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An Intersection Between the Aesthetic and Social Brain: The Role of Empathic Processes towards Negative Emotion within Visual Aesthetic Experience.

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Pegi Nicol Macleod, *The Slough*. 1928.

Abstract

The neuroscientific investigation of visual aesthetic experience (henceforth aesthetic experience) has been largely investigated visual artwork's positive affectual characteristics, such as beauty and appreciation; however, negative aspects (i.e., negative aesthetic experience), such as disgust and immorality, have been commonly portrayed in artwork across centuries, yet little traction towards its neural underpinnings has occurred to date. Psychological and philosophical inquiries into negative aesthetic experience posit that a viewer employs a psychological distance to appropriately embrace negative emotion as a secondhand experience, perhaps through empathic processes that promote the sharing, feeling, and understanding of another's emotions that are commonly employed by the social brain. Therefore, an intersection of the social and aesthetic brain towards negativity deems present, while the small body of literature directly assessing the neural underpinnings of negative aesthetic experience permits further investigation.

Accordingly, a meta-analysis assessing neural correlates of negative emotion was conducted across three visual stimuli domains: artistic (VAE), social (VSE), and non-artistic (VNE) stimuli. Literature search screenings resulted in the inclusion of 22 studies and 23 experiments for VAE, 97 studies and 98 experiments for VNE, and 45 studies and experiments for VSE. GingerALE software employed ALE analyses to specify neural correlates within and between VAE, VNE, and VSE. At 1,000 permutations, individual and conjunction analyses had a cluster-level FWE threshold of 0.05 and a general cluster threshold of 0.001, while contrast analyses had a minimum cluster volume of $20m^3$ and a general cluster threshold of 0.001.

Meta-analytic results solely revealed the early visual cortex for VAE, while activations across the mirror neuron, empathic, and social systems were shown for VNE and VSE. However, VAE broadly contributed to VNE and VSE conjunction analyses that

replicated their respective individual meta-analytic activations, and VAE's sole cluster survived the contrast analysis against VNE yet not VSE. These results suggest that the context of stimulus engagement, such as aesthetic, generates top-down effects on the employment of neural systems in how one feels, shares, and understands another's negative emotion. Importantly, the VAE may demonstrate more similarities with the VSE, implying a shared neural infrastructure between the social and aesthetic brain. Therefore, an employment of neural systems denoting empathy and social processes may underly *how* the negative aesthetic experience emerges, yet the question remains, *why?*

Feeling moved is posited to be an empathic and emotionally intense experience based within self-relevancy that may emerge from gaining meaningful new experiences, and it has been shown to occur more towards negative content within an aesthetic context. Grounded within functional and anatomical connections throughout the cerebrum, the posterior cerebellum may be a predictive machine to implicitly learn about one's environment by employing empathic, social, and motor faculties in a particularly negative affectual space and has further been implicated within aesthetic experience. The predictive processing accounts for aesthetic experience suggest that the brain employs implicit learning to compare incoming sensory information (e.g., a painting) with previous knowledge to explain the aesthetic experience in hand. High perceptual learning may base as feeling moved, which may result from an eventual coherency between the self and the artwork via empathic processes alongside experience with the arts.

Transcranial direct current stimulation (tDCS) modulates a neural resting state's subthreshold potential by delivering a low-voltage current through a pair of bipolar electrodes, with anodal stimulation boosting neural firing rate and cathodal stimulation reducing neural firing rate (Jacobsen et al., 2012). tDCS over the cerebellum (ctDCS) has been employed to investigate the cerebellum's functional role across social, emotional, and

motor domains within an implicit learning perspective. Hence, ctDCS over the right posterior cerebellum was utilized to investigate the role of feeling moved by visual artwork in relation to individual differences in empathy and art experience. Following an aesthetic evaluation paradigm, individuals felt more moved by negative artwork than positive artwork, with feeling moved by negative artwork being positively impacted by an individual's empathic abilities. Negative artwork may underly higher instances of implicit learning within an aesthetic context that is facilitated by an individual's ability to empathically engage with an artwork. Moreover, those individuals with higher levels of empathy and art experience felt less moved after anodal ctDCS, suggesting that a subjective ease in aesthetic engagement is impaired by a procession of internal models to implicitly learn from the aesthetic experience in hand. In all, feeling moved by artwork may occur through routes of empathy and art experience to promote meaningful experiences via a self-relevant mechanism.

