Individual Conscious and Unconscious Perception of Emotion: Theory, Methodology and Applications

Tsikandilakis, Myron[1, 2]

Bali, Persefoni[1]

Yu, Zhaoliang[3]

Madan, Christopher[1]

Derrfuss, Jan[1]

Chapman, Peter[1]

Groeger, John[4]

[1] School of Psychology, University of Nottingham

[2] Medical School, Faculty of Medicine and Health Sciences, University of Nottingham

[3] Department of Psychology, National University of Singapore

[4] School of Social Sciences, Nottingham Trent University

Address for correspondence:
Dr Myron Tsikandilakis
School of Psychology,
School of Medicine,
Faculty of Medical and
Health Sciences
University of Nottingham
tsikandilakismyron@gmail.com

Key words: individuality; consciousness; unconsciousness; perception

Word Count: 6,076

Abstract

In this manuscript we review a seminal debate related to subliminality and concerning the relationship of consciousness, unconsciousness, and perception. We present the methodological implementations that contemporary psychology introduced to explore this relationship, such as the application of unbiased self-report metrics and Bayesian analyses for assessing detection and discrimination. We present evidence concerning an unaddressed issue, namely, that different participants and stimulus types require different thresholds for subliminal presentation. We proceed to a step-by-step experimental illustration of a method involving individual thresholds for the presentation of masked emotional faces. We show that individual thresholds provide Bayesian evidence for null responses to the presented faces. Conversely, we show in the same database that when applying established but biased non-individual criteria for subliminality physiological changes occur and relate – correctly, and most importantly incorrectly – to perception concerning the emotional type, and the valence and intensity of a presented masked emotional face.

Introduction:

A Formative Theoretical Debate

An important component for understanding why subliminality is so widely contested in contemporary psychological science is its lineage to older, formative debates (Phillips & Block, 2016). One important, very often undeservedly understated and – more than often – even forgotten such debate relates to the definition of the relation of consciousness, unconsciousness, and perception (Dixon, 1971, 1981; Merikle. 1983, 1984; Holender, 1986; Merikle & Cheesman, 1987). One of the academic protagonists of this debate was Norman Dixon (see Armstrong, 1981). In his early (1971) and his subsequent works (1981), Dixon was a supporter of the notion of unconscious processing. He was also 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 subliminality.

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 controversy with regards the method – and even the feasibility – of their experimental implementation (see Merikle, 1983).

Dixon's argument led to a series of published correspondences between authors supporting, contesting and even struggling with his propositions (Marcel 1983a, 1983b;

Merikle 1983, 1984; Henley, 1984; Holender, 1986). The response to Dixon’s thesis of subliminal perception was simple and straightforward: perception implies the involvement of conscious awareness unless a model that distinguishes perception from consciousness can be provided and defended (Marcel, 1983b). In response, Dixon (1981) revised the term subliminal perception to preconscious processing and, although the debate was not uncontestably resolved, and conflicting publications from both sides continued as normal (Nolan & Caramazza, 1982; Zimba & Blake, 1983; Underwood, Rusted & Thwaites, 1983; Groeger, 1984; see also Kouider & Dupoux, 2004), a less provocative hypothesis 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; see also James, 1877; Lange 1885; Sidis, 1983/1898) in the sense that it proposed that the cognitive faculties that underlie the experience of consciousness and the conscious perception of a stimulus – to which the former outcome – are distinct phenomena. This point was also supported by Marcel (1983b) who proposed that, outside the area of semantic processing, the conscious experience of emotion and the conscious 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 that it is influenced by whether there is need for action or reflection in response to an elicitor. Marcel (1983b) also suggested that conscious perception is an epiphenomenon of – or in simpler terms, depends on – the ability or necessity to distinguish a condition or elicitor to which an emotional experience could be associated with.

Marcel’s seminal thesis would later develop to what Dehaene, Changeux, Naccache, Sackur and Sergent (2006) and Bargh and Morsella (2008) termed preconscious processing in contemporary psychological research. In this context this signifies that the automatic processing of cues 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. This phenomenon is suggested to relate to meta-cognition (Fleming & Lau, 2014). It signifies an ability to recognize one's own psychological processes, such as the physiological, emotional and cognitive processes and experiences, that take place after an encounter with an elicitor or the presentation of an experimental trial (Tsikandilakis & Chapman, 2018; Tsikandilakis, Chapman & Peirce, 2018).

The reformation of subliminal perception to preconscious processing signified progress. Holender (1986) suggested that this approach – possibly correctly (Armstrong, 1981) – compartmentalised the underlying mechanisms of consciousness and the more selective and narrow process of consciously perceiving a condition or elicitor (see also Baars, 1997a). Nevertheless, this theoretical reconceptualization did not offer a remedy as regards the methodological canon for the assessment of unconsciousness (Baumeister, Vohs & Funder, 2007). It conceptually progressed but it did not methodologically reform the empirical exploration of the unconscious (see for example, Shevrin & Dickman,1980; Dixon & Henley, 1980; Dixon, 1981).

Methodology:

Contemporary Psychological Responses

Mathematical psychology would eventually rise to this challenge (see Shiffrin & Schneider, 1977; 1984). As early as 1964, Pollack and Norman had provided a method for assessing the reliability of self-reports in psychological research. However, 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 for assessing detection and discrimination (Pessoa, Japee, Sturman & Ungerleider, 2005). Many psychologists would be familiar with this method today as signal detection theory and/or receiver operating characteristics (ROC) analysis (Macmillan & Creelman, 2004). This approach was used to provide a reliable metric for assessing self-reports relating to the detection or discrimination of a stimulus. The basic principle of this approach involved – but was not restricted to (see for example, Steiner & Cairney, 2007) – that, given a binary task for detecting or discriminating a stimulus, a participant could provide a set type of responses. These responses were hits and misses. Hits were most commonly conceptualized as responding that a presented stimulus was presented in a post-trial engagement task, while misses were most commonly conceptualized as responding that a presented stimulus was not presented in a post-trial engagement task (Green & Swets, 1966, 1974; Swets, 2014). Hits and misses could be further considered, respectively, in terms of true positives (TP), responding that a presented a stimulus was presented, true negatives (TN), reporting that a stimulus that was not presented was not presented, false positives (FP), reporting that a stimulus that was not presented was presented, and false negatives (FN), reporting that a stimulus that was presented was not presented in a post-trial engagement task (Schwenke & Schering, 2007).

