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 has been interpreted to suggest that survival and social communication related visual cues can elicit physiological changes without awareness to enable us to instantly respond to our environment. Previous studies that tested this hypothesis using skin conductance have reported some evidence for physiological changes in response to masked emotional faces. In the current paper, we argue that this evidence is subject to possible methodological confounds. These include the use of a universal masked presentation threshold (e.g. 16.67 ms), the employment of possibly biased criteria such hit rates to measure meta-awareness and the assertion of overall guess-level target detection using non-significance. In the current report, we attempt to 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 hit rates and signal detection theory measures. We assess detection performance using a strict Bayesian criterion for guess-level target meta-awareness. Our findings reveal that hit rate 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 unbiased 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 to 83.33 ms) emotional stimuli (van der Ploeg et al., 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 et al., 2015).

The theoretical foundation for this unconscious processing stems from what psychologists term the biological preparedness model (Mineka & Öhman, 2002; LeDoux, 2003). 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., 2006) 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 et al., 1994a; 1994b; Morris et al., 1998; Lapate et al, 2014) employed skin conductance recordings (SCR) to assess the effect because SCR is a measure of sympathetic autonomic nervous system arousal (Carlson, 2014) that can record physiological responses that are not under conscious regulation (Öhman,

2005) - such as fight or flight responses (Flykt et al., 2007) - and is also relatively impenetrable to parasympathetic nervous system arousal artefacts (Cacioppo et al., 2007).

For example, Williams and colleagues (2006) reported a significance trend (p = .08) for higher SCR in response to backwards masked fearful faces compared to neutral faces when presented for 16.67 ms but several follow-up studies failed to replicate this trend (Nielsen & Kaszniak, 2006; Codispoti et al., 2009). In more recent studies, Najstrom and Jansson (2007) reported that police officers (Mann et al., 2004; Correll et al., 2006; McCasslin et al., 2006) experience higher SCR in response to backwards masked threatening pictures for 6 ms compared to neutral pictures for 6 ms and Lapate and colleagues (2014) also reported significant findings for higher SCR and decreased liking ratings for subsequently presented neutral targets (see also Winkielman et al., 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 et al., 2015; p. 2-5). The most important possible confound in previous research is the employment of a universal threshold for masked stimuli presentation (Pessoa et al., 2005a; 2005b). Previous studies presented masked stimuli for 6.25 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 et al, 2005a; 2005b) differences in the ability to detect masked stimuli. For example, the happy face superiority effect (Calvo & Lundqvist, 2008; p. 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 and 33.33 ms - and *underachievers* - that could not discriminate the presence of a masked fearful face even at 67 ms (Pessoa et al., 2005a; 2005b; 2017). 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 et al., 2005a; 2005b). 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 hit rates (Brooks et al, 2012) and almost unanimously asserted using non-significance to chance-level detection performance (Dienes, 2015).

The possible limitation with using hit rates is quite straight-forward (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 hit rates 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 (false alarms) responses (Stanislaw & Todorov, 1999) for the assessment of detection and discrimination tasks (Pessoa et al., 2005a; 2005b).

The issue with non-significance is that - irrespectively of using hit rates 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 hit rate 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 non-significant 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 non-sensical 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, 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 pre-experimentally adjusted for subjective differences in the detection threshold (Pessoa et al., 2005a; 2005b) using hit rate and non-parametric 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 pre-experimentally defined thresholds for masked stimuli presentation and explored if masked angry, fearful, happy and neutral faces can elicit changes in physiology using skin conductance recording.

Methods

Participants

Twenty-five (fourteen female) 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 on-line 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 post-experimentally to contact several of the participants to acquire ethnic backwards 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 and colleagues (2002). A total of one-hundred photos per emotional category (angry, fearful, happy and neutral) were resized to a standard 1024x768 resolution, converted to greyscale 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 greyscale, 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 pre-Selection

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 one second preceded by a fixation cross for three seconds. Pretarget baseline and maximum deferral skin conductance (1-3 seconds) 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 six seconds to choose what emotion the presented face was expressing. They made this response using their keyboard, choosing from an on-screen list – angry (a), fearful (f), happy (h), surprised (s), neutral (n), or other (o). Subsequently, they were asked to rate from one (not at all) to ten (extremely) the ambiguity and intensity of the presented faces. The order of stimuli was randomised and participants were allowed six seconds to perform each task. An inter-trial blank screen period of eight seconds was used to allow skin conductance responses to return to baseline.