The social brain may be employed within an aesthetic context to engender aesthetic engagement with artwork depicting negativity, and through an empathic distance and embracement, negative artwork may provide meaning to the viewer. Therefore, engaging with negative artwork may allow the attainment of new experiences that an individual may not been keen to engage with or even have the chance to experience across real-life contexts.

Henri Matisse. *Interior with a Young Girl (Girl Reading).* 1906.

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Glenn Brown. *Kinder Transport.* 1999

Introduction

To date, numerous cognitive models explain the *visual* aesthetic experience of artwork (henceforth deemed aesthetic experience), which denotes a viewer's engagement with a piece of visual artwork, such as a painting or sculpture. These models generally describe three distinct components: inputs, processing mechanisms, and outputs (for a review, see Pelowski et al., 2016). Inputs refer to the individual personality traits, social and cultural contexts, the emotional state of the viewers, an artwork's information (e.g., an artist's statement), a viewer's art expertise, among others (Jacobsen, 2010; Pelowski et al., 2016). Processing mechanisms refer to the bottom–up and top–down processes behind the perception of visual artwork with higher–level cognitive processes adjusting the visual information coded by lower–level brain areas (for a review, please see Teufel & Nanay, 2017).

Depending on the model, processing mechanisms include both subconscious and conscious processing (Chatterjee, 2003; Locher et al., 2010) with special consideration given to memory in both the implicit activation of schematic information (Locher et al., 2010, Pelowski et al., 2017; Silvia & Brown, 2007) and the explicit attention–driven classification (Chatterjee, 2003, Pelowski et al., 2017) needed for the recognition of objects present within a visual work of art. Moreover, emotion plays a vital role in the processing of artwork in that the viewer's emotional reaction to an artwork depends on the artwork's congruency to the viewer's self–image, current emotional state, and/or previous emotional life experiences (Pelowski et al., 2017; Silvia & Brown, 2007). Noteworthy as the most recent model, The Vienna Integrated Model of top–down and bottom–up processes in Art Perception (VIMAP; Pelowski et al., 2017) proposes an interplay between a cognitive mastering stage, the discovery of meaning via associations to existing knowledge, and an evaluation stage, the

understanding of an artwork's ambiguity, as a necessary late–stage processing mechanism for art perception. Although processing mechanisms may differ in one model versus another, the outputs describe mental and behavioral effects from the visual aesthetic experience which are generally compatible across theories (Pelowski et al., 2016) with utmost consideration given to the aesthetic judgment of *beauty*, aesthetic *appreciation (i.e., liking)*, and the experienced aesthetic *emotion*.

Accordingly, empirical research generally pertains to explaining the visual aesthetic experience through these outputs; however, some issues arise in the appropriateness of language. For example, the use of the word beauty to aesthetically judge artwork may be built upon semantically through prior activities and experiences (Wittgenstein, 1958/1968) and may be related more towards the feeling of beauty as an aesthetic emotion (Kant 1790/2001; Menninghaus et al., 2019). Although aesthetic appreciation is related to the liking of an artwork or the pleasure (even this dichotomy is debatable) associated with an artwork (Kant 1790/2001; Menninghaus et al., 2019), the use of the word appreciation may be explicit to a singular case of the visual aesthetic experience and may not be used as a general descriptor for all cases of the aesthetic experience as these all differ in their context (Wittgenstein, 1966/1987). Moreover, aesthetic appreciation may be explicitly related to the aesthetic emotions experienced throughout a viewer's engagement with an artwork, and these aesthetic emotions may be respective to different emotional categories, such as happiness and sadness (Menninghaus et al., 2019). Therefore, the language used to evaluate the visual aesthetic experience may be specific to the viewer, which poses an issue in empirical research investigating the visual aesthetic experience as a whole (i.e., from a representative sample). Hence, differences on the meaning of terms employed within empirical aesthetics between researchers and participants may impact study results and should be considered as one interprets findings across empirical aesthetics.