By combining these response types in a single signal to noise ratio metric – e.g., Sensitivity = TP/(TP + FN) = 1 - False Negative Rate (FNR) (for a comprehensive review see Krupinski, 2017) – self-report errors, liberal and conservative biases and criteria, and response strategies (Stanislaw & Todorov, 1999) could be reliably overcome (Tuzlukov, 2013). Additionally, influential for perception underlying physiological and cognitive processes that previously biased perceptual processes could become transparent (Dixon, 1981), assessed (Pessoa et al., 2005) and explored (see Tsikandilakis, Bali, Derrfuss & Chapman, 2020a). The application of receiver operating characteristics metrics provided a reliable index that could be applied for exploring whether detection or discrimination performance were at-chance (e.g., d’ = 0; A = .5), meaning in this context that a stimulus was presented subliminally (Erdelyi, 2004; p. 79; but see also Yonelinas, 1994).

Additionally, to these advancements, the current group (Tsikandilakis et al., 2019; Tsikandilakis, Bali, Derrfuss & Chapman, 2020a; 2020b) provided a discrimination variation of this method. For a non-binary multiple-choice task, subliminality was defined as A = 1 divided by n when n equals the number of types of stimuli. In this manner if, for example, six types of stimuli were presented and the participants were asked post-trial to select from a list of six stimulus types which type was presented during the trial, chance-level performance was conceptualized as 1/(n (6)) = 16.67% or A = .167. This, in simpler terms, signified what participants would be expected to reply if they replied by chance given the available options for discrimination (see Tsikandilakis, Bali, Derrfuss & Chapman, 2019; Tsikandilakis, Bali, Derrfuss & Chapman, 2020a), or to put it more elegantly "like a blind person would reply" given the available options for discrimination (Erdelyi, 2004; p. 79).

The implementation of unbiased self-report metrics for perception was a successful experimental and methodological step (Pessoa et al., 2005). Another challenge that this debate raised was of a statistical nature. Mathematical psychology had achieved the provision of a potentially reliable metric for self-reports for assessing with an objective criterion (Erdelyi, 2004) subliminality, but the statistical process which was applied for this inference was of debatable validity (Dienes, 2016). Most of the relevant research in this area employed a one-sample t-test methodology for inferring unconscious presentation (Brooks et al., 2012).

According to this statistical approach the reported detection or discrimination performance during an experiment is compared to absolute chance (e.g., d' = 0; A = .5). In case of non-significant findings, the researchers would claim that the reported detection or discrimination performance was not significantly different to chance and, therefore, that this was evidence for unconscious processing. The problem with this approach was that not significantly different to chance – lack of evidence for the alternate hypothesis – was interpreted as evidence for the null (see Dienes, 2014).

This hurdle could be readily addressed using Bayesian inference (Dienes, 2016). We have previously elaborated this approach and provided simple steps for its implementation for the interested reader using a practical illustration in real data in another publication

(Tsikandilakis, Bali, Derrfuss & Chapman, 2019; pp. 5-9). Briefly, in the current context, Bayesian inference can be used to apply a two-tailed credible intervals analysis, between a higher (e.g., A = .55) and a lower (e.g., A = .45) bound using a ± 2 standard errors of the mean assessment of equivalence of significance testing between absolute chance and the reported participant detection or discrimination performance. This analysis can be implemented with or without a-priori effect size predictions (see Dienes, 2019; see also Tendeiro & Kiers, 2019)[1]. Bayesian inference can be used to provide a calculation for a Bayes factor that would indicate whether detection or discrimination performance is outside the credible intervals and provided evidence for the alternate hypothesis ($B > 3$), whether the data were inconclusive and the analysis provided evidence for being insensitive to both hypotheses ($.33 < B < 3$), or whether the analysis provided evidence for the null ($B < .33$); meaning that detection or discrimination performance were within a-priori criteria for subliminality (see Dienes, 2016, Dienes, 2019).

Individual Consciousness and Unconsciousness

The history and the contemporary methodological advancements, that endeavoured to provide a solid methodological foundation for the experimental exploration of consciousness, unconsciousness and perception, have important pedagogical value. This value is particularly significant for our younger colleagues who found the area of subliminal or unconscious or implicit processing at the prime of its popularity in the early 21st century without possibly being aware of the formative origins of the contemporary methodological canon (see also Tsikandilakis, Bali, Derrfuss & Chapman, 2019). Nevertheless, these theoretical and methodological advancements did not address an important issue that relates to consciousness,

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[1] Here it must be noted that an adaptation of the traditional Pearson and Neymar model for p-value significance has been proposed to resolve this issue (see Sandberg, Timmermans, Overgaard, & Cleeremans. 2010; Overgaard, 2015). This adaptation suggests the use of two one-tailed t-tests that would test detection or discrimination performance for being respectively not above and not below chance-level. Given evidence for non-significance for both tests, the argument can be made that detection or discrimination performance were at chance (see also Overgaard, 2017). Therefore, contemporary psychologists have suggested that Bayesian inference is – arguably (Rescorla, 2015; Wagenmakers et al., 2017) – not the only reliable statistical method for the assessment of subliminality (see Timmermans & Cleeremans, 2015).

unconsciousness and perception. Namely, previous research (see Brooks et al., 2012) had repeatedly reported findings for per participant and stimulus type differences in signal detection performance (see Pessoa, Medina, Hof & Desfilis, 2019). In simpler terms, previous research suggested that to achieve subliminality, such as making a stimulus imperceptible, one should address differences in perceptibility between different participants and different stimuli. These differences were suggested to occur due to several factors. These include individual differences in cognitive and attentional resources between participants (Pessoa, Padmala & Morland, 2005; see also Donges, Kersting & Suslow, 2012). These include higher perceptual sensitivity to elicitors with evolutionary important sociobiological and survival value, such as faces showing basic universal emotions (Ekman & Keltner, 1997) and predatory threat (Öhman, 2009). These also include higher perceptibility due to variability in the intensity of the mask (neutral face) to masked (emotional face) facial-emotional mismatch (Maxwell & Davidson, 2004; Kim et al., 2010; see also Figure 1). These finally have been shown to include that, even outside the area of facial-emotional processing, uniquely human cultural products, such as language, could operate outside conscious awareness (see Dehaene et al., 2006). Nevertheless, violations of the coherence of meaning during semantic processes require significantly less time to break through visual suppression compared to coherent sentences particularly when the former include negative content (see particularly Sklar et al., 2012).