We ran two different stages of stimuli pre-selection. 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 et al., 2010). These were not included because the stimuli number that produced a statistically significant emotional type recognition effect (n = 14) during the first stimuli pre-selection stage was smaller than the required number of stimuli (n = 30). We chose from the available subset the thirty angry, fearful and happy stimuli that reported the highest scores in a self-developed percentage based metric (I.F. (%): Impact Factor) that took under equal consideration (50%) reports for stimuli ambiguity and intensity, and maximum deferral skin conductance arousal (Appendix 1.1):

$$\text{I.F. }(\%) = \left(\frac{(10 - \text{Amb}^{1}.) + (\text{Int.}^{2})}{2}\right) * \ 50) + \left(\left(\frac{\text{SCR Maximum Deferral}^{3}}{\text{Max }\{\text{SCR Maximum Deferral for Stimuli Type}^{4}\}}\right) * 50\right)$$

The final stimuli set comprised of 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 dataset (Gur et al., 2002) did not contain ethnic and cultural origin labels. The selected stimuli were therefore, post-experimentally assessed using Noldus, Face Reader 6.1 (Noldus, 2017). The facial set comprised of 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 (Tsikandilakis et al., 2018; in preparation).

[1] Amb: Ambiguity using a one (not at all) to ten (extremely) scale. This item is reversed (10 - x).
[2] Int: Intensity using a one (not at all) to ten (extremely) scale.
[3] SCR Maximum Deferral: Highest unambiguous increase of a phasic skin conductance response one to three second post stimulus with respect to pretarget baseline for the specific stimuli.
[4] Max {SCR Maximum Deferral for Stimuli Type}: The score for the stimuli with the highest unambiguous increase in phasic skin conductance response one to three second post stimulus with respect to pretarget baseline for the specific emotional stimuli category (angry, fearful or happy).

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 five-volt 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 5000 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 et al., 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 et al., 2013). We used the higher end of recommended specification for recording skin conductance (EDA channel sample rate: 2 Khz; acquisition rate: 2000 samples/per-second; gain: x1000).

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 1-3 seconds 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; p. 1027-29). Non-responders were included in the analysis.

Stage One: 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) seconds 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 backwards masking to a 108.33 ms neutral face. Twenty emotional faces for each duration, eighty pattern blur trials and fifteen neutral masks showing actors who were not part of the masked stimuli subset were presented in total. All stimuli were presented in randomised 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 seven days before and at the exact same time of day as stage two.

Stage One: Data Processing

The individual per stimulus type detection threshold was calculated separately using hit rates (percentage of true positives) and non-parametric signal detection theory (Zhang & Mueller, 2005). For each participant, the duration of presentation (8.33 or 16.67 or 25ms) that produced the smallest negative or positive overall detection performance difference to chance per stimulus type was imported separately for hit rates and signal detection theory measures to the main experiment (i.e. the duration for which the value of [0.5. - $P_{threshold}$] 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 Two: 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 fifteen-minute sessions with a five-minute interval break. In one of the sessions, participants watched masked emotional stimuli that were adjusted using hit rates 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 randomised.

In both sessions, we presented a fixation cross for 3 (± 1) seconds 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 backwards masking to a 108.33 ms neutral face (Figure 1). Five novel stimuli per emotional category and twenty pattern-blur trials were presented in total.

Fifteen neutral masks were presented in total showing actors who were not part of the masked stimuli subset for either neutral or emotional masked faces for stage one or two of the experimental process. All stimuli were presented in randomised 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 eight seconds blank interval screen was presented to allow physiology to return to baseline.