1. Neuroaesthetics

The aesthetic experience has been explored by artists, art historians, philosophers, psychologists, and most recently, neuroscientists, who have established the field known as "neuroaesthetics". In the past years, neuroscientists have more than scratched the surface uncovering the neural correlates of aesthetic experience, with a particular focus on the visual aesthetic experience. Both neuroimaging (Chatterjee & Vartanian, 2014) and non-invasive brain stimulation (Ciricugno et al., 2023) have been applied to investigate its neural underpinnings, which has even played part in the fruition of a plethora of theories and models explaining the visual aesthetic experience (Pelowski et al., 2016). The models generally propose that aesthetic experience is birthed through the interplay of different neural systems behind sensation, emotion, and cognition (e.g., Chatterjee & Vartanian, 2014; Pelowski et al., 2017).

Concerning nodes of these systems, aesthetic appreciation, generally operationalized as liking, has been positively associated with frontal cortical areas including the left dorsolateral prefrontal cortex (dlPFC; Cattaneo et al., 2014a, b), the posterior parietal cortex (Cattaneo et al., 2014b), and visual cortical areas such as the lateral occipital complex (Cattaneo et al., 2015; Lacey et al., 2011). Likewise, frontal cortical activation has also been shown during the aesthetic judgment of beauty with the left dlPFC (Cela-Conde et al., 2004, 2009, 2013; Ishizu & Zeki, 2013), PFC (Cela-Conde et al, 2004; Jacobsen 2006), frontomedian cortex (Jacobs et al., 2012; Jacobsen et al., 2006), and medial orbitofrontal cortex (mOFC; Kawabata & Zeki, 2004; Ishizu & Zeki, 2011; 2013) showing higher engagement when participants aesthetically judged artwork as beautiful. In contrast, a reduced engagement of regions within the frontal lobe (Nakamura & Kawabata, 2015) and an increased engagement of the motor cortex (Kawabata & Zeki, 2004; Nakamura & Kawabata,

2015) was shown when participants aesthetically judged artwork as ugly, which suggests an action readied aversion effect during the viewing of artwork that is judged as ugly by the viewer. Therefore, the frontal lobe and its associated neural networks may be significant for aesthetic appreciation and the aesthetic judgment of beauty, which implies partial common neurological underpinnings for both aesthetic appreciation and the aesthetic judgment of beauty (for a meta–analysis, please see Boccia et al., 2016). In a similar vein, brain regions involved in reward computation and emotional processing, such as the caudate nucleus (Vartanian & Goel, 2004), cingulate gyrus (Jacobs et al., 2012; Vartanian & Goel, 2004), insula (Cupchik et al., 2009; Di Dio et al., 2007, 2011, 2016; Ishizu & Zeki, 2013; Osaka et al. 2012), and ventral striatum (Lacey et al., 2011; Vessel et al., 2012), have been shown to be engaged during aesthetic appreciation and the aesthetic judgement of beauty. Although aesthetic appreciation and the aesthetic judgment of beauty may employ different cognitive processes, the aesthetic appreciation and aesthetic judgment of beauty towards artwork may recruit similar brain areas, and likewise, their underlying neural networks that facilitate the experience of emotion.