As an illustration of the aforementioned concepts, Pessoa and colleagues (2005) presented fearful faces for 33 and 67 ms with backward masking to neutral faces for 83 or 117 ms (order randomised) to thirty-seven participants. They showed that a subset of overachievers ($n = 8$) were able to reliably detect fearful faces when presented for 33 ms ($A' \geq .69$). Conversely, another subset of participants ($n = 5$) performed worse than chance level at detecting fearful faces even when these were presented for 67 ms ($A' \leq .5$). In an equally seminal study, Lähteenmäki, Hyönä, Koivisto and Nummenmaa (2015) presented evidence for per stimulus type differences in signal detection performance. They presented participants (n = 34) with images of pleasant and unpleasant animals, such as puppies and kittens, and snakes and spiders, and other elicitors, such as sweets and fruits, and rotten food and human organs. The images were presented for 10, 40 and 80 ms (order randomised). These stimuli were backward masked with 250 ms scrambled patterns. The researchers showed that unpleasant stimuli were detected above chance level even when presented for 10 ms (*d*’ = .77) and progressively increased in signal detection performance for 40 ms (*d*’ = .89) and 80 ms (*d*’ = .91). They replicated their experimental design using happy and fearful faces (Lähteenmäki et al., 2015; pp. 8-10). They showed that participants performed close to chance for detecting fearful and happy faces presented for 10 ms but that fearful faces presented for 40 ms (*d*’ = .81) and 80 ms (*d*’ = .85) were consciously perceived.

These findings have been repeatedly replicated in several studies and different areas (see Maxwell & Davidson, 2004; Wiens, 2006; Rolls, 2008; Sklar et al., 2012; Svard, Wiens & Fischer, 2012; Zhang, Wang, Luo & Luo, 2012; Axelrod, Bar & Rees, 2015; Khalid. & Ansorge, 2017). Our lab has also replicated these findings in several previous designs and publications (Tsikandilakis & Chapman, 2018; Tsikandilakis, Chapman & Pierce, 2018; Tsikandilakis, Bali, Chapman, 2019; Tsikandilakis et al., 2019; Tsikandilakis, Bali, Derrfuss & Chapman, 2019; Tsikandilakis et al., 2020; Tsikandilakis et al., 2021a; 2021b; see Figure 1; see also Appendix 1a & 1b). To address the important issue that different individuals and stimulus types require different signal strengths for the duration of their presentation for accomplishing subliminality, we introduced, in our experimental designs, a stage during which we calculated the durations of presentation that provided Bayesian evidence (Dienes, 2014) for unbiased (Zhang & Mueller, 2005) chance-level performance (Erdelyi, 2004) in response to masked cues. This implementation was applied individually for each participant (Pessoa et al., 2005) and each presented stimulus type (Lähteenmäki et al., 2015). We used the output from this stage to adjust the durations of presentation for masked cues during a subsequent stage to explore responses to masked emotional faces (see Figure 1; see also Tsikandilakis, Bali, Derrfuss & Chapman, 2020a; pp. 5-9).

Figure 1: ROC performance (A) to Different Presentation Durations for Masked Faces

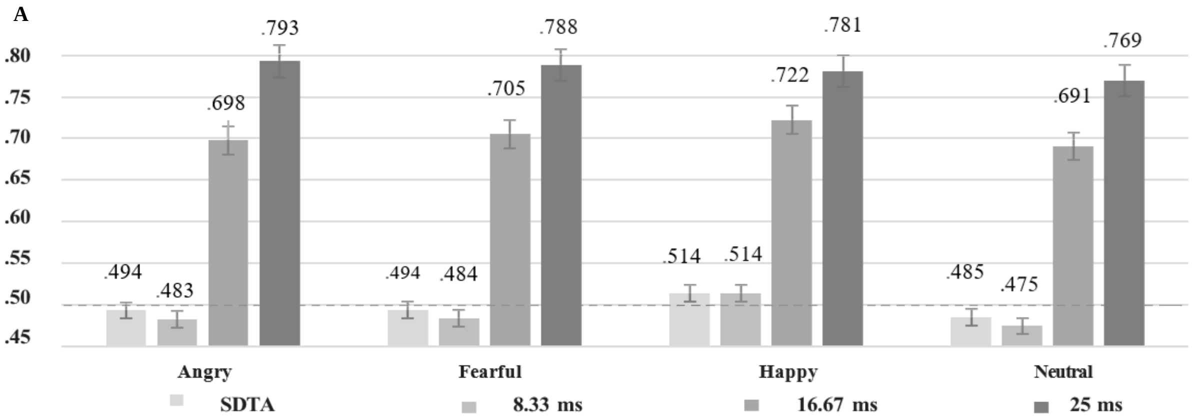

Fig.1: Adapted from Tsikandilakis and Chapman (2018; p. 440; see also Appendix 1a & 1b). Signal detection theory performance (A) per emotional face type (angry, fearful, happy, neutral) and presentation duration (8.33, 16,67 and 25 ms) for backward masked faces using a neutral face mask (108.33 ms). SDTA (Signal Detection Theory Adjusted) refers to adjusted presentation durations using Bayesian analyses and signal detection theory criteria (A) for chance-level performance. The adjustments were made per participant and stimulus type for the duration of masked stimuli presentation. The dashed line (A = .5) indicates chance-level performance. Bars indicate ± 2 standard errors from the mean

Applications:

An Illustration of Unconsciousness

In this manuscript we provide a manual for replicating this method. We provide a step-by-step experimental illustration of this method. We do so because by assembling the aforementioned methodological developments and introducing individual thresholds for unconscious presentation it deviates significantly from the experimental canon in relevant research (see van den Ploeg et al., 2017). We also undertake this illustration because of the potentially important and unexpected outcomes relating to its implementation. Our first application of this method took place in a study conducted in 2017 (see https://osf.io/3v4uh/). This previously unpublished study was the foundation for the majority of our subsequent work (see for example, Tsikandilakis, Chapman & Peirce, 2018)[2]. In this study, we recruited 43 (24 female) participants ($P_{(1-\beta)} = .91$; Faul, Erdfelder, Buchner & Lang, 2009). The age of the participants ranged from 19 to 57 years (*M* = 34.23; *SD* = 8.38). In this first attempt to incorporate contemporary developments for the study of subliminality in a design that involved individually adjusted thresholds for unconscious processing, we presented in an initial stage single masked emotional faces (fearful, angry, happy, sad, neutral and non-facial blurs) at fixation for varying durations (see Figure 2).