Figure 1: Example of Stimuli Sequence with Fearful Masked Target

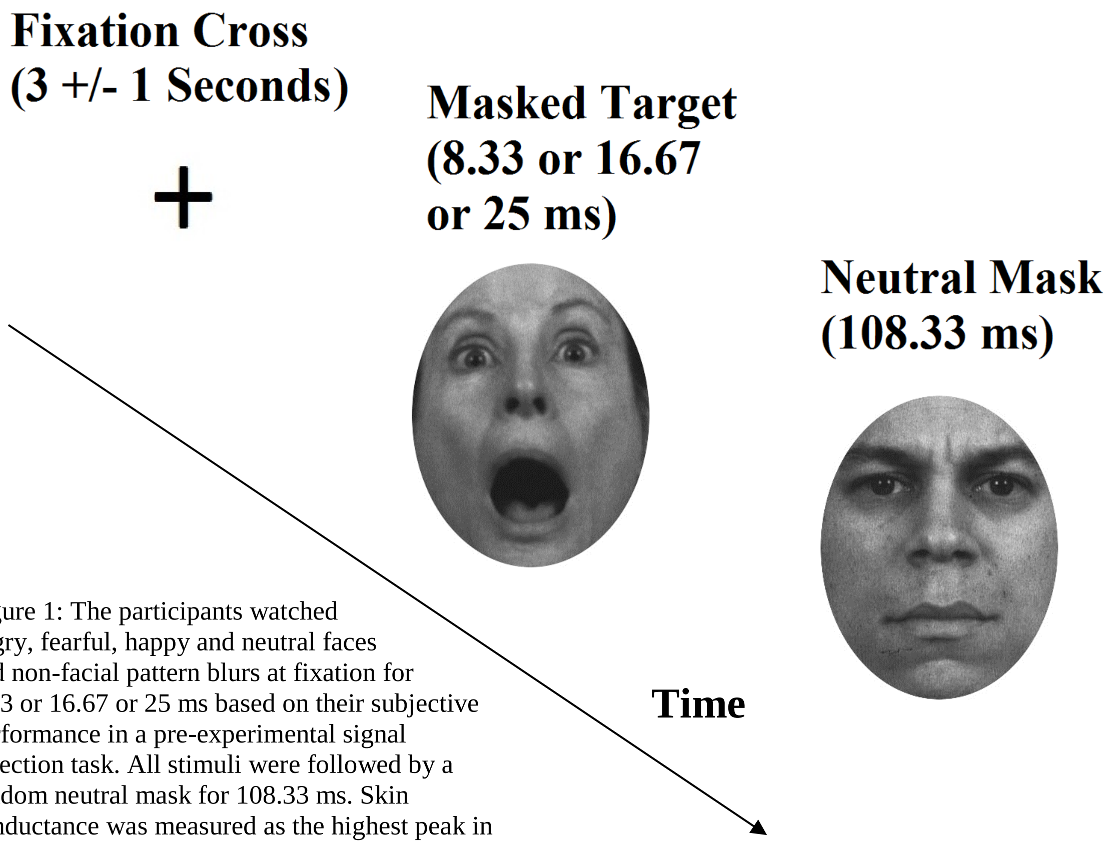

Figure 1: The participants watched angry, fearful, happy and neutral faces and non-facial pattern blurs at fixation for 8.33 or 16.67 or 25 ms based on their subjective performance in a pre-experimental signal detection task. All stimuli were followed by a random neutral mask for 108.33 ms. Skin conductance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

Results

Stage One: Hit Rate Thresholds

To explore if masked faces using hit rates 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 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. = 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; SE = (SE x $(1 + \frac{20}{df x df})$) (Berry, 1996) was run using the Dienes calculator (2014; 2015). We set the higher and lower bounds for chance-level hit rate performance to a conservative -.5 (45%) and .5 (55%) criterion with 0 representing absolute chance-level performance. Overall hit rate performance (S.E. = .37; B = .2) was significantly at-chance. The same effect was reported for fearful faces (S.E. = .79; B = .23), happy faces (S.E. = .89; B = .23), neutral faces (S.E. = .8; B = .26) but not angry faces (S.E. = 1; B = .43) suggesting that the latter was the only type that was insensitive to both competing hypothesis (Figure 2; Individual Thresholds in Appendix 2.1).

Figure 2: Overall, per threshold and per Stimulus Type Detection Performance for Hit Rates

