; $p < .001$, $d = 1.36$) and neutral faces ($M = .01$, $SD = .007$; $p < .001$, $d = 2.05$) and for the pattern blur condition ($M = .01$, $SD = .003$; $p < .001$, $d = 1.34$). SCR scores were also significantly higher for fearful faces ($M = .045$, $SD = .022$) than for angry ($p < .01$, $d = .58$), happy ($p < .001$, $d = 1.65$), neutral faces ($p < .001$, $d = 2.14$), and for the pattern blur condition ($p < .001$, $d = 2.22$). Happy faces were also higher for SCR than neutral faces ($p = .001$, $d = 1.14$) and the pattern blur condition ($p < .001$, $d = 1.49$). Skin conductance responses were not significantly different between different stimulus types for signal detection theory adjusted emotional faces, $F(2.47, 56.84) = 1.24$, $p = .3$; $\eta^2 = .05$; Greenhouse–Geiser corrected, suggesting that only HR adjusted angry, fearful, and happy faces elicited higher skin conductance scores in the current experimental setup (see also Table C1).

Discussion

In the current experimental design, we tested if subjective adjustments in the threshold of presentation for masked emotional faces can elicit skin conductance responses. We used HR and signal detection theory adjustments in the threshold of presentation and we also implemented a combined frequentist and Bayesian assessment of chance-level detection performance. The frequentist analysis of detection performance showed that overall and per stimulus type masked faces were not processed significantly different to chance. Bayesian analysis of the same data revealed that both HR and signal detection theory

adjusted faces were overall significantly at-chance. HR-adjusted angry faces and signal detection theory adjusted happy and neutral faces were insensitive to both competing hypothesis. For the physiological assessment, our analysis revealed evidence for higher skin conductance for masked angry, fearful, and happy faces that were adjusted using HRs. Masked targets that were adjusted using signal detection theory measures did not report significant differences in skin conductance between different emotional faces.

The biological preparedness theory (Mineka & Öhman, 2002) suggests that particularly fear is an evolutionary important, encapsulated module. Fear responses according to this model are elicited in response to preferentially pretechnological (Seligman, 1971) survival threats that have phylogenetic and neural evolutionary precedence and are therefore, impenetrable to the more recent emergence of cognitive control (see also Lapate et al., 2014). These threats include angry faces—as a mean for ingroup social submission—and fearful faces—as an indication of unseen environmental danger (Öhman, 2009), and elicit automatic and involuntary physiological responses before cognitive analysis of the fear-related stimulus using a dedicated subcortical neural pathway (Brooks et al., 2012). Several previous studies (Van der Ploeg et al., 2017) have tested this model using masked emotional faces and suggested that physiological changes to biologically relevant stimuli can also occur without conscious target meta-awareness (Pessoa & Adolphs, 2010).

The current data support that at least the latter is not the case (Van der Ploeg et al., 2017). As mentioned in the Introduction section, in the current report, we addressed several possible confounds in previous research including subjective differences in the detection threshold (Pessoa, 2005; Pessoa et al., 2006) and per stimuli type differences in the detection threshold (Calvo & Lundqvist, 2008). We particularly noted that masked neutral faces for set presentation thresholds (8.33 or 16.67 or 25 ms) were detected less accurately than other stimuli types (Figure 2) possibly as a function of emotional congruence with the neutral mask (Kim et al., 2010). Irrespectively of stimulus type, post the adjustments in the detection threshold all masked targets were not significantly different to chance-level meta-awareness and most stimuli types were significantly at-chance (Figures 2 and 3). This means that in the current report, participants had approximately equal visual accessibility for different emotional stimuli and that this accessibility was as close to chance as the experimental parameters allowed using HRs and signal detection theory.

As Erdelyi (2004) posits unconscious or masked or implicit or subliminal processing (Dehaene, Changeux, Naccache, Sackur, & Sergent, 2006) is based on empirical evidence using a dissociation paradigm where availability (ε) exceeds accessibility (α) such as that for $\alpha = 0$, $\varepsilon > \alpha$. In the current context, our results suggest that when visual accessibility is equal to zero using HRs angry, fearful, and happy faces elicited higher skin conductance responses than neutral and nonfacial pattern stimuli. When visual accessibility was equal to zero using unbiased signal detection theory measures, there were no significant differences in skin conductance responses between different emotions. In simple terms, when participants individually and objectively responded "like a blind person would" (Erdelyi, 2004; p. 79), we could not report evidence for *subliminal* or unconscious physiological responses.

In respect to the biological preparedness model, this suggests that—even if masked targets are physiologically processed before cognitive analysis (Mineka & Öhman, 2002)—they cannot be physiologically processed without conscious meta-awareness (Pessoa, 2005; Pessoa et al., 2006). These results also suggest that previous findings in the area (van der Ploeg et al., 2017) that have reported that target meta-awareness is not a necessary condition for physiological responses to masked emotional faces might have been the outcome of insufficient target masking (Kim et al., 2010) and that further methodological developments such as signal detection theory (Pessoa, 2005) subjective adjustments (Calvo

& Lundqvist, 2008) and analysis for chance-level significance (Dienes, 2015) were required to properly assess and assert unconscious processing.

Our report also poses several additional limitations that should be further addressed (Tsikandilakis, Chapman, & Peirce, 2018). A basic limitation of the current design is that we need to factor time as a possible variable in signal detection (Erdelyi, 2004). Preexperimentally defining chance-level processing is indicative for participant meta-awareness, but it does not imply that the implemented threshold might not vary from the threshold definition to the physiological assessment stages. Physiological correlates of awareness by condition such as further analysis of hits and misses (Pessoa, 2005; Pessoa et al., 2006) and subjective detection confidence reports (Overgaard et al., 2013) during the physiological assessment stage are needed to further assess unconscious processing (Lau, 2008). The current results are also limited by our method of assessment and cannot address whether further physiological measures such as heart rate or EMG, neural responses or behavioral responses will report the same effect when controlled for individual differences in signal detection (Brooks et al., 2012; Lapate et al., 2014; Van der Ploeg et al., 2017)

Conclusions

The current study is to our knowledge the first attempt in implementing subjective adjustments and Bayesian analysis for chance-level detection performance for the assessment of physiological responses to masked emotional faces. Our findings suggest that brief angry, fearful, and happy emotional faces can elicit changes in skin conductance but that when these emotional faces are adjusted for subjective differences in target detection using unbiased signal detection theory measures, there are no differences in skin conductance responses between different emotions. These findings cast doubt to the extent that we can physiologically respond to truly unconscious targets.

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Note

1. Heart rate was measured during the preselection stage but was not used in the analysis because heart rate responses were not included in the main experimental stage.

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Appendix A

Table A1. I.F. Scores for Different Stimuli Types.

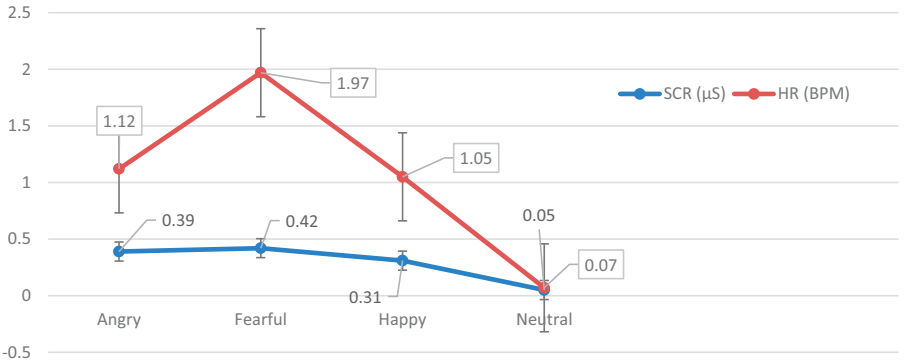
Stimuli type	Accuracy (%)	Stimuli type	Intensity (1–10)	Stimuli type	Ambiguity (1–10)
Angry	78.67 (8.49)	Angry	6.68 (1.15)	Angry	5.12 (.99)
Fearful	79.74 (8.38)	Fearful	6.89 (1.13)	Fearful	5.45 (.92)
Happy	82.67 (8.66)	Happy	5.91 (1.19)	Happy	5.14 (1)
Neutral	89.05 (8.19)			Neutral	3.55 (1.42)

Angry ($M = 87.82$, $SD = 1.97$), fearful ($M = 87.91$, $SD = 1.92$), and happy ($M = 86.61$, $SD = 1.97$) that were included in the final selection were not significantly different ($F = 1.41$, $p = .19$) in I.F. (%) scores.

To explore the effect of emotional stimuli on skin conductance a repeated measures ANOVA was run with independent variable Stimuli Type (angry, fearful, happy, and neutral) and dependent variable SCR (maximum deferral). The model reported a significant effect of stimuli type ($p < .01$; $\eta^2 = .56$) An additional repeated measures ANOVA was run with independent variable stimuli type (angry, fearful, happy, and neutral) and dependent variable HR[1] (maximum deferral BPM) scores. The model reported a significant effect of stimuli type ($p < .01$; $\eta^2 = .67$).

Adjusted *p* values	SCR			HR		
	Fear	Happy	Neutral	Fear	Happy	Neutral
Anger	.15	.21	.00	.14	.52	.01
Fear		.18	.00		.09	.00
Happy			.01			.03

HR = hit rate.



Appendix B

Three participants (11, 22, and 23) scored zero for one stimulus type (angry, fearful, and neutral) for 8.33 ms and the next available duration was imported in Stage 2 (Zhang & Mueller, 2005).

Table B1. Thresholds Hit Rates.

Column1	Angry	Column2	Fearful	Column5	Happy	Column8	Neutral	Column11
	HR threshold	Performance	HR Threshold	Performance	HR Threshold	Performance	HR Threshold	Performance
1	16	45	16	50	16	55	25	50
2	16	45	16	45	16	50	25	50
3	16	50	16	50	16	50	16	45
4	16	40	16	45	16	55	16	55
5	16	45	16	50	16	50	16	45
6	25	55	16	40	16	45	25	50
7	16	50	16	50	16	50	25	50
8	25	55	25	50	16	55	25	55
9	25	60	16	50	16	55	16	45
10	16	45	16	55	16	40	16	45
11	16	40	16	55	25	50	16	50
12	16	50	16	50	16	50	16	50
13	16	55	16	45	16	45	16	45
14	16	55	16	50	16	55	16	45
15	16	50	16	55	16	45	25	50
16	16	50	16	45	16	45	25	55

(continued)

Table B1. Continued.

Column1	Angry	Column2	Fearful	Column5	Happy	Column8	Neutral	Column11
	HR threshold	Performance	HR Threshold	Performance	HR Threshold	Performance	HR Threshold	Performance
17	16	45	16	50	16	50	25	50
18	16	50	16	50	16	55	25	55
19	16	45	16	45	16	55	16	50
20	16	50	16	55	16	50	16	50
21	16	45	16	50	16	50	16	50
22	16	50	16	50	16	50	16	50
23	16	50	16	55	16	45	16	45
24	25	50	25	50	25	55	16	50

HR = hit rate.

Table B2. Individual Thresholds for Signal Detection Theory Faces.

	Angry		Fearful		Happy		Neutral	
	Threshold (ms)	*A*	Threshold (ms)	*A*	Threshold (ms)	*A*	Threshold (ms)	*A*
1	8.33 ms	.40	8.33 ms	.44	8.33 ms	.44	8.33 ms	.40
2	8.33 ms	.42	8.33 ms	.45	8.33 ms	.53	8.33 ms	.49
3	8.33 ms	.52	8.33 ms	.52	8.33 ms	.52	8.33 ms	.48
4	8.33 ms	.56	8.33 ms	.53	8.33 ms	.56	8.33 ms	.53
5	8.33 ms	.47	8.33 ms	.44	8.33 ms	.47	8.33 ms	.44
6	8.33 ms	.46	8.33 ms	.46	8.33 ms	.50	8.33 ms	.46
7	8.33 ms	.52	8.33 ms	.45	8.33 ms	.52	8.33 ms	.45
8	8.33 ms	.42	8.33 ms	.45	8.33 ms	.49	8.33 ms	.42
9	8.33 ms	.46	8.33 ms	.46	8.33 ms	.54	8.33 ms	.46
10	8.33 ms	.44	8.33 ms	.47	8.33 ms	.51	8.33 ms	.51
11	16.67 ms	.66	8.33 ms	.45	8.33 ms	.48	8.33 ms	.48
12	8.33 ms	.53	8.33 ms	.53	8.33 ms	.56	8.33 ms	.49
13	8.33 ms	.57	8.33 ms	.50	8.33 ms	.57	8.33 ms	.54
14	8.33 ms	.53	8.33 ms	.53	8.33 ms	.53	8.33 ms	.49
15	8.33 ms	.50	8.33 ms	.50	8.33 ms	.57	8.33 ms	.54
16	8.33 ms	.53	8.33 ms	.53	8.33 ms	.56	8.33 ms	.49
17	8.33 ms	.50	8.33 ms	.57	8.33 ms	.54	8.33 ms	.50
18	8.33 ms	.53	8.33 ms	.53	8.33 ms	.56	8.33 ms	.53
19	8.33 ms	.54	8.33 ms	.46	8.33 ms	.54	8.33 ms	.50
20	8.33 ms	.44	8.33 ms	.44	8.33 ms	.44	8.33 ms	.44
21	8.33 ms	.42	8.33 ms	.49	8.33 ms	.49	8.33 ms	.42
22	8.33 ms	.54	8.33 ms	.46	8.33 ms	.46	16.67 ms	.70
23	8.33 ms	.41	16.67 ms	.72	8.33 ms	.45	8.33 ms	.45
24	8.33 ms	.46	8.33 ms	.46	8.33 ms	.50	8.33 ms	.43

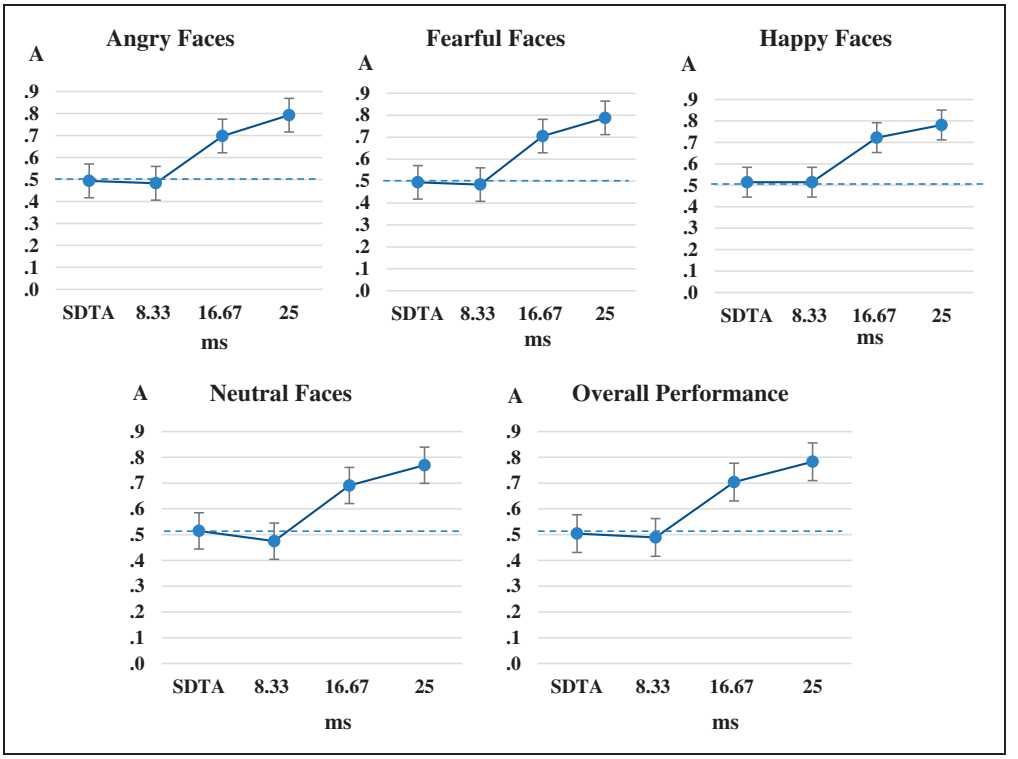


Figure B1. Signal detection performance per available threshold including signal detection theory adjusted faces (SDAT). Midline represents chance-level performance. Bars show standard error of the mean.

Appendix C: Factorial ANOVA Analysis

Table C1. Descriptive Statistics.

	Mean	Standard deviation	*N*
Angry	.0336	.01508	24
Fear	.0448	.02161	24
Happy	.0177	.00738	24
Neutral	.0104	.00675	24
Bubble	.0085	.00316	24
AngryA	.0056	.00517	24
FearA	.0055	.00518	24
HappyA	.0046	.00182	24
NeutralA	.0036	.00257	24
BubbleA	.0050	.00253	24

Table C2. Mauchly's Test of Sphericity.[a]

Measure: MEASURE_1

Within subjects effect	Mauchly's *W*	Approximately chi-square	*df*	Significance.	Epsilon[b] Greenhouse–Geisser	Huynh–Feldt	Lower bound
Adjustment	1.000	.000	0	.	1.000	1.000	1.000
Stimuli_Type	.071	56.714	9	.000	.483	.527	.250
Adjustment * Stimuli_Type	.061	59.812	9	.000	.411	.438	.250

Note. Mauchly's test tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

[a]Design: Intercept; Within subjects design: Adjustment + Stimuli_Type + Adjustment * Stimuli_Type.

[b]May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within subjects effects table.

Table C3. Tests of Within-Subjects Effects.

Measure: MEASURE_1

Source		Type III sum of squares	*df*	Mean square	*F*	Significance	Partial η^2
Adjustment	Sphericity assumed	.020	1	.020	98.611	.000	.811
	Greenhouse–Geisser	.020	1.000	.020	98.611	.000	.811
	Huynh–Feldt	.020	1.000	.020	98.611	.000	.811
	Lower bound	.020	1.000	.020	98.611	.000	.811
Error(Adjustment)	Sphericity assumed	.005	23	.000			
	Greenhouse–Geisser	.005	23.000	.000			
	Huynh–Feldt	.005	23.000	.000			
	Lower bound	.005	23.000	.000			
Stimuli_Type	Sphericity assumed	.013	4	.003	50.613	.000	.688
	Greenhouse–Geisser	.013	1.933	.007	50.613	.000	.688
	Huynh–Feldt	.013	2.107	.006	50.613	.000	.688
	Lower bound	.013	1.000	.013	50.613	.000	.688
Error(Stimuli_Type)	Sphericity assumed	.006	92	6.313E-005			
	Greenhouse–Geisser	.006	44.453	.000			
	Huynh–Feldt	.006	48.457	.000			
	Lower bound	.006	23.000	.000			
Adjustment * Stimuli_Type	Sphericity assumed	.011	4	.003	52.407	.000	.695
	Greenhouse–Geisser	.011	1.643	.007	52.407	.000	.695
	Huynh–Feldt	.011	1.753	.006	52.407	.000	.695
	Lower bound	.011	1.000	.011	52.407	.000	.695
Error(Adjustment* Stimuli_Type)	Sphericity assumed	.005	92	5.233E-005			
	Greenhouse–Geisser	.005	37.792	.000			
	Huynh–Feldt	.005	40.315	.000			
	Lower bound	.005	23.000	.000			

Table C4. Pairwise Comparisons.

Measure: MEASURE_1						
					95% confidence interval for difference[a]	
(*I*) Adjustment	(*J*) Adjustment	Mean difference (*I* − *J*)	Standard error	Significance[a]	Lower bound	Upper bound
1	2	.018*	.002	.000	.014	.022
2	1	−.018*	.002	.000	−.022	−.014

Note. Based on estimated marginal means.
[a]Adjustment for multiple comparisons: Bonferroni.
* The mean difference is significant at the .05 level.

Table C5. Pairwise Comparisons.

Measure: MEASURE_1						
					95% confidence interval for difference[a]	
(*I*) Stimuli_Type	(*J*) Stimuli_Type	Mean difference (*I* − *J*)	Standard error	Significance[a]	Lower bound	Upper bound
1	2	−.006*	.002	.027	−.011	.000
	3	.008*	.001	.000	.004	.013
	4	.013*	.002	.000	.007	.018
	5	.013*	.002	.000	.008	.018
2	1	.006*	.002	.027	.000	.011
	3	.014*	.002	.000	.008	.020
	4	.018*	.002	.000	.011	.025
	5	.018*	.002	.000	.011	.025
3	1	−.008*	.001	.000	−.013	−.004
	2	−.014*	.002	.000	−.020	−.008
	4	.004*	.001	.002	.001	.007
	5	.004*	.001	.000	.002	.007
4	1	−.013*	.002	.000	−.018	−.007
	2	−.018*	.002	.000	−.025	−.011
	3	−.004*	.001	.002	−.007	−.001
	5	.000	.001	1.000	−.002	.002
5	1	−.013*	.002	.000	−.018	−.008
	2	−.018*	.002	.000	−.025	−.011
	3	−.004*	.001	.000	−.007	−.002
	4	.000	.001	1.000	−.002	.002

Note. Based on estimated marginal means.
[a]Adjustment for multiple comparisons: Bonferroni.
*The mean difference is significant at the .05 level.

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Target meta-awareness is a necessary condition for physiological responses to masked emotional faces: Evidence from combined skin conductance and heart rate assessment

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ABSTRACT

Much heated debate surrounds the extent to which we can process emotional stimuli without awareness. In particular the extent to which masked emotional faces can elicit changes in physiology measurements, such as heart rate and skin conductance responses, has produced controversial findings. In the present study, we aimed to determine whether briefly presented faces can elicit physiological changes and, specifically, whether this is due to unconscious processing. We measured and adjusted for individual differences in the detection threshold using both receiver operating characteristics and hit rates. For this we also used a strict Bayesian assessment of participant thresholds. We then measured physiological responses to threshold adjusted emotional faces and for hits, misses and post-binary subdivisions of target meta-awareness. Our findings based on receiver operating characteristics revealed that, when faces were successfully masked there were no significant physiological differences in response to stimuli with different emotional connotations. In contrast, when targets were masked based on hit rates we did find physiological responses to masked emotional faces. With further analysis we found that this effect was specific to correct detection of angry and fearful faces and that increases in experienced arousal were associated with higher confidence ratings for correct detection of these stimuli. Collectively, our results do not support the notion of unconscious processing when using markers of physiological processes. Rather they suggest that target meta-awareness is a necessary condition for – and possibly determined by – physiological changes in response to masked emotional faces.

1. Introduction

Can emotional responses be evoked without awareness? Is it possible that we can be scared, happy, sad, or simply aroused without being consciously aware of what has triggered this experience? These questions are as tantalizing in modern psychological research today (Pessoa, 2017) as they were in psychoanalytic theory almost one hundred years ago (Freud, 1923/1962). In the last thirty years, psychologists have devoted significant resources in providing an answer (Brooks et al., 2012). The method typically employed in the area (van der Ploeg, Brosschot, Versluis, & Verkuil, 2017) is to present very brief (6.25–83.33 ms) emotional stimuli preceded (forward masking) and/or followed (backward masking) by non-emotional stimuli used in order to mask - i.e., make *invisible* - the emotional targets (Bachmann & Francis, 2013). Neural, physiological or behavioural responses to these masked targets are suggested as evidence for unconscious processing (Pessoa & Adolphs, 2010).

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This field of research has produced extensive (Brooks et al., 2012), though theoretically controversial, findings (Pessoa, 2005; Pessoa, Japee, Sturman, & Ungerleider, 2005). For example, fMRI activation in emotion processing areas such as the amygdala has been reported in response to masked angry (Nomura et al., 2004), fearful (Liddell et al., 2005) and happy faces (Duan, Dai, Gong, & Chen, 2010) among other masked stimuli types (Brooks et al., 2012). Masked emotional faces have also been shown to elicit specific markers of bioelectric activity recorded from cortical brain regions (Lu, Zhang, Hu, & Luo, 2011). They have been shown to induce liking and dislike to subsequently presented targets (Winkielman & Berridge, 2004; Winkielman, Berridge, & Wilbarger, 2005; Lapate, Rokers, Li, & Davidson, 2014) and direct our attention as visual cues processed without explicit awareness (Yiend, 2010).

The biological preparedness model that has been put forth to explain these neural and behavioural responses suggests that unaware emotional targets can induce changes in physiological processes (van der Ploeg et al., 2017) that enable us to make automatic and involuntary responses to environmental stimuli (LeDoux, 2003). This model suggests that when stimuli confer survival value (Liddell et al., 2005) and social communication value (Hess & Fischer, 2013) and require an instant reaction they do not rely on slow-cortical pathways that enable awareness of the presented visual stimuli to produce a response. Instead they recruit a fast-subcortical pathway to the amygdala that disseminates automatic nervous system arousal and allows us to respond and adapt to our environment without conscious awareness (Pessoa & Adolphs, 2010).

When this theoretical notion was put to the test using physiological assessment such as sweating (skin conductance response) and cardiovascular changes (heart rate and blood pressure) there was evidence of an effect (van der Ploeg et al., 2017) such as higher physiological changes for masked fearful faces (Williams et al., 2004, 2006; Lapate et al., 2014) and threatening pictures (Najström & Jansson, 2007) compared to masked neutral stimuli. Nevertheless, the extent to which these findings represent unconscious processing has been extensively debated in the relevant literature. The main critical themes include the presentation of a set duration threshold for masked faces that is assumed "to remain consistently below the detection threshold on all trials and across all participants" (Lähteenmäki, Hyönä, Koivisto, & Nummenmaa, 2015; p. 341), the assessment of detection performance using hit rates (Pessoa, 2005; Pessoa et al., 2005) and the assertion of unawareness using non-significance (Dienes, 2015).

For example, previous studies presented masked emotional faces for durations spanning from 6.25 to 83.33 ms and compared the concomitant physiological effects to the effects caused by masked neutral faces (presented for the same duration). Signal detection research has suggested that masked emotional faces are more clearly detected than masked neutral faces for set durations (e.g. 16.67 ms) because they confer emotional incongruence with the neutral mask (Calvo & Lundqvist, 2008; Kim et al., 2010). Previous research has also suggested that some participants are able to reliably discriminate what kind of face was presented at 16.67 and 33.33 ms (Pessoa, 2005; Pessoa et al., 2005). This casts doubt on whether previous studies reported results that were indeed indicative of the response to unseen stimuli and suggest that the duration of the masked targets should be adjusted both for per participant and stimuli type differences to ensure truly unconscious presentation.

Hit rates and non-significance for differences to chance-level meta-awareness have also been used in previous studies to assess and assert target awareness respectively (van der Ploeg et al., 2017). In this context, the consensus in previous research has been that if correct detection rate as assessed usually in a post-experimental task (Lähteenmäki et al., 2015) is not significantly different from chance this is evidence that the participants were guessing and were unaware of the presented target (Stanislaw & Todorov, 1999). The first problem with this approach is that hit rates are a possibly biased measure. It allows participants to reply using different subjective criteria. For example, chance-level performance can be the outcome of conservative or liberal detection strategies such as replying seeing a masked face only when one is completely certain a face was presented or replying yes when one is quite unsure that a face was presented (Pessoa, 2005; Pessoa et al., 2005). The inclusion of unbiased signal detection measures such as d' and A' that produce a ratio between hits (correct answers) and false alarms (wrong answers) has been suggested as a more reliable alternative for assessing chance-level performance.

In respect to asserting chance-level awareness previous studies compared participant detection performance to absolute chance (e.g., 50%). If the analysis returned non-significant differences from chance the researchers claimed unconscious perception. The important problem with this approach is that "non-significantly different from chance" – lack of evidence for the alternative hypothesis - is misinterpreted as significantly at-chance and thus as evidence for the null (Overgaard et al., 2013). Previous research has suggested that instead of the traditional frequentist approach, Bayesian inference should be used to assert if performance is significantly at-chance ($B < 1/3$) and infer unconscious processing (Dienes, 2015).

These possible biases cast some doubt to the extent that emotional signals were adequately masked in previous studies. The primary aim of the current report was, therefore, to address these issues and provide necessary methodological conditions to answer whether we can evoke physiological changes in response to unconscious emotional faces. To achieve this goal, we pre-experimentally adjusted for per participant and stimuli type differences in detection performance using both hit rates and signal detection theory and we also assessed target meta-awareness using Bayesian significance for chance-level detection performance (Tsikandilakis & Chapman, 2017; in print); furthermore, we analysed separately correct and incorrect responses and target detection confidence responses to masked angry, fearful, sad and neutral faces using combined skin conductance and heart rate recordings.

2. Methods

2.1. Participants

Twenty-four volunteers (thirteen females) participated in the current study. The mean age for the participants was 33.2 years (S.D. = 8.98). The exclusion criteria for the current study were history of head trauma, current medical treatment, current or previous DSM Axis I or II diagnosis and current or previous alcohol/drug abuse - assessed through self-report. Participants were screened

before the experiment with the Somatic and Psychological Health Report Questionnaire; participants with scores at or below 1.0 were included. The experiment was approved by the Ethics Committee of the School of Psychology of the University of Nottingham.

2.2. Facial stimuli

The facial stimuli used were taken from the dataset created by Gur et al. (2002). They included faces with angry, fearful, sad and neutral facial expressions. The stimuli were adjusted for interpupillary distance, transformed to grey scale and resized to a standard 1024 × 768 pixels resolution. Their luminescence was averaged in SHINE, Matlab Toolbox and Fourier Painter and finally they were spatially aligned and framed into pure white within a cropped circle (Height: 6 cm, Width: 4 cm).

2.3. Pilot stages: stimuli pre-selection

The processed faces were presented to a separate set of participants (n = 17). Stimuli were presented for one second preceded by a fixation cross for three seconds. Pre-target baseline and maximum deferral skin conductance (3 s post stimuli offset; van der Ploeg et al., 2017) and heart rate (4 s post stimuli offset; Critchley, 2005) were recorded during the presentation. After each trial participants were assigned a stimuli classification, a stimuli intensity and a stimuli ambiguity task. A blank inter-screen interval for eight seconds was presented after the engagement tasks to allow skin conductance and heart rate responses to return to baseline.

After collecting the results for this pilot stage, we selected the angry, fearful, sad and neutral stimuli that produced a significant effect ($p \leq .01$) for correct classification of emotional valence. From this subset, we further chose as the most representative examples for their emotional valence thirty angry, fearful and sad stimuli that produced the highest scores in a self-developed percentage based metric (Appendix A.1 and A.2):

$$IF(\%) = \left(\left(\frac{(10-\text{Amb.}) + (\text{Int.})}{2}\right)*50\right) + \left(\left(\left(\frac{\text{SCR Maximum Deferral}}{\text{Max}\{\text{SCR Maximum Deferral Stimuli Type}\}}\right)*25\right) + \left(\left(\frac{\text{HR Maximum Deferral}}{\text{Max}\{\text{HR Maximum Deferral Stimuli Type}\}}\right)*25\right)\right)$$

2.4. Pilot Stages: Visual contrast discrimination

The selected subset of processed faces and a total of forty non-facial blur patterns matched for cropped spatial alignment and luminance were presented to a different set of participants (n = 17). The stimuli were presented for 33.3 ms with backwards masking produced by neutral faces presented for 116.67 ms. Participants were asked to rate their subjective experience of visual contrast after each presentation using ratings on a scale from one (not at all) to ten (intense). Subjective experience of contrast for the non-facial patterns (M = 2.19, S.D = 1.08) was not rated higher than contrast in the face condition (M = 2.23, S.D. = 1.1; t (16) = 1.41, p = .17; d = 0.03; Appendix B.1) suggesting that differences of visual contrast between the non-facial patterns and the emotional faces, and the neutral masks would not artefactually impact target detection (Bachmann & Francis, 2013) and physiological responses (Kim et al., 2010) in subsequent experimental stages.

2.5. Pilot stages: adaptation of the perceptual awareness scale

In a final pilot experimental stage, we implemented and tested an initial post-binary adaptation of the Perceptual Awareness Scale (PAS - Sandberg & Overgaard, 2015). We presented a different set of participants (n = 23) with hit rate threshold adjusted masked angry, sad, neutral and no facial stimuli for per participant and stimulus type durations. We assigned participants with a binary detection task (How many stimuli did you see? 1 or 2). Subsequently, for i being the reply to the binary task we asked them to rate their perceptual experience between unsure, possibly i, most likely i and definitely i. We measured skin conductance during the presentation.