Figure 2: First Experimental Stage

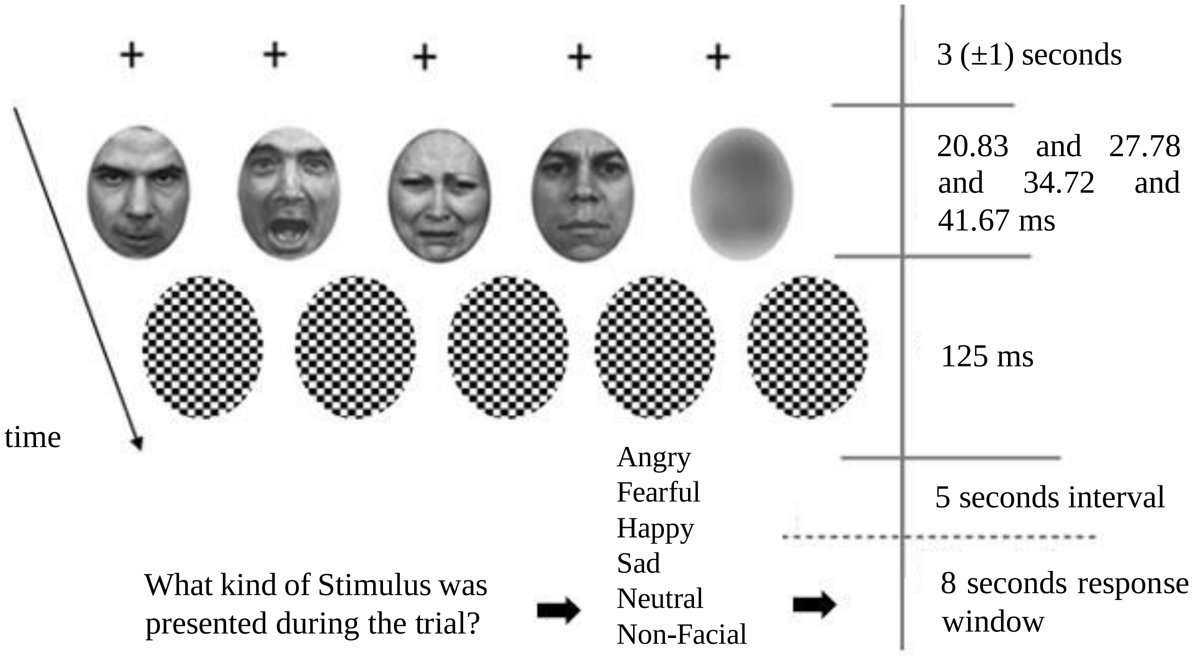

Fig. 2: An example of emotional faces and pattern masked presented in the first experimental stage with durations of presentation in the left of the screen. The angry, fearful, happy, sad and neutral faces were presented at fixation one at a time (see Tsikandilakis, Bali, Derrfuss & Chapman, 2020a). Happy faces are not included in the current figure. Participants were instructed to respond to the engagement task. The engagement task was presented on-screen after an interval of five seconds post-stimulus offset. It required the participants to select, using their keyboard, from a list which emotion was presented during the preceding trial (e.g., "Please press A for Angry, F for Fearful, H for Happy). The order of the presentation of the emotional list was randomised in each trial. Engagement tasks have been used before to ensure participant attendance (Tsikandilakis, Bali, Derrfuss & Chapman, 2019), but in the current design the engagement task was used also to measure signal discrimination performance in response to backward masked stimuli. A simplified illustration of the post-trial engagement task for this experimental stage can be seen in the lower middle section of the figure.

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[2] All efforts were made for the statistical output in this section to be in the same format as the related previously published studies of our group (Tsikandilakis & Chapman, 2018; Tsikandilakis, Chapman & Peirce, 2018; Tsikandilakis, Bali, Derrfuss & Chapman, 2019; Tsikandilakis et al., 2019; Tsikandilakis, Bali & Chapman, 2019; Tsikandilakis, Bali, Derrfuss & Chapman, 2020a, 2020b; Tsikandilakis, Bali, Haralabopoulos, Derrfuss & Chapman, 2020; Tsikandilakis et al., 2021).

Subsequently, we used a manual Python function (see https://osf.io/3v4uh/) to select the durations of presentation for each participant for each stimulus type that provided Bayesian evidence for chance-level discrimination performance using unbiased (Pessoa et al., 2005) non-parametric receiver operating characteristics (Zhang & Mueller, 2005). Since six types of stimuli were presented in this design, a Bayesian analysis with lower bounds set at A = .117 and higher bounds ser at A = .217, and absolute chance set at A = .167 (Dienes, 2014) confirmed that discrimination performance using this method was proximate to chance for each individual, for each type of emotional face (*M* = .164; *SD* = .019; *SE* = .003; *B* = .06; see Figure 3). In a subsequent stage, a week after, we explored whether the presentation of emotional faces using receiver operating characteristics individual adjustments that provided Bayesian evidence for chance-level discrimination performance can lead to physiological response differences, such as skin conductance (SCR) and heart rate (HR) responses, and emotional-perceptual differences between different emotional faces as illustrated in Figure 3 (see Appendix 2).

