The Unconscious Mind: from Classical Theoretical Controversy to Controversial Contemporary Research and a practical illustration of the "Error of our Ways"

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Abstract

In this manuscript, the authors present an overview of the history, an account of the theoretical and methodological controversy, and an illustration of contemporary and revised methods for the exploration of unconscious processing. Initially we discuss historical approaches relating to unconsciousness that are, arguably, defamed and considered extraneous to contemporary psychological research. We support that awareness of the history of the current subject is pedagogically essential to understand the transition to empirical research and the reasons for which the current area is still so contentious among contemporary psychologists. We proceed to explore the current experimental canon. Contemporary theoretical and methodological issues relating to unconscious processing are discussed in detail and key issues and key advancements in contemporary research are presented. Developments that have, in recent years, being suggested to contribute to a possibly reliable method for the assessment of unconscious processing are practically - methodologically and statistically – illustrated using easy-to-follow steps applied in real experimental data. Mindful of our own place in the long history of this topic, we conclude the manuscript with suggestions concerning the future of the current area.

Key words: unconscious, emotion, methodology, error

The History of the Unconscious and its Significance

Like psychology itself (Ebbinghaus, 1908), the study of the unconscious has a long past, but a short history. The unconscious already appears in Plato's Socratic dialogues (Devereux, 2016). Plato describes how Socrates, after successfully demonstrating to Meno that one of his uneducated servants was knowledgeable of the Pythagorean theorem, advocated that we possess untaught, unaware and innate knowledge (*anamnesis*) that could originate from inborn and pre-corporeal experiences of the human soul (Cornelli, 2019). Similar arguments for a transcendental unconscious were made by Carl Gustav Carus (1846) and were part of philosophical-religious texts by Friedrich Schelling (1858) and Eduard von Hartmann (1869). The first dedicated phenomenological analysis of the unconscious, as a regression to the patterns of thinking of the "primitive man", was made by Friedrich Nietzsche (1876). In his book *Human, all too Human*, Nietzsche adopted the style of romantic era writers, such as William Wordsworth, Samuel Taylor Coleridge and William Blake, and wondered, with poetical and philosophical eloquence, "how comes it that the mind of the dreamer goes so far astray when the same mind, awake, is habitually cautious, careful, and so conservative in its dealings with hypotheses? […] In the dream this atavistic relic of humanity manifests its existence within us, for it is the foundation upon which the higher rational faculty developed itself and still develops itself in every individual. Dreams carry us back to the earlier stages of human culture […] we can see how late strict, logical thought, the true notion of cause and effect must have been in developing, since our intellectual and rational faculties to this very day revert to these primitive processes of deduction […].— Even the poet, the artist, ascribes to his sentimental and emotional states causes which are not the true ones." (Nietzsche, 1876, p. 34).

Twenty years after Nietzsche's *Human, all too Human*, the *Studies in Hysteria* (Breuer & Freud, 1895) were published. In the *Studies*, the concept of the unconscious was for the first time used in an applied psychological context. Sigmund Freud, living in what was one of the

most puritanical and religious eras of continental philosophy (Smith, 1994), suggested that the human psyche was governed by a phylogenetically shaped topography (Freud, 1910; Figure 1). Freud's psychoanalytic theory outlined that we are driven by fierce instinctual and moral impulses (Freud, 1933), and that neurosis is due to the repression of incestuous sexual desires to the unconscious (Freud, 1942). Freud expounded that the means to reaching this previously uncharted territory of the human psyche is psychoanalysis and the psychoanalyst (Freud, 1921).

Figure 1: Psychoanalytic Topography

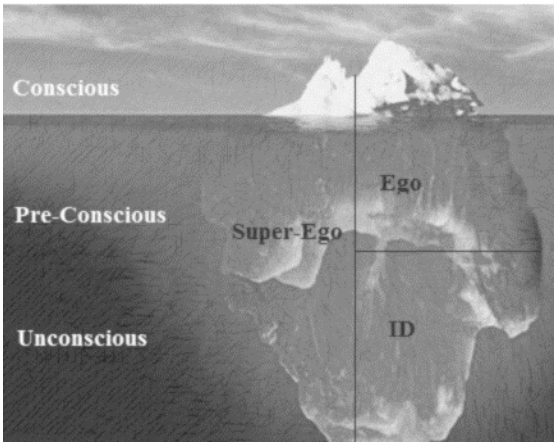

Fig. 1: A visual representation of the psychoanalytic topography. The Psychoanalytic model included the Ego, thoughts and perceptions, the Super-Ego, moral judgement, and the ID; our instinctual impulses; such as Eros and Thanatos, and traumatic experiences, as well as irrational, unacceptable and violent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

Freudian psychoanalysis was applied in clinical settings for the better part of the 20th century despite ferocious and relentless clinical and philosophical (Wallace & Edwin, 1983), and intra-psychoanalytic dispute (Jung, 1928; Klein, 1946). Freud fiercely advocated that psychoanalysis was a natural science (Wittels, 2016) and that unconscious repression was a heritable trait that followed Darwinian and neo-Lamarckian evolutionary patterns (for a review, see Smith, 2016). He suggested that the unconscious manifested since the very early beginnings of human culture (Freud, 1913) as a repository for the repression of inappropriate sexual impulses (Freud, 1905).

Freud considered that psychoanalysis should progress using a unitary theory of the unconscious. He exercised strict exclusion tactics to any and all members of the psychoanalytic movement who did not share his *observations* concerning the unconscious mind (Britzman,

2016). Despite these tactics, eventually, Carl Jung (1928) and Melanie Klein (1946) divided psychoanalysis by proposing that sexuality is not the only driving force of the unconscious mind and that the existential struggle for self-understanding, pre-sexual affect and developmental attachment also underlie unconscious processes (Brown, 1961).

While these concepts were debated and developed by psychoanalytic theorists and practitioners, empirical science was also developing as a philosophical concept (Broadbent, 2004). Karl Popper (1962) was one of the major figures that contributed to the formulation of the contemporary scientific method and also argued towards an irreparable paradigm "breach" between psychoanalysis and psychology (Bargh & Morsella, 2008; Morsella & Reyes, 2016). Popper proposed that science should postulate a testable hypothesis, that this hypothesis should be falsifiable, and that the concept of psychoanalytic repression, being an interpretive axiom, had no scientific validity; it could not be disproven and, therefore, it could not provide any credible and testable proof to support its theoretical postulations (Laguex, 1993).