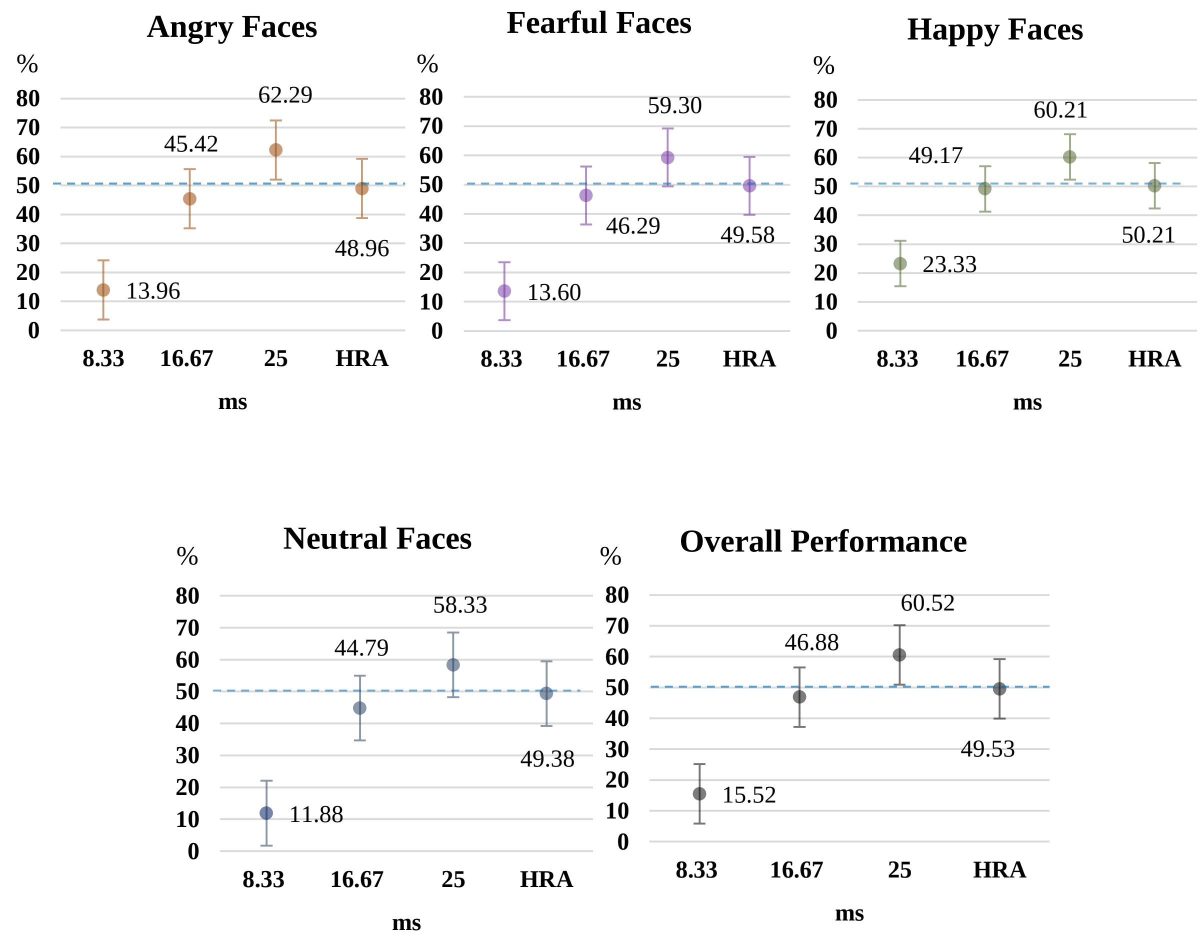

Figure 2: Overall and per stimulus type hit rate percentage performance for 8.33, 16.67, 25 ms and hit rate adjusted faces (HRA). Midline indicates chance-level performance. Error bars for each score indicate Standard Error of the mean.

Stage One: 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, S.D. = .037) were not significantly different to chance (t (23) = .49; p = .63). The same effect was reported for angry (M = .494, S.D. = .062; t (23) = .55; p = .59), fearful (M = .494, S.D. = .061; t (23) = .53; p = .6), happy (M = .514, S.D. = .042; t (23) = 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 ($df < 30$; $SE = (SE \times (1 + \frac{20}{df x df}))$) (Berry, 1996) was run using the Dienes calculator (2014; 2015). 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 (S.E. = .008; B = .22) was significantly at-chance. Fearful faces (S.E. = .013; B = .37) and angry faces (S.E. = .013; B = .38) showed trends for at-chance level processing and happy faces (S.E. = .009; B = .73), and neutral faces (S.E. = .013; B = .64) were insensitive to both competing hypothesis (Figure 3; Individual Thresholds in Appendix 2.2).