In consideration of the neural networks engendering aesthetic experience, simply viewing (Lacey et al., 2011 and Mizokami et al., 2014) and aesthetically judging (Ishizu & Zeki, 2011; Rasche et al., 2023) visual art demonstrated a coupling between visual and prefrontal limbic areas, suggesting an interplay between perception and the coding of emotion and reward (i.e., hedonic value; Rolls et al., 2019; 2020; 2022). The executive control network (ECN) is predominantly characterized by the dlPFC and posterior parietal cortex and bases executive function and external cognition (Corbetta & Shulman, 2002; Menon & Uddin, 2010; Shen et al., 2020). Hence, the ECN may aid in sustaining a viewer's engagement, such as aesthetic evaluation, throughout a pleasurable aesthetic experience (Belfi et al., 2019; Cattaneo et al., 2014; Cela Conde et al., 2004; Kirsch et al., 2016). The default mode network (DMN),

with main hubs in the medial prefrontal cortex (mPFC) and posterior cingulate cortex extending into the precuneus (PCC), is active at rest and sustains internally directed cognition associated with prior experience and knowledge (i.e., memory), such as imagination, self-referential processing, and hypothetical thinking (Buckner et al., 2008; Raichle & Snyder, 2007). It has shown a reduced suppression towards increased feelings of being moved by artwork, suggesting an increased engagement of self-referential processing throughout pleasurable experiences towards emotionally evocative and moving artwork (Belfi et al., 2019; Vessel et al., 2012; 2019; but also see Cela-Conde et al., 2013). The ECN and DMN fluctuate with one another via frontal-striatal circuitry situated within the reward network (Ciricugno et al., 2023) to generate pleasure (Berridge & Kringelbach, 2015) within an affective space (Rolls, et al., 2019; 2020; 2022).

Moreover, the salience network (SN), consisting mainly of the insula and anterior cingulate cortex (ACC), dynamically switches engagement between the ECN and DMN to direct cognition towards (Menon & Uddin, 2010; Seeley et al., 2007) and process the emotion of salient stimuli (Uddin, 2015; Uddin et al., 2017), such as an artwork's salient perceptual or emotional features. Indeed, the SN and ECN have been recruited in judging a painting's beauty and perceptual features (Ishizu & Zeki, 2013) alongside engaging with a painting's depicted emotions (Cupchik et al., 2009). Moreover, passively viewing (Lacey et al., 2011; Vartanian & Goel, 2004) and judging visual artwork as beautiful (Di Dio et al., 2007; 2011; Rasche et al., 2023; Zeki et al., 2011) led to neural activation spanning across the visual cortex, SN, and DMN. Comprised of the inferiorparietal sulcus, superior temporal sulcus, and premotor cortices, the mirror neuron system (MNS) supports the comprehension of another's actions and intentions, alongside the physical imitation of them (Rizzolatti & Craighero, 2004); the recruitment of sensorimotor areas throughout aesthetic experience may be indicative of implicit motor responses that simulate an artwork's depicted actions yet also the techniques to produce

such artwork. This bodily engagement may be further be associated with the emotional salience of artwork via the employment of empathic processes to feel into artwork (Kirsch et al., 2016; Freedberg & Gallese, 2007; Gallese 2017; 2019). Therefore, the general functionality of neural networks based within perception, emotion, reward, and cognition may be catered to generate pleasure and engagement throughout aesthetic experience.

Taken together, the aesthetic experience may depute the co–activation of neural networks and their associated nodes engendering reward computation and emotional processes, which may contribute to the both the viewer's judgement of beauty on and their appreciation of visual artwork. Indeed, aesthetic emotions have been posited to consist of two classes (Kant 1790/2001; Menninghaus et al., 2019). The first class designates more ordinary emotions (e.g., sadness, happiness), while the second class is related to aesthetic feelings, such as the feeling of beauty. Therefore, the activation of neural networks and regions associated with emotion during the aesthetic judgement of beauty may be due to the viewer's feeling of beauty, while the activation of neural networks and regions associated with emotion during aesthetic appreciation (i.e., liking) may be due to the viewer's subjective felt pleasure associated with the emotions felt throughout aesthetic experience.