As a simple illustration of his argument, Popper made reference to *Totem and Taboo* and *Civilization and its Discontents*, where Freud (1913, 1927, 1930) – in one of, admittedly, his most controversial theories – suggested that repression could be traced back to an actual occurrence of an Oedipal incident in a prehistoric human society. In this society, tyrannical paternal hierarchy resulted in patricide for the re-distribution of ruling privileges and sexual access to female members of the social group. Freud argued that the murder of the father in this society resulted in extreme and terrorizing guilt that contributed to the formulation of repressive mechanisms (Freud, 1913). Popper considered this theory retrospective, lacking in hypothetical predictions and therefore, unscientific. Popper emphasized that psychoanalysis applied the notion of repression in the phenomena it examined as opposed to explore whether the phenomena under investigation provided evidence for repression (Thornton, 1997). He suggested that the

psychoanalytic assessment of the unconscious was infallible and, therefore, *hermeneutic* (see Blight, 1981).

Popper's authoritative tone – that several authors have found comparable to Freud's own authoritative tone (Kirsner, 2007) – caused notable reactions amongst psychoanalysts. Members of the psychoanalytic movement supported that the refutation that Popper offered was not privy to the internal workings of the psychoanalytic method (Ahumada, 1997), that it did not refute the validity of the experiential evaluation of the psychic life of the individual (Edelson, 1985) and reflected Popper's own unconscious processes (Levy, 1996). Popper considered that his critique was validated by, particularly, the latter argument (Grünbaum, 1977, 1984, 1993). He suggested that psychoanalysis used psychoanalysis to defend psychoanalysis and therefore, that it is an untestable and infallible *pseudoscience* (for a comprehensive and thorough review of the term, see Hansson, 2008).

Popper and his contemporaries (Mayo, 1996), although largely disagreeing between them concerning the reasons for which one should disagree with the psychoanalytic assessment (for a thorough review, see Maxwell, 2005), unanimously suggested that psychology should adopt testable criteria for exploring the unconscious mind (Shearmur & Stokes, 2016). Several researchers had – prior to the aforementioned debate – proposed neural and cognitive models that could relate to unconscious processes (see for example Sidis, 1898; Peirce, 1906; Landis, 1930; Papez, 1937; MacLean, 1955; Bridgeman, 1971) and several researchers had proposed the implementation of testable psychological and sociological experimental methods for exploring concepts related to the unconscious mind (Bartlett, 1920, 1932, 1955; Erdelyi, 1974, 1985, 1992; Greenwald, 1992; Conway, 2001). These approaches were not the result of the controversy, these simply deservedly received more, wider, and perhaps, in certain cases (see Cory & Gardner, 2002) even belated, acknowledgement as a result (Mancia, 2007).

For example, James Papez, as early as 1937, had proposed a neuroanatomical model of automatic emotional neurocircuitry. Papez suggested that a circuit of neural structures including the fornix, the anterior thalamic nucleus and the hippocampus could be associated with the experience of emotion. His observations were based on patients with lesions located at or proximate to the hippocampus who displayed involuntary aggression. Paul D. McLean (1949, 1952, 1955) suggested that patients with amygdala and septal nuclei lesions showed dysregulations in the expression of fear and aggression, and that these structures could also play an important role in unaware emotional expression. Though both the septal nuclei and the hippocampus were eventually shown to be part of the neural pathway, and not *per se* the key processing structures, for emotional responses (Pessoa & Adolphs, 2010), the models proposed by Papez and McLean formed the foundation for contemporary models relating to unconscious emotion (Roxo, 2011).

Conversely, Bartlett, in his pivotal works (1920, 1932, 1955) on anthropology and psychology, suggested that our memories (personally and culturally) could be regulated and re-shaped by cognitive psychological mechanisms, as opposed to shaping our unconscious impulses (see also the seminal work in this area by Collins & Quillian, 1972 and Collins & Loftus, 1975). Eventually, Greenwald (1992) and Erdelyi (1992) proposed testable experimental models for unconscious processing (see also Dehaene, Changeux, Naccache, Sackur & Sergent, 2006). They suggested that the unconscious could manifest as implicit cognition, meaning that a salient cue could be unattended and rendered pre-conscious (presently unaware but potentially accessible by conscious awareness), due to, for example, experimental manipulations relating to a distracting engagement task (see for example van der Hout et al., 1997). Greenwald and Erdelyi also proposed that unconscious processing can manifest as an inability to recollect the presentation of a visual or auditory stimulus (see also Shiffrin & Schneider, 1977; Schacter, 1986; Schacter & Graf, 1986). This could include the inability to report the occurrence of a

stimulus that nevertheless provided empirical evidence for perceptual processing during engagement task responses, such as higher response times for the evaluation of conscious stimuli when exposed to a confounding unconscious prime and involuntary attentional switches from or towards conscious stimuli when these were, respectively, incompatible or compatible with a presented unconscious cue (see for example Jacoby, 1991). This distinction between pre-conscious (unaware but potentially accessible) and unconscious (unaware and inaccessible) (Freud, 1942; Dehaene et al., 2006; Kihlstrom, 1990, 1996, 2013) was preserved in contemporary psychological research and formed the basis for the contemporary assessment of unconscious processes (Lapate et al., 2017; Siegel et al., 2018).

By the late 20th century, psychology was almost entirely dedicated to cognitive models of unconscious processes and to some extent – in this area – became synonymous with these. The early theoretical notions of unconsciousness were – for better or for worse – eclipsed from psychological textbooks (Thorn & Henley, 1997) and this *ostracization* had *bipolar* repercussions (Gergen, 2001; Benjamin, 2007, see also McWilliam, Poronnik & Taylor, 2008). Several contemporary psychologists "felt" that any association with unconscious research was an unwelcome and excommunicated reminder of a taboo era of pre-scientific psychology (Pratkanis, 1992). Conversely, several of, particularly, our younger colleagues were simply unaware of what had transpired before the current area of research was – arguably and for a while – a trend in contemporary psychological settings (Conway, 2001).