Figure 3: Second Experimental Stage

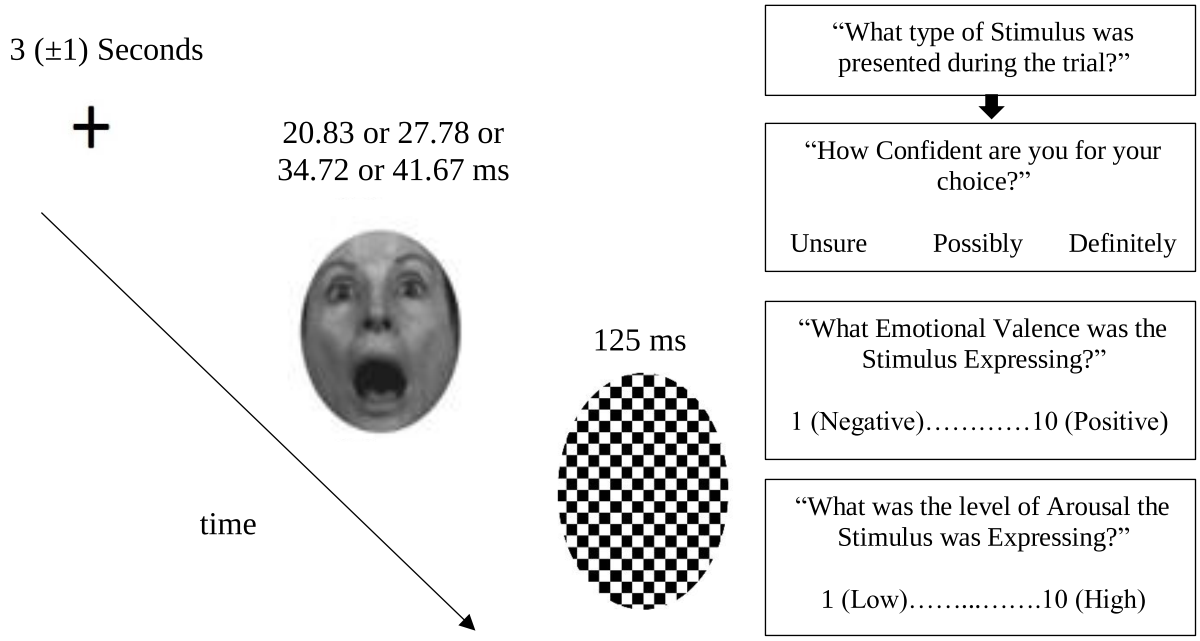

Fig.3: Participants watched masked stimuli for adjusted durations (20.83 or 27.78 or 34.72 or 41.67 ms). The stimuli were backward masked with a black and white pattern (125 ms). SCR and HR responses, and emotional-perception responses were measured (see Tsikandilakis, Bali, Derrfuss & Chapman, 2020a).

Our analysis did not provide evidence for significant differences between different emotional faces for skin-conductance (F (4, 168) = 1.21; p = .31; η^2_p = .03; B = .17) and heart-rate responses (F (4, 168) = 1.92; p =.11; η^2_p = .04; B = .21). Differences between emotional faces were also not found for ratings for valence (F (4, 168) = 1.38; p = .24; η^2_p = .03; B = .14) and arousal (F (4, 168) = .63; p = .64; η^2_p = .02; B = .15). These outcomes suggested that, using signal detection theory criteria, masked faces were not associated with significant differences and provided Bayesian evidence for null responses for physiological changes and emotional-perceptual ratings (see Appendix 3).

An Illustration of Conscious Perception, Part I: False Positives for Subliminality

This outcome made the case that "if a participant performed like a blind person would for perceiving an emotional stimulus" (Erdelyi, 2004; p. 79) – meaning by replying at-chance or *guessing* what stimulus was presented – there were proximate to null differences between different stimuli and baseline physiological responses and perceptual-emotional ratings for the presented emotional faces. This finding although, it could – arguably (Baars, 1997a; 1997b) –

be a sufficient refutation of subliminal perception for certain researchers (see for example, Holender, 1986), did not, firstly, beyond any reasonable doubt provide evidence that these outcomes were not due to non-responder effects, such as due to participants who do not physiologically respond to emotional faces (see particularly, van der Ploeg et al., 2017), and, secondly, it did not illustrate how such a plethora of previous studies were able to report subliminal effects (Brooks et al., 2012).

To explore these issues, we implemented a second condition in our design. This condition was intentionally biased. In this condition the durations of presentation that provided Bayesian evidence for chance-level performance were per participant and stimulus type selected using hit-rates; instead of receiver operating characteristics (see Stanislaw & Todorov, 1999)[3]. These stimuli were presented in a separate session (order randomised) during the second experimental stage without any other change in the design (see Figure 3). A Bayesian analysis with the same parameters as the ROC condition confirmed that discrimination performance using hit rates (*M* = 16.42%; *SD* = 5.77%; *SE* = .98%; *B* = .12; see Figure 4) was proximate to chance and did not differ in Bayesian factor (*B*) values from the receiver operating characteristics condition (*SE* = 5.05; *B* = .15; see Figure 4).

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[3] Stanislaw & Todorov (1999) suggested that hit-rates – as opposed to receiver operating characteristics (see Macmillan & Creelman, 2004) - are subject to biases. These included conservative response strategy biases, such as replying that a face was presented only when the participant was certain beyond a shadow of a doubt that a face was part of the experimental trial, and liberal strategy response biases, such as replying that a face was presented even when the participant was quite unsure whether a face was part of the experimental trial (see also Krupinski, 2017).