Importantly, a problem arises within neuroscientific methodology in how the aesthetic experience is evaluated. Indeed, a clear criterion in asking the viewer to evaluate artwork has not been determined. For example, Jacobsen and colleagues (2006) asked participants to indicate whether a pattern was beautiful on a dichotomous scale (yes vs. no) while Ishizu and Zeki (2011) asked participants to group paintings into beautiful, indifferent, or ugly. Cattaneo and colleagues (2015) asked participants to indicate if they liked a painting on a dichotomous scale (yes vs. no), while Lacey and colleagues (2011) asked participants to rate on a 5–point scale how much they like a painting. Alongside the differences in the stimuli investigated, the differences in methodological paradigms for aesthetic evaluation may address different

constructs of “beauty” or “appreciation”, which may be reflected in the difference of neurological findings across studies. This aim is to not critique the methodology of neuroscientific research investigating the aesthetic experience, yet to bring attention to the manner (please see Wittgenstein, 1958/1968; 1966/1987) when interpreting their findings.

2. Predictive Processing

The predictive processing account claims that the brain uses previous knowledge to explain incoming sensory information, and this predictive nature of the brain minimizes the mismatch between sensory and expected information spawned by one’s environment (Kesner, 2014; Van de Cruys, 2017; Van de Cruys & Wagemans, 2011). As an up–and–coming theoretical account of aesthetic experience, predictive processing catered to aesthetic experience suggests that the brain actively predicts sensory information regarding the aesthetic experience in hand (Kesner, 2014; Sarasso et al., 2020; Van de Cruys, 2017; Van de Cruys & Wagemans, 2011). These predictions are grounded on an interplay between low–sensory information and high–order cognitive processes to compare incoming sensory data with internal schematic representations. Mismatches denoting incongruencies (i.e., ambiguity) within these comparisons are deemed prediction errors, which occurs when a visual artwork presents salient (e.g., novel) content that is not initially represented by previous knowledge. Therefore, prediction errors mark perceptual saliency, which is consequentially reduced by updating previous knowledge via predictive feedback loops to decipher an artwork’s ambiguity. This allows a viewer to make sense of or understand visual artwork and consequently experience pleasure (Kesner et al., 2014; Sarasso et al., 2020; Van de Cruys, 2017; Van de Cruys & Wagemans, 2011). In other words, deciphering an artwork’s ambiguity may be described as the processes behind identifying and understanding what is depicted by the artwork, regardless of its content.

As such, aesthetic appreciation may be linked to an intrinsically rewarding state of perceptual learning from solving perceptual saliency that promotes attentional resources to an artwork (Sarasso et al., 2020). This may be seen within the coupling of visual and prefrontal limbic areas throughout aesthetic engagement (Ishizu & Zeki, 2011; Lacey et al., 2011; Mizokami et al., 2014; Rasche et al., 2023) that is further impacted by a facilitation of pleasurable aesthetic engagement via the ECN (Cattaneo et al., 2014; Cela-Conde et a., 2013). This function of predictive processing within aesthetic experience may be seen within the recognition and understanding of facial configuration as depicted within Frances Bacon's *Autoportrait* (1971). Likewise, The VIMAP (Pelowski et al., 2017) suggests that the interplay between explicit classification and cognitive mastery engenders a latter evaluation stage via feedback loops to clarify an artwork's ambiguity. Therefore, the identification and classification of *what an artwork is* may occur through understanding an artwork's ambiguity via the updating of prediction errors through feedback loops between low–level and high–level brain areas, which may be partly attributed to the top–down and bottom–up processes employed by neural networks, such as the DMN, throughout the aesthetic experience (Belfi et al., 2019; Cela-Conde et al., 2009, 2013; Vessel et al., 2019). This interplay may provide an eventual sense of congruency between the viewer's perception and the artist's intentional portrayal of an artwork during the aesthetic experience.