Contemporary Models of Unconscious Processing

By the turn of the 21th century, Joseph LeDoux was one of the first (Wiens & Öhman, 2007; Pessoa & Adolphs, 2010) modern researchers to propose an acknowledged neural processing model for the unconscious mind that had a significant impact in the psychological community (LeDoux, 1989; 1992; 1993). LeDoux's model suggested that a subcortical pathway from the visual thalamus to the amygdala regulates the processing of emotional stimuli that

require an imminent "fight-or-flight" defence response (Airapetyantz & Bykov, 1945; Bruner & Postman, 1949; Plutchik, Kellerman, & Conte, 1979; Öhman, 1986a, 1986b; Power & Brewin, 1991). This subcortical pathway was suggested to bypass the occipital cortex and render higher cortical executive functions, in the pre-frontal cortex, unnecessary. The purpose of this pathway was to elicit survival-related responses to emotional elicitors, without relying on relatively slow cortical systems for the initiation or inhibition of action and do so by triggering automatic and involuntary, peripheral, sympathetic and parasympathetic, nervous system arousal (van der Ploeg et al., 2017). LeDoux's model suggested that we can experience fear without the need for conscious awareness because we require a mechanism for immediate responses to survival-related environmental cues.

Subsequent conceptual and experimental contributions to the study of unconscious emotion were, with notable exceptions (Pessoa & Adolphs, 2010), "rapt" by the appeal of the LeDoux model. As a result a substantial part of subsequent research did not conceptually or methodologically address many important issues that were considered seminal rally points for the exploration of emotional processing in other areas of experimental psychology (see particularly Lazarus, 1991). These included the consideration of parallel central and peripheral nervous system processing (Bard, 1934), and particularly the debate concerning whether affective processing has priority over semantic processing (Zajonc, 1980; Lazarus, 1981, 1982; Lai, 2012), the importance of context in the interpretation of physiological arousal (Schachter & Singer, 1962; Marcel, 1983) and the consideration of the distinction between unconscious (unaware and inaccessible) and pre-conscious (currently unaware but potentially conscious) emotional processes (Dehaene et al., 2006; Bargh & Morsella, 2008).

In their majority, but not exclusively (Pessoa et al., 2005a; 2005b), publications in the area of unconscious processing expanded the neurocircuitry and the evolutionary utility of the original model (Brooks et al., 2012). The locus coeruleus and several parts of the lower brainstem

were added to the neurocircuitry of subliminal pathways and were suggested as 'hubs' for the dissemination of peripheral nervous system arousal in response to unconscious emotional cues (Liddell et al., 2005). Numerous studies using backward masking, interocular rivalry and continuous flash suppression (see Figure 2), with healthy participants and participants with visual scotomas [1] provided empirical support for physiological changes in response to unconscious emotion (van der Ploeg et al., 2017). These studies presented masked emotional faces, emotional pictures, spiders, snakes and other evolutionary important stimuli (Williams, 2018), assessed neural (e.g. EEG, fMRI, and PET) and physiological responses (e.g. skin conductance[2], heart rate, and blood pressure), and suggested that we can experience neural activation and physiological arousal in response to subliminal emotional stimuli, meaning literally in Latin emotional stimuli that are below the threshold; implied here: *of conscious awareness* (Williams et al., 2005).

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

[2] Skin conductance is a method of assessing sympathetic peripheral nervous system arousal via the application of a small electrical charge and the measurement of subcutaneous sweating between typically the first (index) and second (middle) finger of a participant's hand (see van der Ploeg et al., 2017).