We found that no differences in SCR changes were reported between possibly and most likely for any stimulus type and binary response type (hits, misses, correct rejects, false alarms; $p > .05$). On a follow-up stage, we could contact fifteen participants included in the original pilot and asked them to rate the ambiguity between each item on the four-point scale from one (not at all) to ten (intense). Ambiguity between possibly and most likely (M = 6.8, S.D. = 0.94) was rated significantly higher than any other category combination ($F(2.47, 34.51) = 28.63$. $p < .01$; $\eta^2 = 0.67$; Greenhouse-Geisser corrected; Appendix C.1; 3.2). Based on these findings and in order to avoid possible linguistic ambiguity between these categories we collapsed the four-point scale into a three-point scale including ‘unsure’, ‘possibly’ and ‘definitely’ as subjective measures.

2.6. Main experiment: physiological recording and analysis

During the main experiment skin conductance and heart rate were used to assess physiological responses. Skin conductance responses were measured from the non-dominant hand (index/first and middle/s fingers; Banks, Bellerose, Douglas, & Jones-Gotman, 2012) of each participant using disposable Ag/AgCl gelled electrodes. The signals were received by a BIOPAC System, EDA100C in

units of microsiemens and recorded in *AcqKnowledge* (Braithwaite, Watson, Jones, & Rowe, 2013). Heart rate was measured via a double finger cuff from the non-dominant hand (ring/third and little/fourth finger) using an ambulatory CNAP™ MONITOR 500 and responses were recorded in beats per minute (bpm) also in *AcqKnowledge*.

To make our data comparable with previous research we used similar analysis parameters. The presence of a phasic skin conductance response was defined as an unambiguous increase (0.01 μS) with respect to each pre-target baseline occurring 3 s post stimuli offset (van der Ploeg et al., 2017). The presence of a heart rate response was defined as an event-related heart rate peak in beats per minute with respect to each pre-target baseline occurring 4 s post stimuli offset (Critchley, 2005). The raw signals for both measures were processed using the Derive Phasic from Tonic and manual Dirac Delta (Δ) functions. The data did not require additional smoothing, filtering or transformations (Braithwaite et al., 2013; p. 10–12). Non-responders for physiological changes were included in the data analysis (Venables & Mitchell, 1996).

3. Main experiment: presentation testing

The stimuli were presented on a high frequency LED monitor set at 120 Hz (8.33 ms per frame). A Canon G16 camera with 240 Hz refresh rate (4.17 ms) recorded two pilot runs of the experiment and the stimuli presentation was assessed frame by frame; no instances of dropped frames were detected. A self-developed dropped frame report script with one frame (8.33 ms) tolerance threshold was coded in Python and two pilot experimental diagnostic sessions were run. The presenting monitor operated at 8.33 ms refresh rate for checking dropped framed diagnostics and reported no dropped frames; prognostic dropped frame rate was estimated at 1/5000 trials. Experimental stages were, subsequently, run using dropped frames diagnostics and per stimuli presentation frame rate performance of the stimuli presenting monitor; no instances of dropped frames were detected.

4. Main experiment: detection threshold

In the first part of the main experiment we defined the detection threshold individually per participant and stimulus type. We presented participants with a fixation cross for 3 (± 1) seconds. After the fixation cross an angry or fearful or sad or neutral face or a non-facial blur pattern was presented for 8.33 or 16.67 or 25 ms with backward masking by a neutral face presented for 108.33 ms. Twenty angry, twenty sad, twenty neutral and twenty-six non-facial blur patterns were presented for each duration (8.33, 16.67, and 25 ms); presentation order was randomised. Five seconds after each presentation, an on-screen message asked participants to decide how many stimuli were presented during the trial. Participants were asked to press 1 if they saw one face or 2 if the saw two faces (using the keyboard).

To define the detection threshold per participant and stimulus type non-parametric receiver operating characteristics (Zhang & Mueller, 2005) and hit rate performance were calculated separately. The duration of presentation (8.33 or 16.67 or 25 ms) that marked the smallest negative or positive difference from chance per stimulus type was imported separately for ROC and hit rate performance to the main experiment; [0.5. - $P_{threshold}$] closest to 0.5 (Figs. 1 and 2). When participants reported equal differences from chance between two thresholds (e.g., 16 ms: 0.45; 25 ms: 0.55) the briefer duration was imported in the main stage. This stage was performed for each participant seven days before and at the same time slot as the skin conductance and heart rate responses stage below.

5. Main experiment: skin conductance and heart rate responses

In the second part of the main experimental stage we tested if, as assessed per participant and stimulus type, the threshold adjusted faces can elicit changes in physiological processes. Participants were invited to the same laboratory space under identical conditions. They took part in two 15-min experimental sessions separated by a 5 min long break; session order was randomised. In both sessions participants were presented with a fixation cross for 3 (± 1) seconds. After the fixation cross an angry or fearful or sad or neutral face or a non-facial blur pattern were presented. In one session, the faces were presented for hit rate adjusted durations and in the other session they were presented for ROC adjusted durations (Fig. 1). In both sessions, faces were backward-masked with a neutral face presented for 108.33 ms. Five different angry, sad, fearful, neutral and a total of twenty different non-facial blur patterns were presented in each session with order randomised.

Five seconds after each presentation an on-screen message asked participants to decide how many stimuli were presented during the trial. Participants were asked to press 1 if they saw one face or 2 if the saw two faces, using the keyboard. After this task, participants were asked to rate their confidence for their decision using the adjusted form of the PAS (Ramsøy & Overgaard, 2004). Using conditional branching for *i* being the participant response during the binary signal detection task participants were asked how they would rate their confidence for their reply between one (unsure), two (possibly i) and three (definitely i). Participants were allowed six seconds to complete each task. A blank screen for eight seconds was presented after the completion of the engagement tasks to allow physiological measures to return to baseline (Cacioppo, Tassinary, & Berntson, 2007).

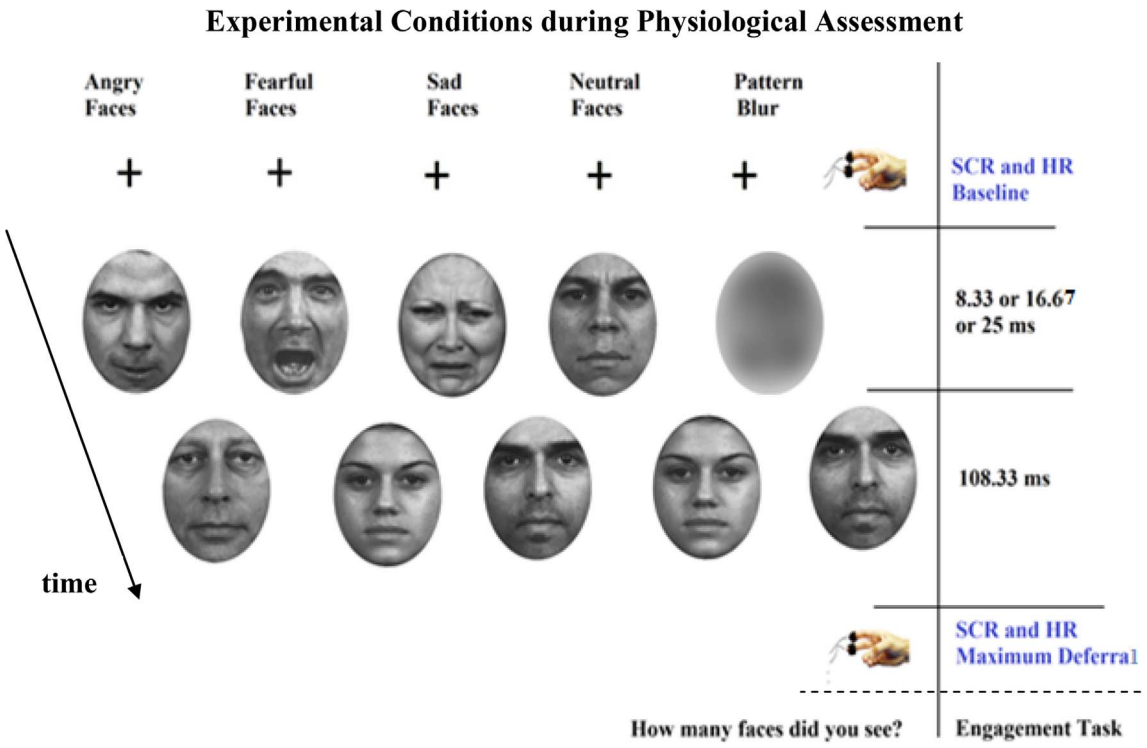


Fig. 1. Participants watched masked stimuli for ROC and Hit Rate adjusted durations (8.33 or 16.67 or 25 ms). The stimuli were backward-masked with neutral faces (108.33 ms). Heart rate and skin conductance responses were measured during the presentation.

6. Results

6.1. ROC threshold adjusted faces

6.1.1. Signal detection

We wanted to explore if ROC threshold adjusted stimuli were processed significantly at-chance (A = 0.5). A uniform Bayesian analysis with corrected degrees of freedom (df < 30; SE = (SE × ((1 + $\frac{20}{df x df}$))) (Berry, 1996)) was run using the Dienes calculator (2014, 2015) to assess chance-level processing; B < 1/3. The credible intervals were defined at −0.05 (lower bound) and 0.05 (higher bound) with 0 representing absolute chance-level performance. Detection performance using non-parametric receiver operating characteristics revealed significant evidence for overall chance-level processing (M = 0.49, S.D. = 0.03; S.E. = 0.01 (0.01); B = 0.29). When tested separately, however, individual stimuli types indicated insensitivity to chance-level processing (1/3 > B < 3; Fig. 2).

6.1.2. Physiological responses

The ROC Threshold adjusted faces did not lead to significant differences between different emotions in terms of respective skin conductance ($F(4, 92) = 1.51$, $p = 21$; $\eta^2 = 0.06$) or heart rate responses ($F(4, 92) = 0.34$, $p = .85$; $\eta^2 = 0.02$). Angry (SCR: M = 0.01, S.D. = 01; HR: M = 0.37, S.D. = 0.64), fearful (SCR: M = 01, S.D. = 01; HR: M = 0.39, S.D. = 0.63), sad (SCR: M = 01, S.D. = 01; HR: M = 0.36, S.D. = 0.55) and neutral faces (SCR: M = 01, S.D. = 01; HR: M = 0.36, S.D. = 0.51), and pattern blur stimuli (SCR: M = 01, S.D. = 01; HR: M = 0.53, S.D. = 0.65) were not processed differently in terms of physiological arousal.

6.2. Hit rate adjusted faces

6.2.1. Signal detection

To explore if hit rate adjusted faces were processed significantly at chance-level a uniform Bayesian analysis was run using the Dienes calculator and the exact same parameters used for ROC adjusted faces; credible intervals set at −5% to 5% with standard error corrected for degrees of freedom (df < 30). Detection performance using hit rates showed insensitivity for chance-level processing (M = 49.01%, S.D. = 2.85%; S.E. = 0.1 (0.2); B = 0.55); sensitivity for individual stimuli can be seen in Fig. 2.

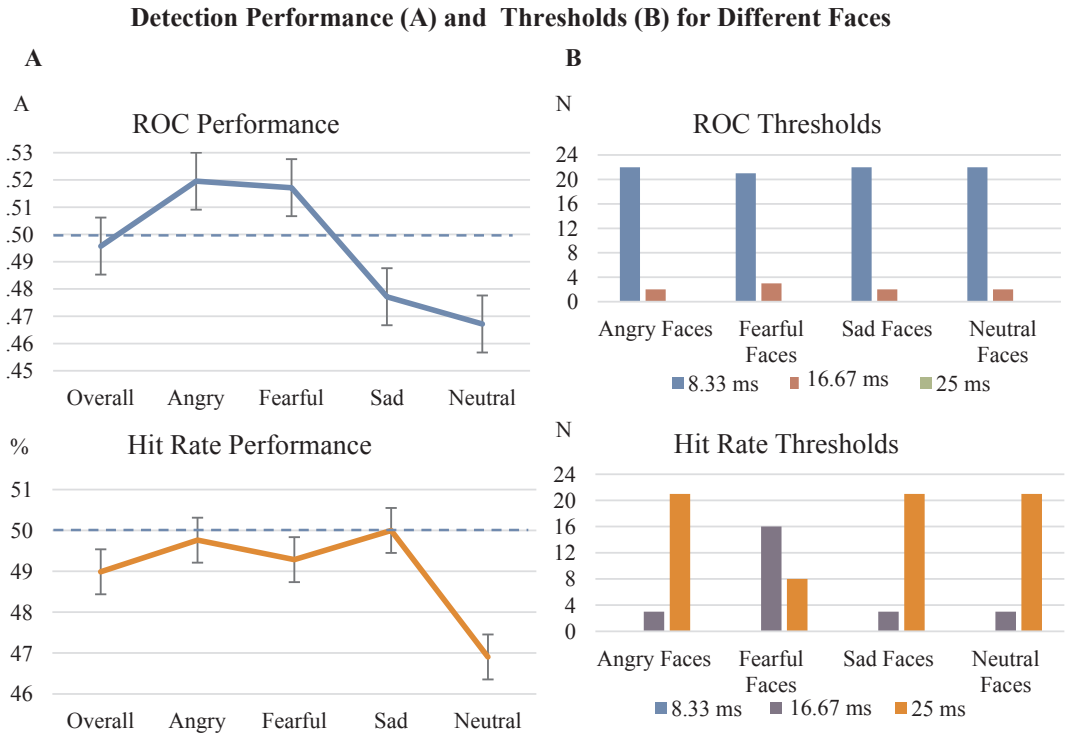


Fig. 2. Detection performance for ROC adjusted and Hit Rate adjusted faces and participant count (N) per assessed threshold of presentation (8.33, 16.67 or 25 ms) and stimuli type. Most of the participants were clustered (by ROC) across faces in the lowest available threshold condition (8.33 ms) where correct detection was lowest in comparison to other available durations.

6.3. Overall physiological responses

The hit rate adjusted faces reported significant differences in SCR changes between different stimuli types ($F(2.1, 48.32) = 25.16$, $p < .01$; $\eta^2 = 0.52$; Greenhouse-Geisser corrected). When adjusted using Bonferroni corrections for multiple comparisons our findings revealed that the effect was specific to angry and fearful faces. Angry faces ($M = 0.04$, S.D. = 0.02) elicited higher SCR changes than sad ($M = 0.01$, S.D. = 0.01, $p < .01$; $d = 1.21$), neutral ($M = 0.01$, S.D. = 0.01, $p < .01$; $d = 1.38$) and pattern blur stimuli ($M = 0.01$, S.D. = 0.01, $p < .01$; $d = 1.37$). Similarly, fearful faces ($M = 0.04$, S.D. = 0.02) also elicited higher scores for SCR changes than sad ($M = 0.01$, S.D. = 0.01, $p < .01$; $d = 1.63$), neutral ($M = 0.01$, S.D. = 0.01, $p < .01$; $d = 1.83$) and pattern blur stimuli ($M = 0.01$, S.D. = 0.01, $p < .01$; $d = 1.76$).

Heart rate responses reported a similar effect ($F(2.05, 47.09) = 10.09$, $p < .01$; $\eta^2 = 0.31$). The effect was again specific to angry and fearful faces. Angry faces ($M = 1.46$, S.D. = 1.28) elicited higher heart rate changes than sad ($M = 0.57$, S.D. = 0.47, $p = .04$; $d = 0.92$), neutral ($M = 0.5$, S.D. = 0.34, $p = .03$; $d = 1.02$) and pattern blur stimuli ($M = 0.63$, S.D. = 0.61, $p < .01$; $d = 0.82$). Fearful faces ($M = 1.32$, S.D. = 0.89) also elicited higher heart rate changes than sad ($M = 0.57$, S.D. = 0.47, $p = .01$; $d = 1.05$), neutral ($M = 0.5$, S.D. = 0.34, $p = .01$; $d = 1.21$) and pattern blur stimuli ($M = 0.63$, S.D. = 0.61, $p < .01$; $d = 0.9$).

6.4. Hits and misses

To further understand this effect, we compared SCR and HR changes per stimuli type (angry, fearful, sad, neutral and pattern blur) and detection response (hits, misses, correct rejects and false alarms). Our findings revealed that there were significant differences for SCR between stimuli ($F(2.36, 54.34) = 20.37$, $p < .01$; $\eta^2 = 0.47$; Greenhouse-Geisser corrected). There were also significant differences per detection response type ($F(1, 23) = 35.99$, $p < .01$; $\eta^2 = 0.61$) and a significant stimuli type by detection response interaction ($F(4, 92) = 19.65$, $p < .01$; $\eta^2 = 0.46$). When adjusted using Bonferroni corrections this effect revealed that hits for angry ($M = 0.05$, S.D. = 0.04) and fearful faces ($M = 0.06$, S.D. = 0.04) elicited significantly higher SCR than any other response combination and stimulus type ($p < .01$; Table 1). The same effect was reported for heart rate responses ($F(1.89, 43.57) = 5.93$, $p = .01$; $\eta^2 = 0.21$; Greenhouse-Geisser corrected). The effect was again specific to hits for angry ($M = 1.78$, S.D. = 1.33) and fearful faces ($M = 1.92$, S.D. = 1.29) in comparison to all other stimuli types ($p < .01$; Table 1) suggesting that the overall effect reported in the previous analysis was specific to correct detection for angry and fearful faces (Table 1; Appendix D.1).

Table 1
Hits and Misses SCR (μS) and HR (bpm) Changes for different Stimuli.

Stimulus Type	Detection Response	SCR Change (μS)	SCR S.D. (μS)	HR Change (bpm)	HR S.D. (bpm)
Angry	Hits*	0.05	04	1.78	1.33
	Misses	0.01	0.02	0.89	2.63
Fearful	Hits*	0.06	0.04	1.92	1.29
	Misses	0.01	0.01	0.67	1.45
Sad	Hits	0.02	0.01	0.72	0.75
	Misses	0.01	0.02	0.39	0.47
Neutral	Hits	0.01	0.01	0.5	0.79
	Misses	0.01	0.01	0.58	0.68
Pattern Blur	Correct Rejects	0.01	0.01	0.49	0.49
	False Alarms**	0.02	0.02	0.95	1.36

SCR and HR per stimulus type and response for meta-awareness.

* (Asterisk) signifies that the specific subdivision for meta-awareness for the specific stimuli type reported higher physiological changes (SCR and HR) than other stimuli types after adjusting for multiple Bonferroni comparisons.

** Items that were associated with significance trends compared to other non-asterisk types after adjusting for multiple Bonferroni comparisons (Appendix D.1 and F.1).

6.5. Adjusted PAS scale

We further chased these significant results to explore if hits for angry and fearful faces could be associated with skin conductance and heart rate changes for different categories of the adjusted PAS scale (unsure, possibly and definitely). Our data showed two significant effects. Although there were no overall differences per adjusted PAS scale reply, hits for angry faces demonstrated a significant linear trend for skin conductance ($F(2, 49) = 4.37$, $p = .02$) and heart rate responses ($F(2, 49) = 15.28$, $p < .01$). The same effect was revealed in response to hits for fearful faces for skin conductance ($F(2, 48) = 10$, $p < .01$) and heart rate changes ($F(2, 48) = 25.63$, $p < .01$) suggesting that physiological arousal interacted with confidence ratings for correct detection for angry and fearful faces (Fig. 3; Appendix E).

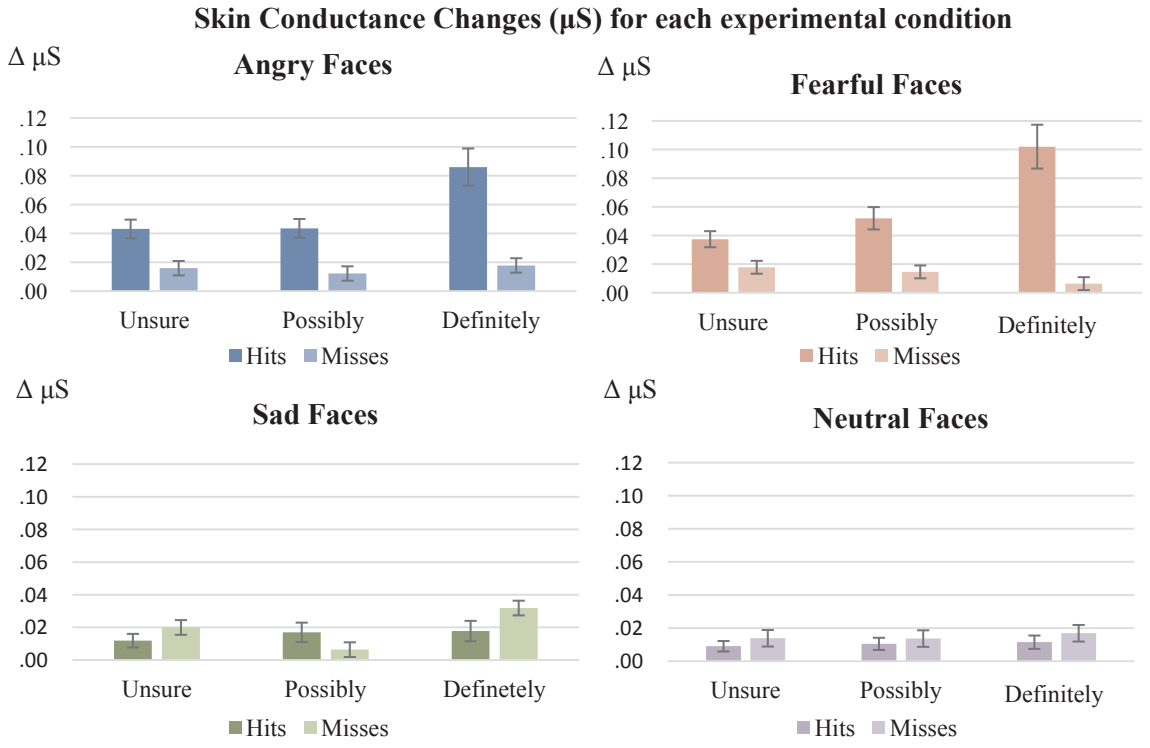


Fig. 3. Skin Conductance Changes (μS) for each experimental condition. Skin conductance changes for different stimuli types. SCR scores are arranged per signal detection response type (hits, misses) and detection confidence (unsure, possibly, definitely) ratings. Error bars show the standard error of the mean. A Linear trend was reported for skin conductance and detection confidence that suggested higher arousal interacted with confidence for target meta-awareness.

7. Discussion

In this experimental study, we examined if backward masked emotional faces can elicit physiological changes (Williams et al., 2004; Williams et al., 2006). We also examined whether these changes can be due to unconscious processing (Pessoa, 2005; Pessoa et al., 2005). We implemented several methodological developments to explore this question such as separate ROC and hit rate adjustments in the detection threshold and Bayesian assessment of significance for chance-level detection performance. We found that ROC threshold adjusted faces did not elicit changes in physiological responses. Hit rate threshold adjusted faces elicited physiological changes that further analysis proved to be associated with correct detection for masked angry and fearful faces. We found a significant linear relationship between physiological arousal and detection confidence that was again specific to correct detection for angry and fearful faces.

Previous research has suggested that if a stimulus has biological relevance – such as survival value (Liddell et al., 2005) –, it can elicit automatic and involuntary changes in physiological processes irrespectively of whether it is consciously perceived (LeDoux, 2003). Our findings support the idea that biologically relevant stimuli can induce changes in skin conductance and heart rate (van der Ploeg et al., 2017) but suggest that target meta-awareness at some sufficient level of confidence is a necessary condition for these changes (Pessoa, 2005; Pessoa et al., 2005). In the current study, only angry and fearful faces produced an effect and only in trials that included correct detection of these stimuli. This result is partly counter to what prevails in topical publications (van der Ploeg et al., 2017). We could not provide evidence for unconscious processing of fully masked emotional faces that we had expected to be indicated using physiological assessment, and we could not support previous findings where fMRI, (Brooks et al., 2012), EEG (Zhang et al., 2011), behavioural responses (Winkielman & Berridge, 2004; Winkielman et al., 2005) or skin conductance (Lapate et al., 2014) were used – all suggesting that emotional processing can occur without meta-awareness.

We suggest that this discrepancy is due to the substantial methodological differences between the current study and previous research (van der Ploeg et al., 2017). In the current investigation, we utilized previous signal detection findings (Calvo & Lundqvist, 2008; Lähteenmäki et al., 2015) and implemented subjective thresholds for detection performance. This could have been the catalyst for eliminating physiological differences using unbiased criteria for meta-awareness such as receiver operating characteristics (Stanislaw & Todorov, 1999). The alternative implementation of detection threshold durations using traditional detection criteria such as hit rates provided similar results to those obtained in previous studies and is the kind of evidence that has previously been used to conclude that masked angry and fearful faces induce changes in physiology (see also van der Ploeg et al., 2017). However, further analysis of the current data provided support for the Pessoa (2005), Pessoa (2017) and Pessoa et al. (2005), Pessoa, Japee, Sturman, and Ungerleider (2006) model that suggests that trial-by-trial response analysis reveals that the subset of trials that included correct detection modulates physiological changes to masked emotional content and creates the overall effect (Pessoa et al., 2005; p. 370). These findings cast doubt on the extent that physiological changes can be elicited without meta-awareness (Pessoa & Adolphs, 2010).

The critical question that the current study sets – and one that has also been raised by Pessoa (2005) and Pessoa et al. (2005) – is whether physiological changes influence correctness for target meta-awareness (Pessoa, 2017). Previous research has suggested that our behavioural responses to masked stimuli can be influenced by introspective cognitive and emotional criteria (Kouider, De Gardelle, Sackur, & Dupoux, 2010; Aru, Bachmann, Singer, & Melloni, 2012). In relation to the current results, this suggests either that arousal could have been higher when target visibility was higher (Adolphs, 2008) or that arousal modulated target meta-awareness and shaped the confidence of the perceptual experience (Anderson, 2005).

For example, Lapate et al. (2014) suggested that conscious processing has a regulatory role and disrupts the automatic associations between experienced arousal and evaluative judgement. Arousal elicited by unaware stimuli, on the other hand, decreases likeability for subsequent presented targets because the experience of affect is not subject to executive control (Pessoa & Adolphs, 2010). Evaluative judgement in relation to target presentation could also be regulated by experienced arousal by allowing participants to rely on the experience of affect to respond to the detection task. This would suggest that participant responses did not necessarily indicate whether a stimulus was consciously perceived but whether there was sufficient experienced affect and sufficient awareness of the experienced affect allowing to assume target presentation (Critchley, Wiens, Rotshtein, & Dolan, 2004; Critchley, 2005). In simpler terms, it is possible that participants could have responded in the laboratory in the same way that we respond in real-life when we experience physiological changes and environmental ambiguity: by inferring that “something must have happened”.

This is a promising hypothesis that can nonetheless be quite controversial. Initially, the linear trend effect currently reported was significant only for correct detection of angry and fearful faces. This suggests that it is confidence for meta-awareness and not unawareness that is regulated by fluctuations in the experience of arousal for these faces. On the other hand, if we suggest that physiological changes can regulate meta-awareness and shape perceptual experience this can be extended to posit that false alarms for either detection or discrimination performance would also be associated with physiological changes (Pessoa, 2005; Pessoa, 2017; Pessoa et al., 2005; Pessoa et al., 2006). This effect was not significant in the current research (Table 1; Appendix F.1), although there were trends in the predicted direction. This makes unclear whether it is only post-binary detection confidence or also binary target detection responses that are determined by the experience of arousal during the presentation (Pessoa, 2005; Pessoa et al., 2005).

Finally, a limitation of the current study must be noted. The reported effect was assessed using only measures of autonomic nervous system arousal such as skin conductance and heart rate responses. Our findings cannot answer whether emotional and behavioural reports, neural processing or different methods for the assessment of physiological changes will demonstrate the same linear trend between participants’ responses and confidence for meta-awareness.

8. Conclusions

The current study suggests that successfully masked emotional faces do not elicit changes in physiological processes. Instead, the

current results point to the possibility that autonomic nervous system arousal is specific to trials that include masked target meta-awareness. The current findings allow the hypothesis that arousal could be a possible determinant for target meta-awareness by shaping perceptual experience and influencing confidence reports for the correct detection of angry and fearful faces.

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Appendix A

A.1. Stimuli pre-selection

See Fig. 4.

	Session					
	A (type): Mean (S.D.)		B (experience) Mean (S.D.)			
Accuracy (%)	Group AB	Group BA	Group AB	Group BA	Overall Session A	Overall Session B
Angry*	71.97 (9.97)	80.55 (5.27)	46.35 (11.25)	44.44 (8.07)	76.47 (8.79)	45 .29 (9.43)
Fearful	75 (8.01)	77.22 (6.66)	53.12 (7.98)	57.22 (11.48)	76.17 (7.18)	55.29 (9.91)
Disgusted	73.12 (10.66)	67.77 (8.7)	45 (8.45)	40.55 (7.26)	70.29 (9.75)	42.64 (7.92)
Happy	81.25 (9.54)	81.11 (10.24)	60 (11.95)	66.66 (12.74)	81.17 (9.6)	63.52 (12.47)
Sad	85.62 (5.62)	80 (9.35)	54.37 (8.63)	57.55 (7.94)	82.64 (8.12)	56.17 (8.2)
Neutral	88.75 (4.43)	85.55 (8.45)	66.9 (4.58)	70 (16.95)	87.05 (6.85)	68.52 (12.47)
Intensity (1 - 10)						
Angry	6.3 (.89)	6.02 (1.32)	7.35 (1.09)	7.13 (1.69)	6.15 (1.11)	7.23 (1.4)
Fearful	5.91 (.46)	5.48 (,63)	7.06 (.35)	6.71 (1.14)	5.68 (.58)	6.88 (.86)
Disgusted	5.46 (.34)	5.88 (.67)	6.43 (.26)	6.92 (1.01)	5.68 (.56)	6.69 (.77)
Happy	5.96 (.59)	5.87 (.45)	7.51 (1.01)	7.42 (.64)	5.91 (.5)	7.46 (.81)
Sad	4.88 (,48)	4.81 (.59)	5.06 (1.15)	5.26 (.77)	4.84 (.52)	5.16 (.94)
Ambiguity (1 - 10)**						
Angry	5.62 (1.02)	5.66 (1.34)	4.63 (1.29)	3.5 (1.07)	5.64 (1.16)	4.03 (1.28)
Fearful	5.24 (1.13)	5.16 (.81)	4.19 (.73)	4.05 (1)	5.19 (.94)	4.12 (.86)
Disgusted	6.23 (.58)	5.29 (.51)	4.98 (.85)	4.49 (.32)	5.74 (.71)	4.72 (.65)
Happy	5.28 (.48)	5.2 (.56)	3.69 (.66)	3.61 (.55)	5.24 (.51)	3.64 (.59)
Sad	5.61 (.58)	5.52 (.48)	3.79 (.75)	3.96 (.65)	5.56 (.51)	3.88 (.68)
Neutral	4.38 (.6)	4.93 (.84)	2.93 (.96)	3.26 (.96)	4.67 (.77)	3.1 (.94)
Accuracy Analysis (p values)						
	(AT Task)					
(AE Task)	Angry	Fearful	Disgusted	Happy	Sad	Neutral
Angry*	**.00*** **	.138	.365	**.016**	**.005**	**.00**
Fearful	.	**.00*** **	**.003**	.65	1	**.007**
Disgusted		.	**.00*** **	**.003**	**.00**	**.00**
Happy		.	.	**.00*** **	1	1
Sad	.				**.00*** **	.001
Neutral		.	.		.	**.00*** **

Fig. 4. Accuracy, Intensity and Ambiguity Ratings in respect to emotional category for session A (stimuli type) and B (current mood) per participant group; AB (type first), BA (experience first) and overall. In the bottom part Bonferonni **adjusted** ($p \leq .05$) Post Hoc analysis for overall accuracy. Green items signify higher scores for left column; red items for top row. *BA > AB, AE order effect; **AB > BA, AT order effect. ***Same stimuli are compared between tasks (task/type interaction); Bonferonni **corrected** ($p \leq .01$) paired samples *t*-test. Left column refers to **AE task**, top row refers to **AT task**. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

A.2. Percentage metric

$$IF\ (\%) = \left(\left(\frac{(10-\text{Amb.}) + (\text{Int.})}{2}\right)*50\right) + \left(\left(\frac{\text{SCR Maximum Deferral}}{\text{Max\{SCR Maximum Deferral Stimuli Type\}}}\right)*25\right) + \left(\left(\frac{\text{HR Maximum Deferral}}{\text{Max\{HR Maximum Deferral Stimuli Type\}}}\right)*25\right)$$

Ambiguity using a one (not at all) to ten (extremely) scale. This item is reversed (10 – x).