Notably, perceptual learning is linked with emotionality: positive affect arises from a continuous reduction of prediction errors while negative affect arises from an increase or lack of reduction of prediction errors. Therefore, intense emotion and pleasure may arise from a state of high perceptual learning by reducing an artwork's perceptual saliency to its minimum, yet the artwork must initially induce a moderate to high level of perceptual saliency within the viewer (Kesner et al., 2014; Sarasso et al., 2020; Van de Cruys, 2017; Van de Cruys & Wagemans, 2011). Therefore, the updating of prediction errors may be a

transformative emotional experience incasing positive affect and reward (Kesner, 2014; Van de Cruys, 2017; Van de Cruys & Wagemans, 2011), and thus, vital to the intensity of an aesthetic experience (Sarasso et al., 2020; Van de Cruys et al., 2023). Indeed, Lacey and colleagues (2011) found that viewing images of artwork vs. photographic replications of such artwork lead to a higher recruitment of the ventral striatum, which was driven by the activation of visual occipital areas responsible for the processing of low–sensory information. Therefore, the intensity of reward during the viewing of artwork may be higher when compared to more daily visual experiences that is based within aesthetic context. In a similar vein, the VIMAP (Pelowski et al., 2017) states that, depending on the self–relevance and schematic congruency promoted by the cognitive mastery processing stage, the aesthetic experience's intensity of emotion and reward has transformative potential within the individual, which compliments the recruitment of the DMN and its role in self–referential processing (Buckner et al., 2008; Raichle & Snyder, 2007). Therefore, commonalties between accounts explaining the aesthetic experience lies within the viewer's emotional experience, which may have direct implications on the aesthetic appreciation of artwork. In conclusion, predictive processing theory agrees with neurological findings in that both emotional and reward–related processes are pivotal to the aesthetic experience and its corresponding outputs.

3. Embodiment and Empathy

For situations with an abundance of prediction errors and, consequently, strong negative emotion, the predictive brain may recruit the body's motor system to efficiently predict the external environment in hand (Sarasso et al., 2020; Van de Cruys, 2017). This compliments motor embodiment's, the engagement of motor neural areas during cognitive processes, and empathy's, the ability to understand another person's emotions, recruitment of

the MNS, which is engaged for the execution and perception of an action (Bonini et al., 2017; 2022; Thompson et al., 2019). Within an aesthetic context, Einfühlung, translating to "feeling into", posits that viewers may feel into and comprehend a visual artwork by employing empathetic processes via bodily perspective taking (Ganczarek et al., 2018; Vischer, 1994). In hand, the Embodied Simulation Account for Aesthetic Experience (Freedberg & Gallese, 2007; Gallese 2017;2019) suggests that the MNS is utilized to mirror and "feel into" artworks via motor resonance, which facilitates the application of bodily engagement throughout aesthetic experience (Kirsch et al., 2016). The crux of these theories postulates that visual art perception simulates an artwork's content via a motor-induced empathic resonance to take perspective and viscerally feel an artwork's depicted emotion, thus bridging emotional processing and bodily engagement within aesthetic experience.

In parallel, emotional empathy is associated with sharing and feeling another's emotions (Dvash & Shamay-Tsoory, 2014), perhaps through an automatic simulation of another's emotions regardless of the valence, with the fronto-insular and anterior cingulate cortices (ACC) being hubs within this experience (Bernhardt & Singer, 2012; Fallon et al., 2020). This neural system underlying emotional empathy further overlaps with the SN, which outside orienting attention towards unexpected or novel stimuli (Seeley et al., 2007; Menon & Uddin, 2011), is associated with emotional and bodily interoception (Berntson & Khalsa, 2021; Fallon et al., 2020)., mirroring particularly subjective (i.e., disgust) and objective (i.e., pain) negative feelings (Uddin, 2015; Uddin et al., 2017), alongside affective and hedonic valuation, especially towards others (Apps & Ramnani, 2014; Rolls et al., 2019). Hence, many neuroscientific studies investigating aesthetic experience show that the SN is compounded by activation of the sensorimotor network extending into the MNS (Cupchik et al., 2009; Di Dio et al., 2007; 2011; Ishizu & Zeki, 2013; Lacey et al., 2011; Lutz et al., 2013; Vartanian & Goel, 2004), indicating that the neural intricacies behind sharing and feeling