Figure 2: Contemporary Methods for the Presentation of Unconscious Stimuli

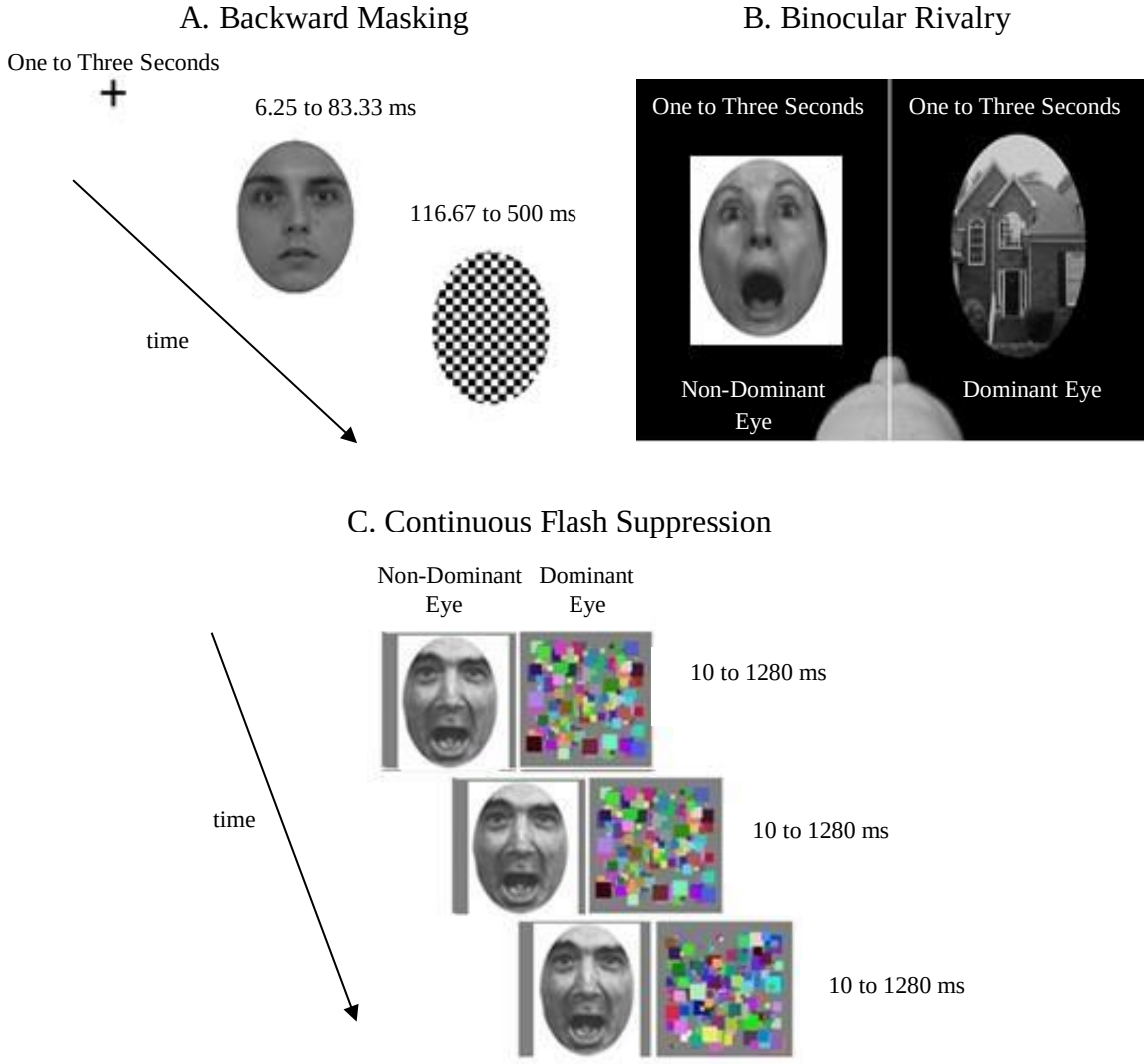

Fig. 2: Visual suppression techniques used in contemporary research. Previous research has proposed that these techniques operate via similar suppressive processes associated with the inhibition of the V1 in the primary visual cortex (Baker & Graf, 2008; Jeroen et al., 2007). Several previous studies suggested that Continuous Flash Suppression (CFS) (Figure 2; C.) utilizes secondary visual cortex areas (see for example, Tsuchiya et al., 2006). These relate to the perception of movement and make CFS a more effective method for the suppression of emotional stimuli compared to its alternatives (Tsuchiya & Koch, 2005). Breitmeyer (2007; 2018) also proposed that Backward Masking (Figure 2; A.) does not include para and meta-contrast effects (signifying in this context post-trial retinal-thalamic contrast residues relating to the presentation of the mask and masked stimuli in different locations of the perceptual vector) as compared to CFS and Binocular Rivalry (BR) (Figure 2; B.). Therefore, backward masking could elicit more effective visual suppression relating to detecting whether a potentially emotional masked stimulus was presented (but see also Kim et al., 2010). CFS and BR, on the other hand, could elicit more efficient suppression concerning what type of emotional stimulus was presented. This is suggested to occur due to para and meta-contrast effects. These could result in parallel and increased retinal-thalamic input and could induce higher cognitive load to occipital/primary and secondary visual cortex structures, and ventral and dorsal pathways associated with stimulus recognition (Breitmeyer, Ogmen & Öğmen, 2006). For a comprehensive review on this topic, the authors suggest the excellent work published by Bachmann and Francis (2013).

"Subliminal"

Despite its conceptual appeal, this revised notion of subliminality (Dehaene et al., 2006), once more divided psychology and neuroscience (Pessoa, 2005). Erdelyi (2004) suggested that a substantial number of publications in the field of psychological research referred to some variation of subliminal processing and few of these agreed as to the definition or the validity of the concept (Pessoa & Adolphs, 2010; see particularly Shevrin & Dickman, 1980). Relative consensus was achieved in the area using a simple mathematical equation: for any type of participant response or informational availability defined as ε, and for conscious accessibility to the presented information defined as α, subliminal processing occurs when $\alpha = 0$ and $\varepsilon > \alpha$ (Erdelyi, 2004). Support for and against the validity of subliminal processing was provided by subsequent empirical research (for a review, see Brooks et al., 2012) and the empirical diversity induced a rather polarizing effect; researchers were either firm supporters (Morris & Dolan, 2001; Pessiglione et al., 2008; Phillips, 2016) or sceptics (Seitz & Watanabe, 2003; Wiens, 2006; Lähteenmäki et al., 2015; Tsikandilakis, Chapman & Peirce, 2018) of the idea that we can be influenced by subliminal emotion.

The Controversy in Contemporary Psychological Research

Several fMRI studies (for a review, see Brooks et al., 2012) were able to provide evidence supporting that we can experience emotion without conscious awareness. This line of research suggested that the neural structures associated with the processing of emotion (e.g. the amygdala, the locus coeruleus, and the cingulate cortex) can be activated automatically and without conscious awareness via a subcortical collico-pulvinar pathway (Liddell et al., 2005). This subcortical pathway was suggested to elicit, via the brainstem, involuntary physiological arousal in response to subliminal emotional cues to enable us to automatically adapt to our environment. Several studies expanded on these neural findings and were able to report increased skin conductance and heart rate responses during the presentation of subliminal emotional stimuli

(van der Ploeg et al., 2017). The argument raised by this line of research was that emotional cues can elicit physiological changes in the complete absence of awareness because they pose a demand for imminent, automatic and involuntary "fight-or-flight" and social-adaptive responses to unconscious evolutionary important environmental cues that confer survival-related value (Meneguzzo, Tsakiris, Schioth & Brooks, 2014).