Intensity using a one (not at all) to ten (extremely) scale.

Highest unambiguous increase of a phasic skin conductance response three seconds post stimulus offset with respect to pretarget baseline for the specific stimuli.

The score for the stimuli with the highest unambiguous increase in phasic skin conductance response three seconds post stimulus offset with respect to pretarget baseline for the specific emotional stimuli category.

Highest unambiguous increase of a phasic heart rate response four seconds post stimulus offset with respect to pretarget baseline for the specific stimuli.

The score for the stimuli with the highest unambiguous increase in phasic heart rate four seconds post stimulus offset with respect to pretarget baseline for the specific emotional stimuli category.

Appendix B

B.1. Visual contrast

Gender

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Male	8	47.1	47.1	47.1
	Female	9	52.9	52.9	100.0
	Total	17	100.0	100.0	

Descriptive Statistics

	N	Range	Minimum	Maximum	Sum	Mean		Std. Deviation	Variance
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Statistic
Face	17	3.75	1.10	4.85	38.05	22382	0.26725	1.10192	1.214
NoFace	17	3.80	1.15	4.95	37.35	21971	0.26211	1.08072	1.168
Angry	17	4.00	1.20	5.20	38.40	22588	0.28787	1.18694	1.409
Fear	17	4.00	1.20	5.20	40.40	23765	0.30384	1.25276	1.569
Sad	17	3.80	1.00	4.80	37.80	22235	0.26172	1.07908	1.164
Neutral	17	3.20	1.00	4.20	35.00	20588	0.23374	0.96375	0.929
Valid N (listwise)	17								

Appendix C

C.1. Ambiguity descriptives

Descriptive Statistics

	Mean	Std. Deviation	N
Unsure_vs_Possibly	3.8000	1.52128	15
Unsure_vs_Most_Likely	2.4667	0.74322	15
Unsure_vs_Definetely	2.4000	0.82808	15

Possibly_vs_Most_Likely	6.8000	0.94112	15
Possibly_vs_Definetely	3.6000	1.63881	15
Definetely_vs_Most_Likely	4.2000	1.08233	15

C.2. Ambiguity pairwise comparisons

Pairwise Comparisons

Measure: MEASURE_1

(I) factor1	(J) factor1	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
1	2	1.333*	0.333	0.020	0.157	2.510
	3	1.400	0.423	0.078	−0.094	2.894
	4	−3.000*	0.338	0.000	−4.193	−1.807
	5	0.200	0.698	1.000	−2.265	2.665
	6	−0.400	0.423	1.000	−1.894	1.094
2	1	−1.333*	0.333	0.020	−2.510	−0.157
	3	0.067	0.284	1.000	−0.936	1.069
	4	−4.333*	0.252	0.000	−5.223	−3.444
	5	−1.133	0.477	0.484	−2.816	0.549
	6	−1.733*	0.316	0.001	−2.848	−0.619
3	1	−1.400	0.423	0.078	−2.894	0.094
	2	−.067	0.284	1.000	−1.069	0.936
	4	−4.400*	0.289	0.000	−5.422	−3.378
	5	−1.200	0.509	0.502	−2.996	0.596
	6	−1.800*	0.312	0.001	−2.900	−0.700
4	1	3.000*	0.338	0.000	1.807	4.193
	2	4.333*	0.252	0.000	3.444	5.223
	3	4.400*	0.289	0.000	3.378	5.422
	5	3.200*	0.595	0.001	1.099	5.301
	6	2.600*	0.335	0.000	1.417	3.783
5	1	−0.200	0.698	1.000	−2.665	2.265
	2	1.133	0.477	0.484	−0.549	2.816
	3	1.200	0.509	0.502	−0.596	2.996
	4	−3.200*	0.595	0.001	−5.301	−1.099
	6	−0.600	0.505	1.000	−2.383	1.183
6	1	0.400	0.423	1.000	−1.094	1.894
	2	1.733*	0.316	0.001	0.619	2.848
	3	1.800*	0.312	0.001	0.700	2.900
	4	−2.600*	0.335	0.000	−3.783	−1.417
	5	0.600	0.505	1.000	−1.183	2.383

Appendix D

D.1. Comparison between hits and misses per stimuli type

Descriptive Statistics

	Mean	Std. Deviation	N
TPAngry	0.0527	0.04005	24
FNAngry	0.0124	0.01632	24
TPFear	0.0641	0.03669	24

FNFear	0.0094	0.01443	24
TPSad	0.0154	0.01368	24
FNSad	0.0109	0.01929	24
TPNeutral	0.0093	0.01359	24
FNNeutral	0.0120	0.01444	24
TNNoFace	0.0094	0.00673	24
FPNoFace	0.0159	0.01576	24

Pairwise Comparisons

Measure: MEASURE_1

(I) Stimuli_Type	(J) Stimuli_Type	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
1	2	−0.004	0.004	1.000	−0.016	0.008
	3	0.019*	0.005	0.009	0.004	0.035
	4	0.022*	0.005	0.002	0.007	0.037
	5	0.020*	0.005	0.003	0.005	0.035
2	1	0.004	0.004	1.000	−0.008	0.016
	3	0.024*	0.004	0.000	0.011	0.036
	4	0.026*	0.004	0.000	0.013	0.040
	5	0.024*	0.004	0.000	0.013	0.035
3	1	−0.019*	0.005	0.009	−0.035	−0.004
	2	−0.024*	0.004	0.000	−0.036	−0.011
	4	0.003	0.002	1.000	−0.004	0.009
	5	0.001	0.003	1.000	−0.009	0.010
4	1	−0.022*	0.005	0.002	−0.037	−0.007
	2	−0.026*	0.004	0.000	−0.040	−0.013
	3	−0.003	0.002	1.000	−0.009	0.004
	5	−0.002	0.002	1.000	−0.009	0.005
5	1	−0.020*	0.005	0.003	−0.035	−0.005
	2	−0.024*	0.004	0.000	−0.035	−0.013
	3	−0.001	0.003	1.000	−0.010	0.009
	4	0.002	0.002	1.000	−0.005	0.009

Based on estimated marginal means

* The mean difference is significant at the 0.05 level.

[b] Adjustment for multiple comparisons: Bonferroni.

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	TPAngry - TPSad	0.03731	0.04129	0.00843	0.01987	0.05474	4.427	23	0.000
Pair 2	TPAngry - TPNeutral	0.04345	0.03826	0.00781	0.02730	0.05961	5.564	23	0.000
Pair 3	TPAngry - TNNoFace	0.04336	0.04021	0.00821	0.02638	0.06034	5.283	23	0.000
Pair 4	TPFear - TPSad	0.04872	0.03821	0.00780	0.03258	0.06485	6.246	23	0.000
Pair 5	TPFear - TPNeutral	0.05486	0.03604	0.00736	0.03964	0.07008	7.457	23	0.000
Pair 6	TPFear - TNNoFace	0.05477	0.03843	0.00784	0.03855	0.07100	6.983	23	0.000

Appendix E

See Fig. 5.

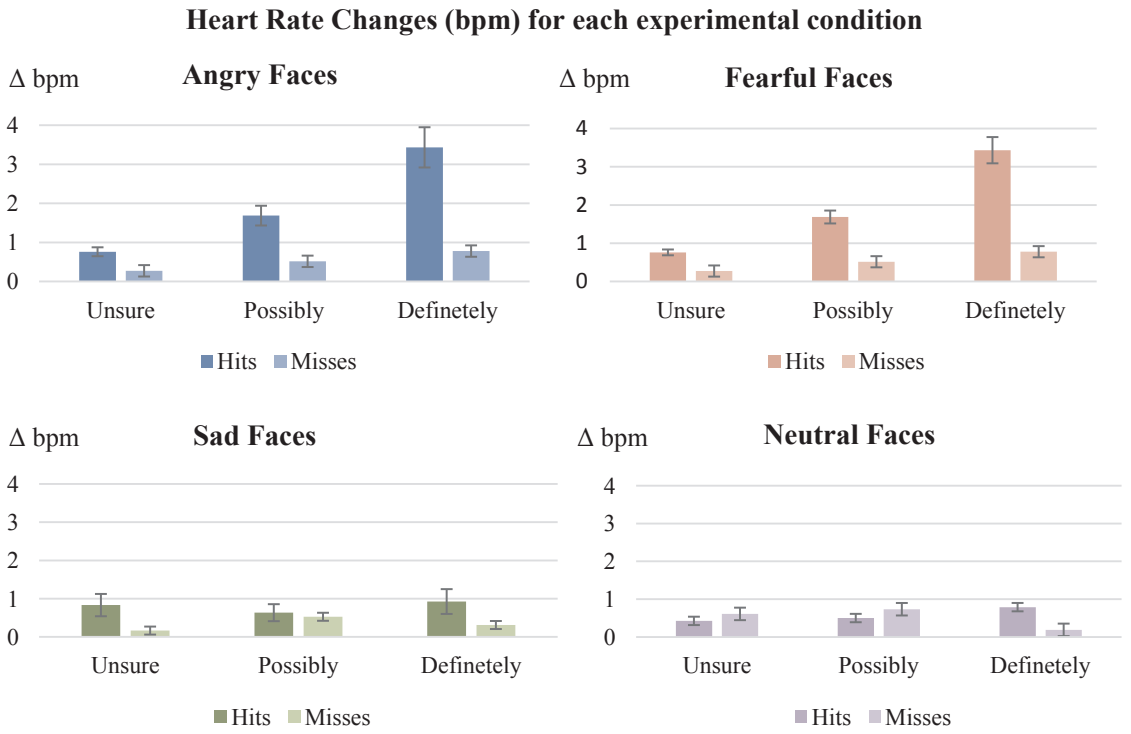


Fig. 5. Heart rate changes in beats per minute for different stimuli types arranged for signal detection (hits, misses, correct rejects, false alarms) and detection confidence replies (unsure, possibly, definitely). Error bars how ± 1 standard error of the mean.

Appendix F

F.1. Trends for false alarms

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	TNNoFaceHR	0.4988	24	0.49545	0.10113
	FPNoFaceHR	0.9478	24	1.36430	0.27849
Pair 2	TNNoFace	0.0094	24	0.00673	0.00137
	FPNoFace	0.0159	24	0.01576	0.00322

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	TNNoFaceHR - FPNoFaceHR	−0.44897	1.14660	0.23405	−0.93313	0.03520	−1.918	23	0.068
Pair 2	TNNoFace - FPNoFace	−0.00654	0.01772	0.00362	−0.01402	0.00094	−1.808	23	0.084

Appendix G. Supplementary material

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.concog.2017.10.013.

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"I can see you; I can feel it; and vice-versa": consciousness and its relation to emotional physiology

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"I can see you; I can feel it; and vice-versa": consciousness and its relation to emotional physiology

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ABSTRACT

In this paper, we explore whether masked emotional faces can elicit changes in physiology without awareness. We also explore whether emotional miss-discrimination involves the physiological correlates associated with the perception of an emotion. We adjust the discrimination threshold of presentation per participant and stimulus type to chance-level performance using hit rates and receiver-operating characteristics (ROC). We assess subliminality using an adjusted Bayesian criterion for awareness ($A = .167$). We measure skin-conductance, heart-rate, facial-emotional and engagement-task force-pressure responses to masked fearful, angry, happy, sad and neutral faces. We report that when faces were subjectively adjusted using unbiased ROC criteria for awareness, we found non-significant differences between emotions and Bayesian evidence for null responses. Hit-rate adjustments were associated with physiological changes for hits and misses for fearful, angry and happy faces. For misses for discrimination performance, participants could correctly appraise the valence and arousal of the presented face. Miss-discrimination for seeing a fearful face when presented with innocuous cues was also associated with high arousal responses. These findings suggest that if physiological arousal is elicited during the presentation of masked emotion, conscious assessment is, upon explicit post-trial inquiry, involved in the evaluation of the elicited emotion and the emotional elicitor.

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Subliminal; emotion; physiology

More than one hundred years since the first approaches to the subconscious by Carl Gustav Carus (1851), Friedrich Nietzsche (1876), and Josef Breuer and Sigmund Freud (1895), experimental psychology and cognitive neuroscience still seek to answer whether we can be influenced by unconscious emotional cues (Brooks et al., 2012). In contemporary psychological research, one frequently employed method for addressing this enduring research question is to briefly present (6.25–83.33 ms) emotional faces followed by clearly visible non-emotional masks that aim to render the emotional targets invisible (Bachmann & Francis, 2013). Physiological responses, such as skin-conductance (SCR: subcutaneous sweating) and heart-rate responses (HR), as well as neural responses, such as fMRI activation and cortical bioelectrical activity, to these brief emotional targets are interpreted as evidence for unconscious processing (Pessoa, 2005).

This technique for presenting emotional faces – termed backwards masking – has produced an abundant array of findings. For example, several fMRI studies have reported limbic system activation in response to masked fearful, angry and happy faces, and the suggestion has been put forth that a dedicated subcortical neural pathway to the amygdala elicits autonomic nervous system arousal in response to very brief stimuli when these confer evolutionary important survival and sociobiological value (Brooks et al., 2012). It is suggested that the purpose of this hypothesised arousal pathway is to make us biologically prepared to adapt to environmental cues that require an imminent, automatic and involuntary response (Liddell et al., 2005).

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When this theoretical notion was put to the test, several studies using skin- conductance and heart-rate responses were able to provide support that very brief (6.25–83.33 ms) masked emotional faces indeed elicit higher autonomic nervous system arousal compared to non-emotional masked stimuli or masked neutral faces (van der Ploeg, Brosschot, Versluis, & Verkuil, 2017). Masked emotional stimuli were also suggested to emotionally *colour* our first impressions of clearly visible subsequently presented neutral targets (Lapate, Rokers, Li, & Davidson, 2014), affectively influence our perception of reality (Siegel, Wormwood, Quigley, & Barrett, 2018) and even exert influence on how much we like, or dislike subsequently presented food and beverage (Winkielman & Gogolushko, 2018).

Although these findings are well-documented and partly replicated (Brooks et al., 2012), they have been extensively criticised. The main themes of criticism are the set duration of subconscious presentation (Lähteenmäki, Hyönä, Koivisto, & Nummenmaa, 2015), the assessment of detection or discrimination[1] performance using hit rates (Pessoa, Japee, Sturman, & Ungerleider, 2006) and the assessment of awareness using non-significance (Dienes, 2015). For example, previous research presented masked emotional faces for 6.25–83.33 ms and assumed that the presented faces will remain below the threshold of conscious awareness irrespective of individual differences, such as differences in attentional resources (Aru & Bachmann, 2017), and stimulus type differences, such as higher visibility of emotional faces due to emotional incongruence with the neutral mask (Calvo & Lundqvist, 2008; Kim et al., 2010). Additionally, according to the current paradigm, stimulus invisibility occurs when the participant detects or discriminates at chance what type of stimulus was presented in a post-trial or post-experimental task. In this manner, chance-level performance indicates that the participant responded randomly, *like a blind person would* when asked to identify a face (Erdelyi, 2004). The assessment of this chance-level criterion is commonly based on hit rates and the failure to reject the null hypothesis of chance performance. The problem with hit rates is that the participants often display response biases (Stanislaw & Todorov, 1999), such as replying having seen a face only when they are certain beyond a shadow of a doubt that a face was presented (conservative bias) or replying having seen a face when they are quite unsure whether a face was presented (liberal bias). The problem with non-significance is that, to infer subconscious processing, the lack of evidence for the alternative hypothesis is misinterpreted as positive evidence for the null (Dienes, 2015).

In our previous work on consciousness and emotion, we attempted to address these issues (Tsikandilakis, Bali, & Chapman, 2019a, 2019b; Tsikandilakis, Chapman, & Peirce, 2018; Tsikandilakis & Chapman, 2018). We used per-participant and stimulus-type-adjusted thresholds for the presentation of masked emotional faces, assessed awareness using both hit rates and non-parametric signal detection criteria (Zhang & Mueller, 2005), applied Bayesian analyses to provide evidence for the null, and ran post-trial response confidence and hits (correct detection/discrimination) and misses (incorrect detection/discrimination) analysis for participant responses. We reported that skin-conductance and heart-rate responses for angry, fearful and happy faces require a sufficient level of confidence for target-detection meta-awareness and, critically, that hits but not misses for detection confer these physiological changes. The questions that our previous work has, nevertheless, left unanswered are whether these findings apply for face-detection as well as for the discrimination of emotion from faces, whether there are levels of emotional awareness between the detection and discrimination of emotional faces, and whether misclassification of a brief stimulus is sufficient to affectively impact our biological preparedness by driving our physiological responses.

In the current study, we expand our model to address these questions. We test whether emotional faces (fearful, angry, happy, and sad), neutral faces, and non-facial blurs that are adjusted per participant and stimulus type using both hit rates and receiver operating characteristics elicit physiological changes when presented at discrimination threshold durations. To implement an adjusted discrimination threshold criterion we set the chance-level threshold criterion at $A = .167$ and 16.67% when using hit rates, that would indicate chance-level performance given the available options for discrimination. We explore whether responses for hits and misses include correct appraisal of emotional information such as ratings for the type of emotional valence and the level of expressed arousal of the presented stimulus. Furthermore, we explore whether brief stimuli that are not associated with physiological arousal such as sad and neutral faces and non-facial pattern blurs,

induce physiological changes when misclassified as emotionally arousing stimuli, such as fearful faces.

1. Method

1.1. Participants

An a-prior power analysis using GPOWER (Faul, Erdfelder, Buchner, & Lang, 2009) revealed that thirty-six participants would be required for $P_{(1-\beta)} \geq .9$ for a medium effect size $f = .25$. Eighty-two right-handed volunteers (42 female) participated in the current study. The exclusion criteria were current or previous DSM Axis I or II diagnosis and current or previous alcohol/drug abuse through self-reports. The participants were screened with the Somatic and Psychological Health Report Questionnaire (Berryman, McAuley, & Moseley, 2012) and participants with scores above 1.0 (indicating an undiagnosed mental-health disorder) were excluded from the analysis ($n = 2$). Participants were screened with an online alexithymia questionnaire (Alexithymia, 2018) and participants with scores over 94 (indicating alexithymic traits) were excluded from the analysis ($n = 2$). Participants were also screened with a hyperactivity-impulsivity questionnaire (Kooij & Francken, 2010) and participants whose scores indicated a possible hyperactivity-impulsivity disorder were excluded from the analysis ($n = 1$). The final sample consisted of 77 participants ($P_{(1-\beta)} = .99$) (39 females) with a mean age of 31.79 year (S.D. = 8.31). The experiment was approved by the Ethics Committee of the School of Psychology of the University of Nottingham.

1.2. Facial stimuli

The facial stimuli used were taken from the dataset created by Gur et al. (2002). They included faces with angry, fearful, happy, sad and neutral facial expressions. Non-facial blurs were generated from black and white pattern stimuli and scrambled using pseudo-randomised pixel permutation in MATLAB. All the stimuli were adjusted for interpupillary distance, transformed to grey scale and resized to a 1024×768 pixels resolution. Their average luminance was controlled using SHINE, MATLAB Toolbox. Finally, they were spatially aligned and placed in a white circle (height: 6 cm, width: 4 cm). The included stimuli were tested for physiological arousal during supraliminal presentations (1 s) and validated for emotional discrimination with Face-Reader software (Noldus, 2018) and participant assessment, they were controlled for low-level visual features, such as spatial frequency and gradient orientation differences, and the black and white pattern mask was also separately compared and adjusted for luminance contrast with the presented faces (see Tsikandilakis, Bali et al., 2019a; Tsikandilakis & Chapman, 2018; Tsikandilakis, Peirce et al., 2018).

1.3. Participant assessment

1.3.1. Physiological recording and analysis

During the main experiment skin conductance and heart rate were used to assess physiological responses. Skin-conductance responses were measured from the left hand (index/first and middle/second fingers) of each participant using disposable Ag/AgCl gelled electrodes. The signals were received by a BIOPAC System, EDA100C in units of microsiemens and recorded in AcqKnowledge (Braithwaite, Watson, Jones, & Rowe, 2013). Heart rate was measured via a single finger sensor from the left hand (ring/third finger). The signal was measured by a BIOPAC System, PPG100C using infra-red photoplethysmogramy of blood flow fluctuations and converted and recorded in beats per minute (bpm) in AcqKnowledge. To make our data comparable with previous research we used similar analysis parameters (van der Ploeg et al., 2017). The presence of a phasic skin conductance response was defined as an unambiguous increase (.01 μS) with respect to each pre-target SCR score occurring one to three seconds post-stimulus offset (Critchley, 2002; Williams et al., 2005). The presence of a heart-rate response was defined as an event-related heart-rate peak in beats per minute with respect to each pre-target heart-rate score occurring one to five seconds post-stimulus offset (Critchley et al., 2005). The raw signals for both measures were processed using the Derive Phasic from Tonic and manual Dirac Delta (Δ) functions. No additional smoothing, filtering or transformations were applied (Braithwaite et al., 2013). Non-responders for physiological changes were also included in the data analysis ($n = 4$).

1.3.2. Analysis of facial responses

The analysis of facial expressions was conducted using Noldus 7.1 using an HD camera mounted on the bottom of the presenting screen and centred on the participant's face. The analysis was run using the

maximum video capture frames per second allowed by the face-reader equipment (30 fps). The analyses employed the Viola-Jones cascaded algorithm and an active appearance model (AAM) with a 500-point Euclidean transformation to eliminate static identification variability for image quality, lighting, background variation and orientation. The analysis included a custom template analysis and each participant was evaluated in respect to the expressed emotion after controlling for the influence of action units that were present in their own neutral expressions using the participant calibration module (Noldus, 2018). The General61 face module was used to assess European participants and the Asian and East Asian face modules were used to assess participants with an Asian ethnic background. Expression of an emotion was defined as recognition of an emotional expression up to five seconds post-stimulus offset (Lewinski, den Uyl, & Butler, 2014) using non-parametric receiver operating characteristics (Zhang & Mueller, 2005). Participants were aware that their facial expressions were recorded.

1.3.3. Engagement task response force plate

To measure whether participants had different patterns of response intensity and post-response task disengagement durations per stimulus type (angry, fearful, happy, sad and neutral), confidence (possibly, likely and definitely) and response type (hits and misses), we developed a mouse pad device that could measure mouse press force during the engagement tasks. The device included a working measurement area of 210–160 mm mechanically coupled to four 5 kgf load cells. The signals from these cells were then amplified and converted to a digital signal via a 24-bit ADCs that operated at 120 Hz with a minimum force accuracy of .01 g (.00098 N). The device operated using its own parallel port input and interfaced with the stimulus presenting computer using a USB 2.0 (Figure 1). The participant's right hand was rested upon a 45 by 20 by 3 cm forearm support and the device calculated mouse press pressure via drift filtering and mapping the location of the mouse to an on-screen visual matrix, and subsequently by subtracting the hand weight of the participant and the force applied after each bilateral movement from the force applied every time the participant replied using a mouse click. To avoid artefacts and outliers due to individual pressure strength, each participant was asked during a training session to press 20 times on one of six randomly positioned boxes on the screen and then confirm their choice by pressing a button labelled "OK" at the lower part of the screen. *Z*-scores for click pressure per participant were calculated and the force applied during the main experimental stage was measured in units of standard deviations from the performance in the training phase. In addition to force pressure, the Response Disengagement Residue (RDR) was also calculated as the time in milliseconds that each participant took to release the "OK" button after making an engagement task response. This was used as a measure of confidence/ambiguity response. Participants were aware that their engagement task responses were recorded.

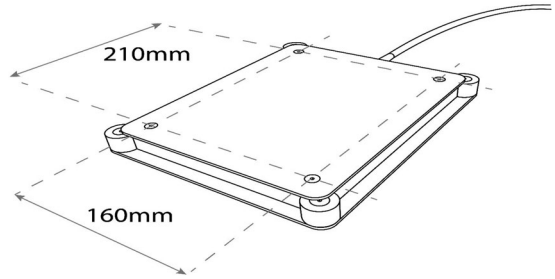


Figure 1. A graphic illustration of the mouse pad force-plate device. The device was placed on a solid and even surface. The participants' hands were placed on a levelled wrist rest and the participants were asked to respond during the training and main experimental phases using the mouse.

1.4. Apparatus and presentation-testing

All stimuli were presented on a high frequency LED monitor set at 144 Hz (6.94 ms) and created in the Builder and Coder components of PsychoPy v.1.90.02 (Peirce, 2007). An IPAD PRO camera with 240 Hz refresh rate (4.17 ms) recorded two pilot runs of the experiment and the stimulus presentation was assessed frame by frame; no instances of dropped frames were detected. A self-developed dropped frame report script with one frame (6.94 ms) tolerance threshold was coded in Python and two pilot experimental diagnostic sessions were run. The presenting monitor reported no dropped frames; prognostic dropped frame rate was estimated at 1/5000 trials. Experimental stages were, subsequently, run using dropped frames diagnostics and per stimulus presentation frame rate performance of the stimulus presenting monitor; no instances of dropped frames were reported.

1.5. Threshold adjustment experiment: discrimination phase

In the first part of the experiment, we defined the discrimination threshold individually per participant and stimulus type. We presented participants with a fixation cross for 3 (±1) seconds. After the fixation cross an angry or fearful or happy or sad or neutral face or a non-facial blur pattern was presented for 13.89 or 20.83 or 27.78 or 34.72 or 41.67 ms with backward masking by a neutral black and white pattern for 125 ms. Twelve different fearful, angry, happy, sad and neutral faces, and sixty non-facial blur patterns were presented for each duration (13.89 and 20.83 and 27.78 and 34.72 and 41.67 ms); the presentation order was randomised. Five seconds after each presentation, an onscreen message asked participants to decide what kind of face was presented during the trial using their mouse. Participants were asked to press on one of six boxes labelled Angry, Fearful, Happy, Sad, Neutral or Non-Facial placed in random positions on the screen to indicate their choice. Then they were asked to press on a fixed position button in the lower part of the screen labelled "OK" to confirm their choice.

To define the discrimination threshold per participant and stimulus type, nonparametric receiver operating characteristics (ROC; Zhang & Mueller, 2005) and hit rate performance were calculated separately. The duration of presentation (13.89 or 20.83 or 27.78 or 34.72 or 41.67 ms) that marked the smallest absolute difference from chance per stimulus type was imported separately for ROC and hit rate performance to the main experiment; [.167. – $P_{Threshold}$] closest to .167 (Figures 2 and 3; see also Supplemental Material 1.1 and 1.2). This phase was performed seven days before and at the same time-slot as the main experiment.

1.6. Main experiment: physiological responses phase

In the main experiment, we tested whether the threshold adjusted faces can elicit changes in physiological responses, facial responses and engagement task pressure responses. Participants were invited to the same laboratory space under identical conditions. They took part in two 15-min. experimental sessions separated by a 5 min. long break; session order was randomised (see Supplemental Material 2.1 and 2.2). In both sessions, participants were presented with a fixation cross for 3 (±1) seconds. After the fixation cross an angry or fearful or happy or sad or neutral face or a non-facial blur was presented. In one session, the faces were presented for hit-rate adjusted durations and in the other session they were presented for ROC adjusted durations (Figure 2). In both sessions, faces were backward-masked with a neutral pattern mask presented for 125 ms. Twelve different

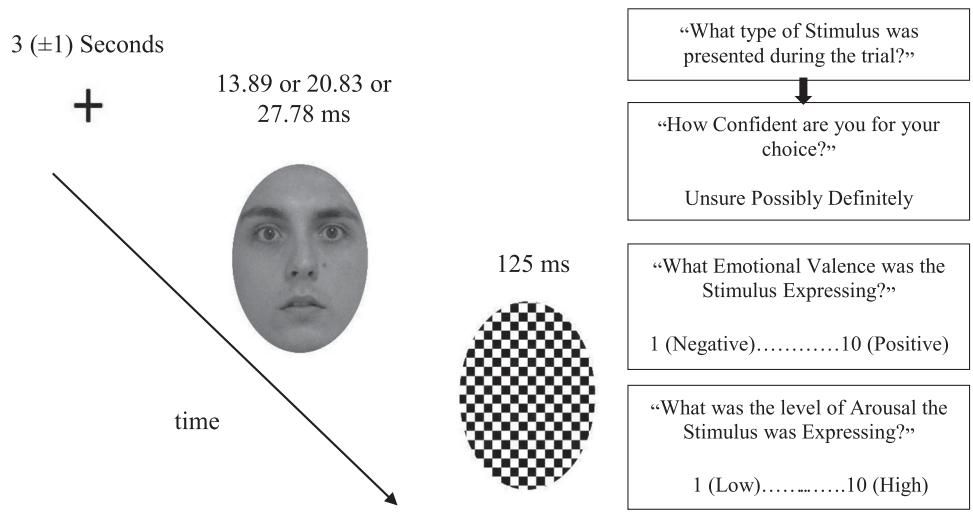


Figure 2. Participants watched masked stimuli for ROC and hit-rate adjusted durations (13.89 or 20.83 or 27.78). The stimuli were backward-masked with a black and white pattern mask (125 ms). Heart-rate, skin-conductance, facial and engagement task pressure responses were measured in each trial.

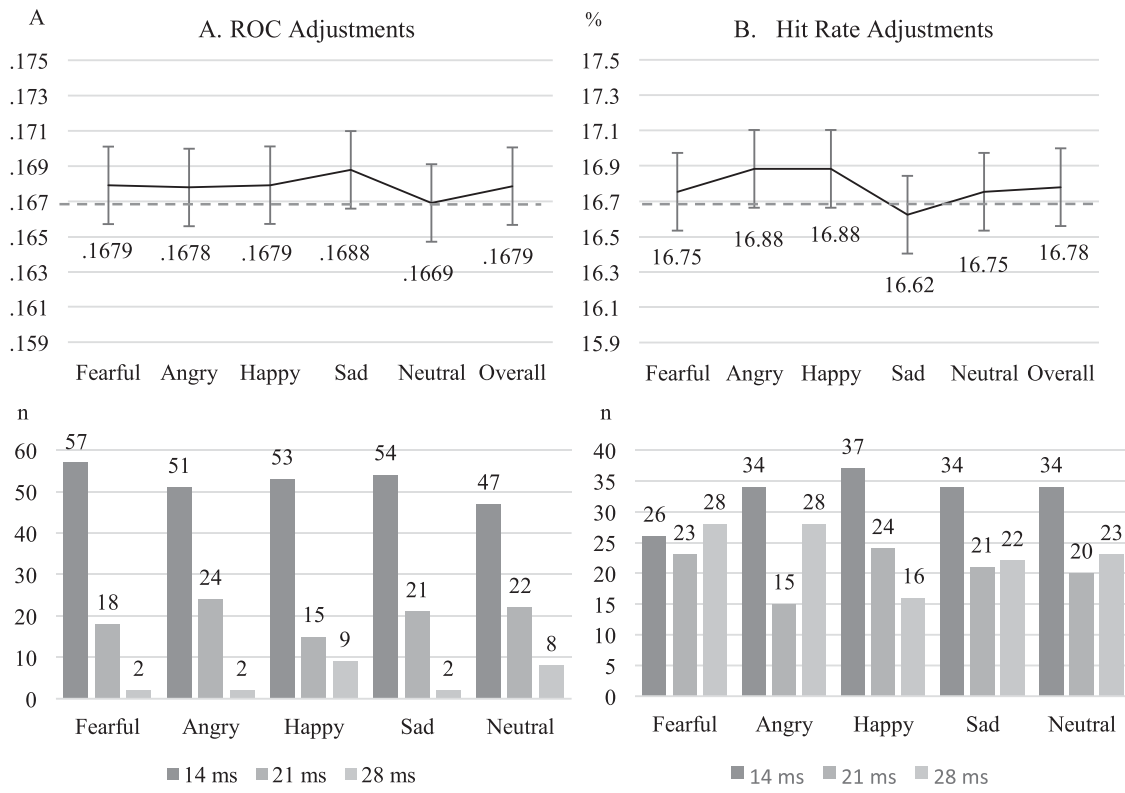


Figure 3. Discrimination performance for ROC and hit-rate adjustments and participant count (n) per threshold of presentation (13.89 or 20.83 or 27.78) and stimulus type. Mid-line indicates chance-level performance. Bars indicate standard error of the mean (±2).

angry, sad, fearful, happy, neutral and a total of 60 different non-facial blur patterns were presented in each session with order randomised.