another person's emotions stem onto sharing and feeling an artwork's depicted emotional content (please see van Leeuwen et al., 2022). Therefore, individuals may empathetically engage with artwork through an inward imitation of the actions and emotions depicted within artwork, which may occur through the activation of a viewer's internal schematic representations of such empathic-motor resonance as delegated by neural systems underlying empathy and mirroring another (Freedberg & Gallese, 2007; Gallese, 2017; 2019).

Indeed, emotions elicited by art can be attributed to the self–reported activation and deactivation of bodily sensations regardless of the artwork's content (Schino et al., 2021). Furthermore, increased bodily engagement has been associated with negative emotional stimuli, such as threatening (Gough et al., 2013), fearful (Schutter et al., 2008), and disgusting (Lagravinese et al., 2017; Vicario et al., 2017) stimuli. Notably, a suppression of bodily recruitment may occur due to empathetic cognitive processes associated with distancing oneself from such pain (Avenanti et al., 2006). Of interest, mimicry of painful facial expressions was shown to increase beauty judgement ratings for painful vs. neutral portraits and was positively modulated by art expertise and empathic ability (Ardizzi et al., 2020) and may be reflected by the recruitment of mirror neuron and empathy systems (Adrizzi et al., 2021). Furthermore, higher bodily engagement during the viewing of *non–figural* representational paintings was associated with prior training in replicating brushstroke movements inherent to the stylistic method used to produce such paintings (Finisguerra et al., 2021), and a negative association was found between bodily engagement and aesthetic appreciation, which was partly mediated by a higher empathetic disposition (Finisguerra et al., 2021). In line with empathetic ability positively modulating the effect of bodily mimicry on aesthetic judgement (Ardizzi et al., 2020), individuals with a stronger ability to understand another's emotions may experience more reward during aesthetic experience that is heightened by reduced explicit bodily engagement (Sarasso et al., 2020). Considerably, the

viewer may be able to feel into artwork with and without human figures (Ganczarek et al., 2018; Vischer 1873/1994), such as empathetically engaging with visual artwork solely depicting objects (Freedberg & Gallese, 2007). Therefore, the intersection of emotion, empathy, and bodily processes proves pivotal to the aesthetic experience and may play a significant role in the viewer's aesthetic experience. In line with predictive processing theory (e.g., Van de Cruys, 2017), this specific recruitment of the mirror neuron system in displeasure, yet not within the realm of negative emotional content, may partly explain the heightened recruitment of motor brain areas during the aesthetic experience of artwork judged to be ugly (Kawabata & Zeki, 2004; Nakamura & Kawabata, 2015); the feeling of ugliness may arise from a unpleasant experience and employ more bodily processes in comparison to the feeling of beauty, which may arise from a pleasant experience and employ less bodily processes.

Deemed the "stopping for knowledge" account for aesthetic experience (for a discussion, please see Sarasso et al., 2020), two learning approaches may be utilized to solve an artwork's saliency and obtain pleasure: either through reward-seeking behavior to modify the external environmental representations for extrinsic reward (i.e., wanting) or through a cognitive approach to modify internal representations to generate intrinsic reward (i.e., liking). In the case of aesthetic experience, physically modifying the artwork in question may not be feasible. Thus, motor inhibition may diminish the desire for extrinsic reward and generate intrinsic reward by allocating attentional resources for implicit learning alongside employing implicit mirroring mechanisms to make sense of an artwork (Gallese et al., 2017). As such, aesthetic experience may be a self-referential process situated within empathic-motor resonance to reduce perceptual saliency through the updating of prior knowledge (please see further Sachelli et al., 2022).