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

Understanding the Controversy

One important issue that sceptics debated in previous methods, that provided evidence for subliminal emotional responses, was that the experimenters presented masked emotion for fixed durations of presentation (Lähteenmäki et al., 2015). For example, emotional and neutral

faces were presented for durations ranging from 6.25 to 83.33 ms[3] with backward masking to overt neutral faces and the assumption was made that these masked stimuli will be processed below the threshold of conscious awareness indiscriminately of within and between-participants, and between-stimulus type differences (Bachmann & Francis, 2013). The issue with this approach was that several studies (Pessoa, 2005) reported groups of under- and over-achievers in respect to signal detection and discrimination performance, and also differences in detection and discrimination performance between different emotional types (Calvo & Lundqvist, 2008). For several researchers in the field that meant that differences between participants due to, for example, differences in experiential sensitivity (Aru & Bachmann, 2007; Mather & Sutherland, 2011; Lundqvist, Juth, & Öhman, 2014) and attentional resources (Aru, Bachmann, Singer & Melloni, 2012), and differences between facial-emotional characteristics due to, for example, differences in emotional recognition reward value (Adolphs, 2002), emotional incongruence with the neutral mask (Kim et al., 2010) and higher perceptual acuity in response to pronounced facial features, such as valence and arousal (Nummenmaa & Calvo, 2015), attractiveness (Tsikandilakis, Bali & Chapman, 2019) and cultural background (Tsikandilakis et al., 2019), were sufficient to induce variations in face-detection and emotion-recognition performance, and lead to conscious awareness. Therefore, the studies that reported responses to subliminal cues were, according to subliminal sceptics, subject to a fundamental misinterpretation, i.e. that subliminal perception can be treated as a constant without adjusting for individual differences (for a review, see Tsikandilakis, Chapman & Peirce, 2018).

In addition to this limitation, the method of assessment and the statistical analysis for subliminality were subject to criticism. The vast majority of neuroimaging studies (for a review, see Brooks et al., 2012) and peripheral nervous system response studies (for a review, see van der Ploeg et al., 2017) employed hit rates and frequentist analysis for the assessment of

[3] These durations are provided by the authors given the possible intervals allowed by the refresh rate of the monitor as reported in previous studies (van der Ploeg et al., 2017). An exact index of how these calculations were made is included in the on-line material (https://osf.io/mp8jx/).

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

Table 1: Technical Terms

Backward masking	A method for suppressing visual stimuli. It consists of the presentation of a masked visual cue, such as a face, a picture or a shape presented for a brief duration, typically ranging from approximately 5 to 80 ms. The masked cue is followed by a neutral stimulus, called a mask, such as a blur, a pattern or a neutral face (> 100 ms). The mask is suggested to render the masked cue imperceptible (see also Figure 2).
Bayesian Analysis	A dynamic and probabilistic inferential method of statistical analysis. It can be applied to explore whether the data show evidence for the alternate (or research) hypothesis $B > 3$ (Dienes, 2014; 2015) or $B_{10} \geq 10$ (Jaronsz & Willey, 2014), whether the data show evidence for the null hypothesis ($B < .33$ or $B_{01} \geq 10$), or whether the data are insensitive to both hypotheses ($.33 > B < .3$ or $1 > B_{01 \text{ or } 10} < 10$).
Bayes Factor	Bayesian analysis allows the researcher to compute a likelihood ratio for the probability of observing the data under the alternative vs. the null hypothesis. This is the so-called Bayes factor B_{10}, where $B_{10} \geq 10$ or $B > 3$ stand for evidence for the alternative relative to the null hypothesis, while conversely $B_{01} \geq 10$ or $B < .33$ stand for evidence for the null relative to the alternate hypothesis (Jarosz & Wiley, 2014; Dienes, 2014; 2015). The Bayes factor was adjusted using the logic of a one-sample t-test to the study of conscious awareness. Given that performance in a signal detection or discrimination task was different to chance (.5) by a defined numerical variable x, if x - .5 was within a priori defined criteria for chance level performance, the analysis indicated a Bayes factor of $B_{01} \geq 10$ or $B < .33$ or less and evidence for the null, in this case subliminal processing.
Binocular Rivalry	A method for suppressing visual stimuli. It consists of the presentation of a target stimulus, such as a face, a picture or a shape to, typically, the non-dominant eye, and the parallel presentation of a neutral distractor, such as a blur, a pattern or a neutral stimulus, to the dominant eye. The simultaneous presentation of these stimuli is suggested to render the target stimulus imperceptible (see also Figure 2).
Continuous Flash Suppression	A method for suppressing visual stimuli. It consists of the presentation of a static target stimulus in, typically, the non- dominant eye, such as a face, a picture or a shape, and the parallel presentation of a series of distractors to the dominant eye. The presentation of a series of multiple distractors is suggested to render the static target stimulus imperceptible (see also Figure 2).
Detection (Threshold)	Frequently referred to as the detection threshold. It indicates whether the participant was able to respond whether a visually suppressed stimulus was presented or not.
Discrimination (Threshold)	Frequently referred to as the discrimination threshold. It indicates whether the participant was able to respond what type of visually suppressed stimulus was presented. It is sometimes referred to as stimulus or emotional type recognition.
Meta-Awareness	The ability to report in a post-trial or post-experimental assessment task whether a target stimulus was presented. Originally considered synonymous to meta-cognition. In contemporary research, meta-cognition is considered a separate phenomenon relating to experiential awareness, such as subjective awareness of having a cognition or subjective ability to regulate a cognition.
Signal Detection Theory	A method for providing a more unbiased assessment for participant response to an engagement task. It includes combining in a single metric the correct (hits) and incorrect (misses) replies that a participant made.

Visual Staircase Reduction	A method for suppression of visual stimuli that can be used in addition to backward masking, binocular rivalry and continuous flash suppression. It consists of a post-trial assessment task during which the participant is asked whether they were aware of the target stimulus. If the reply is "yes", the duration, pixelation or saturation of the target stimulus is adjusted to render it imperceptible.

Table 1: Technical terms. The authors suggest that the reader could find thorough and comprehensive reviews in relation to masking techniques (Bachmann & Francis, 2013), Bayesian and signal detection terms (Dienes, 2014; 2015; Jarosz & Wiley, 2014; Kellen & Klauer, 2018) and a review of terms relating to distinctions in perceptual processing (Dehaene et al., 2006; Bargh & Morsella, 2008; Morsella & Reyes, 2016) in key previous publications. For a comprehensive review concerning on-topic terminology in general, see the excellent work provided by Axelrod, Bar and Rees (2015).