Seven seconds after each presentation, an on-screen message asked participants to choose what type of stimulus was presented. Participants were asked to choose using the mouse from randomly positioned on-screen boxes labelled Angry, Fearful, Happy, Sad, Neutral and Non-Facial. They were then asked to press on a fixed position button in the lower part of the screen labelled "OK" to confirm their choice. After this task, participants were asked to rate their confidence for their decision using the mouse between unsure, possibly and definitely and click "OK". Participants were also asked to rate using the mouse the Emotional Valence of the presented stimulus from one (negative) to ten (positive) and click "OK". They were also asked to rate using the mouse the Expressed Arousal of the presented stimulus from one (low arousal) to ten (high arousal) and click "OK". The order of the three tasks was randomised in each trial and participants were allowed six seconds to complete each task. A blank screen was presented for eight seconds after the completion of the engagement tasks to allow physiological measures to return to baseline.

2. Results

2.1. Threshold adjustment experiment: discrimination phase

We wanted to explore whether ROC adjustments in the threshold of presentation were associated with chance-level performance. We defined the threshold for chance-level performance at $A = .167$ and 16.67% when using hit rates. A Bayesian analysis with uncorrected degrees of freedom ($n = 77$; see Berry, 1996) was run using the Dienes calculator (2015) to assess chance-level processing, with substantial evidence for the null hypothesis defined as a Bayes factor B below 1/3. The intervals were conservatively defined at −.05 (.117; lower bound) and .05 (.217; higher bound) with 0 (.167) representing chance level performance. Discrimination performance using non-parametric receiver operating characteristics was at

chance ($M. = .1679$; S.D. = .019; S.E. = .002 $B = .06$; Figure 2).

To explore whether hit-rate adjustments in the threshold of presentation faces were associated with chance-level performance, another Bayesian analysis was run using the exact same parameters used for ROC adjustments; intervals set at −5% (11.67%; lower bound) to 5% (21.67%; higher bound) with 0 (16.67%) representing perfect chance-level performance and standard error uncorrected for degrees of freedom. Discrimination performance using hit rates was at chance ($M. = 16.78$; S.D. = 5.08; S.E. = .58; $B = .02$); Discrimination performance for individual stimuli can be seen in Figure 3.

2.2. Main experiment: SCR and heart-rate responses to masked faces

Adjustments using receiver operating characteristics did not lead to significant differences between different emotions in terms of skin-conductance (F (4, 304) = 1.29, $p = .27$; $\eta^2 = .02$) and heart-rate responses (F (4, 304) = .51, $p = .73$; $\eta^2 = .01$). Differences between stimulus types were also not found for ratings for valence (F (4, 304) = 1.01, $p = .41$; $\eta^2 = .01$) and arousal (F (4, 304) = .87, $p = .48$; $\eta^2 = .01$) suggesting that, using signal detection criteria, masked faces were not associated with significant differences in physiology and emotional ratings (for Bayesian analysis see Supplemental Material 3.1–3.4). Significant differences in SCR changes were found between different stimulus types for adjustments using hit-rates (F (2.89, 219.89) = 552.31, $p < .001$; $\eta^2 = .88$; Huynh–Feldt corrected). A similar effect (F (3.63, 275.47) = 367.15, $p < .001$; $\eta^2 = .83$; Greenhouse–Geisser corrected) was revealed for heart-rate responses (Figure 4).

In the current design, the participants responded with hits (correctly discriminating the presented stimulus type) and misses (incorrectly discriminating the emotion that the face was expressing as expressing another emotional type or a non-facial stimuli). The effect for adjustments using hit-rates was significant both for hits (F (1.93, 146.67) = 292.84, $p < .001$; $\eta^2 = .79$; Huynh–Feldt corrected) and misses (F (4, 304) = 59.35, $p < .001$; $\eta^2 = .44$) for discrimination for SCR. For heart-rate changes, hits (F (3.05, 231.69) = 675.58, $p < .001$; $\eta^2 = .89$; Greenhouse–Geisser corrected) and misses (F (2.03, 158.86) = 41.19, $p < .001$; $\eta^2 = .35$; Huynh–Feldt corrected) also revealed significant differences between stimulus types. For both SCR and heart rate angry, fearful and happy faces were higher compared to other stimuli (Table 1). When we further explored these findings, our analysis revealed that valence ratings for hits (F (3.36, 255.56) = 1591.26, $p < .001$; $\eta^2 = .95$; Huynh–Feldt corrected) and misses (F (4, 304) = 254.53, $p < .001$; $\eta^2 = .77$) were significantly lower for angry, fearful and sad faces and significantly higher for happy faces compared to other categories (Table 1). A similar effect was revealed for hits (F (3.57, 270.97) = 1179.69, $p < .001$; $\eta^2 = .94$; Huynh–Feldt corrected) and misses (F (3.74, 283.9) = 343.5, $p < .001$; $\eta^2 = .82$; Huynh–Feldt corrected) for arousal, with fearful, angry and happy faces being rated higher than other stimulus types (Table 1). These results suggested that

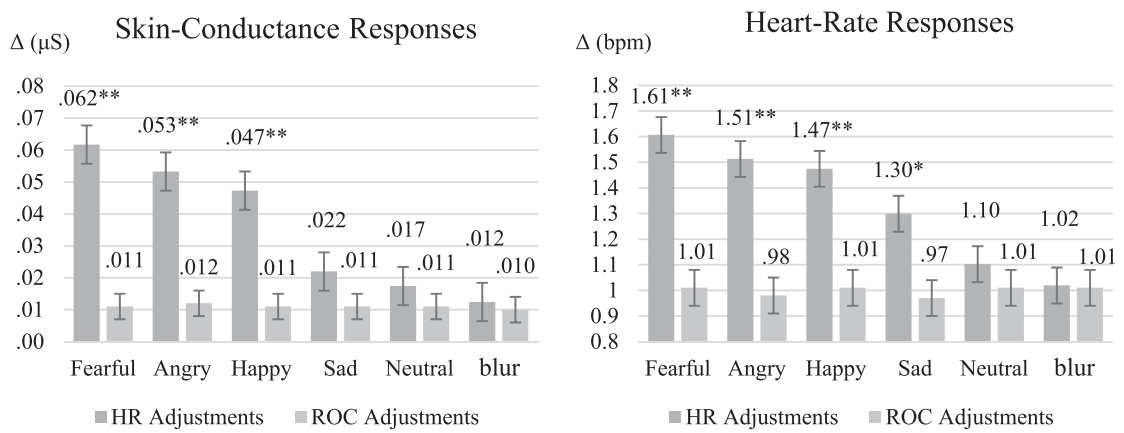


Figure 4. Skin-conductance and heart-rate changes for ROC and hit-rate adjustments. * indicates significance at the <.01 level. ** indicates significance at <.001 level. The Asterisks indicate significance in comparison to all non-asterisk items of the same adjustments category; e.g. Fearful HR Adjustments vs Sad, Neutral and Bubble HR Adjustments. See also Supplemental Material 3.1–3.4 for Bayesian analysis.

Table 1. Physiological and emotional responses for hits and misses for hit-rate adjustments.

Stimulus type	Discrimination response	SCR change Mean (SD)	Heart-rate change Mean (SD)	Valence ratings Mean (SD)	Arousal ratings Mean (SD)
Fearful	Hits**	.092 (.01)	2.209 (.11)	2.001 (.54)	6.467 (.43)
	Misses*	.031 (.01)	1.331 (.13)	4.599 (.22)	5.485 (.41)
Angry	Hits**	.057 (.01)	1.953 (.12)	2.053 (.51)	6.429 (.39)
	Misses*	.029 (.01)	1.182 (.11)	4.621 (.23)	5.393 (.35)
Happy	Hits**	.056 (.01)	1.963 (.12)	7.058 (.96)	6.409 (.39)
	Misses*	.026 (.01)	1.152 (.04)	5.698 (.18)	5.385 (.43)
Sad	Hits	.017 (.01)	1.318 (.18)*	3.129 (.44)*	5.109 (.49)
	Misses	.019 (.01)	1.078 (.27)	5.001 (.29)	4.502 (.34)*
Neutral	Hits	.016 (.03)	1.28 (.09)	5.595 (.67)	2.202 (.61)
	Misses	.011 (.01)	1.065 (.083)	4.997 (.27)	3.859 (.17)
Pattern Blur	Hits	.015 (.01)	1.002 (.09)	5.134 (.31)	2.017 (.21)
	False Alarms	.017 (.03)	1.113 (.18)	5.031 (.21)	5.003 (.22)

Notes: SCR change is described in μS. Heart-rate change is described in bpm. The asterisks indicate significance in comparison to all non-asterisk items of the same discrimination response category; e.g. fearful hits vs sad, neutral and blur hits. For full list of pairwise comparisons see Supplemental Material 4.1 and 4.2 and Supplemental Material 3.1–3.7 for Bayesian analysis for each pairwise comparison.
*Indicates <.01, **<.001.

participants were able to correctly appraise the emotional valence and the level of arousal of the presented stimulus even for misses for discrimination (see also Supplemental Material 4.1 and 4.2).

An additional finding for adjustments using hit-rates was that, as per our previous findings (Tsikandilakis et al., 2018), confidence reports for hits – but not misses – for angry (SCR: F (2, 124) = 68.59, $p < .001$, $\eta^2 = .95$; HR: F (2, 125) = 55.59, $p < .001$, $\eta^2 = .99$), fearful (SCR: F (2, 125) = 43.72, $p < .001$, $\eta^2 = .96$; HR: F (2, 125) = 170.82, $p < .001$, $\eta^2 = .99$), and happy faces (SCR: F (2, 125) = 4.23, $p = .02$, $\eta^2 = .29$; HR: F (2, 125) = 58.06, $p < .001$, $\eta^2 = .99$) revealed significance for a linear trend for skin-conductance and heart-rate responses suggesting that higher confidence for the discrimination of a presented face was associated with higher physiological changes (Figure 5; see also Supplemental Material 5.1).

2.3. Main experiment: SCR and heart-rate responses for emotional misclassification

We wanted to explore whether misclassification for hit-rate adjustments in the discrimination threshold can induce the physiological changes associated with the perception of an emotion. Because misclassification of an arousing emotional type (fear, anger and happiness) as another arousing type would be expected to induce physiological changes (Pessoa et al., 2006) independently of the discrimination response, we compared SCR and heart-rate changes for fearful, angry, happy, sad and neutral faces after excluding misclassification between fearful, angry and happy facial stimuli. An analysis of variance (F (4, 304) = 76.57 $p < .001$; $\eta^2 = .5$) with further Bonferoni corrected pairwise comparisons revealed that faces misclassified as fearful ($M. = .042$, S.D. = .014) were elicited higher SCR scores than faces misclassified as angry ($M. = .024$, S.D. = .011, $p < .001$; $d = 1.43$), happy ($M. = .019$, S.D. = .008, $p < .001$; $d = 2.02$), sad ($M. = .019$, S.D. = .007, $p < .001$; $d = 2.08$) and neutral faces ($M. = .019$, S.D. = .008, $p < .001$; $d = 1.96$). A similar finding was reported for heart-rate responses (F (4, 304) = 33.65, $p < .001$; $\eta^2 = .31$) with faces misclassified as fearful ($M. = 1.401$, S.D. = .124) inducing higher responses than faces misclassified as angry ($M. = 1.213$, S.D. = .122, $p < .001$; $d = 1.53$), happy ($M. = 1.221$, S.D. = .119, $p < .001$; $d = 1.48$), sad ($M. = 1.24$, S.D. = .119, $p < .001$; $d = 1.32$) and neutral faces ($M. = 1.229$, S.D. = .121, $p < .001$; $d = .84$). These results suggested that, after removing the cross-misclassification between arousing emotional types, participants still experienced higher arousal when they misclassified a face as fearful compared to when they misclassified a face as any other emotional type.

2.4. Main experiment: facial-emotional and force-plate responses

ROC adjustments were not associated with significant differences between stimulus types for facial-emotional recognition (F (4, 304) = 1.26, $p = .284$; $\eta^2 = .017$), engagement task responses (F (4, 300) = .98, $p = .42$; $\eta^2 = .013$) and RDR durations (F (4, 300) = .742, $p = .56$; $\eta^2 = .01$; for Bayesian analysis see Supplemental Material 3.5). For hit-rate adjustments, facial-emotional recognition revealed a significant

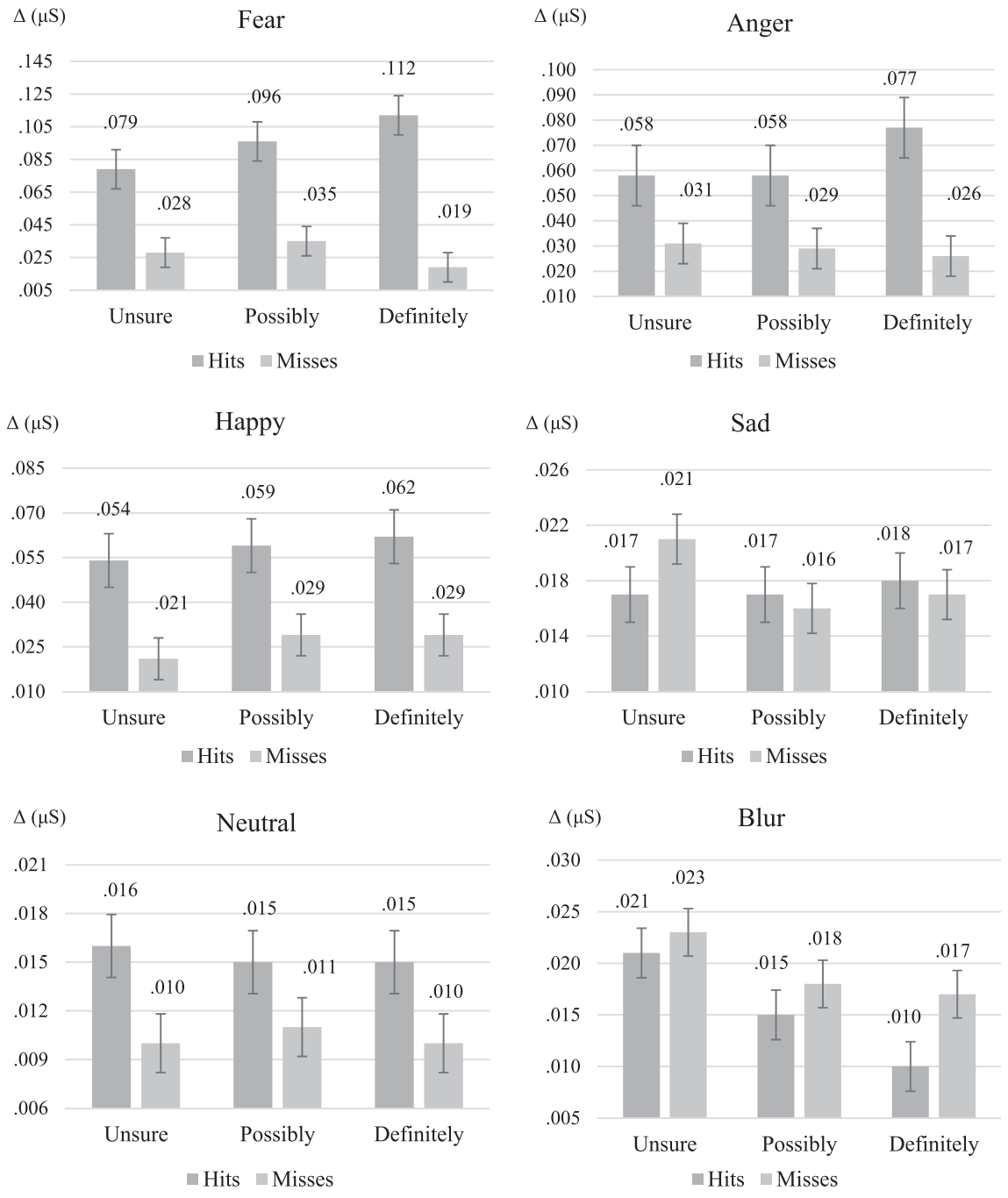


Figure 5. Skin-conductance changes for different stimulus types. SCR scores are arranged per signal detection response type (hits, misses) and detection confidence (unsure, possibly, definitely) ratings. Error bars show the standard error of the mean. See also Supplemental Material 5.1 and 3.1–3.7 for frequentist and Bayesian analysis of the linear trends.

effect for hits in discrimination only (F (2.58, 196.12) = 8.11, $p < .001$; $\eta^2 = .096$; Greenhouse–Geisser corrected). Further Bonferoni corrected pairwise comparisons revealed significance for emotional recognition (nonparametric sensitivity index A) for happy expressions ($M. = .069$, S.D. = .095) compared to fearful ($M. = .027$, S.D. = .055, $p < .01$; $d. = .54$), angry ($M. = .029$, S.D. = .062 $p < .01$; $d. = .49$) and sad

expressions ($M. = .027$, S.D. = .055, $p < .01$; $d. = .54$). These results suggested that participants were to some extend more likely to show happy-related facial expression characteristics in response to correctly discriminated happy faces but also that they could have possibly responded with a negative emotion regulation bias during the presentation (Garnefski & Kraaij, 2007). Differences for overall performance (F (3.32, 248.95) = 375.38, $p < .001$; $\eta^2 = .83$; Huynh–Feldt corrected), hits (F (2.84, 212.81) = 377.27, $p < .001$; $\eta^2 = .83$; Greenhouse–Geisser corrected) and misses (F (3.38, 253.46) = 140.98, $p < .001$; $\eta^2 = .65$; Huynh–Feldt corrected) for hit-rate adjustments in the discrimination threshold were also recorded between different stimulus types for engagement task force responses. Angry, fearful and happy faces were higher than other stimulus types (Figure 6; for Bayesian analysis see Supplemental Material 3.6 and 3.7).

3. Discussion

In the current study, we explored whether brief emotional faces can elicit changes in physiological responses such as SCR and heart rate, as well as changes in facial-emotional expressions and engagement task responses. We also explored whether misclassification of an emotion can lead to the physiological correlates associated with that emotion. When faces were adjusted per participant and stimulus type to the closest available duration to chance-level discrimination performance using unbiased ROC criteria, we could not report significant differences in physiological responses or any differences in reports for emotional type or emotional subtype information such as emotional valence and the level of expressed arousal. When faces were adjusted using hit rates, we reported overall differences in physiological responses as well as differences between stimulus types for hits and misses in discrimination. These differences were recorded for fearful, angry and happy faces compared to other stimulus types.

Further analysis of hits, misses and overall performance for hit-rate adjustments in the discrimination threshold revealed that emotional subtype information, i.e. emotional valence and level of arousal, were correctly appraised by the participants even during misses in discrimination. Interestingly, we also reported that when participant miss-discriminated a face as expressing fear they experienced higher physiological arousal than when they miss-discriminated a face as expressing other emotional types. The application of face-reading software in the current study gave us limited findings, as only hits in discrimination conferred higher facial-expression recognition rates for happy faces compared to other stimulus types. This result suggests that participants might have experienced a negative emotion regulation bias (Garnefski & Kraaij, 2007), particularly since they were aware of the recording of their expressions. The application of the force plate revealed similar findings with SCR and heart-rate responses; angry, fearful and happy faces showed higher pressure responses for

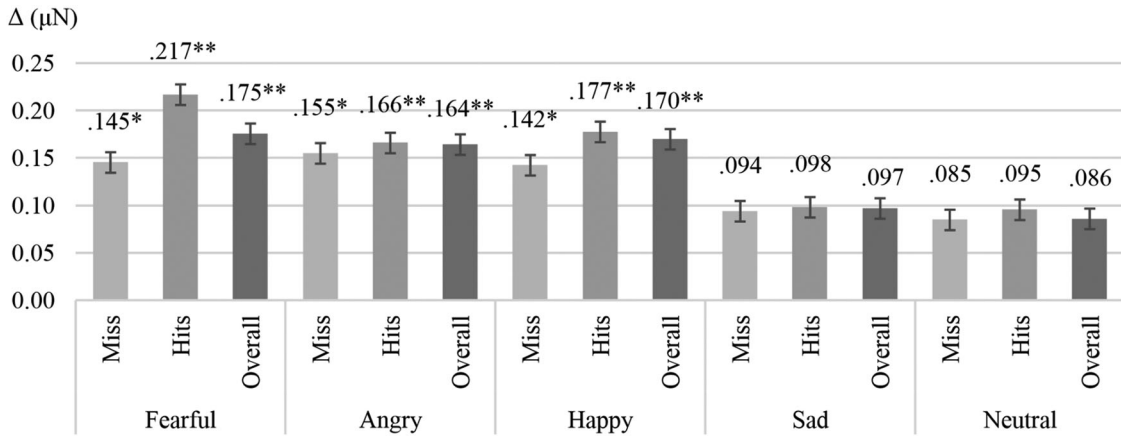


Figure 6. Engagement task force pressure in standardised Z-scores units of pressure (micro-Newtons) based on the preliminary training task. Bars show standard error of the mean. * indicates $p < .01$, ** indicates $p < .001$. The asterisks indicate significance in comparison to all non-asterisk items of the same discrimination response category; e.g. fearful hits vs sad, neutral and blur hits. See also Supplemental Material 3.1–3.7 for Bayesian analysis.

overall performance, and hits and misses responses compared to other stimulus types.

Previous research has suggested that evolutionary important survival-related and sociobiologically relevant facial stimuli can induce automatic and involuntary physiological responses without conscious awareness (van der Ploeg et al., 2017). The purpose of this arousal is to equip us with the ability to respond to environmental cues that require an imminent reaction without necessarily relying on *slow* cortical systems for initiating a course of action. This process is suggested to be *subliminal* in the sense that conscious awareness of the presented stimulus is not required to activate the neural substrates that are recruited for experiencing emotional changes and not required for the experience of physiological arousal (Brooks et al., 2012).

The current findings do not necessarily contest this concept, but they do suggest an additional and rather challenging consideration in relation to subliminality. We have shown in the current manuscript that very brief emotional faces can elicit SCR, heart-rate and force-pressure responses. We have also shown that unbiased ROC adjustments in the duration of presentation were not associated with statistically significant differences for physiological responses (see also Supplemental Material 3.1–3.7 for Bayesian analysis). That means that successfully masked faces did not lead to differences in emotional physiology. Hit-rate adjustments in the duration of presentation were associated with different physiological responses between different stimulus types but they were also associated both with a certain level of post-trial confidence for discrimination and correct appraisal of information such as the emotional valence and the level of expressed arousal of the presented faces.

These findings allow two possible interpretations. Firstly, the argument can be made that when we implemented hit-rate adjustments, the higher ratings for the levels of valence and arousal in response to fearful, angry and happy faces during misses for discrimination indicated that participants were aware of emotion-eliciting facial sub-characteristics. Therefore, the experience of physiological arousal could be due to conscious perception of emotion-eliciting facial features, and this interpretation is supported by the positive association between physiological arousal and confidence ratings for the discrimination of fearful, angry and happy faces. Another interpretation is that during misses for fearful, angry and happy faces, participants were making rating-guesses and not rating-assertion responses, i.e. the stimuli were presented at an appropriate signal-strength level (Morey, Rouder, Pratte, & Speckman, 2017; Rouder, Morey, Speckman, & Pratte, 2007) to preclude correct discrimination but allow introspection or inference (Dehaene, Changeux, Naccache, Sackur, & Sergent, 2006). This interpretation is not supported by the valence and arousal ratings during ROC adjusted presentations, but this finding could be due to the implementation of a corrected chance-level ROC criterion ($A = .167$) that could have served to achieve the implementation of presentation durations that disallowed any – conscious or subconscious – processing of the presented faces (Pessoa, 2005).

These possibilities become further interesting when we consider that misclassification for fearful faces relied on joint physiological and conscious processes, even if these reflected seeing and feeling *what was not there* (Siegel et al., 2018). In simpler terms, when participants misclassified sad, neutral and non-facial stimuli as fearful, the physiological assessment revealed that they had experienced physiological arousal. This suggests that fearful faces were evaluated as the more likely presented stimulus post-hoc to physiological arousal during miss-discrimination and therefore, that participants possibly relied on intuitive and arousal-related criteria to respond to the discrimination task for miss-discrimination responses for fearful faces.

These findings make the point that perception and consciousness, and emotional experience are not necessarily disconnected evolutionary encapsulated modules (van der Ploeg et al., 2017), that consciousness and perception influence and are influenced by emotional arousal in response to masked emotional faces and that physiological responses to masked emotional faces are therefore, not *subliminal* when the latter term is used to describe a state of absolute conscious impenetrability (Brooks et al., 2012). The current data suggest that, as a function of meta-cognition – post-trial intuitive awareness of the experienced emotion – and/or meta-awareness – post-trial conscious awareness of the emotional type or emotional sub-type characteristics – if physiological arousal is elicited during the presentation of masked emotion, conscious assessment will be involved in the evaluation of the elicited emotion and the emotional elicitor.

4. Conclusions

In the current study, we adjusted the duration of presentation for masked emotional faces to the closest available duration to chance-level discrimination performance in a multiple-choice stimulus recognition task using receiver operating characteristics and hit-rate assessment. Only hit-rate adjustments in the threshold of presentation were associated with physiological changes – but not for facial-emotional responses – and these changes were reported both for hits and misses for discrimination performance. We found that when we implemented hit-rate adjustments in the threshold of presentation, for misses for discrimination, participants could correctly appraise the valence and arousal of the presented face and critically, that when participants were presented with sad, neutral and non-facial blur stimuli and experienced physiological arousal, they responded with miss-discrimination responses for seeing a fearful face. These findings suggest that, upon explicit post-trial inquiry, if physiological arousal is elicited during the presentation of masked emotion, conscious assessment is involved in the evaluation of the elicited emotion and the emotional elicitor.

Note

1. The detection threshold is the threshold of presentation (e.g. 16.67 ms) below which a participant cannot and, respectively, above which a participant can report whether a visually suppressed stimulus was presented (e.g. a face was presented, or a face was not presented). The discrimination threshold is the threshold of presentation (e.g. 33.33 ms) below which a participant cannot and, respectively, above which a participant can report what type of visually suppressed stimulus was presented (e.g. a fearful face was presented, an angry face was presented; for a full review on this subject see Tsikandilakis, Bali, Derrfuss, & Chapman, 2019).

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Disclosure statement

No potential conflict of interest was reported by the authors.

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Beauty *Is* in the Eye of the Beholder: The Appraisal of Facial Attractiveness and Its Relation to Conscious Awareness

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Abstract
Previous research suggests that facial attractiveness relies on features such as symmetry, averageness and above-average sexual dimorphic characteristics. Due to the evolutionary and socio-biological value of these characteristics, it has been suggested that attractiveness can be processed in the absence of conscious awareness. This raises the possibility that attractiveness can also be appraised without conscious awareness. In this study, we addressed this hypothesis. We presented neutral and emotional faces that were rated high, medium and low for attractiveness during a pilot experimental stage. We presented these faces for 33.33 ms with backwards masking to a black and white pattern for 116.67 ms and measured face-detection and emotion-discrimination performance, and attractiveness ratings. We found that high-attractiveness faces were detected and discriminated more accurately and rated higher for attractiveness compared with other appearance types. A Bayesian analysis of signal detection performance indicated that faces were not processed significantly at-chance. Further assessment revealed that correct detection (hits) of a presented face was a necessary condition for reporting higher ratings for high-attractiveness faces. These findings suggest that the appraisal of attractiveness requires conscious awareness.

Keywords
attractiveness, masking, awareness

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Introduction

Attractiveness is considered a fundamental aspect of human interactions from infancy (Fisher & Ma, 2014; Thomas, De Bellis, Graham, & LaBar, 2007) to adulthood (Griffin & Langlois, 2006). It has been suggested to positively influence the quality of our peer relations, our behaviour and the behaviour of others towards us throughout our life (Langlois & Stephan, 1981), to influence and inform our mate choices (Saxton, Caryl, & Roberts, 2006), and even exert influence in our professional development and income status (Frieze, Olson, & Russell, 1991). In our modern society, where interpersonal communication, romantic-mate choice and even professional employability rely increasingly on on-line communication and posted photographic material (Hong, Tandoc, Kim, Kim, & Wise, 2012), the perception of facial attractiveness has been re-approached as a highly relevant psychological research subject (Swami & Farnham, 2008).

Facial attractiveness has been associated with certain perceived characteristics; these include – among others (Little, Jones, & DeBruine, 2011) – symmetry (Scheib, Gangestas, & Thornhill, 1999), averageness (Grammer & Thornhill, 1994) and above-average sexually dimorphic characteristics (Barber, 1995). Bilateral facial symmetry, for example, is assumed to function as a cue for developmental health and ontogenetic resistance to parasites (Fink, Neave, Manning, & Grammer, 2006). Facial averageness is also suggested to confer evolutionary important offspring-survival value due to indications of heterozygosity (Roberts et al., 2005) as well as a developmental propensity for familiarity due to average faces being overall more recognisable and prototypical exemplars of the *category* facial stimuli (Fink & Penton-Voak, 2002). In addition, pronounced facial characteristics that signify sexually dimorphic biological markers, such as testosterone in men and oestrogens in women, have been shown to increase gender-specific attractiveness ratings (Smith et al., 2006).

Although recent research has reported evidence that casts doubt on the role of attractiveness particularly as an indication of developmental health and immunocompetence (Cai et al., 2018; Foo, Simmons, & Rhodes, 2017; Jones et al., 2018; Scott, Clark, Boothroyd, & Penton-Voak, 2013), the association of attractiveness with characteristics that could confer evolutionary important sociobiological value was sufficient to prompt researchers to explore whether attractiveness can be processed, reported and appraised under conditions that do not necessarily involve conscious awareness (Mineka & Öhman, 2002; Öhman, 2009). This line of research has suggested that attractiveness is a highly salient visual characteristic (Barber, 1995) that can be appraised even from impoverished (pixelated) visual cues (Bachmann, 2007). Previous research has also suggested that – due to the evolutionary importance of high-attractiveness features – attractiveness can be processed and reported at a glance from faces, after only 13 ms of visual exposure to a high-attractiveness face (Olson & Marshuetz, 2005), and has reported evidence for inhibition of return to lateral Gabor patches preceded by high-attractiveness faces that were adjusted for visibility using staircase visual contrast manipulations (Hung, Nieh, & Hsieh, 2016). Based on these findings, the argument has been raised that attractiveness "can be processed in the absence of conscious awareness" (Hung et al., 2016; p. 6) and that it can be appraised and reported without conscious awareness (Olson & Marshuetz, 2005).

In the current study, we explored whether particularly the appraisal of attractiveness requires conscious awareness. We presented emotional and neutral faces that were rated high, medium and low in attractiveness. We presented these faces for 33.33 ms (Brooks et al., 2012) using backwards masking to a black and white pattern for 116.67 ms. We measured face-detection and emotion-discrimination performance as well as attractiveness ratings in

response to these faces. To accurately assess these responses, we used the paradigm we have developed for the assessment of subliminality described in detail in previous research (Tsikandilakis & Chapman, 2018; Tsikandilakis, Chapman, & Peirce, 2018). This included response assessment using unbiased nonparametric signal detection theory criteria to measure face-detection and emotion-discrimination performance (Stanislaw & Todorov, 1999; Zhang & Mueller, 2005), Bayesian analysis (Dienes, 2015) for the assessment of chance-level significance ($A = .5$) that would indicate stimuli invisibility (Erdelyi, 2004) and hits (correct detection/discrimination) and misses (incorrect detection/discrimination) analysis of participant ratings (Fawcett, 2006).