Figure 3: Signal Detection Theory Performance per Emotion and for Adjusted Faces

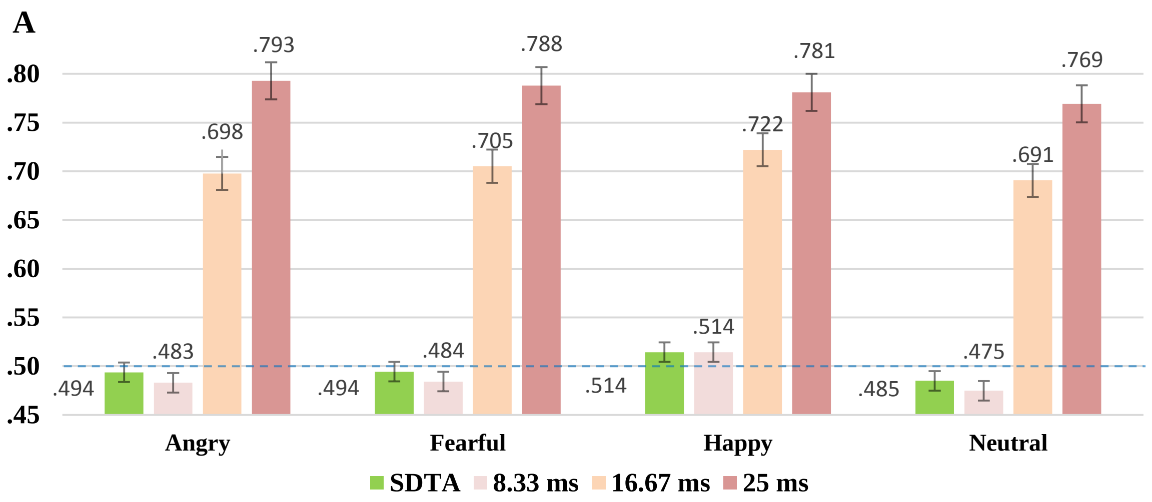

Figure 3: Participant threshold for each masked emotional stimulus for the signal detection theory session in stage two. SDTA refers to faces adjusted using signal detection theory (A) for the duration of masked stimuli presentation.

Stage Two: 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. A main 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 (see also Appendix 3.1).

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 hit rate 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 hit rate and signal detection theory adjusted faces were overall significantly at-chance. Hit rate 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 hit rates. 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 pre-technological (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). A number of 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, in the current report we addressed a number of possible confounds in previous research including subjective differences in the detection threshold (Pessoa et al., 2005a; 2005b) 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 (Figure 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 hit rates and signal detection theory.

As Erdelyi (2004) posits unconscious or masked or implicit or subliminal processing (Dehaene et al., 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 hit rates 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 et al., 2005a; 2005b). 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 et al., 2005a) 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 a number of additional limitations that should be further addressed (Tsikandilakis, Chapman & Peirce, 2017; in print). A basic limitation of the current design is that we need to factor time as a possible variable in signal detection (Erdelyi, 2004). Pre-experimentally 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 et al., 2005a; 2005b) 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 behavioural 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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Appendix

1.1:

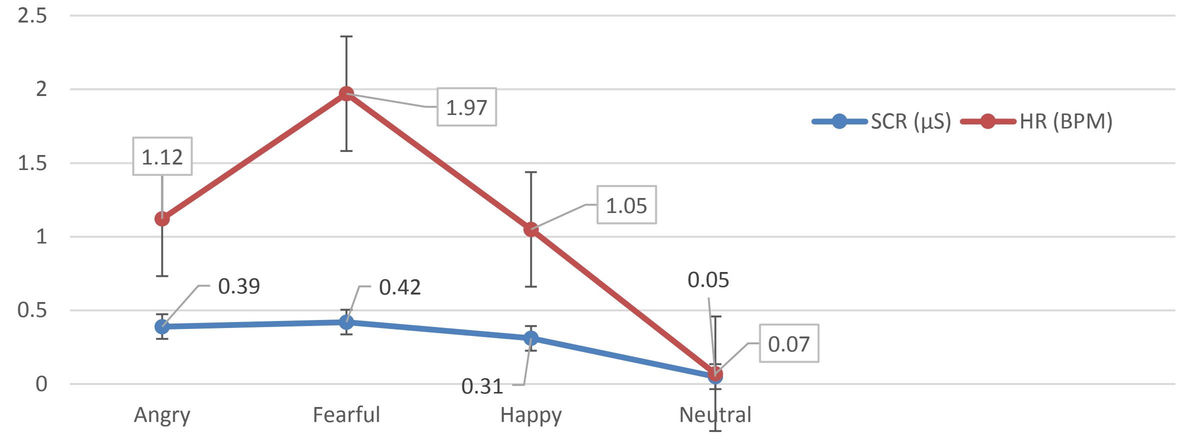
Angry (M: 87.82, S.D.: 1.97), fearful (M: 87.91, S.D.: 1.92) and happy (M: 86.61, S.D.: 1.97) that were included in the final selection were not significantly different (F = 1.41, p = .19) in I.F. (%) scores.