Responses to the Controversy

In response to these issues, several publications emerged in this field (for review, see Axelrod, Bar & Rees, 2015). These attempted to offer solutions for the assessment of subliminality (Brooks et al., 2012; Meneguzzo et al., 2014; van der Ploeg et al., 2017). To address the limitation of inferring chance-level performance by failing to reject the null hypothesis, the assessment of conscious awareness was addressed using dynamic probabilistic inference. Bayesian analysis was employed to assess whether signal detection performance was at chance. Bayesian analysis allows the researcher to compute a likelihood ratio for the probability of observing the data under the alternative vs. the null hypothesis. This is the so-called Bayes factor B_{10}, where 10 stands for alternative relative to null hypothesis. It has been suggested that B_{10} needs to be .33 or smaller to provide substantial evidence for the null (Dienes, 2014). Thus, a Bayesian analysis can provide evidence for the null, something that is not possible using frequentist statistics (Dienes, 2015). To address participant response strategies for awareness, signal detection theory measures (d', A', A", A; Zhang & Mueller, 2005) were used. These provide a more unbiased metric for perception, by taking into account hits (correct detections/discriminations) and false alarms (false positives) to control for participant response strategies, such as tending to reply yes (liberal bias) or tending to reply no (conservative bias), for seeing a masked stimulus (Stanislaw & Todorov, 1999).

A Practical Illustration

To further illustrate how these methodological developments can change the results of an empirical analysis, we present here a practical illustration using an example analysis of previously unpublished data. The current data relate to a pilot study undertaken in 2017 by the current authors. The population sample consisted of 73 (42 female) undergraduate psychology students. The age of participants ranged from 18 to 27 years (M = 21.43, SD = 2.04). The participants were presented with fearful, angry, happy, sad and neutral faces, and non-facial blurs for 34.72 ms. These were backwards masked with a black and white pattern for 125 ms. Skin conductance responses (SCR) were measured after the presentation (maximum deferral; highest peak in amplitude one to three seconds post-stimulus offset minus a calculated aggregate of pre-stimulus baseline scores; see Williams et al., 2005). The participants were then asked to respond whether they saw a face (Y/N; for full study design see Tsikandilakis & Chapman, 2018).

A common analysis for the output provided by the current design would be the calculation of overall hit-rates performance (correctly responding that a face was presented) and the comparison of overall performance to chance (50%) using a one-sample t-test. In this case, overall hit-rate performance was 52.89 % (SD = 14.53%). A one-sample t-test analysis against chance reports t (72) = 1.4; p = .165; C.I.: 5.77 to 1.01. A repeated measures ANOVA shows that there were significant differences between different emotions (F (3.14, 226.26) = 93.47; p < .001; partial eta-squared = .57; Greenhouse-Geisser corrected). Bonferroni-corrected pairwise comparisons also show that fearful faces (M = .063, SD = .019) were significantly higher for SCR than angry (M = .051, SD = .012; p < .001; d = .76), happy (M = .042, SD = .018; p < .001; d = 1.13), sad (M = .024, SD = .011; p < .001; d = 2.51), neutral faces (M = .025, SD = .018; p < .001; d = 2.05) and non-facial blurs (M = .024, SD = .015; p < .001; d = 2.27).

The analysis suggests evidence for subliminal processing. This could form the basis for a publication and yet we have in our current endeavour already made two statistical errors and

allowed for a significant omission. As evident from Table 2, the data are subject to a conservative response bias for awareness (β = .022). This bias is most pronounced for false positive rates (39.42%) and impacts sensitivity (True Positives/ (True Positives + False Negatives)), specificity (True Negatives/ (True Negatives + False Positives)) and accuracy ((True Positives + True Negatives)/(True Positive + True Negatives + False Positives + False Negatives)); for a full review of these terms see Krupinski (2017):

Table 2: Signal Detection Matrix

	Face Presented	Face not Presented
Responded Yes	52.89% (True Positives)	39.42% (False Positives)
Responded No	47.11% (False Negatives)	60.58% (True Negatives)

Table 2: Signal detection matrix for the calculation of non-parametric ROC index A. The table shows evidence for a conservative response bias (A' = .58; A'' = .58; A = .59, SD = .03, SE = .004; β = .022). Manual formulas, code and ways to implement analysis for calculating the response bias β can be found in Stanislaw and Todorov (1999; p. 139-140; 142-147).

In this instance, hit rates are not an appropriate assessment of perception. Receiver operating characteristics (ROC), that can provide a metric between hits and misses, are the appropriate assessment. The current authors suggest the employment of A (Zhang & Mueller, 2005). This suggestion is based on advantages that A has compared to d', A' and A''. For example, compared to d', A is a nonparametric sensitivity index and does not include any specific assumptions about the shape of the underlying distributions (Swats, 2014; but see also Hajian-Tilaki et al., 1997)[4]. A can also provide an index for zero values, such as zero hits or miss responses, and provides diagonal Euclidean corrections to the A' and A'' metrics for scores that lie in the upper left quadrant of the ROC curve. The researchers do not need to write their own

[4] Here we must note that mathematical researchers (Grier, 1971) suggest that violations of normality for ROC cannot be tested for multiple signal to noise intervals by simply exploring overall detection or discrimination performance. This should be provided by testing the normality of all the multiple manipulations of the signal and noise distributions separately (Stanislaw & Todorov, 1999; p. 140) and testing for evidence for the null (Dienes, 2015) for the "proximity of their standard deviations" (Stanislaw & Todorov, 1999; p. 140-141). An additional proposed method is the testing for skewness, kurtosis and linearity between multiple manipulations that vary the signal to noise ratio; meaning in this context testing for multivariate normality or goodness-to-fit evaluation of Gaussian linearity for monotonically increasing signal to noise intervals (see for example. Coroyer, Jorand, & Duvaut, 1994; Macmillan, Rotello & Miller, 2004). The authors also suggest the excellent work by Robin and colleagues (2011) in this area.

code for calculating A. This is provided on-line and includes a series of simple steps[5]. The calculation of accuracy for A informs us that for the current data detection performance has a mean of .59 (SD = .03).