The inclusion of neutral faces (Hung et al., 2016; Olson & Marshuetz, 2005) as well as emotional faces in the current study was necessitated by signal detection theory requirement for the exploration of different levels of conscious awareness (Stanislaw & Todorov, 1999). The inclusion of different emotions enabled us to explore whether the appraisal of attractiveness requires face detection as well as emotion discrimination of the presented face. This signal detection theory distinction could not have been performed without the inclusion of different emotions (Pessoa, 2005). This inclusion also meant that the current study would be the first to our knowledge study (Hung et al., 2016; Olson & Marshuetz, 2005; Ritchie, Palermo, & Rhodes, 2017) that included assessment of different emotional expressions and appearance types (high, medium and low-attractiveness faces) under conditions of backwards masking.

This experimental condition allowed us to formulate a secondary and – in the absence of previous research in the area (Fink & Penton-Voak, 2002) – exploratory hypothesis. We explored whether the interaction between emotional expressions and appearance types can influence face detection, emotion discrimination and attractiveness ratings under conditions of backwards masking, in the same manner that previous research has reported that it influences participant responses during supraliminal presentations (Calvo & Lundqvist, 2008; Lundqvist, Bruce, & Öhman, 2015; O'Doherty et al., 2002). The preliminary hypothesis for this exploratory objective was that faces that have high sociobiological value based on attractiveness ratings, that is, high-attractiveness faces (Bachmann, 2007), would reveal higher face-detection and emotion-discrimination scores when they expressed emotions that also have high sociobiological and survival-related evolutionary value (Brooks et al., 2012), such as fearful (Pessoa, 2005) and angry faces (Lundqvistet al., 2015). We also explored whether higher attractiveness ratings would be reported for high-attractiveness faces that expressed highly salient positive social signals, such as happy expressions, that have been associated with increased emotional-perceptual reward value in previous research (Calvo & Lundqvist, 2008; O'Doherty et al., 2002).

In the current research, it was extremely important that any potential influences of attractiveness could not be interpreted in terms of other evolutionarily relevant or low-level stimulus features. We thus included three pilot experimental stages (Study 1) to ensure that the stimuli we used did not confound attractiveness with gender, emotional expression or detectability through contrast changes. In the first experimental stage, we validated the facial stimuli for gender and emotional characteristics and used strict attractiveness criteria to preselect from an existing database (Gur et al., 2002) faces that were rated high, medium and low in attractiveness. In the second experimental stage, we assessed the preselected stimuli for emotionality to make sure that emotionality differences between appearance types would not bias signal detection performance in subsequent experimental stages (Calvo & Lundqvist, 2008). Finally, in Stage 3, we explored whether there were differences in visual contrast between the selected faces and their control condition during the main experiment (nonfacial pattern stimuli) that could artefactually impact signal

detection and discrimination responses when using backwards masking (Bachmann & Francis, 2013).

Methods

Study 1

Stage 1: Stimuli preselection. Aims: The current stage had two aims. The first aim was to select from an existing database (Gur et al., 2002) the faces that were correctly recognised by participants and automatic facial recognition software (Noldus) for the emotion that they were expressing. The second aim was to select faces that were rated high, medium and low in attractiveness and test whether these faces produced significant differences in attractiveness that would make them appropriate stimuli for the inclusion in the following experimental stages.

Participants: A power calculation based on effect sizes ($d = .81$; $f = .41$) reported in previous research (Tsikandilakis et al., 2018) revealed that 15 participants were required for $P_{(1-\beta)} \geq .8$ (Faul, Erdfelder, Buchner, & Lang, 2009). Eighteen participants (nine females) volunteered to participate in this experiment. All participants reported normal or corrected-to-normal vision. Participants gave informed consent to participate in the current study prior to the experiment. The participants were screened before the experiment with the Somatic and Psychological Health Report Questionnaire (Hickie et al., 2001); participants with scores at or below 1.0 were included. Participants were also screened using an online Alexithymia-Emotional Blindness questionnaire (Alexithymia, 2017) and participants with scores that indicated possible traits ($P > 94$) or diagnosis ($P > 112$) for alexithymia were excluded; data from a single participant were excluded from the study. Two participants were also excluded from the study due to neutral ratings on the attractiveness task (Hung et al., 2016; Olson & Marshuetz, 2005). The final population sample consisted of 15 participants (8 females) with a mean age of 32.87 ($SD = 6.12$). The experiment was approved by the Ethics Committee of the School of Psychology of the University of Nottingham.

Stimuli and procedures: The facial stimuli used were taken from the dataset created by Gur et al. (2002) and included faces with angry, happy, fearful, sad and neutral facial expressions. The stimuli were adjusted for interpupillary distance, transformed to grey scale and resized to a standard $1{,}024 \times 768$ pixels resolution. Their luminescence was averaged in SHINE, MATLAB Toolbox and Fourier Painter, and finally, they were spatially aligned and framed into pure white within a cropped circle (height: 6 cm, width: 4 cm).

A total of 300 faces were presented from 60 different actors. Ninety cropped nonfacial blurs patterns that were matched for luminescence (SHINE and MATLAB Toolbox) with the presented faces were also shown. The experimental trial started with a fixation cross for 2 s (± 1 s). After the fixation cross in random order, a single-face or nonfacial pattern was presented at fixation for 1 s. After each target, a black and white pattern mask was also presented for 1 s. A blank screen interval was then presented for 2 s. After that participants were asked by an on-screen message to rate how attractive the presented stimulus was from 1 (*not attractive at all*) to 10 (*very attractive*) using the keyboard. Participants were also asked to decide from an on-screen list what kind of stimulus was presented during the trial using the keyboard. The list included (a) angry, (f) fearful, (h) happy, (s) sad, (n) neutral, (o) other and (i) nonfacial. The order of the two engagement tasks was randomised in each trial. A 2-s blank screen interval was presented before the next trial.

Stimuli preselection: We selected from the presented faces the ones that reported 100% accuracy in correct discrimination of emotional expression ($n = 248$). These stimuli were

further analysed using Noldus Face Reader 7.0 to validate their emotion. We used the participant calibration module for emotional recognition that controlled for the action units that were present in the neutral expressions of each actor to accurately assess emotional expressions. We also used the cultural-background recognition module and specific cultural-background emotional recognition modules (e.g., General6_1, Asian, etc.) for each actor based on the cultural-background recognition assessment (Noldus, 2018). We set the emotional recognition certainty criteria for inclusion at >.99 for each facial stimulus; no stimuli were excluded (see Noldus Emotional Recognition Certainty Scores (%) section in Appendix). From the resulting dataset, we chose for each emotion (anger, fear, happiness, sadness and neutral) faces that were rated high, medium and low in attractiveness based on the following criteria. Six (three males and three females) high-, medium- and low-attractiveness faces were selected for each emotion. For high-attractiveness faces, the faces with a mean value that was >7 were preselected. For medium-attractiveness faces, we preselected faces that were rated between 4 and 6 on the attractiveness scale. For low-attractiveness faces, we preselected faces that were not rated higher than 3 on the attractiveness scale. Due to rating restrictions and to avoid identity priming due to uneven target repetition (Lander, Bruce, & Hill, 2001), in subsequent stages actors who met the required attractiveness criteria per emotion were selected three times each, resulting in a final sample of 30 actors and 90 emotional expressions.

Results and discussion: To confirm that attractiveness was different between different appearance types, we ran a repeated measures analysis of variance (ANOVA) with independent variables Appearance Type (high, medium and low attractiveness) and Type of Emotion (anger, fear, happiness, sadness, neutral) and dependent variable attractiveness ratings. Appearance Type was significant – $F(2, 28) = 1{,}739.43$, $p < .01$, $\eta^2 = .99$ – confirming that high-attractiveness faces ($M = 7.8$, $SD = .23$) were rated higher – $t(14) = 30.01$, $p < .01$; $d = 9.24$ – than medium-attractiveness faces ($M = 5.17$, $SD = .33$) and higher – $t(14) = 74.08$, $p < .01$; $d = 26.55$ – than low-attractiveness faces ($M = 2.54$, $SD = .16$) in attractiveness ratings. Medium-attractiveness faces were also rated higher than low-attractiveness faces – $t(14) = 46.29$, $p < .01$; $d = 10.14$ – in attractiveness ratings. The findings suggested that appearance types (high, medium and low) were significantly different in attractiveness ratings and that they were appropriate stimuli for their inclusion in the following experimental stages.

In accordance with previous literature in the area (Hung et al., 2016; Olson & Marshuetz, 2005), we did not find any differences for actor gender attractiveness ratings – $F(1, 13) = .11$; $p = .75$; $\eta^2 = .01$ – or with participant gender as a between-subjects variable – $F(1, 13) = .37$; $p = .56$; $\eta^2 = .03$. These findings were confirmed by a separate t-test analysis based on actor, $t(14) = -.473$; $p = .64$; $d = .13$, and participant gender attractiveness ratings, $t(13) = .407$; $p = .69$; $d = .18$. These findings suggested that male and female participants did not differ in their ratings for attractiveness (see also Gender Effects and Bayesian Analysis for Attractiveness in Stage 1 for Gender sections in Appendix; Figure 1).

Stage 2: Emotionality assessment. Aims: The aim of this stage was to assess the faces that were rated high, medium and low in attractiveness for emotionality differences to make sure that emotionality differences between appearance types would not bias signal detection performance in subsequent experimental stages.

Participants: A power calculation based on effect sizes ($d = .86$; $f = .43$) reported in previous research (Tsikandilakis et al., 2018) revealed that 13 participants were required for $P_{(1-\beta)} \geq .8$. Fifteen participants (seven females) who were not part of Stage 1 volunteered to participate in this stage. All participants reported normal or corrected-to-normal vision

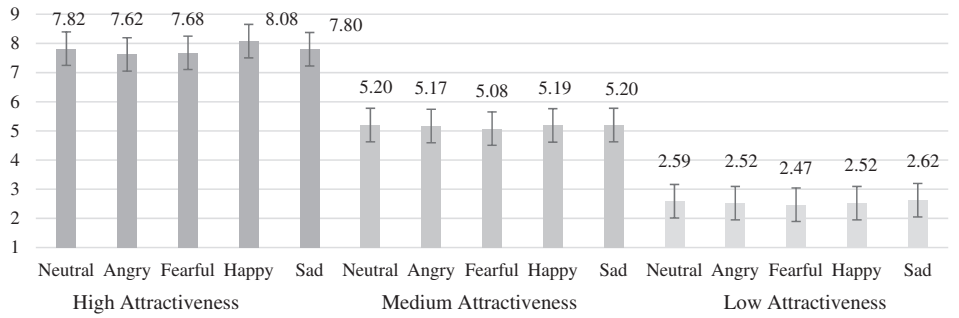


Figure 1. Attractiveness ratings per appearance type and expressed emotion. Mean attractiveness ratings (*y*-axis) per appearance type and expressed emotion (*x*-axis). Error bars indicate *SEM* (±2).

and gave informed consent to participate in the current study prior to the experiment. The participants were screened with the Somatic and Psychological Health Report Questionnaire and an online Alexithymia-Emotional Blindness questionnaire; no participants were excluded. Data from two participants were excluded due to neutral ratings on the emotionality task (Hung et al., 2016; Olson & Marshuetz, 2005). The final population sample consisted of 13 participants (8 females) with a mean age of 24.85 ($SD = 3.95$). This stage was approved by the Ethics Committee of the School of Psychology of the University of Nottingham.

Stimuli and procedures: A total of 90 faces were shown during this stage from 30 actors. An equal number of female and male faces ($n = 45$) and actors ($n = 15$) were presented. Six faces (three males and three females) were shown per emotion (anger, fear, happiness, sadness and neutral) for each appearance type (high, medium and low attractiveness). The faces presented during this stage were the preselected stimuli from Stage 1. The 90 non-facial pattern blurs that were shown during Stage 1 were also shown during this stage. The experimental trial started with a fixation cross for 3 s (±1 s). After the fixation cross in random order, a single-face or nonfacial pattern was presented at fixation for 1 s. After each target, a black and white pattern mask was also presented for 1 s. A blank screen interval was then presented for 2 s. Participants were then asked by an on-screen message to rate how emotional the presented stimulus was from 1 (*not emotional at all*) to 10 (*very emotional*) using the keyboard. A 2-s blank screen interval was presented before the next trial.

Results and discussion: A repeated measures ANOVA tested the effects of Appearance Type (high, medium and low attractiveness) and Type of Emotion (angry, fearful, happy, sad and neutral) on emotional ratings. The analysis revealed that there were no significant differences in emotional ratings between high, medium and low-attractiveness faces – $F(2, 24) = 2.94$, $p = .12$; $\eta^2 = .16$ (see also Bayesian Analysis of Emotionality in Stage 2 Between Appearance Types section in Appendix). These findings suggested that high, medium and low-attractiveness faces were not overall different in emotional ratings and were appropriate stimuli for their inclusion in subsequent experimental stages.

An ANOVA revealed that there were no differences for actor gender in emotionality ratings – $F(1, 11) = .64$; $p = .44$; $\eta^2 = .06$ – or with participant gender as a between-subjects variable – $F(1, 11) = .1$; $p = .75$; $\eta^2 = .01$. This was confirmed by a separate *t*-test analysis based on actor – $t(12) = -.77$; $p = .12$; $d = .05$ – and participant gender emotionality

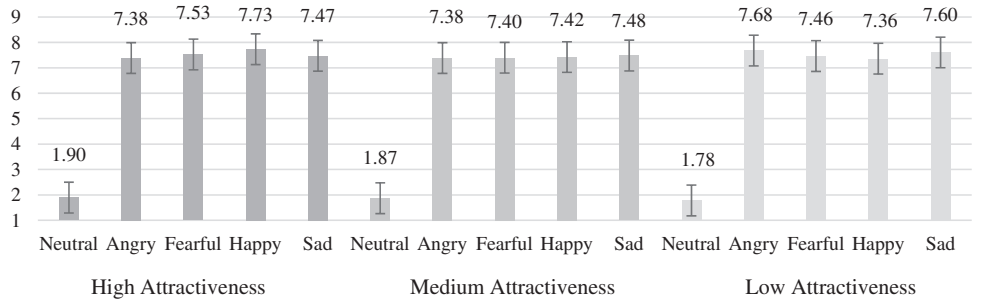


Figure 2. Emotionality ratings per appearance type and expressed emotion. Mean emotionality ratings (*y*-axis) per appearance type and expressed emotion (*x*-axis). Error bars indicate *SEM* (±2).

ratings – $t(11) = 1.41$; $p = .19$; $d = .73$. These findings suggested that male and female participants did not differ in their ratings for emotionality (see also Bayesian Analysis for Emotionality in Stage 2 for Gender section in Appendix; Figure 2).

Stage 3: Subjective contrast discrimination. Aims: Study 2 was designed to include a 116.67 ms black and white pattern mask and 33.33 ms nonfacial blurs as a signal detection control condition for facial stimuli. For such a control condition to work, it is important that low-level changes in contrast cannot be used by participants to detect the presence of faces. The aim of the current stage was to ensure that brief nonfacial blurs did not have differences in visual contrast in respect to the black and white pattern mask when compared with the facial stimuli.

Participants: A power calculation based on effect sizes ($d = .05$; $f = .03$; see Schmider, Ziegler, Danay, Beyer, & Bühner, 2010) reported in previous research (Tsikandilakis et al., 2018) revealed that 14 participants were required for $\beta < .2$ (Soper, 2018; Wessa, 2016). Fifteen participants (seven females) who were not part of Experiment 1 or Experiment 2 volunteered to participate in this experimental stage. All participants reported normal or corrected-to-normal vision and provided informed consent prior to the study. The participants were screened with the Somatic and Psychological Health Report Questionnaire and an online Alexithymia-Emotional Blindness questionnaire; no participants were excluded based on this assessment. One participant was excluded due to noncompliance with the study procedures. The final population sample consisted of 14 participants (seven females) with a mean age of 23.07 ($SD = 2.70$). Participants were briefed in writing concerning the experimental task and were asked to respond in the consent form whether they understood the instructions (yes or no). All participants responded positively. This stage was approved by the Ethics Committee of the School of Psychology of the University of Nottingham.

Stimuli and procedures: Due to experimental time restrictions, a subset of the selected faces including 30 faces and 30 nonfacial blurs were presented during this stage. The presented faces were randomly chosen from the preselected stimuli in Stages 1 and 2. The selected set was assigned two faces per emotion (neutral, angry, fearful, happy and sad) for each appearance type (high, medium and low attractiveness). An equal number of male and female faces ($n = 15$) were presented to participants and no actor was repeated more than once at this stage. The experimental trial started with a fixation cross for 3 s (±1 s). After the fixation cross in random order, a single-face or nonfacial blur was presented for 33.33 ms followed by a black and white patterned mask for 116.67 ms. After the presentation

of the black and white pattern mask, participants were shown a blank screen for 2 s and were then asked by an on-screen message to rate their subjective experience of visual contrast from 1 (*not at all*) to 10 (*intense*). A 2-s blank screen interval was presented before the next trial.

Results and discussion: To test if the nonfacial blurs had significantly different ratings for subjective experience of contrast compared with the presented faces in respect to the pattern mask a paired samples *t*-test was run. Subjective experience of contrast for the nonfacial blurs ($M = 4.95$, $SD = .49$) was not rated higher than contrast in the face condition – $M = 4.96$, $SD = .21$; $t(13) = -.119$, $p = .907$; $d = .03$ (see also Bayesian Analysis in Stage 3 for Visual Contrast section in Appendix). These findings suggested that differences of visual contrast between the nonfacial blurs and the presented faces, and the pattern mask would not artefactually impact signal detection and discrimination performance (Bachmann & Francis, 2013) in subsequent experimental stages.

Study 2

Aims: The primary aims of this study were twofold. First, we wanted to test whether high-attractiveness faces would be detected and discriminated more accurately than other appearance types under conditions of backwards masking. Second, we wanted to test whether the appraisal of attractiveness in high-attractiveness faces requires conscious awareness. Finally, an exploratory aim of the current study was to test if high, medium and low-attractiveness faces interact with different types of emotional expressions (fearful, angry, happy, sad and neutral) to influence face-detection and emotion-discrimination performance as well attractiveness ratings under conditions of backwards masking.

Participants: A power calculation based on medium effect sizes ($\eta^2 = .06$; $f = .25$) revealed that 23 participants would be required for $P_{(1-\beta)} \geq .8$. Twenty-six participants (13 females) that were not part of Study 1 volunteered to participate in this experiment. All participants reported normal or corrected-to-normal vision and gave informed consent to participate in the current study prior to the experiment. The participants were screened with the Somatic and Psychological Health Report Questionnaire (Hickie et al., 2001) and an online Alexithymia-Emotional Blindness questionnaire (Alexithymia, 2017); data from one participant were excluded due to possible Alexithymia traits (>94). Data from two additional participants were also excluded due to neutral ratings on the preexperimental emotionality task and attractiveness tasks (Hung et al., 2016; Olson & Marshuetz, 2005; van der Ploeg, Brosschot, Versluis, & Verkuil, 2017). The final population sample consisted of 23 participants (13 females) with a mean age of 32.13 ($SD = 7.47$). This experiment was approved by the Ethics Committee of the School of Psychology of the University of Nottingham.

Stimuli and procedures: The experiment involved two phases. In Phase 1, participants were presented with 20 faces and 20 nonfacial pattern blurs that were not part of the preselected stimuli. These stimuli were chosen based on discrimination, emotionality, intensity, expression-ambiguity ratings and physiological responses (skin conductance and heart rate) in a previous study (Tsikandilakis et al., 2018). These facial stimuli included four neutral, angry, happy, sad and fearful stimuli from different actors with an equal number ($n = 10$) of males and females. The experimental trial started with a fixation cross for 3 s (±1 s). After the fixation cross in random order, a single-face or nonfacial pattern was presented at fixation for 1 s. After each target, a black and white pattern mask was also presented for 1 s. A blank screen interval was then presented for 2 s. After that participants were asked by an on-screen message to rate how emotional the presented stimulus was from 1 (*not emotional at all*) to 10 (*very emotional*) using the keyboard. The participants were also

asked by an on-screen message to rate how attractive the presented stimulus was from 1 (*not attractive at all*) to 10 (*very attractive*) using the keyboard. The participants were also asked to decide from an on-screen list what kind of stimulus was presented during the trial using the keyboard. The list included (a) angry, (f) fearful, (h) happy, (s) sad, (n) neutral, (o) other and (i) nonfacial. The order of the engagement tasks was randomised in each trial. A blank screen for 2 s was presented before each next trial. Phase 1 was conducted to ensure that participants were familiar with the tasks and stimuli under conditions in which the target stimuli were clearly visible for all participants. In Phase 2, we used the same procedure with brief backwardly masked stimuli presented at durations where they would not necessarily be available to conscious awareness (Dehaene, Changeux, Naccache, Sackur, & Sergent, 2006).

After Phase 1, participants were allowed a 5-min break. After the break, the participants were presented with the 90 preselected faces and 90 nonfacial pattern blurs. The experimental trial started with a fixation cross for 3 s ($\pm$1 s). After the fixation cross in random order, a single-face or nonfacial pattern was presented at fixation for 33.33 ms. After each target, a black and white pattern mask was also presented for 116.67 ms. A blank screen interval was then presented for 2 s. After that participants were asked to reply to a set of engagement tasks with order randomised. They were asked by an on-screen message to press E if they saw a facial stimuli or W if the presented target was nonfacial; the assignment of the keyboard responses was randomly counterbalanced in each trial. After this initial task, we used conditional branching to present the participants with additional engagement tasks. If the participant responded having seen a facial stimulus, an on-screen message asked participants to decide from a list what kind of emotion the facial stimulus was expressing using the keyboard. The list included (a) angry, (f) fearful, (h) happy, (s) sad, (n) neutral and (o) other. If the participants replied not having seen facial stimulus, an on-screen message asked them to decide what kind of emotion best described their experience during the presentation using the keyboard. The list included (a) anger, (f) fear, (h) happiness, (s) sadness, (n) neutral and (o) other. Participants were also asked by an on-screen message to rate how attractive the presentation was from 1 (*not attractive at all*) to 10 (*very attractive*) using the keyboard (Figure 3). A blank screen for 2 s was presented before the next trial.

Apparatus and presentation testing: All experiments were generated using the coder and builder components of Psychopy version 1.90d (Peirce, 2007). All stimuli for all experimental stages were presented on a standard 60 Hz Toshiba monitor in the same quiet laboratory space. To ensure that particularly brief stimuli (33.33 and 116.67 ms) were correctly presented, an IPAD PRO camera with 120 Hz refresh rate (8.33 ms) recorded two pilot runs for Study 1 (Stage 3) and Study 2. The stimuli presentation was assessed frame by frame; no instances of dropped frames were detected. Subsequently, a self-developed dropped frame report script with one frame (16.67 ms) tolerance threshold was coded in Python and two pilot experimental diagnostic sessions were run. The presenting monitor reported no dropped frames; prognostic dropped frame rate was estimated at 1/5,000 trials. Experimental stages were, subsequently, run using dropped frames diagnostics; no instances of dropped frames were reported.

Results and discussion: Does attractiveness influence face detection under conditions of backwards of masking?: To test whether high-attractiveness faces are detected and discriminated more accurately than other appearance types, the participants' face detection responses were transformed to nonparametric sensitivity index A (Zhang & Mueller, 2005). An ANOVA with independent variables Appearance Type (high, medium and low attractiveness) and Type of Emotion (angry, fearful, happy, sad and neutral) and dependent variable face-detection performance (A) was run. The analysis revealed a significant effect of Appearance Type – $F(2,\ 44) = 9.49$, $p < .01$; $\eta^2 = .3$ – and a significant effect of

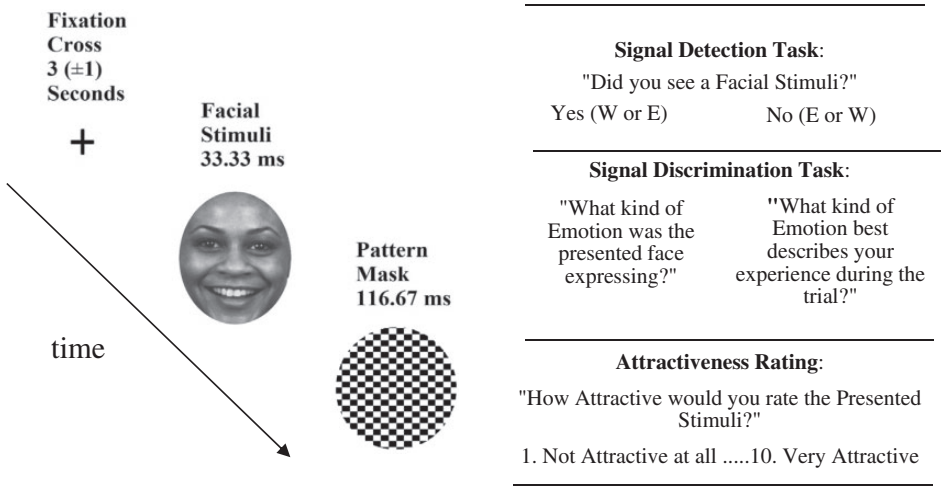


Figure 3. Example stimuli sequence with high-attractiveness happy masked face. During the main experimental stage, participants were presented with 30 high-attractiveness, 30 medium-attractiveness and 30 low-attractiveness emotional faces (angry, fearful, happy, sad and neutral) and 90 pattern blurs for 33.33 ms. Subsequently, they were asked to make face-detection and emotion-discrimination, and attractiveness-rating responses.

Type of Emotion – $F(2.81,\ 61.79) = 5.27$, $p < .01$; $\eta^2 = .19$; Greenhouse-Geisser corrected. Further, Bonferonni-corrected pairwise comparisons revealed that high-attractiveness faces – M (A) = .797, SD (A) = .088; M (hit rates [HR]) = 74.07%, SD (HR) = 14.64% – were detected more accurately than medium-attractiveness faces – M (A) = .768, SD (A) = .093; M (HR) = 69.72%, SD (HR) = 20.77%; $p < .01$; $d = .32$. We did not observe any gender effects – $F(2, 42) = .71$, $p = .49$; $\eta^2 = .03$.

Emotion discrimination was also calculated using nonparametric sensitivity index A (Zhang & Mueller, 2005). An ANOVA was run to assess the effects of Appearance Type and Type of Emotion with dependent variable emotion-discrimination performance (A). The analysis revealed a significant effect of Appearance Type – $F(2, 44) = 4.97$, $p = .01$; $\eta^2 = .18$ – a significant effect of Type of Emotion – $F(40.6, 2.57) = 12.58$, $p < .01$; $\eta^2 = .36$ – and a significant interaction – $F(8, 176) = 10.81$, $p < .01$; $\eta^2 = .32$. Further, Bonferonni-corrected pairwise comparisons revealed that high-attractiveness faces – M (A) = .756, SD (A) = .082; M (H.R.) = 66.82% SD (H.R.) = 20.37% – were discriminated better than low-attractiveness faces – M (A) = .734, SD (A) = .087; M (H.R.) = 63.78% SD (H.R.) = 20.51%; $p < .01$; $d = .26$. We did not observe any gender effects – $F(2, 42) = 1.65$, $p = .2$; $\eta^2 = .07$. These results suggested that attractiveness influenced face detection and emotion discrimination under conditions of backwards masking and more specifically that high-attractiveness faces were detected more accurately than medium-attractiveness faces and discriminated more acutely than low attractiveness-faces.

Exploratory analysis: The exploratory analysis in the current stage tested whether appearance type and emotion interact under conditions of backwards masking to influence face-detection and emotion-discrimination performance. The analysis revealed a significant interaction between Appearance Type and Emotion – $F(8, 176) = 10.81$, $p < .01$; $\eta^2 = .32$. Further, Bonferonni-corrected pairwise comparisons revealed that fearful ($p < .01$; $d = .36$) and sad ($p < .01$; $d = 42$) high-attractiveness faces were detected more accurately than other

Table 1. Detection and Discrimination Performance per Appearance Type and Emotion.

Appearance type	Type of emotion	Detection (A)		Discrimination (A)		Cohen's *d*	
		Mean	*SD*	Mean	*SD*	Detection	Discrimination
High attractiveness	Fearful	.818	.132	.782	.101	.357*	.355*
	Angry	.798	.094	.815	.102	.161	.654**
	Happy	.752	.127	.687	.102	–.281	–.535**
	Sad	.825	.094	.747	.115	.416*	.026
	Neutral	.79	.08	.75	.09	.085	.05
Medium attractiveness	Fearful	.756	.112	.725	.11	–.242	–.184
	Angry	.788	.095	.76	.102	.067	.14
	Happy	.751	.113	.701	.098	–.287	–.409**
	Sad	.777	.139	.771	.11	–.044	.245
	Neutral	.766	.093	.716	.099	–.151	–.266
Low attractiveness	Fearful	.77	.098	.717	.128	–.108	–.256
	Angry	.809	.094	.734	.125	.267	–.099
	Happy	.742	.102	.683	.102	–.378*	–.576**
	Sad	.809	.1	.729	.139	.262	–.143
	Neutral	.768	.090	.851	.086	–.125	.996**

Note. The two end-right columns show the standardised effect size (Cohen's *d*) per stimuli type in units of standard deviations from the overall mean for detection ($M = .781$, $SD = .104$) and discrimination performance ($M = .745$, $SD = .107$). Asterisk (*) indicates significance at $< .01$ level. Double asterisk (**) indicates significance at $< .001$ level.

appearance type to emotion combinations, and that fearful ($p < .01$; $d = 36$) and angry ($p < .001$; $d = .65$) high-attractiveness faces, and also neutral low-attractiveness faces ($p < .001$; $d = .99$) were discriminated more accurately than other appearance type to emotion combinations. These results suggested that a significant interaction between attractiveness and emotion influenced face detection and emotion discrimination for the presented faces (Table 1).

Results and discussion: Does the appraisal of Attractiveness require conscious awareness?: To test if high-attractiveness faces can be processed without conscious awareness, a Bayesian analysis (Dienes, 2015) with corrected degrees of freedom ($df < 30$; $SE = \left(SE \times \left(1 + \left(\frac{20}{df \times df}\right)\right)\right)$ (Berry, 1996)) and higher and lower bounds set at .6 and .4 with .5 indicating absolute chance-level performance was run. The analysis revealed that face detection (A) for high-attractiveness ($M = .796$, $SE = .019$; $B > 3$), medium-attractiveness ($M = .768$, $SE = .017$; $B > 3$) and low-attractiveness ($M = .779$, $SE = .02$; $B > 3$) faces, and emotion-discrimination performance for high-attractiveness ($M = .756$, $SE = .018$; $B > 3$), medium-attractiveness ($M = .743$, $SE = .021$; $B > 3$) and low-attractiveness ($M = .734$, $SE = .019$; $B > 3$) faces were above chance-level (Dienes, 2015) that would indicate stimuli invisibility (Erdelyi, 2004). An analysis of overall attractiveness ratings was not appropriate for the exploration of whether the appraisal of attractiveness requires conscious awareness (Figure 5(a) and (b)).

To further explore whether attractiveness could influence ratings without conscious awareness, we ran an analysis of hits and misses per appearance type for face-detection and emotion-discrimination performance (Pessoa, 2005). For face-detection performance, a factorial ANOVA with independent variables Appearance Type (high, medium and low attractiveness), Emotional Type (fearful, angry, happy, sad and neutral) and Detection

Response (hits, misses) and dependent variable attractiveness ratings was performed. The analysis revealed a significant effect of Appearance Type – $F(2, 22) = 122.14$, $p < .01$; $\eta^2 = .92$ – a significant effect of Emotion – $F(4, 44) = 3.37$, $p = .02$; $\eta^2 = .23$ – and a significant effect of Detection Response – $F(1, 11) = 51.47$, $p < .01$; $\eta^2 = .63$. Critically, an Appearance Type by Detection Response interaction was reported – $F(2, 22) = 167.08$, $p < .01$; $\eta^2 = .94$ – suggesting that there were attractiveness-rating differences between hits and misses for different appearance types.