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 ($p < .01$; $\eta^2 = .67$).

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

[5] 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.



2.1:

Thresholds Hit Rates

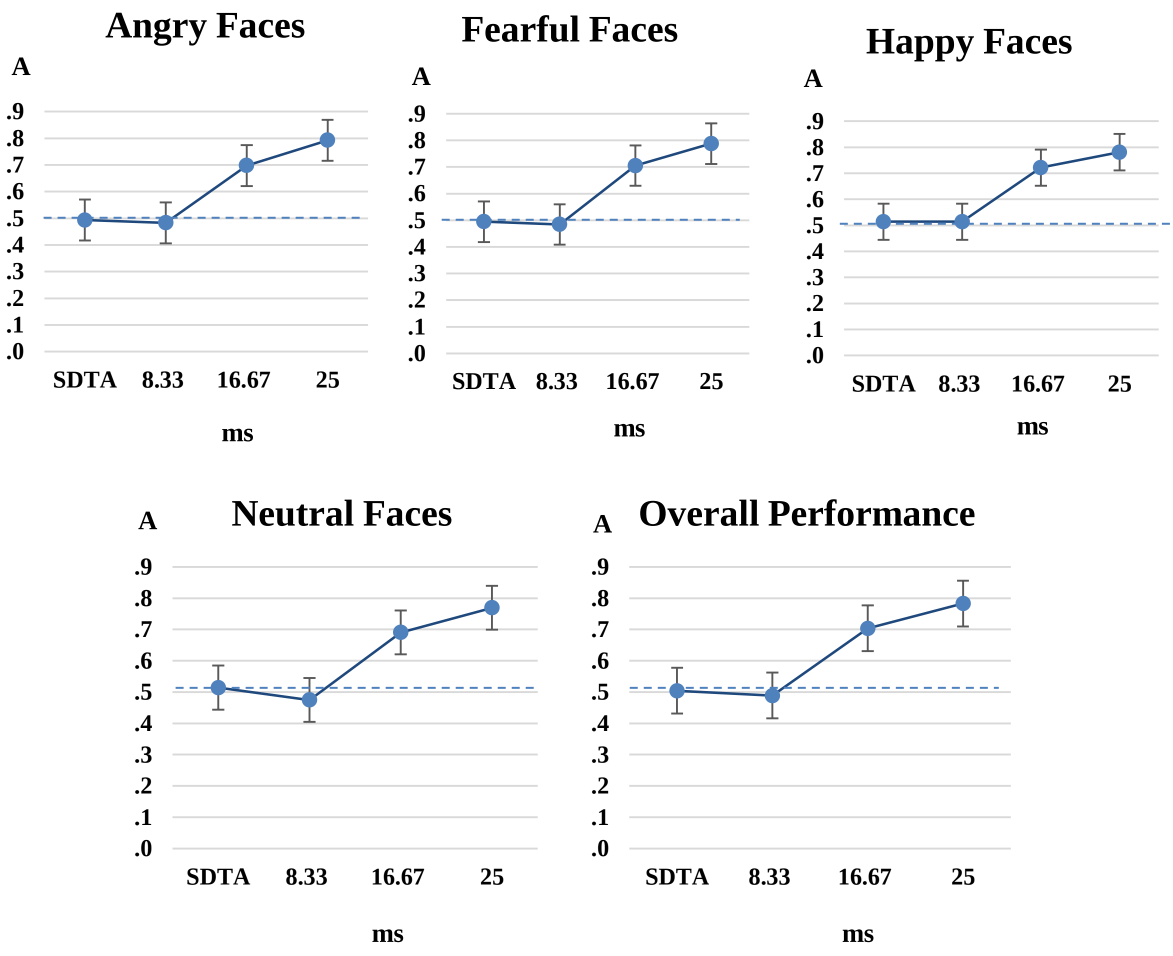
Column1	Angry	Column 2	Fearful	Column 5	Happy	Column 8	Neutral	Column 11
	HR Threshold	Performance	HR Threshold	Performance	HR Threshold	Performance	HR Threshold	Performance
1	16	45	16	50	16	55	25	50
2	16	45	16	45	16	50	25	50
3	16	50	16	50	16	50	16	45
4	16	40	16	45	16	55	16	55
5	16	45	16	50	16	50	16	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

24	25	50	25	50	25	55	16	50

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

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).



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

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.

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	-.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

Based on estimated marginal means

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

b. Adjustment for multiple comparisons: Bonferroni.