At this point we have successfully incorporated in our data a non-biased assessment for participant performance. We still, nevertheless, require an important revision. In our previous analysis we used a one-sample t-test and found that hit-rate performance was not significantly different to chance; we failed to reject the null. This should not be misinterpreted as evidence for the data being "significantly" at chance. In fact, the term significantly at-chance is, debatably, a statistical impossibility (see also Dienes, 2014). Our finding simply and literally means that we cannot reject the possibility that the null is true. Dienes (2015) provided an easy-to-follow way to provide evidence for the null and again the researchers do not need to write code for this calculation; the process requires a series of simple steps on-line[6]. The Dienes method suggests that Bayesian analysis can be used to provide a Bayes factor that can indicate at B > 3 evidence for the alternate hypothesis, at B < .33 evidence for the null and at .33 > B < 3 insensitivity for either hypothesis, meaning that based on the current data we cannot provide a conclusive assessment.

The calculation of the B factor relies on the mean difference of the observed effect and the compared value, in this case .59 - .5 = .09. It requires the estimation of the standard error, in this case SE = (SD/ square root (n = 73)) = .004. It also requires the definition of intervals for testing whether the mean difference provides evidence for being within an a priori defined range. The definition of these intervals can be based on previous findings or defined by the researcher (Dienes, 2016). For the purpose of the current example, we can set our criteria at reasonable intervals around chance (A = .5) at -.1 (lower bound = .4) and .1 (higher bound = .6). If the current data are at-least three times more likely to be within (as opposed to outside) standard

[5] https://sites.google.com/a/mtu.edu/whynotaprime/

[6] http://www.lifesci.sussex.ac.uk/home/Zoltan_Dienes/inference/Bayes.htm

error adjustments of these a priori intervals, the analysis will provide evidence for the null. In this case using the Dienes method a uniform model with a mean difference of .09, SE = .004 and a priori defined intervals at .4 and .6 reveals a Bayes factor of B > 3. The figure below graphically depicts the current result:

Figure 3: Graphical Illustration of Bayesian Analysis

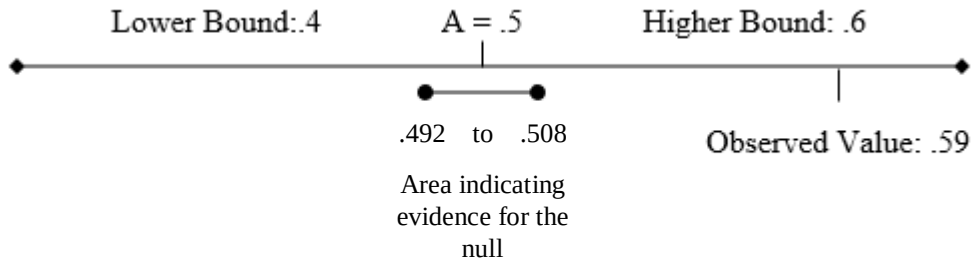

Fig. 3: Graphical illustration of the Bayesian analysis. The figure includes the lower (A = .4) and higher (A = .6) bounds that were used to calculate the intervals that would suggest evidence for chance-level performance (A = .5) given the standard error of the mean (.004) in the current data (.49 ≤ Observed Value ≤ .51)[7].

The analysis no longer suggests evidence for subliminal processing. In fact, at this stage even if we run a one sample t-test against chance (A = .5), the results would, using ROC criteria for awareness, report significant differences to chance level performance (t (72) = 28.19; p < .001; C.I.: 7.46 to 8.59). The analysis of variance for SCR scores can now only stand as proof that brief backwards masked emotional faces elicit changes in physiology, but that this effect is not due to *subliminal* processing. Note here that even if overall performance was at-chance, the analysis would have to be repeated for each emotional type (Hand & Till, 2001) to ensure that the overall effect is not an aggregate of perceptual diversity as a function of emotion, such as lower detection performance for neutral faces and higher detection performance for fearful faces (see for example, Kim et al., 2010).

The "Error of our Ways"

The current example should illustrate how unbiased assessment of binary detection (or discrimination) responses, direct evidence for the null – in this case chance-level detection (or

[7] For an adaptation of standard models of ROC, that treat chance-level performance (A = .5) as a minimum-baseline value, to an accuracy index with possible below chance-level values see on-line material (https://osf.io/mp8jx/).

discrimination) performance – and further per stimulus type assessment (using these methods) could change the results of an analysis. These are the possible *practical* "errors of our ways", or more precisely in this instance an illustration on how to control for these. After the application of the aforementioned methods in the above dataset, we controlled for methodologically important issues in the assessment of subconscious experience and these steps have disallowed us to treat the current data as indicating subliminal processing.

In addition to these, at this stage in the manuscript, the authors will have to add (theoretical) *insult* to (statistical) *injury* and suggest that we assessed the experience of awareness using measures of perceptual accuracy. The argument could be made here that subjective assessment of non-dichotomous and gradual measures of awareness should be included in our engagement tasks. This is a fine argument and it has been made – quite convincingly so – before (Ramsøy & Overgaard, 2004; Overgaard et al., 2006; Overgaard, Timmermans, Sandberg & Cleeremans, 2010; Overgaard & Mogensen, 2017; Tsikandilakis, Peirce & Chapman, 2018). We would also like, at this stage, to make a case for the analysis of "error". If we revisit the original argument in relation to subliminality, we will recall that for α being perception of a stimulus and ε the response to a stimulus, subliminality occurs when $\alpha = 0$ and $\varepsilon > \alpha$. Let us now add an additional variable to this equation. Let us assume that for α being stimulus perception, A is the perception of the bodily response elicited by the stimulus (e.g. changes in heart rate). Subliminality stands now as $\alpha = 0$, $\varepsilon > \alpha$ and $A = \alpha$.

Subliminality requires that an *invisible* emotional stimulus will induce an imperceptible response and will be significantly different from the response to an *invisible* non-emotional (or less emotionally salient) stimulus in an explicit or implicit empirical assessment. The evolutionary disadvantage of experiencing an emotional response that will not automatically and involuntarily elicit the involvement of meta-awareness and meta-cognition, and alarm both limbic and higher executive structures to the potentiality of endangering or sociobiologically

relevant environmental cues, possibly contradicts the original conception of the notion of subliminal processing. Note that here we are not questioning the – indeed unlikely – possibility of reporting significantly different responses between stimuli that have provided evidence for null perception; we are, in fact, questioning the extent to which emotionally responding to a stimulus can evade self-monitoring and awareness. To this end, we cannot use arousal in response to *invisible* emotional stimuli to support our argument – without at least falling in a circular debate concerning whether these were indeed *subliminal* – but we can use responses to innocuous stimuli to assess how misperception can be influenced by *noise*-arousal to lead to the experience of awareness (see also MacMillan, 2002; p. 43-45).