To further explore these findings, Bonferonni-corrected pairwise comparisons were run. The comparisons revealed that for face detection high-attractiveness facial-hits ($M = 7.21$, $SD = .42$) were rated higher than medium-attractiveness facial-hits – $M = 4.79$, $SD = .24$; $t(22) = 30.55$, $p < .01$; $d = 7.07$ – and low-attractiveness facial-hits – $M = 3.78$, $SD = .54$; $t(22) = 22.29$, $p < .01$; $d = 7.09$. No significant differences in attractiveness ratings were reported for misses for face detection – $F(1.08, 20.5) = 1.10$, $p = .38$; $\eta^2 = .06$; Greenhouse-Geisser corrected. For detection-misses, high-attractiveness faces were not significantly different than medium-attractiveness ($p = 1$; $d = .22$) and low-attractiveness faces ($p = .96$; $d = .19$) and medium-attractiveness faces were not significantly different than low-attractiveness faces ($p = .85$; $d = .1$).

A similar pattern was reported for emotion-discrimination responses. An ANOVA was run with independent variables Appearance Type (high, medium and low attractiveness), Emotion (fearful, angry, happy, sad and neutral) and Discrimination Response (hits and misses) with attractiveness ratings as the dependent variable. The analysis revealed a significant effect of Appearance Type – $F(2, 14) = 74.01$, $p < .01$; $\eta^2 = .91$ – a significant effect of Emotion – $F(4, 28) = 2.98$, $p = .04$; $\eta^2 = .29$ – and a significant effect of Discrimination Response – $F(1, 7) = 132.55$, $p < .01$; $\eta^2 = .95$. Critically, a significant Appearance Type by Discrimination Response interaction was revealed –$F(2, 14) = 39.78$, $p < .01$; $\eta^2 = .85$.

To further explore these findings, Bonferonni-corrected pairwise comparisons were run. For emotion-discrimination performance, high-attractiveness facial-hits were rated higher ($M = 7.44$, $SD = .45$) than medium-attractiveness facial-hits – $M = 4.83$, $SD = .25$; $t(22) = 26.46$, $p < .01$; $d = 7.17$ – and low-attractiveness facial-hits – $M = 3.58$, $SD = .53$; $t(22) = 23.12$, $p < .01$; $d = 7.85$. Medium-attractiveness facial-hits were also rated higher for attractiveness ratings than low-attractiveness facial-hits ($p < .01$; $d = 3.02$). For emotion discrimination, high-attractiveness facial-misses ($M = 6.23$, $SD = .68$) reported significantly higher attractiveness ratings compared with medium-attractiveness facial-misses – $M = 4.23$, $SD = 1.14$; $t(15) = 4.91$, $p < .01$; $d = 2.13$ – and low-attractiveness facial-misses – $M = 4.59$, $SD = .49$; $t(11) = 9.44$, $p < .01$; $d = 2.77$.

These results suggested that the appraisal of attractiveness could not be performed in the absence of conscious awareness (face-detection misses) and that correct face detection (hits) was a necessary condition for the appraisal of attractiveness (see Figure 4). Interestingly, although correct emotion discrimination (hits) enhanced the acuity of the appraisal for attractiveness, incorrect emotion discrimination (misses) reported significant differences between different appearance types, suggesting that emotion discrimination was not necessary for the appraisal of attractiveness from faces.

Exploratory analysis: The exploratory analysis in the current stage tested whether appearance type and emotion interact under conditions of backwards masking to influence attractiveness ratings. The analysis revealed a trend for significance for an interaction between Appearance Type and Emotion – $F(4, 28) = 2.01$, $p = .06$; $\eta^2 = .22$; no pairwise comparisons survived the Bonferonni corrections (Figure 5). These findings suggested that the interaction between emotion and attractiveness was associated with minor differences in attractiveness ratings. Further hits and misses analysis for this interaction

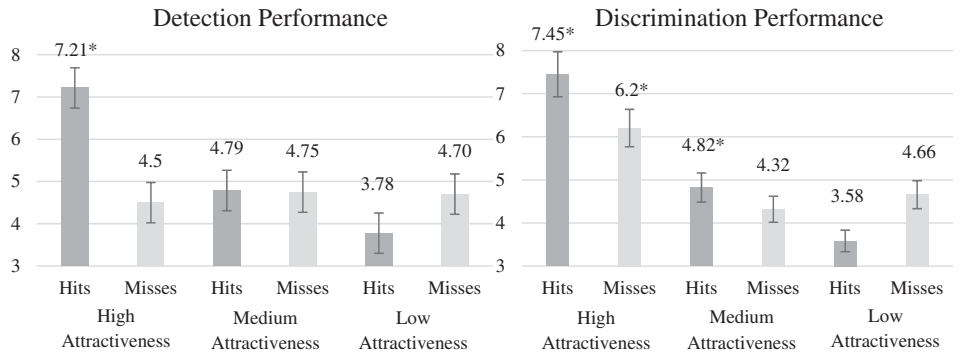


Figure 4. Attractiveness ratings for hits and misses. Mean attractiveness ratings per appearance type for hits and misses for face-detection and emotion-discrimination performance in Study 2. Error bars indicate *SEM* (±2). Asterisks (*) indicate significance at $p < .01$ level.

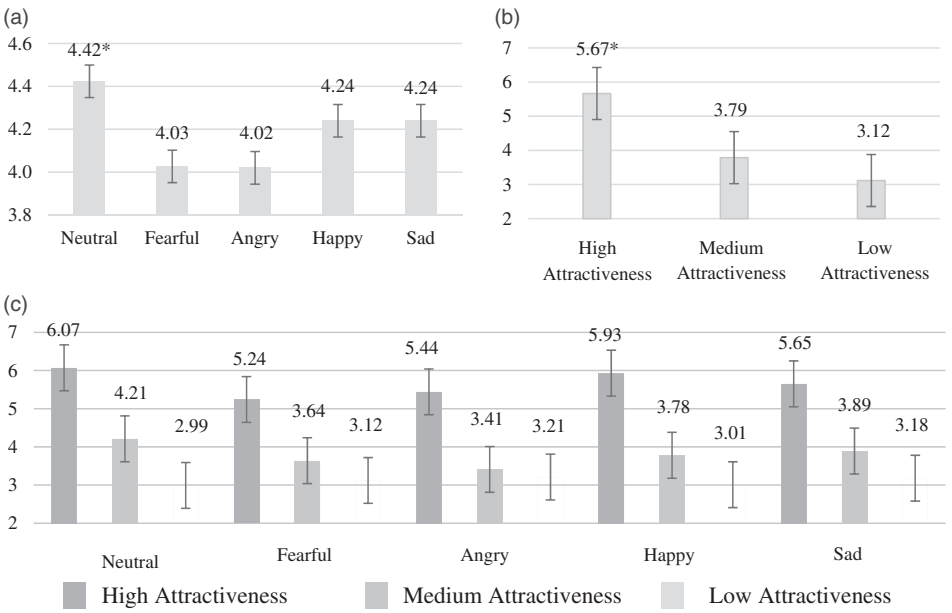


Figure 5. Attractiveness and emotion under conditions of backwards masking. Attractiveness ratings for each Appearance type (high, medium and low attractiveness) for each Emotion (neutral, fearful, angry, happy and sad). A significance trend ($p = .06$) for an Appearance to Emotion Interaction was reported although no pairwise comparisons survived the Bonferonni corrections. Asterisks (*) indicate significance at $p < .01$ level.

could not be performed because of insufficient face-detection and emotion-discrimination hits and misses responses for several appearance type and emotion combinations (e.g., high-attractiveness angry faces, low-attractiveness neutral faces) and because the available responses did not meet – $P_{(1-\beta)} = .34$ – the minimum statistical power requirement criteria – $P_{(1-\beta)} \geq .8$.

Summary of Findings

The primary aim of the current article was to explore whether attractiveness influences face-detection and emotion-discrimination performance and whether self-reports for the appraisal of facial attractiveness require conscious awareness. We implemented several methodological developments to explore these hypotheses such as extensive pilot experimental stimuli controls, signal detection analysis using sensitivity index A, Bayesian assessment for chance-level significance that would indicate stimuli invisibility and analysis of hits and misses in face-detection and emotion-discrimination performance for attractiveness-rating responses. We found that attractiveness influences face-detection and emotion-discrimination performance, and more specifically that high-attractiveness faces can be detected and discriminated more accurately than other appearance types. Our analysis also revealed that specific appearance type and emotion combinations such as high-attractiveness fearful, angry and sad faces, and low-attractiveness neutral faces were detected and discriminated more accurately than other appearance type to emotion combinations. Critically, we found that face detection (hits) was a necessary condition for the appraisal of attractiveness for high-attractiveness faces and that when participants had absence of conscious awareness of the presented face (face-detection misses) they did not rate high-attractiveness faces higher than other appearance types. Interestingly, although correct emotion discrimination (hits) enhanced the acuity of the appraisal for high-attractiveness faces, incorrect emotion discrimination (misses) also reported higher ratings for high-attractiveness faces compared with other appearance types, suggesting that emotion discrimination is not necessary for the appraisal of attractiveness from faces. Finally, our exploratory analysis revealed that the interaction of emotion and appearance type impacts face-detection and emotion-discrimination performance but has only a minor effect in ratings for attractiveness.

General Discussion

Previous research has reported that attractiveness can be appraised from minimal information, such as pixelated images (Bachmann, 2007) and brief presentations (Olson & Marshuetz, 2005), and processed despite interocular suppression (Hung et al., 2016). For example, Olson and Marshuetz (2005) reported that high-attractiveness faces presented for as little as 13 ms, preceded by a high-frequency contour scrambled face mask for 39 ms and followed by a carton mask for 39 ms, were associated with higher attractiveness ratings than low-attractiveness faces presented under the same conditions. They also reported that 13 ms high-attractiveness faces elicited shorter reaction times for the appraisal of subsequently presented positively valanced words than low-attractiveness faces (Olson & Marshuetz, 2005; p. 500). Similarly, Hung et al. (2016) ran a series of experiments using interocular suppression (Sengpiel, Blakemore, & Harrad, 1995). They used staircase reduction of contrast visibility when bilaterally presenting high-attractiveness and low-attractiveness faces followed by Gabor patches. They reported a reduction in Gabor lines orientation discrimination performance for lateral high-attractiveness faces due to perceptual inhibition of return, suggesting that high-attractiveness faces were attended despite the staircase reduction in visual contrast (Klein, 2000). These findings have been used to propose that attractiveness can be appraised from minimal information and have also been used to suggest that attractiveness can be processed and reported in the absence of conscious awareness (see also Kleckner et al., 2018).

The current findings refer to whether attractiveness can be appraised (Olson & Marshuetz, 2005) without conscious awareness. Our findings support previous research (Bachmann, 2007; Hung et al., 2016; Olson & Marshuetz, 2005) in that – like other evolutionary important stimuli (Mineka & Öhman, 2002; Öhman, 2009) that confer "sociobiological value" (Bachmann, 2007; p. 848) – high-attractiveness faces convey highly salient cues (Fink & Penton-Voak, 2002) that render them more accurately detectable during brief presentations (Calvo & Lundqvist, 2008; Lähteenmäki, Hyönä, Koivisto, & Nummenmaa, 2015). The current findings also add to the existing literature by suggesting that high-attractiveness faces are discriminated more accurately (Adolphs, 2008) and that correct discrimination of the expressed emotion enhances the acuity but is not a necessary condition for the appraisal of the attractiveness from faces (Sergent & Dehaene, 2004).

Despite this partial consensus with previous research, the current article employed different methodological assessment and statistical applications (Tsikandilakis & Chapman, 2018; Tsikandilakis et al., 2018) compared with previous publications. These included the application of signal detection theory (Zhang & Mueller, 2005), Bayesian analysis of chance-level significance (Dienes, 2015) that would indicate stimuli invisibility (Erdelyi, 2004) and separate analysis for hits and misses for attractiveness ratings (Pessoa, 2005). Based on the current methods, our results also partly disagree with previous findings and we propose that the appraisal of attractiveness does require conscious target-detection meta-awareness of facial characteristics (Tsikandilakis et al., 2018). This finding does not *per se* oppose previous findings that have suggested that attractiveness can be processed in the absence of awareness (Hung et al., 2016) because ratings for attractiveness were explicitly measured in the current study. Instead, the key finding of the current report is that the appraisal of attractiveness cannot be reported in the absence of awareness and that correct detection (hits) of a masked face was a required condition for the appraisal of attractiveness. Therefore, we suggest that to make conscious judgements (see also Lau, 2008) in relation to the attractiveness of a presented face, conscious detection of that face is a necessary condition.

Finally, in respect to our exploratory analysis, we reported that high-attractiveness angry, fearful and sad faces as well as low-attractiveness neutral faces were detected and discriminated more accurately than other appearance type to emotion combinations. We also reported a trend for an interaction between emotion and appearance type in relation to attractiveness ratings under conditions of backwards masking. These findings are a novel contribution to the field and support that high-attractiveness angry and fearful faces confer a face-detection superiority effect (Lundqvist et al., 2015) compared with other stimuli, possibly due to their high-salience and sociobiological value (Brooks et al., 2012). The finding that emotion and appearance type revealed only a trend for an interaction in relation to attractiveness ratings means that we could not provide solid support for the idea that particularly positive emotional expressions influence attractiveness ratings when these are presented under conditions of backwards masking (O'Doherty et al., 2002). This could relate to low power in the current experiment or relate to participants' inability to process and integrate multiple informational input when the signal strength is reduced under conditions of backwards masking (Baars, 2002).

Limitations

To our knowledge, the current study is the first attempt to explore the appraisal of attractiveness using backwards masking and angry, fearful, sad and happy faces in addition to neutral faces that have been employed in previous research (Hung et al.,

2016; Olson & Marshuetz, 2005). Despite previous research suggesting a happy face detection superiority effect during low-level visual processing (Miyazawa & Iwasaki, 2010) and higher attractiveness ratings for happy faces during supraliminal presentations (O'Doherty et al., 2003), we were not able to find higher face-detection or emotion-discrimination responses for happy faces for any appearance type. In addition, emotional expression and appearance type provided only an overall trend for an interaction with attractiveness ratings as the dependent variable. Future research could benefit from a dedicated and appropriately powered exploration of the interaction between emotional expressions and appearance types (Penton-Voak & Chang, 2008) under conditions of backwards masking, and particularly the exploration of the possibility that different emotional type (fearful, angry, happy, sad and neutral) to appearance type (high, medium and low attractiveness) combinations could result in differentiating patterns of attractiveness reports (Rhodes, 2006). In the same context, it is possible, although outside the scope of the current article, that low-attractiveness faces could also report face-detection and emotion-discrimination differences compared with other appearance types, such as mid-attractiveness faces, because they confer health- and fitness-related perceptual cues with avoidance response value (Jaeger, Wagemans, Evans, & van Beest, 2018; Pazda, Thorstenson, Elliot, & Perrett, 2016). This possibility is also supported by the data in the current article (see Table 1), and future research could benefit from a dedicated exploration of face-detection and emotion-discrimination performance of low-attractiveness faces under conditions of backwards masking.

Conclusions

The current study assessed whether attractiveness has an impact on face detection and emotion discrimination using backwards masking, and whether attractiveness ratings require conscious awareness. Our results revealed that high-attractiveness faces were detected and discriminated more accurately than other appearance types and also that detection of a face was a necessary condition for the appraisal of attractiveness. This is a novel contribution to the field and suggests that appraisal of attractiveness requires conscious awareness of a presented face.

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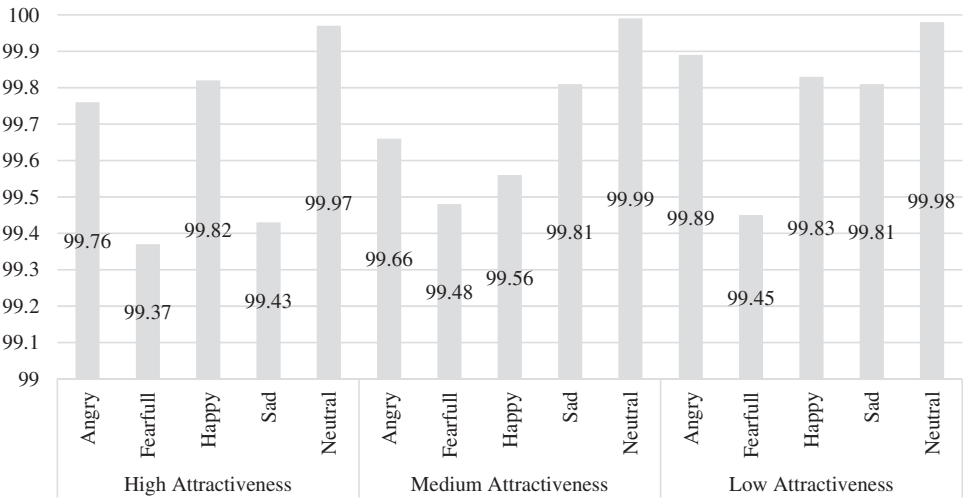
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Appendix

Noldus Emotional Recognition Certainty Scores (%)



Gender Effects

In accordance with previous research that used frequentist statistics (Olson & Marshuetz, 2005), we were not able to report actor- or participant-related gender effects in our analysis. This is a counterintuitive and yet recurrently reported finding in the current research area (Little et al., 2011). Future research could benefit from an assessment of the possible effects of facial cropping techniques (Lyons et al., 2000) and the possible role of bodily characteristics (Winkler & Rhodes, 2005) in exploring gender-specific differences in attractiveness ratings.

Bayesian Analysis for Attractiveness in Stage 1 for Gender

A Bayesian analysis (Dienes, 2015) with corrected degrees of freedom ($df < 30$; $SE = \left(SE \times \left(1 + \left(\frac{20}{df \times df}\right)\right)\right)$ (Berry, 1996) revealed that for attractiveness ratings in Stage 1 male ($SE = .07$; $B = .09$) and female ($SE = .07$; $B = .09$) participant responses were significantly within the predefined uniform credible intervals ($4 < M > 6$).

Bayesian Analysis of Emotionality in Stage 2 Between Appearance Types

A Bayesian analysis (Dienes, 2015) with corrected degrees of freedom ($df < 30$; $SE = \left(SE \times \left(1 + \left(\frac{20}{df \times df}\right)\right)\right)$ (Berry, 1996) revealed that in stage two emotionality ratings for high-attractiveness faces ($SE = .05$; $B = .08$), medium-attractiveness faces ($SE = .04$; $B = .06$) and low-attractiveness faces ($SE = .04$; $B = .07$) were significantly within the predefined uniform credible intervals ($5 > M < 7$).

Bayesian Analysis for Emotionality in Stage 2 for Gender

A Bayesian analysis (Dienes, 2015) with corrected degrees of freedom ($df < 30$; $SE = \left(SE \times \left(1 + \left(\frac{20}{df \times df}\right)\right)\right)$ (Berry, 1996) revealed that in stage two emotionality ratings for male ($SE = .03$; $B = .07$) and female ($SE = .03$; $B = .07$) were significantly within the predefined credible intervals ($5 > M < 7$).

Bayesian Analysis in Stage 3 for Visual Contrast

A Bayesian analysis (Dienes, 2015) with corrected degrees of freedom ($df < 30$; $SE = \left(\text{SE x } \left(1 + \left(\frac{20}{\text{dfxdf}}\right)\right)\right)$ (Berry, 1996) revealed that nonfacial blurs ($SE = .13$; $B = .16$) and facial stimuli ($SE = .06$; $B = .08$) were significantly within the predefined uniform credible intervals ($4 > M < 6$).

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"There Is No *Face* Like Home": Ratings for Cultural Familiarity to Own and Other Facial *Dialects* of Emotion With and Without Conscious Awareness in a British Sample

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Abstract
The *dialects* theory of cross-cultural communication suggests that due to culture-specific characteristics in the expression of emotion, we can recognise own-culture emotional expressions more accurately than other-culture emotional expressions. This effect is suggested to occur due to the nonconvergent social evolution that takes place in different geographical regions. Based on the evolutionary value of own-culture social signals, previous research has suggested that own-culture emotional expressions can be appraised without conscious awareness. The current study tested this hypothesis. We developed, validated, and made open access what is to our knowledge the first labelled, multicultural facial stimuli set, including freely expressed and Facial Action Coding System instructed emotional expressions. We assessed emotional recognition and cultural familiarity responses during brief backward-masked presentations in British participants. We found that emotional recognition and cultural familiarity were higher for own-culture faces. A Bayesian analysis of face-detection and emotional-recognition performance revealed that faces were not processed subliminally. Further analysis of awareness, using hits (correct detection/recognition) and misses (incorrect detection/recognition), showed that face-detection hits were a necessary condition for reporting higher familiarity for own-culture faces. These findings suggest that the own-culture emotional recognition advantage is preserved under conditions of backwards masking and that the appraisal of cultural familiarity involves conscious awareness.

Keywords
culture, consciousness, backward masking

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Introduction

In the past 15 years, we have been provided with an unprecedented access to cross-cultural communication. Not only are we now, more than ever, part of multicultural societies, but we can have face-to-face personal and professional contact with individuals from other nations without leaving the comfort of our living room or office. These contemporary privileges have yielded an increase in cross-cultural professional collaborations and have even influenced peer and romantic partner selection (Bochner, 2013). In our contemporary world, cross-cultural emotional recognition is vital and necessary on a social (Castells, 2004) and a professional level. But do we recognise emotion equally well in individuals from our own culture compared with other cultures, and do we recognise emotion equally well across other cultures indiscriminately?

Psychologists have spent considerable resources in the past decades exploring these questions. Cultural agreement in the expression of emotion was first addressed in the popularised studies conducted by Ekman and Friesen (1971) in indigenous tribal populations. Their seminal, for social and cultural psychology, findings suggested that basic facial emotions such as fear, anger, surprise, happiness, sadness, and disgust are universally recognised (Ekman, 2004). In more recent years, this concept has been expanded (Elfenbein & Ambady, 2003). Recent psychological research (Elfenbein, 2015) has adopted a linguistic metaphor (Tomkins & McCarter, 1964) for interpreting cross-cultural emotional communication. According to this approach, although basic emotional expressions are considered a universal language, there are culture-specific *dialects* that influence the expression and recognition of emotion (Elfenbein, Beaupré, Lévesque, & Hess, 2007). These dialects include display and decoding rules. Display and decoding rules refer to the particular way that a cultural group is allowed or encouraged or prohibited from expressing and interpreting emotion respectively (Matsumoto, Frank, & Hwang, 2013).

Based on these concepts (Russell, Bachorowski, & Fernández-Dols, 2003), researchers working in this field have suggested that there are subtle but recognisable cross-cultural differences in the expression and recognition of emotion (Elfenbein, 2013). For example, Western individuals are more likely to express high-intensity emotional facial expressions (Marsh, Elfenbein, & Ambady, 2003) and less likely to recognise low-intensity emotions, possibly because these are not accurately recognised as communicating salient emotional information. On the other hand, Eastern individuals are more likely to express context-specific positive emotional expressions (Masuda, Gonzalez, Kwan, & Nisbett, 2008) and less likely to express or acknowledge negative affect, possibly because it could signify an abrupt termination of the social transaction (Matsumoto et al., 2013). These cultural *accents* are suggested to confer an in-group emotional recognition advantage for own-culture faces (Elfenbein & Ambady, 2003) and an out-group emotional recognition disadvantage for cultures that are distinctly different to our own (cross-cultural bias, see Elfenbein, 2017).

Along these lines, freely expressed emotion could potentially enhance the own-culture recognition advantage and instructed emotion could possibly decrease or eliminate it (Elfenbein & Ambady, 2003). In this context, freely expressed emotion could enhance the effect because it allows culture-specific expressions that can be more accurately recognised by own-culture members due to their in-group social value. Instructed emotion, on the other hand, could decrease the effect because it forces cross-cultural homogeneity in the expression of emotion and eliminates in-group emotional expressive characteristics (for comprehensive review, see Elfenbein & Ambady, 2002a, 2002b, 2003). The suggestion that

particularly freely expressed culture-specific emotion induces higher in-group emotional recognition accuracy (Haxby, Hoffman, & Gobbini, 2002) has resulted in the hypothesis that own-culture emotional expressions have shared region-specific evolutionary and socio-biological value, and that they could be processed without conscious awareness (Chiao et al., 2008; Smith, Dijksterhuis, & Chaiken, 2008).

Previous research has provided some findings that could be relevant here. For example, Chiao et al. (2008) showed that both Japanese and Caucasian participants automatically responded with higher bilateral, and more pronounced right-lateral, BOLD[1] activation in the amygdala, when presented for 1 s with own-culture instructed fearful faces compared with instructed fearful faces from other cultures. This could be interpreted to suggest that own-culture fearful expressions were more salient elicitors of fear compared with other-culture fearful expressions. Previous research (Eberhardt, Goff, Purdie, & Davies, 2004; Smith et al., 2008) also reported that different-culture and different-race neutral faces presented either for very brief durations (e.g., 33.33 milliseconds) or suppressed by separately presenting colour patterns to the dominant or nondominant eye (Schlossmacher, Junghöfer, Straube, & Bruchmann, 2017; Tong, Meng, & Blake, 2006) decrease emotional recognition accuracy for subsequently presented supraliminal faces showing own-culture expressions of emotion (Nosek, Hawkings, & Frasier, 2011). This could be interpreted to suggest that even when presented under conditions that could preclude conscious awareness, other-culture and other-race faces decrease the ability to recognise emotion in subsequently presented faces.

Although *subliminal* and *unconscious* processing is in general supported by several studies (for review, see Brooks et al., 2012), many researchers disagree that subliminal emotional processing is possible (Pessoa & Adolphs, 2010). For example, Pessoa, Japee, Sturman, and Ungerleider (2005) showed that bilateral BOLD activation in the amygdala during brief presentations (33.33 and 66.67 milliseconds) occurs only when the participants correctly detected (hits) fearful faces and not when participants did not detect a presented fearful face (misses) in a posttrial signal detection assessment task. In a study related to cross-cultural emotional processing and consciousness, Amihai, Deouell, and Bentin (2011) used continuous-flash-suppression (Tsuchiya & Koch, 2004, 2005) and showed that exposure to racially ambiguous artificial faces (adaptors) biased recognition accuracy for subsequent supraliminal racially unambiguous artificial faces in the opposite category of the adaptor only when the adaptors were not successfully suppressed, such as when participants responded with hits (correct detection) for seeing an artificial adaptor, but not when participants responded with misses (incorrect nondetection) for not seeing an artificial adaptor in a posttrial signal detection assessment task (Gaillard et al., 2009; Pessoa, 2005; Pessoa & Adolphs, 2010, 2017). These findings suggest that there is an effect of culture and race in emotional recognition but that this is not necessarily due to subliminal or unconscious processing.

The current study follows from these findings. Our first objective was to test if the own-group emotional recognition advantage can be preserved during visual suppression such as backward-masked presentations of faces for the durations for which they were presented in previous studies (e.g., 33.33 milliseconds). Our second objective was to test whether cultural familiarity can be appraised without conscious awareness, such as for misses for face-detection and emotional-recognition responses in a posttrial signal detection assessment task, or whether the appraisal of cultural familiarity requires conscious awareness of the presented faces, such as hits for face-detection and emotional-recognition responses in a posttrial signal detection assessment task (Pessoa, 2005).

An important motivation for the current research was to test if faces showing freely expressed emotions and instructed emotions from different cultures can influence conscious and unconscious emotional processing (Ekman, Friesen, & Ellsworth, 2013). Hence, we included freely expressed and instructed facial expressions in our experimental design (Elfenbein & Ambady, 2002a, 2002b, 2003). Due to the lack of a labelled multicultural facial dataset in the area, we developed a cross-cultural facial stimuli dataset that included freely expressed and Facial Action Coding System (FACS) instructed facial expressions from different continental geographical regions based on U21[2] institutional availability (Britain, New Zealand, Chile, and Singapore). We tested the dataset using cultural and emotional questionnaires, participant assessment, and automatic emotional recognition software, to validate whether differences between cultures were due to cultural differences in the expression of emotion. The purpose of this assessment was to test whether the expressed emotional *dialects* conferred cross-cultural communication differences as opposed to differences due to sampling variables, such as occupational and life-style choices, that are not necessarily and uncontestedly related to emotional culturation (see Russell et al., 2003, pp. 331–337).

We used this dataset to present British participants with backward-masked own-culture and other-culture FACS instructed and freely expressed emotional faces and assessed responses for face detection, emotional recognition, and cultural familiarity. To implement a balanced design for the exploration of cross-cultural emotional differences, we treated each culture as a separate emotional elicitor and presented an equal number of repetitions per type of emotion and expression for each country of origin (see Elfenbein & Ambady, 2002b, pp. 223–227). To accurately assess participant responses during the masking condition, we used the method we developed for the assessment for conscious awareness described in detail in our previous research (Tsikandilakis, Bali, & Chapman, 2019; Tsikandilakis, Bali, Derrfuss, & Chapman, 2019a, 2019b, 2019c; Tsikandilakis & Chapman, 2018; Tsikandilakis, Chapman, & Peirce, 2018). This method included unbiased nonparametric signal detection theory criteria to measure face-detection and emotional-recognition performance (Stanislaw & Todorov, 1999; Zhang & Mueller, 2005), Bayesian analysis for the assessment of chance-level signal detection performance (Dienes, 2015), that would indicate unawareness for the presentation of facial targets and their expressed emotional type (Erdelyi, 2004), and hits (correct detection/recognition) and misses (incorrect detection/recognition) analysis (Fawcett, 2006) for the assessment of cultural familiarity responses (Pessoa, 2005).

Using these criteria, we tested whether the own-culture emotional-recognition advantage can be preserved under conditions of backwards masking for freely expressed and FACS instructed cross-cultural emotional expressions, and whether cultural familiarity can be appraised during backwards masking with and without conscious awareness, such as for hits and misses for face-detection and emotional-recognition responses.

Study 1

Stage 1: Stimulus Development

Aims. The first objective of the current stage was to develop a multicultural facial dataset that would include nonprofessional actors from Britain, New Zealand, Chile, and Singapore. The second objective of the current stage was to assess the actors that were part of the dataset using cultural and emotional questionnaires to explore if emotional

differences between cultures were due to cultural—and not random population sampling—differences (Russell et al., 2003).

Participants. A total of 104 nonprofessional actors (58 females) from Britain, New Zealand, Chile, and Singapore volunteered to participate in this stage. All participants reported normal or corrected-to-normal vision. The inclusion criteria for the current stage were having been born in the country of interest, having attended primary, secondary, and higher education in the country of interest and in the language of the country of interest; having previously resided only and currently residing permanently in the country of interest; and characterising themselves as part of the culture of the country of interest (Yes/No). Participants were additionally screened with the Somatic and Psychological Health Report Questionnaire (SPHRQ; Hickie et al., 2001) and an online Alexithymia-Emotional Blindness questionnaire (Alexithymia, 2018). Two participants were excluded from the study due to having a joint nationality. Data from one participant were excluded from further analysis due to having a SPHRQ score that indicated a possible psychiatric diagnosis. Data from three participants were excluded due to scores that indicated possible alexithymic traits. Data from one participant were excluded due to lack of compliance with the experimental tasks. The final sample consisted of 97 participants (56 females) with mean age of 24.19 years ($SD = 3.69$) from Britain ($n = 29$; mean age = 22.93 years ($SD = 3.63$); 18 females), New Zealand ($n = 22$; mean age = 23.67 years ($SD = 4.27$); 15 females), Chile ($n = 20$; mean age = 22.47 years ($SD = 2.5$); 10 females), and Singapore ($n = 26$; mean age = 23.2 years ($SD = 2.2$); 13 females). All participants gave informed consent to participate in the study and for their data to be used for further research purposes. The experiment was approved separately by the Ethics Committee of the School or Department of Psychology or Medicine of each contributing institution.

Stimuli and procedures. This stage took place at universities in Britain, New Zealand, Chile, and Singapore. Questionnaires and instruction material were provided in the participants' native language. Participants in each contributing institution were invited into a brightly illuminated laboratory space. After the initial screening processes, they were asked to complete the Hofstede Cultural Dimensions Questionnaire (CDQ; Hofstede, 2003) and the Emotional Regulation Questionnaire (ERQ; Gross & John, 2003). Subsequently, they were asked to produce a set of expressions including fearful, angry, happy, sad, disgusted, neutral (Ekman, 1999), and calm (Tottenham et al., 2009) facial expressions in different conditions.