Figure 4: Discrimination Performance for ROC and Hit-Rate Adjustments

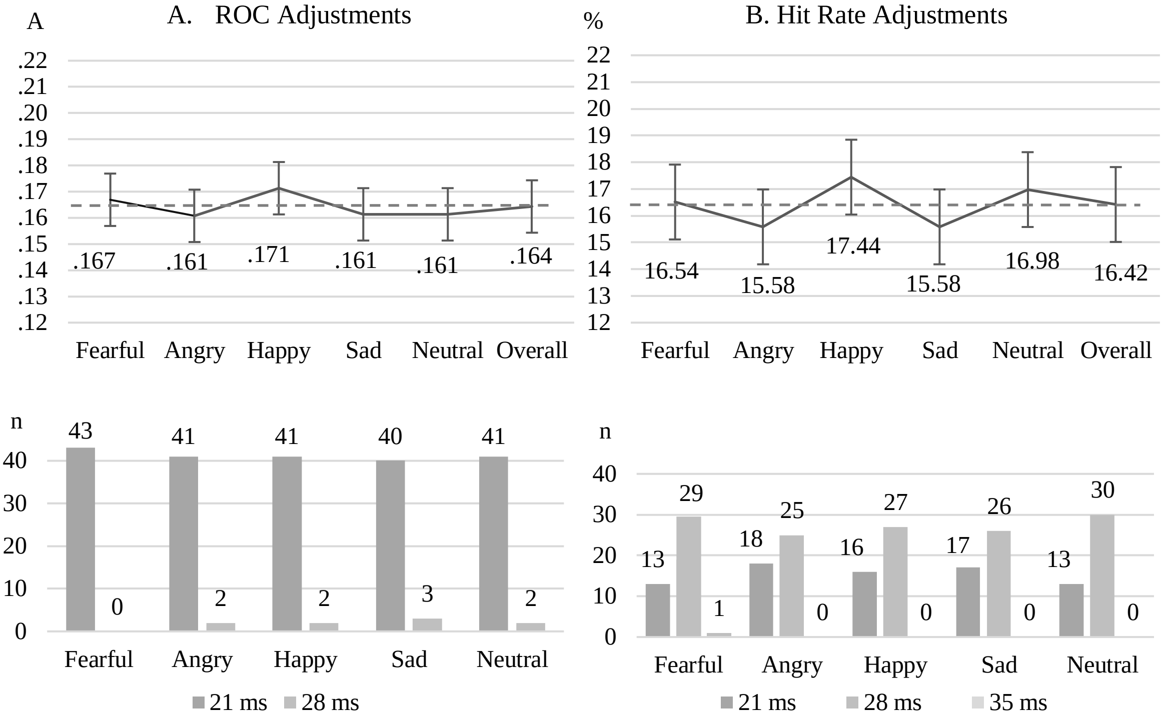

Fig. 4: Discrimination performance for ROC (A.) and hit-rate adjustments (B.) and participant count (n). Mid-line indicates chance-level performance. The bars show proximity to Bayesian evidence for the null (B < .33; see Dienes, 2019).

The results of this implementation were different. Significant differences in SCR changes were found between different emotional faces for adjustments using hit-rates (*F* (2.81, 118.2) = 588.05; $p < .001$; $\eta^2_p = .93$; Huynh-Feldt corrected; *SE* = .001; $B = +\infty$). A similar effect (*F* (3.12, 131.21) = 208.61; $p < .001$; $\eta^2_p = .83$; Greenhouse-Geisser corrected; *SE* = .008; $B = +\infty$) was revealed for heart-rate responses (see Figure 5).

Figure 5: Physiological Responses for ROC and Hit-Rate Adjustments

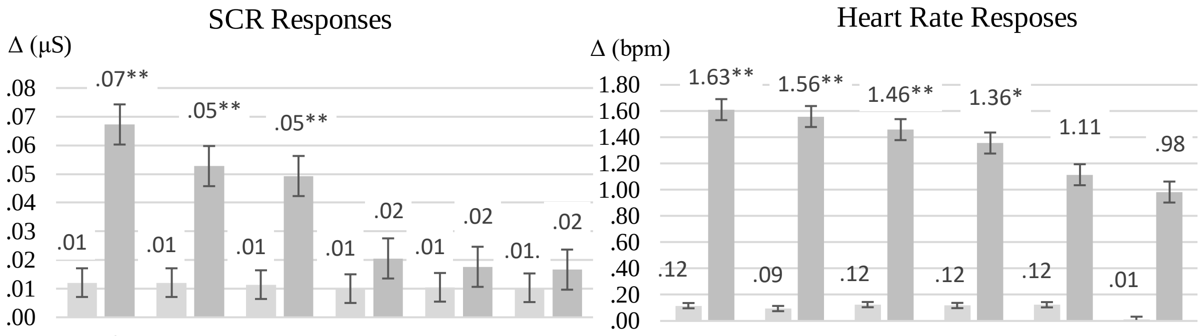

Fig. 5.: Skin-conductance and heart-rate changes for ROC and hit-rate adjustments. * indicates significance at the < .01 level. ** indicates significance at < .001 level. Bars indicate ±2 standard errors from the mean.

The effect for adjustments using hit rates was significant both for hits (*F* (2.69, 113.08) = 1035.99, $p < .001$; $\eta^2_p = .96$; Huynh-Feldt corrected) and misses (*F* (1.61, 67.55) = 57.95, $p < .001$; $\eta^2_p = .58$; Huynh-Feldt corrected) for discrimination for SCR. For heart-rate changes, responses for hits (*F* (3.44, 144.53) = 269.77, $p < .001$; $\eta^2_p = .87$; Greenhouse-Geisser corrected) and misses (*F* (2.77, 116.35) = 36.91, $p < .001$; $\eta^2_p = .47$; 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 for valence, overall ratings (*F* (3, 126) = 403.29, $p < .001$; $\eta^2_p = .91$; Greenhouse-Geisser corrected) and ratings for hits (*F* (2.99, 125.48) = 361.36, $p < .001$; $\eta^2_p = .89$; Greenhouse-Geisser corrected) and misses (*F* (4, 168) = 65.56, $p < .001$; $\eta^2_p = .61$; 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, $p < .001$; $\eta^2_p = .9$; Greenhouse- Geisser corrected), hits (*F* (4, 168) = 409.96, $p < .001$; $\eta^2_p = .91$) and misses (*F* (4, 168) = 362.91, $p < .001$; $\eta^2_p = .89$) for arousal, with fearful, angry and happy faces being rated higher than other stimulus types (see Table 1). These results showed that conscious awareness was involved and related to the experience of physiological responses.

Table 1: Hits and Misses Analyses 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)	2.49 (.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. 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. Asterisk (*) indicates significance at p < .01. Double Asterisk (**) indicates significance at p < .001; for full pairwise comparisons and effect size calculations, see also https://osf.io/3v4uh/.

An Illustration of *Conscious* Perception, Part II: False Positives for Conscious Awareness

This finding was not the key contribution of the current method and in a way forced us to divert from the initial hypotheses and rationale of the research project. The key contribution of the current study came from an exploratory objective. In this design, we wanted to exploratively assess whether emotional misclassification can include 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 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; $p < .01$; $\eta^2_p = .31$; Greenhouse-Geisser corrected) with further Bonferroni corrected pairwise comparisons revealed that misclassified fearful faces were higher for SCR scores ($M = .0471$, $SD = .0121$) than angry ($M = .0272$, $SD = .0103$, $p < .01$; $d = 1.59$), happy ($M = .025$, $SD = .0112$, $p < .01$; $d = 1.71$), sad ($M = .0253$, $SD = .0125$, $p < .01$;

d = 1.59) and neutral faces (M = .0251, SD = .0149, $p < .01$; d = 1.46)[4]. A similar pattern was reported for heart rate responses (F (4, 152) = 5.61; $p < .01$; η^2_p = .13) with false positives for fearful faces (M = 2, SD = .61) inducing higher responses than false positives for angry (M = 1.49; SD = .49, $p < .01$; d = .92), sad (M = 1.45, SD = .72, p = .01; d = .82) and neutral faces (M = 1.46, SD = .67, p = .01; d = .84). These results suggested that, after removing the cross-misclassification between arousing emotional types, participants experienced false positives for fearful faces as more arousing compared to other stimulus types.