Let us return to our previous data to test, to the extent that our design allows, this possibility. In our previous signal detection table we calculated the instances of false positive responses. False positive responses indicated that a non-facial stimulus (blur) was presented but the participants responded that a facial stimulus was presented. These responses were at 39.42%. We also calculated the instances of false negative responses. False negative responses indicated that a face was presented but the participants responded that they did not see a facial stimulus. These responses were at 47.11%. If we run a simple paired samples t-test for SCR scores between these two response types, we find that overall false positive responses were higher for SCR ($M = .025$, $SD = .013$; $D(73) = .982$; $p = .38$) than false negative responses ($M = .021$, $SD = .008$; $t(72) = 2.22$, $p = .029$; $d = .39$; $D(73) = .983$; $p = .41$).

Participants experienced higher arousal when they thought that they saw a face that was not presented compared to when they responded that they did not see a face that was. This finding is intriguing, but it is not novel. It is simply understated. Similar findings have been reported multiple times by several research groups (Pessoa, Japee, Sturman & Ungerleider, 2005; Pessoa, Padmala & Morland, 2005) and also previously by the current authors (Tsikandilakis, Chapman & Peirce, 2018; Tsikandilakis, Bali, Derrfuss & Chapman, 2019a, 2019b). For example, in a

previous publication (Tsikandilakis, Chapman & Peirce, 2018) we reported a trend for higher SCR ($p = .084$; $d = .51$) and heart-rate arousal ($p = .063$; $d = .44$) for false positive responses, responding having seen a face when a face was not presented, compared to true negative responses, responding not having seen a face when a face was not presented. In a more recent publication (Tsikandilakis, Bali, Derrfuss & Chapman, 2019a) we were able to extend these findings and show that false positive responses for having seen a fearful face were significantly higher for SCR and heart-rate ($p < .001$; $d_{SCR} = 1.43$, $d_{HR} = 1.53$) compared to true negative responses for not having seen a fearful face when participants were presented in both cases with stimulus types that were not associated with physiological arousal, such as sad, neutral and non-facial-blur stimuli. In this instance the argument we can make is quite interesting: physiological arousal was associated with awareness; and vice-versa (see also Lapate et al., 2014 and Siegel et al., 2017).

"The Road less Travelled"

This analytical summary suggests that perception is not equivalent to awareness. Awareness – or more accurately meta-awareness in the aforementioned designs (see Table 1) – could be an interactive process that influences and is influenced by emotion (Lau, 2007, 2008; Aru et al., 2012; Lapate et al., 2014; Siegel et al., 2018). In our case, this is the possible *theoretical* "error of our ways": the experience of awareness is not limited to (stimulus) perception. Perception, of a stimulus and the self, and emotional physiology impact the experience of awareness and unawareness, and, paradoxically, "error" – such as responses that are incorrect – provide a plethora of physiological evidence to allow us to explore how consciousness and unconsciousness function without limiting ourselves to assessing *stimuli invisibility* (Pessoa, 2005).

It might come as no surprise that both the current research group (Tsikandilakis & Chapman, 2018; Tsikandilakis, Chapman & Peirce, 2018; Tsikandilakis, Bali, Derrfuss &

Chapman, 2019a; 2019b) and other research groups (see for example Amihai, Deouell & Bentin, 2011; Lähteenmäki et al., 2015; Pessoa, 2017; 2018) have repeatedly reported that unbiased and rigorously controlled implementation of null perception results in null responses irrespective of the presented stimulus type. Naturally, this should not be considered as a refutation for the concept of gradual awareness and unawareness; it is not. The latter is a concept is very interesting, intricate and promising one (Sergent & Dehaene, 2004; Sandberg, Timmermans, Overgaard, & Cleeremans. 2010; Kouider, De Gardelle, Sackur, & Dupoux, 2010; Schwitzgebel, 2011), that has engaged the attention of past research (Tsikandilakis, Peirce & Chapman, 2018; Rothkirch, Overgaard & Hesselmann, 2018), and will – most certainly – continue to engage the attention of research in this area (Cleeremans, 2019).

What we have not sufficiently acknowledged – at-least yet – is that misperception – or perceptual "error" if you prefer – has offered us "a road not taken" to understanding awareness. To put our argument more provocatively, we stand to gain insight concerning the workings of consciousness and unconsciousness from instances in which participants "err" between presentation and awareness, such as trials in which participants reported consciousness of emotions that were not part of the visual suppression, posing the most interesting and, in fact, classical (James, 1894; Lange. 1885) of research questions: is the experience of awareness and the experience of emotional physiology a *palindrome*? This line of research could provide valuable *insights* relating to consciousness and unconsciousness.

Conclusions

In the current paper, we presented a brief history of conceptualizations relating to the unconscious mind. We acknowledged that the current area was contentious and that it still is. Several contemporary issues and developments relating to the assessment of subliminality were presented, discussed and practically illustrated. We presented the possible *practical* and *theoretical* "error of our ways" raising some fundamental methodological and statistical issues.

We suggested that the practical issue in relevant research is that biased measures of perception (hit rates) and insufficient statistical procedures (one-sample t-test) are used to provide evidence for subliminality. We illustrated how signal detection theory and evidence for null perception can change the outcome of an analysis. We also suggested that the theoretical issue in relevant research is that the experience of awareness and unawareness is not limited to (stimulus) perception. Along these lines, the opinion of the current authors is that at this stage in research relating to unconscious emotion we are studying (also) the subjective experience of awareness and unawareness, and not simply the physics of perceptual processes. In this manner we could benefit from the interpretation and the analysis of "the error of our ways" empirically and – to return to the introduction of the current manuscript, more so, should we be willing to truly learn and understand concepts outside our academic comfort zone – metaphorically. We suggest that "error" is an opportunity for knowledge.

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