In the freely expressed condition, photographs were taken while participants were asked to freely express basic emotions in three levels (mild, moderate, and intense) and neutral and calm expressions (see also Appendix A). Subsequently, actors were asked to show instructed emotional expressions. In the instructed condition, photographs for each emotional expression were taken after the participants were trained and subsequently instructed on how to use specific facial action units (AU)[3] to portray basic emotions according to the FACS (Ekman, 1992a; 1992b; Ekman & Friesen, 1978; Ekman & Rosenberg, 1997; Figure 1). A minimum of three photos per condition and emotional expression were taken for each actor. The resulting stimuli were sorted and labelled. They were adjusted for interpupillary distance, transformed to grey scale, and resized to a standard $1{,}024 \times 768$ pixels resolution. Their luminescence was averaged in SHINE, MATLAB Toolbox, and finally, the stimuli were spatially aligned and framed into pure white within a cropped circle with set dimensions (height: 6 cm and width: 4 cm).

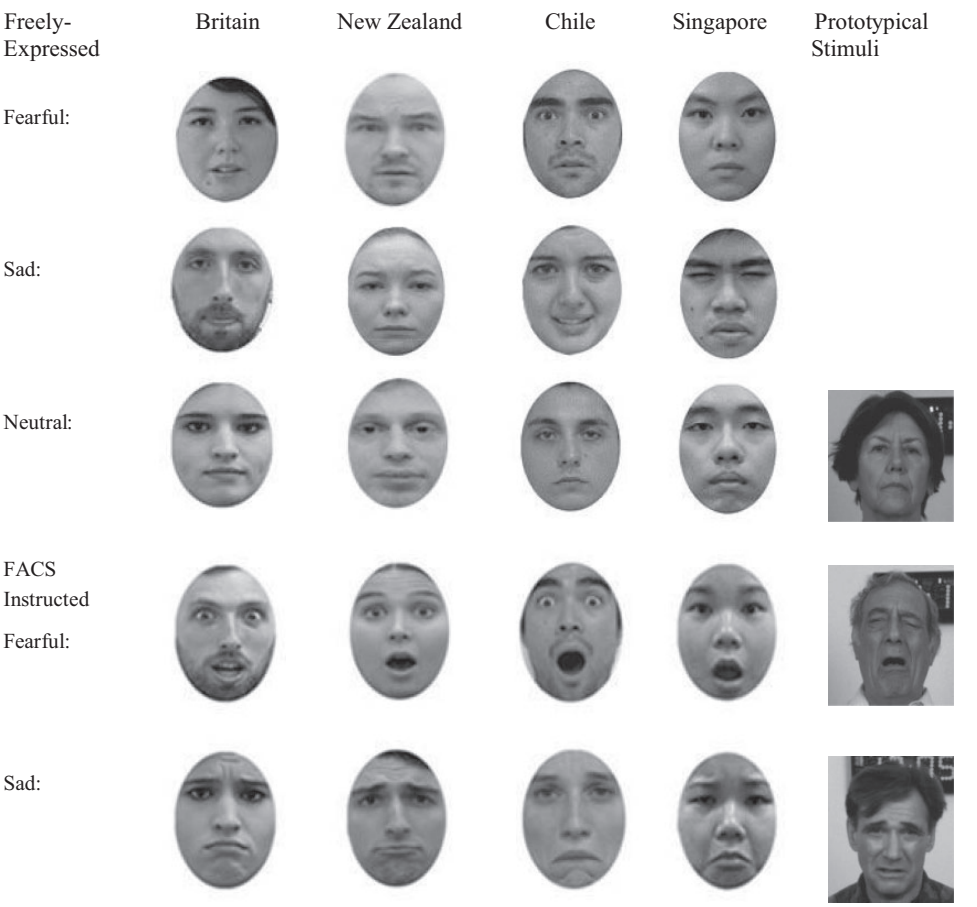


Figure 1. Cross-cultural faces of emotion. Example emotional expressions for each country. Prototypical stimuli were not part of any subsequent stage and are presented here for illustration purposes (Gur et al., 2002).

Analysis and discussion. To explore whether cultural groups were characterised by cultural—and not random sampling—differences in the expression of emotion, the actors' scores in the ERQ and CDQ questionnaires were assessed (Russell et al., 2003; see also Appendix C). An analysis of variance (ANOVA) was run with independent variable Country of Origin of the Actors (Britain, New Zealand, Chile, and Singapore) and dependent variable Cultural Dimensions Scores (power distance, individualism, masculinity, uncertainty-avoidance, and long-term orientation). The analysis revealed a significant Country of Origin of the Actors effect—$F(3,42) = 4.92$, $p < .01$; partial eta-squared = .26. Further Bonferroni-corrected post hoc comparisons revealed that uncertainty avoidance was higher for British actors ($M = 72.14$, $SD = 9.23$) compared with actors from Singapore ($M = 53.23$, $SD = 10.72$; $p < .01$; $d = 1.89$). Actors from New Zealand ($M = 71.45$, $SD = 8.49$; $p < .01$; $d = 1.88$) and Chile ($M = 67.6$, $SD = 9.53$; $p < .01$; $d = 1.42$) also reported higher uncertainty-avoidance scores compared with actors from Singapore. No other comparisons survived the Bonferroni corrections. To further explore emotional differences between cultural groups, an ANOVA was run with independent variable Country of Origin (Britain, New Zealand,

Chile, and Singapore) and dependent variable Emotional Expression Facets (Cognitive Reappraisal and Emotional Suppression). The analysis revealed a significant effect of Country of Origin—$F(3,51) = 4.5$, $p < .01$; partial eta-squared = .21. Further Bonferroni-corrected post hoc comparisons revealed that Expressive Suppression was significantly lower for British actors ($M = 10.97$, $SD = 2.85$) compared with Singaporean actors ($M = 16.11$, $SD = 3.56$; $p < .01$; $d = 1.59$), and for Chilean actors ($M = 10.5$, $SD = 4.51$) compared with Singaporean actors ($p < .01$; $d = 1.38$). No other comparisons survived the Bonferroni corrections.

Stage 2: Automatic Facial Recognition Software Assessment

Aims. The aims of this stage were to assess the dataset using automatic facial recognition software and use the output to select the stimuli that were validated for racial background, gender, and expressed emotion.

Stimuli and procedures. A total of 2,964 photographs from 97 actors were assessed using Noldus Face-Reader 7.0 (Noldus, 2018). The analysis of the stimuli was run using the Viola–Jones cascaded algorithm (Viola & Jones, 2004) and an active appearance model that employed a 500-point Euclidean transformation (Cootes, Edwards, & Taylor, 2001) to eliminate static identification variability for image quality, lighting, background variation, and orientation (Lewinski, den Uyl, & Butler, 2014). The analysis was conducted using a custom template analysis, and each participant was evaluated with respect to the expressed emotion after controlling for the influence of AU that were present in their own neutral expressions using the participant calibration module (Noldus, 2018). The General6_1 face module was used to assess British, New Zealand, and Chilean actors and the East Asian face module was used to assess actors from Singapore. Gender and cultural-background analysis[4] was also conducted per participant and expressed emotion.

Output and discussion. Stimuli that were not correctly identified with respect to gender and cultural background were excluded from further analysis; a total of 47 photographs were excluded. The remaining 2,917 stimuli were further reduced to be able to meet the time restrictions for Study 2. The ethics approval for Study 2 included a time restriction for 1 hour of stimuli presentation. To provide sufficient trial repetitions to achieve the required power ($P_{(1-\beta)} \geq .8$) within the approved time frame we chose, for further facial recognition assessment and consideration for inclusion in the masking stage, the face types that reported a significant in-group advantage and a cross-cultural bias effect in previous research (Elfenbein et al., 2007). We included mid-intensity freely expressed faces, to control for possible effects relating to very subtle (low-intensity) or exaggerated (high-intensity) emotional expressiveness (Ekman & Rosenberg, 1997) and approximate normative and realistic cultural responses (Russell, 1994), and FACS-instructed (Bernstein, Young, & Hugenberg, 2007) fearful (Chiao et al., 2008), sad (Elfenbein & Ambady, 2002a), and neutral (Marsh et al., 2003) faces for each culture. All mid-intensity freely expressed faces that met the cultural-background and gender criteria ($n = 291$) were included for each culture. These could vary in emotion recognition and were not chosen based on Noldus scores (Tables 1 and 2). The FACS instructed facial expressions that reported the highest emotional recognition, racial background, and gender recognition criteria were selected ($n = 291$). The final subset consisted of freely expressed and Facial Action Unit System instructed facial expressions ($n = 582$) with the original sample demographic characteristics (Stage 1).

Table 1. Emotional Recognition Scores (%).

	Freely expressed Mean (*SD*)	FACS instructed Mean (*SD*)	*p*	*d*
Britain				
Fear	85.07 (3.04)	91.18 (2.01)	.01	2.37
Sad	86.41 (2.67)	92.45 (1.97)	.01	2.57
Neutral	86.32 (2.81)			
New Zealand				
Fear	85.12 (3.12)	90.84 (1.92)	.01	2.21
Sad	86.19 (2.92)	92.1 (1.45)	.01	2.56
Neutral	86.41 (2.44)			
Chile				
Fear	85.92 (2.96)	91.18 (2.03)	.01	2.07
Sad	86.15 (2.58)	93.45 (1.46)	.01	3.48
Neutral	86.19 (2.45)			
Singapore				
Fear	81.31 (4.23)	91.07 (2.93)	.01	2.68
Sad	81.72 (3.91)	92.86 (2.84)	.01	3.26
Neutral	89.43 (2.21)			

Note. Means and *SD* (%) certainty of emotional categorisation (Noldus, 2018). Instructed facial expressions were recognised more accurately than freely expressed faces ($p < .01$; partial eta-squared = .49). Significance values and Cohen's *d*, in far-right columns; see also Appendix I.

Table 2. Number of Actors Showing Key AUs for Instructed and Freely Expressed Emotion.

	FACS instructed fear (freely expressed)					FACS instructed sadness (freely expressed)				
	Britain	New Zealand	Chile	Singapore	*p*	Britain	New Zealand	Chile	Singapore	*p*
1. In brow raiser	24 (21)	23 (20)	24 (22)	22 (6*)	.01	21 (14)	19 (11)	21 (14)	18 (13)	.28
2. Out Brow raiser	23 (20)	22 (20)	23 (21)	23 (7*)	.01	2 (3)	1 (2)	2 (2)	1 (5)	.32
4. Brow lowerer	2 (7)	4 (8)	3 (6)	2 (2*)	.04	22 (11)	23 (13)	22 (12)	23 (12)	.81
5.Lid raiser	23 (15)	23 (16)	24 (23)	22 (18)	.24	0 (2)	1 (2)	1 (9)	0 (7)	.19
7. Lid tightener	0 (2)	0 (7)	0 (0*)	1 (9)	.01	2 (6)	2 (9)	0 (4)	2 (11)	.21
15. Lip depressor	0 (1)	0 (0)	0 (0)	2 (12*)	.01	23 (16)	24 (15)	23 (17)	23 (16)	.82
20. Lip stretcher	13 (12)	12 (12)	13 (14)	11 (18)	.27	2 (6)	1 (5)	1 (5)	0 (8)	.19
25. Lips part	20 (21)	22 (23)	24 (24)	21 (7*)	.01	0 (3)	0 (3)	1 (7)	0 (2)	.17
27. Head down	1 (5)	1 (3)	0 (4)	1 (12*)	.01	0 (2)	1 (3)	0 (1)	1 (9*)	.03
43. Eyes closed	0 (0)	0 (1)	0 (0)	1 (4)	.21	0 (0)	0 (0)	0 (1)	0 (4)	.19

Note. Number of actors showing innervation of key action units per cultural background and emotion. Facial Coding System Instructed expressions are presented in each box with freely expressed expressions per cultural background and emotion in brackets. Significance for each AU for freely expressed emotion in *p* column, individual groups conferring significant differences marked with asterisk (*). Instructed emotion did not report significant differences or sensitivity for AUs ($p = .87$; partial eta-squared = .01; $B = .07$); see also Appendix D.

Stage 3: Overt Assessment

Aims. The aim in this stage was to assess participant responses for emotional recognition and cultural familiarity when the selected stimuli were presented for 1 second.

Participants. A power calculation based on medium effect sizes (partial eta-squared = .06; $f = .25$) and within-subject experimental trial repetitions ($n = 582$) was performed. The results revealed that 17 participants would be required for $P_{(1-\beta)} \geq .8$ (Faul, Erdfelder, Buchner, & Lang, 2009). Nineteen participants (nine females) who were not part of Stage 1 volunteered to participate in the experiment. All participants reported normal or corrected-to-normal vision. The inclusion criteria for the current study were having been born in the United Kingdom of Great Britain (hereafter United Kingdom),[5] having attended primary, secondary, and higher education in English in the United Kingdom, having previously resided only and currently residing permanently in the United Kingdom, and characterising themselves as part of the culture of the United Kingdom (Yes/No). The participants were screened for psychiatric diagnosis (Hickie et al., 2001) and alexithymia (Alexithymia, 2018). Data for one participant were excluded due to possible Alexithymic traits. Data from one participant were excluded due to possible psychiatric diagnosis. The final population sample consisted of 17 participants (9 females). The mean participant age was 27.48 years ($SD = 4.71$). All participants gave informed consent to participate in the study. The experiment was approved by the local Ethics Committee of the School of Psychology.

Stimuli and procedures. Participants were invited in a laboratory space in the local School of Psychology. Participants took part in two experimental runs scheduled 1-week apart at the same time slot. Each run consisted of 291 faces that were pseudo-randomised using Python to include approximately equal (± 1) numbers of faces for expression type, country of origin, emotional expression, and gender. The stimuli were presented on a 60 Hz HD Lenovo monitor (16.67 milliseconds per frame). The presentation was programmed in the coder and builder components of Psychopy version 1.85.3 (Peirce, 2007).

The experimental trial started with a fixation cross for 3 seconds (± 1 second). After the fixation cross, a single freely expressed or instructed face from Britain or New Zealand or Chile or Singapore showing a fearful or sad or neutral expression was presented at fixation for 1 second; order randomised. The face was immediately followed by a black and white pattern mask for 1 second (see also Figure 2). A blank screen interval was presented for 2 seconds before the rating tasks.[6] Participants were asked to respond to two on-screen stimuli-rating tasks using the keyboard; task order randomised. The participants were asked "What emotion best describes the emotion that the presented face was expressing? (*fearful* (f), *sad* (s), *neutral* (n), or *other* (o))" and "How culturally familiar was the presented face? (1: *not familiar at all* to 10: *very familiar*)." After the engagement tasks, a 2-second blank screen interval was presented before the next trial. The participants were not made aware in any way of the country of origin of the presented faces before or during the current experimental stage.

Analysis and discussion

Emotional recognition. Emotional recognition was transformed to nonparametric sensitivity index A. This measure was used for all subsequent analyses (Zhang & Mueller, 2005). Descriptive statistics for each condition can be seen in Table 3. An ANOVA with independent variables Country of Origin (Britain, New Zealand, Chile, and Singapore) and Type of Expression (freely expressed and instructed), and dependent variable emotional recognition performance (A) was run. The analysis revealed a significant effect of Country of Origin, $F(3, 48) = 968.06$, $p < .001$; partial eta-squared = .99, a significant effect of Type of Expression, $F(1, 16) = 225.92$, $p < .001$; partial eta-squared = .93, and a significant interaction, $F(1.68, 26.81) = 194.4$, $p < .001$; partial eta-squared = .93; Greenhouse-Geisser corrected.

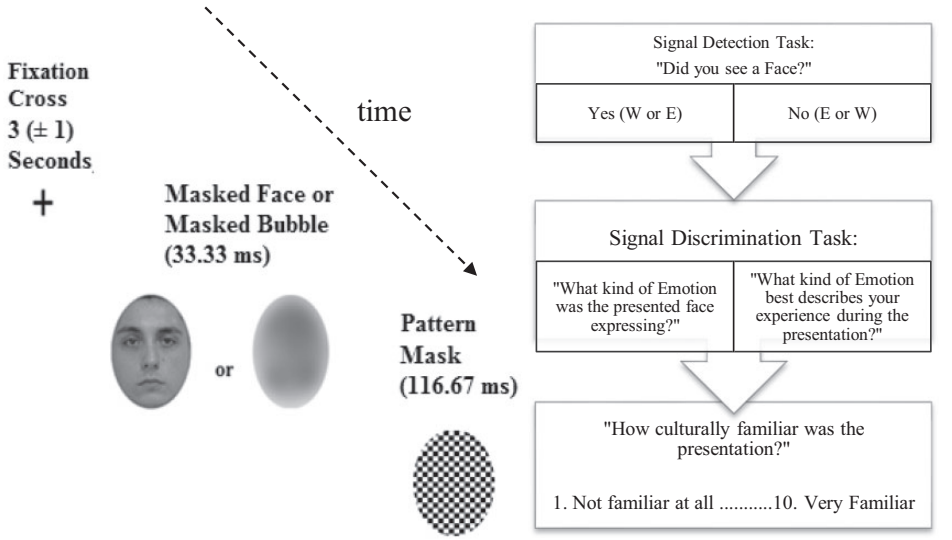


Figure 2. Stimuli sequence. Example stimuli sequences including a neutral Chilean face or a nonfacial blur. Participants were presented with brief culturally diverse faces. They were asked to reply if they saw a face using the keyboard by pressing W or E; key order randomised. They were then assigned with either an emotional recognition or emotional self-assessment task. Finally, they were asked to rate cultural familiarity for the presentation.

Table 3. Emotional Recognition and Cultural Familiarity.

	Freely expressed				Instructed			
	Mean (*SD*)				Mean (*SD*)			
	Britain	New Zealand	Chile	Singapore	Britain	New Zealand	Chile	Singapore
Emotional recognition (%)	91.48 (3.59)	87.09 (1.94)	87.27 (2.19)	75.64 (2.65)	98.49 (1.37)	97.95 (1.49)	97.41 (1.65)	96.39 (1.9)
Emotional recognition (A)	.95 (.01)	.93 (.01)	.94 (.01)	.85 (.01)	.98 (.01)	.98 (.01)	.98 (.01)	.98 (.01)
Cultural familiarity	7.33 (.33)	6.27 (.51)	6.68 (.46)	3.39 (.52)	7.86 (.47)	6.95 (.38)	7.08 (.41)	4.19 (.42)

Note. Means and standard deviation for each condition for Stage 3. Emotional recognition and cultural recognition performance are presented here both in hit rates (percentage correct) and nonparametric index A (Zhang & Mueller, 2005).

Further Bonferroni-corrected pairwise comparisons revealed that British actors were emotionally recognised more accurately than actors from New Zealand ($p < .01$, $d = 1.55$), Chile ($p < .01$, $d = 1.55$), and Singapore ($p < .01$, $d = 8.52$) for the freely expressed emotional condition. New Zealand ($p < .01$, $d = 1.28$) and Chilean ($p < .01$, $d = 1.43$) actors were emotionally recognised more accurately than actors from Singapore. No other comparisons survived the Bonferroni corrections. No significant differences were reported for instructed emotion, $F(3, 48) = .3$, $p = .82$; partial eta-squared = .02; $\beta^7 = .03$.

Cultural familiarity. An ANOVA with independent variables Country of Origin (Britain, New Zealand, Chile, and Singapore) and Type of Expression (freely expressed and instructed), and dependent variable cultural familiarity ratings was run. The analysis revealed a significant effect of Country of Origin, $F(3, 48) = 553.56$, $p < .001$; partial eta-squared = .97, a significant effect of Type of Expression, $F(1, 16) = 119.05$, $p < .001$; partial eta-squared = .88, but not a significant interaction, $F(3, 48) = 1.8$, $p = .16$; partial eta-squared = .1; $\beta = .09$. Further Bonferroni-corrected pairwise comparisons revealed that British actors were rated higher for cultural familiarity than actors from New Zealand ($p < .001$; d (F.E.[8]) = 2.47, d (I.[9]) = 2.12), Chile ($p < .01$; d (F.E.) = 1.62, d (I.) = 1.77), and Singapore ($p < .001$; d (F.E.) = 9.05, d (I.) = 8.23). Chilean actors were rated as more culturally familiar than actors from New Zealand ($p < .01$; d (F.E.) = .43, d (I.) = .33) and Singapore ($p < .001$; d (F.E.) = 6.29, d (I.) = 6.96). New Zealand actors were also rated higher for familiarity than actors from Singapore ($p < .001$; d (F.E.) = 5.59, d (I.) = 6.89).

Study 2

Aims. The first objective of the current study was to test if the own-group emotional recognition advantage—and the other-culture emotional recognition bias—can be preserved during backward-masked presentations of brief faces for freely expressed and instructed, own, and other-culture emotional expressions. The second objective of the current study was to test whether cultural familiarity can be appraised from hits and miss responses for face detection and emotional recognition in a posttrial signal detection assessment task.

Participants. A power calculation based on medium effect sizes (partial eta-squared = .06; $f = .25$) and within-subject experimental trial repetitions ($n = 480$) was performed. The result revealed that 21 participants would be required for $P_{(1-\beta)} \geq .8$ (Faul et al., 2009). Twenty-six participants (13 females) who were not part of Study 1 volunteered to participate in the experiment. All participants reported normal or corrected-to-normal vision. The inclusion criteria for the current study were having been born in the United Kingdom; having attended primary, secondary, and higher education in English in the United Kingdom; having previously resided only and currently residing permanently in the United Kingdom; and characterising themselves as part of the culture of the United Kingdom (Yes/No). Participants were additionally screened with the Somatic and Psychological Health Report Questionnaire (Hickie et al., 2001) and an online Alexithymia Emotional Blindness questionnaire (Alexithymia, 2018). Three participants were excluded from the study due to joint nationality. Data from one participant were excluded from further analysis due to possible alexithymic traits and data from one participant were excluded due to possible psychiatric diagnosis. The final population sample consisted of 21 participants (10 females). The mean age for this stage was 30.21 years ($SD = 5.07$). All participants gave informed consent to participate in the study. The experiment was approved by the local Ethics Committee of the School of Psychology.

Stimuli and Procedures. Participants were invited into a laboratory space at the local School of Psychology. After the initial screening processes, they were administered the ERQ and CDQ.[10] They were then allowed a small break. The main experiment started with a 5-minute response training task and participants were then asked to indicate when they were ready to start the stimuli presentation using the keyboard. Previous research (Elfenbein & Ambady, 2002a, 2002b, pp. 243–247) suggests that to accomplish a balanced design when a single cultural group is exposed to cross-cultural stimuli an equal number of

stimuli from each selected culture should be presented to the participants including equal emotional expression and type, and gender distributions per cultural group during the presentation. In this study, we followed these experimental guidelines to attain a balanced cross-cultural emotional recognition design. Two hundred and forty faces and an equal number of randomly generated nonfacial pattern blurs were shown (see Appendix E). Each presentation run was pseudorandomised for the face condition and assigned 120 faces per type, 80 faces per emotion, and 60 faces per nationality. Each actor identity was repeated three times to attain an equal number of male and female faces ($n = 120$).

The experimental trial started with a fixation cross for 3 seconds (±1 second). After the fixation cross, a nonfacial blur or a single freely expressed or instructed face from Britain or New Zealand or Chile or Singapore showing a fearful or sad or neutral expression was presented at fixation for 33.33 milliseconds; order randomised (see also Appendix F). The target was immediately followed by a black and white pattern mask for 116.67 milliseconds. After the mask, a blank screen interval was presented for 2 seconds. After the presentation, participants were asked to reply to three on-screen questions using the keyboard. First they were asked "Did you see a face? (*Y*/*N*)." After this task, we used conditional branching. If the response was "Yes," an on-screen message asked participants "What kind of emotion was the face expressing? (*fear* (f), *sad* (s), *neutral* (n), or *other* (o))." To balance the task length when using conditional branching, if the participants' response was "No," an on-screen message asked participants "What kind of emotion best describes your experience during the presentation? (*fear* (f), *sadness* (s), *neutral* (n), or *other* (o))." This task was included to disallow participants to make their choice based on shorter engagement task length criteria. After this task, participants were asked by an on-screen message "How culturally familiar was the presentation? (1: *not familiar at all* to 10: *very familiar*)."[11] A blank screen interval was presented for 2 seconds before the next trial (Figure 2).

Apparatus and Presentation Testing

The stimuli were presented on a 60 Hz HD Lenovo monitor. The presentation was programmed in the coder and builder components of Psychopy version 1.85.3. To ensure that brief stimuli were correctly presented, an IPad PRO camera with 120 Hz refresh rate (8.33 milliseconds) recorded two pilot runs. The stimuli presentation was assessed frame by frame; no instances of dropped frames were detected. A self-developed dropped frames script report with one frame (16.67 milliseconds) tolerance threshold was coded in Python and two pilot experimental diagnostic sessions were run. The presenting monitor reported no dropped frames; prognostic estimate 1/5,000 trials. Experimental stages were subsequently run using dropped frames diagnostics; no instances of dropped frames were reported.

Analysis and Discussion

In-group advantage and cross-cultural bias for emotional recognition under conditions of backward masking. Descriptive statistics for signal detection performance can be seen in Table 4. Emotional Recognition was transformed to nonparametric sensitivity index A.[12] This measure was used for all subsequent analysis (Zhang & Mueller, 2005). An ANOVA with independent variables Type of Expression (freely expressed and instructed), Country of Origin (Britain, New Zealand, Chile, and Singapore) and Type of Emotion (fear, sadness, and neutral), and dependent variable emotional recognition performance (A) was run. The analysis revealed significant effect only for Country of Origin, $F(2.01, 40.11) = 33.55$, $p < .001$; partial eta-squared = .63. Further Bonferroni corrected pairwise comparisons revealed that actors from

Table 4. Hit Rates (a) and Sensitivity Index A (b) for Signal Detection Performance.

	Freely expressed condition				Instructed condition			
	Detection		Recognition		Detection		Recognition	
a.	Mean (%)	*SD* (%)	Mean (%)	*SD* (%)	Mean (%)	*SD* (%)	Mean (%)	*SD* (%)
Britain	62.22	15.79	53.02	17.33	76.51	13.35	67.62	17.12
New Zealand	64.44	13.44	53.65	17.15	72.38	13.23	57.78	18.07
Chile	66.67	14.39	54.6	18.57	66.35	13.91	54.29	20.73
Singapore	68.25	13.23	34.29	18.26	75.56	14.01	33.02	19.02
	Detection		Recognition		Detection		Recognition	
b.	Mean (A)	*SD* (A)	Mean (A)	*SD* (A)	Mean (A)	*SD* (A)	Mean (A)	*SD* (A)
Britain	.606	.131	.534	.148	.713	.101	.644	.138
New Zealand	.623	.113	.535	.145	.68	.106	.571	.15
Chile	.64	.114	.546	.155	.637	.111	.543	.165
Singapore	.652	.106	.399	.144	.7	.101	.393	.155

Note. (a) Mean and standard deviation percentage of correct detection (hit rates), and(b) mean and standard deviation sensitivity index A per type of expression (freely expressed and instructed) and per country of origin for detection and recognition performance.

Britain ($M = .64$, $SD = .11$) were recognised more accurately than actors from Singapore ($M = .43$, $SD = .11$; $p < .001$; $d = 1.82$). In addition, *p*-values that approximated Bonferroni-corrected significance in the analysis (Schumm, Pratt, Hartenstein, Jenkins, & Johnson, 2013) were revealed for higher recognition to actors from Britain in comparison to actors from New Zealand ($M = .58$, $SD = .13$; $p = .02$; $d = .5$) and Chile ($M = .58$, $SD = .14$; $p = .04$; $d = .48$).

Actors from New Zealand ($p < .001$; $d = 1.25$) and Chile ($p < .001$; $d = 1.19$) were recognised significantly more accurately with respect to what emotion they were expressing compared with actors from Singapore. This finding indicated that emotional recognition for actors from Singapore was subject to a cross-cultural emotional-recognition bias. Therefore, we tested the exploratory hypothesis that, due to higher emotional suppression scores reported during Study 1, the current results could have occurred because actors from Singapore could have been most commonly misrecognised as expressing emotional neutrality. This hypothesis was investigated further using confusion matrix analysis (Fawcett, 2006). Accuracy for recognition of an expression (A) was calculated for hits and misses for responding having seen a neutral face for each country of origin (Britain, Chile, New Zealand, and Singapore) and an ANOVA was run. We wanted to test if in particular false-positive responses (incorrectly categorising a face as neutral) were higher for participants from Singapore resulting in lower recognition; correct responses. A significant effect of Country of Origin was reported, $F(2.05, 40.89) = 30.15$, $p < .001$; partial eta-squared = .6. Further Bonferroni-corrected pairwise comparisons revealed higher false-positive rates for incorrectly labelling a face as neutral for Singaporean actors ($M = .39$, $SD = .02$), compared with actors from Britain ($M = .67$, $SD = .03$; $p < .001$; $d = 11.51$), New Zealand ($M = .59$, $SD = .03$; $p < .001$; $d = 7.74$), and Chile ($M = .59$, $SD = .04$; $p < .001$; $d = 6.57$).

Does appraisal of cultural familiarity require conscious awareness?. Descriptive statistics can be seen in Tables 4 and 5. A one-sample *t* test against chance-level performance (A) revealed that

Table 5. Hits and Miss Cultural Familiarity Responses Within Cultures.

	Detection						Recognition					
	Freely expressed			Instructed			Freely expressed			Instructed		
	Mean (*SD*)			Mean (*SD*)			Mean (*SD*)			Mean (*SD*)		
	Hits	Miss	Sig.	Hits	Miss	Sig.	Hits	Miss	Sig.	Hits	Miss	Sig.
Britain	5.92	4.79	.001	6.82	4.81	.001	5.99	5.73	.05	7.13	6.73	.04
	(.63)	(.38)	2.17	(.99)	(.14)	2.93	(.7)	(.8)	.35	(.93)	(.67)	.49
New	4.86	4.72	.29	4.79	4.81	.87	4.84	4.88	.68	4.83	4.71	.05
Zealand	(.46)	(.45)	.31	(.38)	(.42)	–.05	(.54)	(.49)	.04	(.42)	(.41)	.32
Chile	4.91	4.83	.4	4.81	4.88	.64	4.97	4.98	.94	4.87	4.46	.03
	(.44)	(.37)	.19	(.53)	(.38)	.06	(.49)	(.59)	–.01	(.52)	(.65)	.69
Singapore	3.39	4.63	.001	3.61	4.84	.001	3.31	3.49	.09	3.46	3.64	.2
	(.6)	(.21)	–2.76	(.68)	(.79)	–1.81	(.72)	(.71)	.25	(.82)	(.76)	–.23

Note. Mean and standard deviation for each condition for hits and misses in Study 2. In Sig. column are Bonferonni corrected α values ($\leq$.001) for each comparison and effect size Cohen's *d*.

masked faces were detected significantly better than chance ($p < .01$), but they were not recognised significantly different from chance ($p = .67$). A Bayesian analysis (Dienes, 2015) with corrected degrees of freedom (Berry, 1996) and higher and lower bounds set at –.1 (.4) and .1 (.6), with 0 (A = .5) representing chance level performance, revealed that face detection for British ($SE = .02$; $B > 3$), New Zealand ($SE = .02$; $B > 3$), Chilean ($SE = .02$; $B > 3$), and Singaporean ($SE = .02$; $B > 3$) faces were higher than chance (Dienes, 2015). A Bayesian analysis (Dienes, 2015) with corrected degrees of freedom and higher and lower bounds set at –.1 (.15) and .1 (.35), with 0 (A = .25) representing chance-level performance, revealed that emotion recognition for British ($SE = .03$; $B > 3$), New Zealand ($SE = .03$; $B > 3$), Chilean ($SE = .03$; $B > 3$), and Singaporean ($SE = .03$; $B > 3$) faces was significantly higher than chance.