Discussion:

Looking Back and *Going Forward* with Backward Masking

Along the lines of these findings, we should mention that scholars of the nature of consciousness, from Hegel (2012/1807) and Sidis (1983/1898) to Dixon (1981), Marcel (1983a, 1983b), Holender (1986), and Merikle and Chessman (1987) collectively agreed on a single but not necessarily simple principle (see Bargh & Morsella, 2008): When the perception of a cue reaches or exceeds a certain signal strength, the perception of a cue becomes accessible by conscious awareness (Dehaene et al., 2006). This approach has prompted the understanding of perception and awareness in contemporary psychology as interactive processes and not separate mechanisms. These interactive processes are suggested to contribute to the experience of consciousness (Pessoa & Adolphs, 2010). The applications we presented above for the individualized presentation of emotion can add to these that this effect can include emotional self-assessment (Marcel, 1983a, 1983b). Our outcomes suggest that physiological and emotional self-assessment can influence perception as radically as to result in the projection of the experience of emotion to the perception of an elicitor even if the latter was not presented and, therefore, could not have been perceived (see also Pessoa et al., 2005).

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[4] Means and standard deviation are presented including four decimal points in the analyses to allow for the replication of the exact Cohen's d effect size values included in the statistical outcomes.

The formative contribution of our method was that we showed that the misclassification of masked physiologically innocuous stimuli involved and related to corresponding increases in physiological responses (Adolphs, Tranel, Damasio & Damasio, 1995). Previous research has been able to provide evidence for misclassification between different types of arousing-emotional stimuli (e.g., angry, happy, fearful and surprised faces) when participants experienced post-trial physiological arousal (see for example, Pessoa et al., 2005; Critchley et al., 2005). In the current design, we showed the first instance for the misclassification of sad, neutral and pattern blur stimuli as fearful during the experience of physiological arousal. To phrase our argument as clearly as possible, firstly, we showed that truly subliminal faces do not lead to physiological and perceptual response differences, and, secondly, we showed that physiological changes can elicit the impression of emotion even in the absence of an emotional elicitor when using biased methods for subliminality.

These findings are radically different to the established canon for subliminality (Brooks et al., 2012; van der Ploeg et al., 2017). Contemporary subliminal models suggest that we can experience physiological changes when we respond with false negatives for the perception of an emotional elicitor (Lapate, Rokers, Li & Davidson, 2014; Lapate et al., 2016; Siegel, Wormwood, Quigley & Barrett, 2018). We showed the inverse effect. We showed that emotional-perceptual acuity is involved in post-trial self-reports when a participant experiences physiological changes in response to masked emotional elicitors. We found that we can experience false positives for the perception of an emotional elicitor when we experience post-trial physiological changes. Finally, the most interesting finding we reported was that under biased – but canonical and established – conditions of backward masking this effect can occur in response to physiologically innocuous stimuli and the absence of an emotional elicitor. These findings signify not only that individual adjustments could stand as a refutation to the contemporary method for implementing subliminality but that – to put our argument more provocatively – our own fascination with subliminal outcomes could have prohibited a deeper understanding of the underlying interactions that contribute to the relationship of consciousness and perception (See Figure 6).

Figure 6: Interactions and Considerations for Further Research

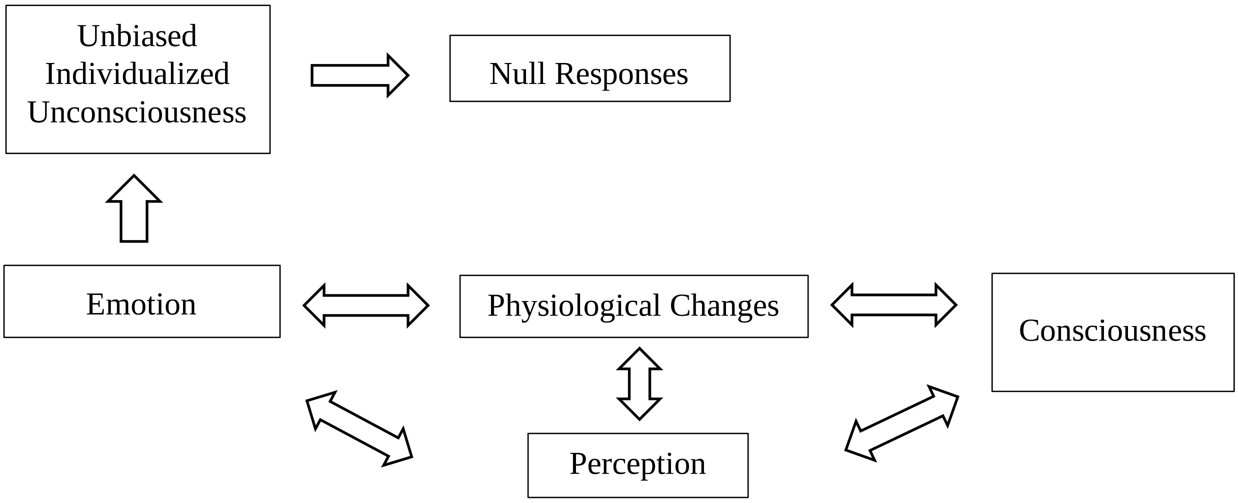

Figure 6: An illustration of the multitude of possible interactions between consciousness, perception and physiological arousal. The exploration of the interaction of the plethora of these processes could be the next most contributing end to which we could apply masking in contemporary psychological research,

Conclusions

In the current manuscript we re-explored a formative historical disagreement relating to the definition of subliminality and concerning the relation and assessment of consciousness, unconsciousness, and perception. We explored this debate for its educational and pedagogical value and also because it allowed us to illustrate part of the scientific precedence that led to several contemporary methodological advancements, such as ROC metrics for self-reports for whether a stimulus was presented and Bayesian analysis for subliminality. These advancements contributed to the contemporary paradigm for exploring subliminal processing. We provided an illustration that when these contemporary advancements are applied for the individual definition of unconsciousness for the processing of masked emotional faces, participants did not respond with physiological changes and perceptual appraisals. When participants were presented with masked emotional faces using biased criteria for subliminality, physiological changes could result to emotional perception. This effect included the misclassification of physiologically innocuous stimuli, such as sad and neutral faces, and pattern blurs, as stimuli that are related with physiological arousal such as fearful faces. Based on these outcomes we contribute to the scholarly exploration of the interaction between consciousness, unconsciousness and perception that the implementation of individualized thresholds for subliminality provides evidence for null responses to the presented elicitors, and that the apprehension of post-trial physiological changes relates to and can even create the impression of the perception of emotion.