To explore if cultural familiarity can be appraised without conscious awareness, we ran an analysis of cultural familiarity scores for hits and misses for detection and recognition performance (Pessoa, 2005). The analysis revealed that hits for face-detection performance were associated with significant differences between cultures, $F(2.33, 46.65) = 68.98$, $p < .001$; partial eta-squared = .44, while misses were not significantly different between cultures, $F(15, 210) = 1.19$, $p = .28$; partial eta-squared = .08; $\beta = .07$. Further Bonferroni-corrected pairwise comparisons revealed that correctly detected British faces ($M = 6.59$, $SD = .86$) were rated higher in cultural familiarity than correctly detected faces from New Zealand ($M = 4.8$, $SD = .39$; $p < .001$; $d = 2.68$), Chile ($M = 4.91$, $SD = .44$; $p < .001$; $d = 2.46$), and Singapore ($M = 3.48$, $SD = .52$; $p < .001$; $d = 4.38$). A different pattern was found for recognition performance. Hits, $F(2.34, 41.13) = 62.78$; $p < .001$; partial eta-squared = .78, and misses, $F(15, 120) = 14.21$; $p < .001$; partial eta-squared = .64, in emotion recognition revealed significant differences in familiarity ratings between different cultures (Figure 3). Further Bonferroni-corrected comparisons revealed that for recognition hits British actors ($M = 6.72$, $SD = .93$) were rated higher for cultural familiarity than actors from New Zealand ($M = 4.89$, $SD = .37$; $p < .001$; $d = 2.59$), Chile ($M = 4.98$, $SD = .46$; $p < .001$; $d = 2.37$) and Singapore ($M = 3.33$, $SD = .64$; $p < .001$; $d = 4.25$). For misses in recognition, British actors ($M = 6.33$, $SD = .68$) were also rated higher than actors from

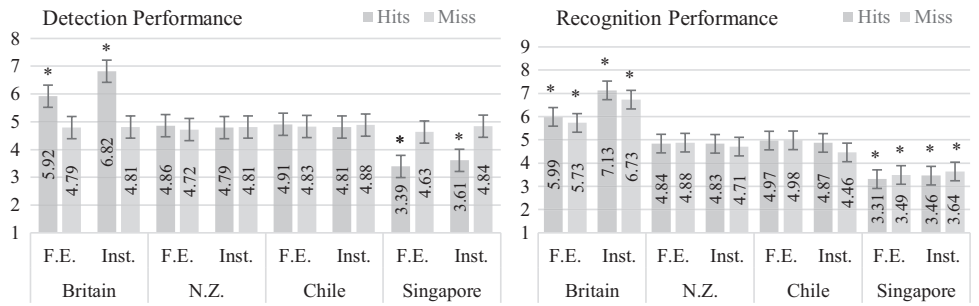


Figure 3: Hits and miss cultural familiarity responses between cultures. Mean cultural familiarity ratings per Country of Origin for Hits and Misses in detection and recognition performance for freely expressed (F.E.) and FACS instructed (Inst.) faces for Study 2. Error bars indicate standard error of the mean (±2). Asterisks indicate Bonferonni corrected significance between different cultures ($p \leq .001$).

New Zealand ($M = 4.84$, $SD = .88$; $p < .001$; $d = 1.89$), Chile ($M = 4.9$, $SD = .82$; $p < .001$; $d = 1.89$) and Singapore ($M = 3.67$, $SD = .98$; $p < .001$; $d = 3.15$).

General Discussion

In Study 1, we developed a cross-cultural facial stimulus dataset including nonprofessional actors from Britain, Chile, Singapore, and New Zealand showing freely expressed and FACS instructed emotional expressions. We assessed and validated the dataset using standard cultural dimensions and emotional expression questionnaires, automatic facial recognition software, and participant assessment. In Study 2, we used the developed dataset to explore whether the own-culture emotional recognition advantage can be preserved under conditions of backward masking and whether the appraisal of cultural familiarity from faces requires conscious awareness. We reported significant findings for an own-group emotional recognition advantage and that face-detection was a necessary condition for the appraisal of cultural familiarity. No effects were reported for misses for face detection between different cultural groups. Correct emotional recognition of own-culture faces increased ratings for cultural familiarity but was not a necessary condition for significant differences between cultures.

Previous research has reported extended evidence for a regional in-group advantage in emotional recognition (Elfenbein & Ambady, 2002a). Higher accuracy for emotional recognition for own-culture compared with other-culture faces has been reported by African American (Wickline, Bailey, & Nowicki, 2009), Canadian (Beaupré & Hess, 2005), American U.S. (Soto & Levenson, 2009), European (Sauter, Eisner, Ekman, & Scott, 2010), Chinese (Han & Northoff, 2008), Australian (Elfenbein, 2006), and Japanese (Chiao et al., 2008) participants and has been used to shape contemporary cross-cultural psychological theories (Elfenbein & Ambady, 2002b; Matsumoto, 2002). This in-group advantage is suggested to rely on culture-specific ways of expressing emotion, that is, display rules, and culture specific ways of responding to emotion, that is, decoding rules.

Contemporary cross-cultural psychologists suggest that the expression of basic emotions such as anger, fear, sadness, happiness, surprise, and disgust is considered a universal language, but they are *pronounced* in different ways due to the nonconvergent social evolution that takes place in different geographical regions (Elfenbein et al., 2007). This nonconvergent evolution has been suggested to confer culture-specific sociobiological value (Adolphs, 2003). Based on this hypothesis, the argument has also been raised that culture-specific

emotional expressions are recognised more accurately because they are appraised without conscious awareness (Eberhardt et al., 2004; Gifford, 2008; Smith et al., 2008). Previous research has provided support for the notion of automatic appraisal of own-culture emotional faces (Chiao et al., 2008) and the notion that other-culture and own-culture faces, that are visually suppressed using either backwards masking or dichoptic rivalry, can influence our subsequent responses to supraliminal cues (Smith et al., 2008). This line of research has been challenged by findings from other research groups that suggest that, although it is possible that facial characteristics can influence participant responses during visual suppression, these effects could be due to inadequate masking of the presented stimuli and conscious awareness (Pessoa et al., 2005; Tsikandilakis et al., 2018).

In the current study, we followed on from these findings. We tested whether the effects of cross-cultural dialects in the expression of emotion can be preserved under conditions of backwards masking and whether the appraisal of cultural familiarity requires conscious awareness, such as hits and miss responses for face detection and emotional recognition in a posttrial signal detection assessment task. We found that British participants could emotionally recognise own-culture emotional faces more accurately than other-culture faces under conditions of backward masking irrespective of type of expression (freely expressed and FACS instructed) and despite the brief duration of presentation (i.e., 33.33 milliseconds). The participants in the current study were, furthermore, able to accurately rate and recognise own-culture masked negative emotions and masked negative emotions expressed by actors from Chile and New Zealand. However, they responded with a cross-cultural misrecognition bias (emotional neutrality) and the lowest familiarity ratings for masked faces from Singapore. These findings suggest that the participants employed cultural and emotional display rules for emotional recognition, and they did not experience a negative emotion decoding bias (Phaf & Rotteveel, 2005), meaning, in this context, that the participants were not reluctant to explicitly categorise a face as expressing a negative emotion (see also Johnson & Fredrickson, 2005).

The finding that the own-culture emotional recognition advantage was preserved under conditions of backward masking, for the duration for which faces were presented in previous research (i.e., 33.33 milliseconds), is not surprising. Using the current method for the assessment of subliminality, the participants did not show evidence for subliminal processing in response to the presented faces (Tsikandilakis & Chapman, 2018). Further analysis of awareness revealed that higher in-group cultural familiarity ratings were specific to the subset of trials that included hits for face detection of the presented stimuli. Emotional recognition enhanced this effect while misses for face detection did not reveal significant differences between cultural groups. During the masking study, British participants displayed an own-group emotional recognition advantage for both freely expressed and FACS instructed facial expressions, but this finding did not extend to higher familiarity and emotion recognition for other-culture FACS instructed facial expressions as compared with other-culture freely expressed faces. This finding suggests that under conditions of backward masking the most pronounced emotional differences survive the reduction in signal strength (Aru, Bachmann, Singer, & Melloni, 2012), and that the presentation of unfamiliar physiognomic characteristics in combination with the challenging task of responding to brief emotional expressions (Gaillard et al., 2009) resulted in the extinction of the other-culture FACS instructed higher emotion recognition effect (Bochner, 2013).

In relation to the dialects theory of emotion, this suggests that culture-specific emotional characteristics have an impact on emotional recognition and the appraisal of cultural familiarity during very brief presentations of facial stimuli. Nevertheless, from a psychophysics perspective, it also indicates that fixed durations of masked presentations might not be

sufficient to induce subliminal visual suppression (Tsikandilakis & Chapman, 2018), particularly for own-culture emotional faces (Schlossmacher et al., 2017). In addition, when using further hits (correct detection/recognition) and miss (incorrect detection/recognition) analysis of participant responses, misses for detection did not reveal significant differences and revealed Bayesian evidence for the null ($\beta = .07$) for ratings for cultural familiarity between own and other-culture emotional faces. Therefore, the current findings suggest that detection is a necessary condition for the appraisal of differences in cultural familiarity and point towards that the appraisal of cultural familiarity from faces involves, and possibly relies on, conscious awareness for the detection of a presented face (Erdelyi, 2004; Etkin, Büchel, & Gross, 2015; Pessoa, 2005; Pessoa & Adolphs, 2010; Tsikandilakis et al., 2018). The current findings point towards that the appraisal of cultural familiarity from faces involves conscious awareness (Gaillard et al., 2009; Schlossmacher et al., 2017).

Limitations

To attain a balanced cross-cultural experimental design (Elfenbein & Ambady, 2002b), given the institutional availability for the current study, the stimuli set included three Caucasian and one Asian physiognomic group. This could have influenced the participant responses for Singaporean actors. The current study also included British participants in the masking stage, due to restrictions relating to the funding scheme that supported the current research. This poses the possibility that the current effect could be specific to the current population sample either as a function of task perception during the main experimental stage or emotional portrayal during the stimuli development stage, such as the ability of British participants to produce more distinguishable freely expressed emotional expressions. Cross-cultural replication is required to further explore if the current effect can be reported by additional cultural groups.

Conclusions

We tested whether British participants can report different cultural familiarity ratings when presented with backwards masked own and other-culture emotional faces. Our findings from the specific population sample suggest that freely expressed and instructed emotional faces from our own-culture are rated higher for cultural familiarity and are more accurately recognised compared with faces from other cultures during backward-masked presentations. Our findings also suggest that the appraisal of cultural familiarity involves, and possibly relies on, conscious awareness, such as face-detection hit responses, and that it could not be reported in the absence of conscious awareness, such as face-detection miss responses.

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Data Accessibility Statement

Raw data for the current report and examples of the photographic material have been made open access at https://osf.io/3z97s/. The entire dataset is available, subject to proof of concept of ethically approved institutional research, from the first author.

Declaration of Conflicting Interests

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Notes

1. Blood-oxygen-level-dependent (imaging)—an assessment used in functional magnetic resonance imaging (Heeger & Ress, 2002) to discriminate active brain regions via exploring what areas of a participant's brain show higher blood-flow during an experimental task or manipulation (see Ekstrom, 2010).
2. U21 refers to Universitas 21, a global networking initiative that funds projects relating to cross-cultural research among international universities (see https://universitas21.com/).
3. For specific training procedures; Appendix B.
4. The in-built module could discriminate between Caucasian, Eastern Asian, African, South Asian, or Other (see Noldus, 2018).
5. Including the geographical areas of England, Scotland, Wales, and Northern Ireland (see also Rhodes, 1997).
6. Sequence adapted from previous research (Elfenbein & Ambady, 2002a).
7. Type II error.
8. Freely expressed emotion.
9. Instructed emotion.
10. For cultural distance analysis (Russell et al., 2003), see Appendix G.
11. Participants were briefed during the preexperimental stage that they should rate cultural familiarity as "the extent to which a specific emotional expression could be encountered in a social interaction with people of the same culture as theirs."
12. A is an index for providing a less biased assessment for participant responses to a detection or discrimination task compared to hit rates (Zhang & Mueller, 2005; for a review, see Stanislaw & Todorov, 1999). It includes combining in a single metric the correct (hits) and incorrect (misses) replies that a participant made to a detection or discrimination task. It is suggested to be less susceptible than hit rates to conservative (tending to reply no to whether a face was presented) and liberal (tending to reply yes to whether a face was presented) biases relating to participant responses.

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Appendix A: Photo Stage

This section of the appendix describes an overview of the process for the photographic stage across the collaborating institutions.

Participants were asked to come to the session without make-up, remove facial items (e.g., earrings, piercings, glasses, etc.), and pull their hair back using pins provided by the researchers. Participants were asked to sit on a chair, keeping a straight posture and upright head position and facing the camera. The cameras used were subject to the availability of each institution with the restriction of at least 1,080 pixels. To be consistent with prior research (Gur et al., 2002), the cameras—with flash deactivated—were set 2 m away from the actors. Photos were taken with similar backgrounds (i.e., white walls) and similar light conditions across the involved institutions. All experimenters were trained to watch out for shadows from around the actor's nose and shadows on the background from the actor's head. Highlights from participants' forehead and reflections in their eyes were also prevented. Several photos for each expression (>3) were taken for each trial to ensure that onset, offset, and holding of an emotion would not influence expressiveness. For the freely expressed condition, participants could take as much time as they wanted to prepare the emotion and then indicate when they were ready to express the emotion as freely as in a social interaction with someone from their own cultural background (Elfenbein et al., 2007).

Appendix B: Action Units

This section describes action units used for instructed facial expressions and a link (copyrighted) to the instructions and training for implementing the Ekman method.

Example Fear AUS: 1, 4, 7 (related also with AUs 2, 5, 20, 25, 26)

Example Sadness AUs: 2, 17 (related also to AUs 1,4,15, 25)

See https://www.paulekman.com/product-category/facs/

Further descriptions concerning the Action Units used to produce Basic Emotional Expressions are subject to copyrights and can be disclosed by contacting the Ekman Foundation.

Appendix C: Descriptive Statistics for CDQ and ERQ Facets in Stage 1

This section of the appendix describes mean scores in percentiles for each actor and country of origin during the photographic stage across the collaborating institutions (see Table C1).

Table C1. Descriptive Statistics for Stage 1.

	Mean				*SD*			
	Britain	New Zealand	Chile	Singapore	Britain	New Zealand	Chile	Singapore
Power distance	48.41	47.64	48.2	46.92	10.44	13.69	11.93	7.72
Individualism	62.76	66.91	65.4	59.08	11.47	11.72	6.9	15.36
Masculinity	46.48	44	41.2	52	8.65	9.72	9.09	18.03
Uncertainty-avoidance	72.14	71.45	67.6	53.23	9.23	8.49	9.53	10.72
Long-term orientation	50.21	50.73	51.6	52.46	5.19	10.57	11.31	8.26
Cognitive reappraisal	28.38	31.55	31.6	32.11	4.08	7.26	5.63	5.18
Emotional suppression	10.97	13.55	10.5	16.11	2.85	5.35	4.51	3.56

Note. Cultural dimensions are adapted in percentage units.

Appendix D: Mean and *SD* Action Unit Recognition Scores in Freely Expressed Faces (%)

In this section, key action units are presented per emotion and country of origin for the final experimental stage.

Table D1.

	Britain		New Zealand		Chile		Singapore	
	Fear	Sad	Fear	Sad	Fear	Sad	Fear	Sad
1. Inner brow raiser	82.67 (8.91)	25.26 (11.17)	65.56 (17.81)	17.65 (2.48)	89.12 (2.21)	18.23 (6.21)	28.76* (17.13)	14.55 (4.51)
2. Outer brow raiser	79.43 (11.35)	4.56 (1.12)	84.58 (7.12)	5.18 (2.34)	91.13* (4.56)	11.41 (4.56)	92.15 (11.22)	19.26 (7.23)
4. Brow lowerer	17.56 (5.04)	29.48 (7.66)	29.45 (4.32)	34.56 (5.55)	11.56 (6.67)	38.41 (5.56)	9.51* (1.79)	67.44* (19.21)
5. Lid raiser	58.46* (7.32)	3.46 (1.43)	28.46 (16.52)	5.56 (2.33)	92.25* (11.6)	22.24* (7.28)	27.67 (8.76)	12.45 (5.71)
7. Lid tightener	32.56* (4.13)	28.67 (5.45)	68.45 (5.49)	69.71* (8.34)	22.31 (3.45)	12.53* (7.45)	58.26 (8.11)	66.87* (17.81)
15. Lip depressor	2.34 (5.17)	56.68 (11.54)	4.56 (3.71)	68.92 (11.12)	8.17 (4.56)	34.56* (13.99)	22.17* (9.16)	45.55 (17.84)
17. Chin raiser	3.45 (2.76)	5.56 (1.12)	4.48 (3.17)	11.45 (5.67)	3.31 (1.76)	9.48 (4.21)	3.67 (1.15)	18.76* (5.52)

(continued)

Table D1. Continued

	Britain		New Zealand		Chile		Singapore	
	Fear	Sad	Fear	Sad	Fear	Sad	Fear	Sad
20. Lip stretcher	12.68 (3.23)	4.48 (2.45)	13.66 (2.12)	5.12 (3.01)	12.98 (2.42)	6.78 (4.21)	14.15 (1.17)	5.77 (2.01)
24. Lip pressor	13.22 (3.12)	54.66* (4.55)	6.56 (2.31)	12.46 (9.12)	13.55 (4.28)	9.21 (2.36)	33.45* (6.22)	21.52 (8.93)
25. Lips part	68.46 (8.72)	5.76 (2.11)	69.71 (5.26)	3.44 (1.07)	70.98 (4.15)	31.21* (18.47)	34.41* (14.56)	9.04 (4.55)
26. Jaw drop	.69 (.31)	37.46 (12.22)	1.12 (.91)	45.54 (13.42)	2.45 (1.16)	21.23 (11.16)	1.91 (.87)	58.84* (18.41)
27. Head down	3.21 (1.72)	2.45 (1.1)	4.76 (2.32)	5.71 (1.24)	3.11 (1.55)	4.07 (2.02)	17.76* (3.45)	29.42* (11.36)
43. Eyes closed	2.31 (1.11)	3.17 (1.07)	2.91 (1.45)	2.87 (1.06)	3.01 (.66)	2.04 (.72)	2.86 (1.07)	9.86* (2.45)

FACS-instructed facial expressions were recognised significantly better than freely expressed emotions ($p < .01$; partial eta-squared = .49). No significant differences were reported for country of origin ($p = .77$; partial eta-squared = .01) and expressed emotion ($p = .41$; partial eta-squared = .03). Mean and standard deviation (%) certainty recognition categorisation for freely expressed photos can be seen in Table D1. A significant effect of Country of Origin ($p < .01$; partial eta-squared = .41), a significant effect of Type of Expression ($p < .01$; partial eta-squared = .78), and a significant interaction ($p < .01$; partial eta-squared = .47) were reported. Asterisks indicate significance for Bonferonni corrected differences in AU scores ($p \leq .001$).

Appendix E: Nonfacial Blurs

This section describes an additional pilot study that was implemented for testing whether there were subjective contrast differences between the presented faces and the nonfacial blurs and the masking stimulus (see Study Description).

Aims

Study 2 was designed to include a 116.67 milliseconds black and white pattern mask and 33.33 milliseconds nonfacial blurs as a signal detection control condition for cross-cultural faces (Bachmann & Francis, 2013). The aim of the current stage was to test if brief nonfacial blurs had different visual contrast with respect to the back and white pattern mask when compared with the facial stimuli (Gorea & Tyler, 1986).

Participants

Fifteen participants (eight females) who were not part of the other experimental stages volunteered to participate in the experiment. All participants reported normal or corrected-to-normal vision. Participants were subject to the same inclusion criteria and questionnaire assessment as Study 1: Stage 2. No participants were excluded. The mean age for this stage was 32.73 years ($SD = 7.37$). All participants gave informed consent to participate in the study. The experiment was approved by the local Ethics Committee of the School of Psychology.

Stimuli and Procedures

Due to ethics approval time restrictions, a total of 108 faces were presented during this stage. The presented faces were selected from Stage 2. Each presentation run was pseudorandomised in Python and assigned 54 faces per duration and emotional type, 36 faces per emotion (fearful, sad, and neutral), and 27 faces per nationality (Britain, New Zealand, Chile, and Singapore). Each actor identity was repeated three times during each run to attain an equal number of male and female faces ($n = 54$). One hundred and eight nonfacial blurs that were generated from black and white pattern stimuli, scrambled using pseudo-randomised pixel permutation and averaged for luminescence (SHINE, MATLAB Toolbox) were also presented. Participants were informed in writing prior to the experiment that a brief facial or nonfacial stimulus was going to be presented in each trial followed by a black and white pattern. Participants were asked to decide whether the stimulus and the pattern differed significantly in luminescence and rate this contrast from 1 (*not intense at all*) to 10 (*very intense*). Participants were asked to respond in the consent form whether they understood the instructions (yes or no). All participants responded positively.

The experimental trial started with a fixation cross for 3 seconds (±1 second). After the fixation cross, a single nonfacial blur or a single freely expressed or instructed face from Britain or New Zealand or Chile or Singapore showing a fearful or sad or neutral expression was presented at fixation for 33.33 milliseconds; order randomised. The target was immediately followed by a black and white pattern mask for 116.67 milliseconds. After the presentation of the black and white pattern mask, participants were shown a blank screen for 2 seconds. After the blank screen, participants were asked by an on-screen message "How would you rate your experience of subjective visual contrast during the presentation? (1: *not intense at all* to 10: *very intense*)". A 2-second blank screen interval was presented before the next trial.

Apparatus and Presentation Testing

The stimuli were presented in an HD Lenovo monitor adjusted at 60 Hz. The presentation was programmed in the coder and builder components of Psychopy version 1.85.3. Brief stimuli (33.33 milliseconds) were assessed using camera recoding and a Python developed dropped-frames script report. No instances of dropped frames were reported.

Analysis and Discussion

To test if the nonfacial blurs had significantly different ratings for subjective experience of contrast than the presented faces with respect to the pattern mask, a paired samples t test was run. Subjective experience of contrast for the nonfacial blurs ($M = 5.13$, $SD = .19$) was not rated significantly higher than contrast in the face condition—$M = 5.11$, $SD = .23$, $t(14) = .44$, $p = .66$; $d = .01$; $\beta = .03$—suggesting that differences of visual contrast between the nonfacial blurs and the presented faces, and the pattern mask would not artefactually impact signal detection performance (Bachmann & Francis, 2013) in subsequent experimental stages.

Appendix F: Original Study Design

This section refers to the first pilots for the current study.

The original study design (2016) included mimicked facial expressions (Gur et al., 2002), emotional stimuli presented for 66.67 milliseconds and participant assessment of subordinate facial characteristics, such as naturalness of expression and emotional intensity. These assessments were excluded from the current study due to study-duration restrictions. The raw data for these conditions are available on request from the primary author.

Appendix G

Distance Analysis: Overall CDQ Scores

This section presents the results of the Cultural Distance Analysis that suggests that differences between cultural groups were due to cultural differences for the CDQ questionnaire (see Table G1).

Table G1. CDQ Questionnaire.

					95% CI for difference	
(I) Country of origin	(J) Country of origin	Mean difference (I–J)	*SE*	Sig.	Lower bound	Upper bound
British actors	New Zealand actors	–3.240	.369	.000	–4.412	–2.068
	Chilean actors	.380	.254	1.000	–.427	1.187
	Singapore actors	–3.930	.313	.000	–4.922	–2.938
	British participants	–1.000	.372	.145	–2.180	.180
New Zealand actors	British actors	3.240	.369	.000	2.068	4.412
	Chilean actors	3.620	.413	.000	2.309	4.931
	Singapore actors	–.690	.293	.292	–1.618	.238
	British participants	2.240	.372	.000	1.060	3.420
Chilean actors	British actors	–.380	.254	1.000	–1.187	.427
	New Zealand actors	–3.620	.413	.000	–4.931	–2.309
	Singapore actors	–4.310	.367	.000	–5.475	–3.145
	British participants	–1.380	.284	.001	–2.282	–.478
Singapore actors	British actors	3.930	.313	.000	2.938	4.922
	New Zealand actors	.690	.293	.292	–.238	1.618
	Chilean actors	4.310	.367	.000	3.145	5.475
	British participants	2.930	.333	.000	1.874	3.986
British participants	British actors	1.000	.372	.145	–.180	2.180
	New Zealand actors	–2.240	.372	.000	–3.420	–1.060
	Chilean actors	1.380	.284	.001	.478	2.282
	Singapore actors	–2.930	.333	.000	–3.986	–1.874

Distance Analysis: Emotional Suppression Facet

This section presents the results of the Cultural Distance Analysis that suggests that differences between cultural groups were due to cultural differences for the ERQ questionnaire (see Table G2).

Table G2. ERQ Questionnaire.

					95% CI for difference[b]	
(I) Country of origin	(J) Country of origin	Mean difference (I–J)	*SE*	Sig.[b]	Lower bound	Upper bound
British actors	New Zealand actors	–3.278	1.762	.802	–8.955	2.399
	Chilean actors	.167	1.422	1.000	–4.415	4.748

(continued)

Table G2. Continued

(I) Country of origin	(J) Country of origin	Mean difference (I–J)	*SE*	Sig.[b]	95% CI for difference[b] Lower bound	Upper bound
	Singapore actors	–5.167*	1.094	.002	–8.693	–1.640
	British participants	.222	.945	1.000	–2.822	3.267
New Zealand actors	British actors	3.278	1.762	.802	–2.399	8.955
	Chilean actors	3.444	1.530	.379	–1.486	8.375
	Singapore actors	–1.889	1.590	1.000	–7.013	3.235
	British participants	3.500	1.344	.185	–.830	7.830
Chilean actors	British actors	–.167	1.422	1.000	–4.748	4.415
	New Zealand actors	–3.444	1.530	.379	–8.375	1.486
	Singapore actors	–5.333*	1.160	.003	–9.072	–1.594
	British participants	.056	1.277	1.000	–4.059	4.170
Singapore actors	British actors	5.167*	1.094	.002	1.640	8.693
	New Zealand actors	1.889	1.590	1.000	–3.235	7.013
	Chilean actors	5.333*	1.160	.003	1.594	9.072
	British participants	5.389*	1.029	.001	2.072	8.706
British participants	British actors	–.222	.945	1.000	–3.267	2.822
	New Zealand actors	–3.500	1.344	.185	–7.830	.830
	Chilean actors	–.056	1.277	1.000	–4.170	4.059
	Singapore actors	–5.389*	1.029	.001	–8.706	–2.072

Appendix H

Analysis of Subliminal Perception for Study 2 Using Previous Methods

This section describes how using frequentist (t test) analysis for biased measures of signal detection performance (hit rates) could lead to evidence for subliminal processing.

To test the hypothesis that cultural familiarity can be processed even in briefly presented and masked stimuli, we run a one-sample t test against absolute chance (50%) for recognition performance (hit rates) 33.33 milliseconds faces. Faces presented for 33.33 milliseconds ($M = 50.67\%$, $SD = 10.49\%$) were not significantly different to chance, $t(20) = .29$, $p = .77$; $d = .06$, although they did not report significance for chance level processing for signal detection theory measures—M (Di) = .66, SE (Di) = .02; M (De) = .59, SE (De) = .03; $B > 3$. An ANOVA was run for 33.33 milliseconds faces with independent variable Country of Origin (Britain, New Zealand, Chile, and Singapore) and dependent variable cultural ratings. The analysis was significant—$F(1.389, 27.74) = 91.17$, $p < .001$; partial eta-squared = .82; Greenhouse-Geisser corrected; $P_{(1-\beta)} = .99$—suggesting that there were significant differences between different cultures. Further Bonferonni corrected pairwise comparisons revealed that British faces were rated higher for familiarity ($M = 6.04$, $SD = .62$) than faces from New Zealand ($M = 4.88$, $SD = .31$; $p < .001$; $d = 2.37$), Chile ($M = 4.34$, $SD = .23$; $p < .001$; $d = 3.58$), and Singapore ($M = 4.01$, $SD = .4$; $p < .001$; $d = 3.89$). The results would initially suggest that cultural familiarity was processed subliminally.

Cultural Familiarity Ratings per Experimental Condition

This section shows summary statistics for each condition during the final experimental stage.

	Mean				*SD*			
	Britain	New Zealand	Chile	Singapore	Britain	New Zealand	Chile	Singapore
Freely expressed								
Fear	5.61	4.81	5.04	3.86	.65	.45	.39	.71
Sadness	5.66	4.81	4.93	3.9	.54	.52	.63	.55
Neutral	5.36	4.89	4.83	3.59	.8	.57	.47	.66
Instructed								
Fear	6.5	4.78	5	3.79	.85	.58	.52	.73
Sadness	6.22	4.75	4.86	3.74	.92	.74	.61	.67
Neutral	6.54	4.84	4.79	3.57	.92	.34	.64	.97

Note. Mean and standard deviation for each condition during Study 2.

Appendix I: The assessment of Subliminality

This section makes reference to issues pertaining to subliminal processing that might require further clarification for the off-topic reader.

Previous research has suggested that facial characteristics such as emotion, racial background (Eberhardt et al., 2004; Smith, Dijksterhuis & Chaiken, 2008), attractiveness (Hung, Nieh & Hsieh, 2016), and sexual cues can be processed automatically and without conscious awareness. These characteristics are suggested to elicit automatic processing because they confer evolutionary important survival and sociobiological value. Subsequent research (Pessoa & Adolphs, 2010; Lähteenmäki, Hyönä, Koivisto & Nummenmaa, 2015; Pessoa, 2017) has suggested that the application of unbiased signal detection theory measures for the assessment of detection and recognition performance (Zhang & Mueller, 2005), Bayesian analysis of chance-level significance (Dienes, 2015), and separate analysis for hits and misses for detection and recognition responses (Pessoa, 2005) should be implemented to assess these effects. In the current study, we used this paradigm for the assessment of subliminality.

Appendix J: Sensitivity Index A Adapted for Multiple Forced Choice Comparisons

This section shows the adaptation of the A metric. The first adaptation can be used in any programming based platform. The second adaptation is presented for excel users.

$$\frac{\sum_{i=1}^{n} xi(\text{hits} + .001)}{\sum_{i=1}^{n} xi\left(\frac{\text{miss} + .001}{(\text{fixed choices} - 1)}\right)} = x, \text{if } x > 1 \Rightarrow \text{A} = \left(.5 - \left(\frac{.5}{x}\right)\right) + .5; \text{if } x < 1 > .5 \Rightarrow$$

$$\text{A} = (.5 - (.5 \text{ x } x) - .5; \text{ if x } < .5 \Rightarrow y = (.5 + x),$$

$$\text{A} = (.5\text{–}(.5\text{x}y))\text{–}.5)$$

$$= \text{IF}(\text{AND}(\text{AN3} <= 0.5, \text{AO3} >= 0.5), 3/4 + (\text{AO3} - \text{AN3})/4\text{AN3} * (1\text{AO3}),$$
$$\times \text{IF}(\text{AND}(\text{AN3} <= \text{AO3}, \text{AO3} < 0.5), 3/4 + (\text{AO3} - \text{AN3})/4 - \text{AN3}/(4 * \text{AO3}),$$
$$\times \text{IF}(\text{AND}(\text{AN3} > 0.5, \text{AO3} > \text{AN3}), 3/4$$
$$+ (\text{AO3} - \text{AN3})/4\text{–}(1 - \text{AO3})/(4 * (1 - \text{AN3})), 0)))$$

Appendix K: Further Possible Limitations of the Current Study

This section includes further considerations and laminations for the current design.

Time allowances in the current design enabled us to assess and control for in-group culturation and acculturation, and personal outgroup contact but not for social media cross-cultural familiarity (Elfenbein & Ambady, 2003). It is possible that the participants responded with a cross-cultural bias due to more limited social media exposure to Singaporean faces as opposed to faces from New Zealand and Chile. Conversely, the participants' life choices for culturation could confer partial generalisation to individuals with increased cross-cultural experience. Finally, the current study included three freely expressed and FACS-instructed emotional expressions for a total of 1 hour of masked presentation. The aim of reducing the type and range of the emotional expressions and for presenting masked stimuli for a prolonged period of time was to present sufficient stimuli repetitions to achieve the necessary power ($P_{(1-\beta)} \geq .8$) to conduct an analysis by condition (hits and misses). This approach could have progressively depleted the required cognitive reserve for cross-cultural emotional recognition and future research could benefit from arranging multiple and smaller in length sections to explore additional emotional types.