Acknowledgements

The first author would like to thank Brooks and colleagues (2012) and van der Ploeg and colleagues (2017) for providing comprehensive meta-analyses in the area of subliminal processing that were invaluable contributions to the current work. The current work was supported by the Economic and Social Research Council in the University of Nottingham. The raw data and the experimental code for the experimental illustration section of this manuscript have been made open access at https://osf.io/3v4uh/

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Appendix

Appendix 1a: Figure 1, ROC Performance for Different Durations

In the experiment relating to Figure 1 participants (n = 25) were presented with brief emotional faces and asked to decide how many faces were presented after each trial. During this experiment, 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. The results in Figure 1 show their performance at 8.33, 16.67, 25 ms and for Signal Detection Theory Adjusted (SDTA) durations. The latter durations varied per participant and stimulus type to bring detection performance within Bayesian credible intervals (Lower Bound: .45 and Higher Bound .55) that provided evidence (B < .33) for the null hypothesis that faces were presented at chance (A = .5).

Appendix 1b: Figure 1, Hit Rate Performance for Different Durations

Below we present the performance of the same participants in a different stage of the experiment (Tsikandilakis & Chapman, 2018) when assessed using hit-rates and hit-rate adjusted for chance- level performance durations. instead of receiver operating characteristics (adapted from Tsikandilakis & Chapman, 2018; p. 439):

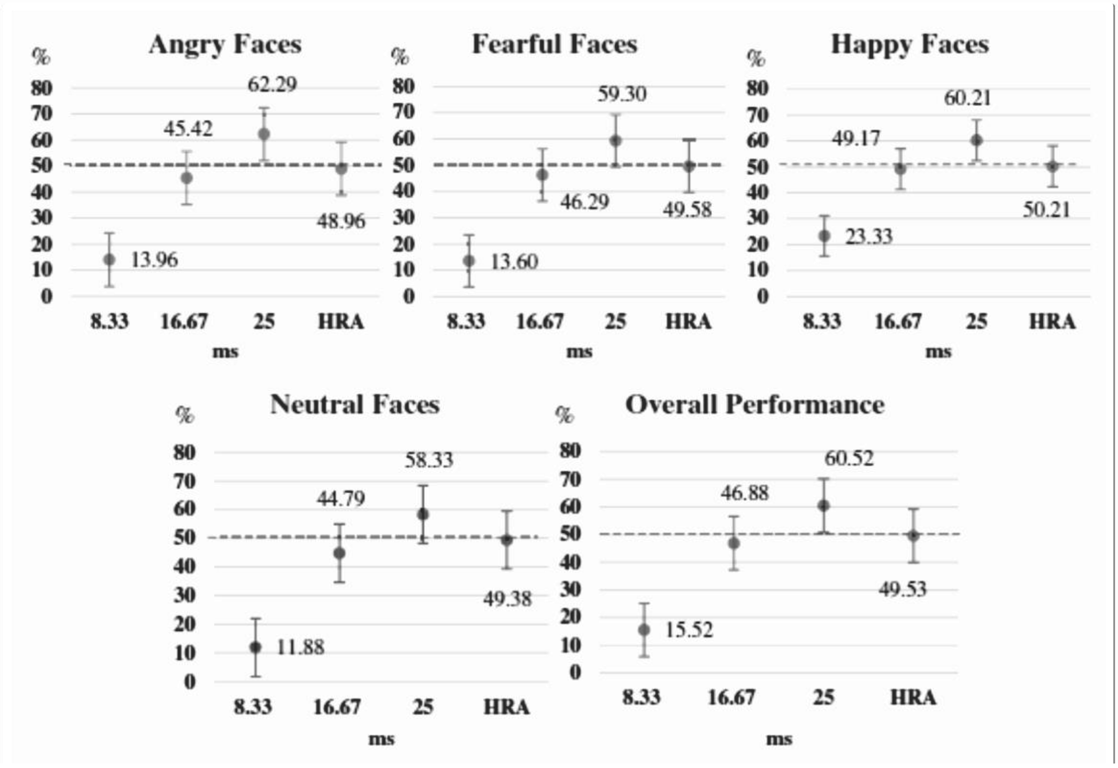

Fig. 7: Overall, per threshold and per stimulus type detection performance for hit rates. Overall and per stimulus type hit rate percentage performance for 8.33, 16.67, 25 ms and hit rate adjusted faces (HRA). Midline indicates chance-level performance. Error bars for each score indicate Standard Error of the mean.

Appendix 2: Experimental Design

In the first experimental stage each participant was presented at fixation with a single angry, fearful, happy, sad or neutral face, or a non-facial pattern blur. The stimuli were presented for discrimination-threshold-related durations (20.83 and 27.78 and 34.72 and 41.67 ms) with backward masking to a black and white pattern for 125 ms. Twelve angry, fearful, happy, sad and neutral faces were presented for each duration. Forty-eight pattern blurs were presented for each duration. After the presentation, the participants were asked whether they could recognize what kind of stimulus was presented during the trial. We used these durations to present participants with masked faces and assess SCR and HR responses. A week later the same participants were invited in the same laboratory space. The participants took part in two fifteen-minute experimental sessions separated by a five-minute break; session order was randomised. In both sessions participants were presented with an angry or fearful or happy or sad or neutral face, or a non-facial blur; no actor identity was repeated between stages. In one session, the faces were presented for hit-rate adjusted durations and in the other session they were presented for ROC adjusted durations (see in-text Figure 1). In both sessions, faces were backward masked with a black and white pattern mask presented for 125 ms. Ten different angry, sad, fearful, happy, neutral faces and a total of fifty different non-facial blur patterns were presented in each session with order randomised.

Appendix 3: Physiological Assessment

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. 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 infrared photoplethysmography 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. 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. 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. 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. Non-responders for physiological changes were also included in the data analysis ($n = 3$).