Indeed, the DMN regulates internally directed cognition, such as self-referential processing and cognitive empathy (i.e., mentalizing,), the adoption and attribution of another's mental state, such as their emotions, intentions and beliefs (Arioli et al., 2021; Buckner et al., 2008; Raichle & Snyder, 2007). Mentalizing recruits the medial prefrontal cortex (dmPFC), posterior inferior frontal gyrus (IFG), and the ventral premotor cortex (Molenberghs et al., 2016), alongside the bilateral temporoparietal junction (TPJ) and the precuneus (Bzdok et al., 2013; Buckner et al., 2008; Dvash & Shamay-Tsoory, 2014). Heightened recruitment of the DMN was found in feeling moved by artwork (Belfi et al., 2019; Vessel et al., 2012; 2019; but also see Cela-Conde et al., 2013), which may reflect an eventual coherency between an artwork's perceptual saliency and the viewer's prior knowledge via a cognitive empathic mechanism. In addition to the SN's roles in emotional empathy, interoception, and stimulus detection, it further acts as a mediatory to dynamically switch between external and internal cognition via employment of the ECN and DMN (Menon & Uddin, 2010), whose fluctuation depends on a dynamic of pleasure based within frontal-striatal circuitry (Berridge & Kringelbach, 2015); Ciricugno & Slaby et al., 2023). Joint recruitment of these networks has been implicated across various paradigms investigating aesthetic experience, including passive viewing (Lacey et al., 2011; Vartanian & Goel, 2004), aesthetic judgement (Di Dio et al., 2007; 2011; Ishizu & Zeki, 2011; 2013; Rasche et al., 2023) and explicitly engaging with an artwork's emotional content (e.g., Cupchcik et al., 2009). Therefore, implicit learning within an aesthetic context may engage neural networks underlying self-referential and empathic processes (Pelowski, 2015; Pelowski et al., 2017; Sarasso et al., 2020), to appreciate and make meaning of artwork (Pelowski et al., 2018ab; Schoeller et al., 2018).

4. The Cerebellum as a Predictive Machine

Of high interest, the cerebellum has been posited to work as a predictive mechanism that matches internal schematic representations with the external environment in a regulatory fashion by integrating both bottom-up and top-down processes to efficiently navigate one's environment, particularly within the social, affective, and motor domains (Adamaszek et al., 2017; Cattaneo et al 2022; Van Overwalle, 2020). Indeed, the cerebellum is considered a regulatory hub orchestrating the call of internal models represented within limbic, subcortical, and associative cortical areas via functional and anatomical connections situated within cerebellar-thalamo-cortical loops (Buckner et al., 2011; Habas et al., 2009; Palesi et al., 2020). The anterior cerebellum plays a role sensorimotor functions, such as mirroring to understand another's actions via functional connections with the MNS/SMN (Adamaszek et al., 2017; Habas et al., 2009; King et al., 2019 Van Overwalle et al., 2014); in parallel, the posterior cerebellum exhibits a medial to lateral functional gradient. Medial portions may play a role in sensorimotor and emotional empathic processes via functional connectivity with the SN and MNS/SMN, while lateral portions (i.e., Crus I/II) may play roles in higher social and affective functions, such as emotional evaluation and mentalizing, via functional connections with the ECN and DMN (Adamaszek et al., 2017; Cattaneo et al., 2022; Guell et al., 2018; Klein et al., 2016; Van Overwalle, 2020). Although the cerebellum may be split into anterior and posterior counterparts, intra-cerebellar connections surmise a partial overlay of these functions, implying that predictive processing may simultaneously utilize affective, cognitive, and motor faculties to make sense and effectively learn about one's environment (Adamaszek et al., 2017; Cattaneo et al., 2022; Timmann et al., 2010; Van Overwalle et al., 2020). Indeed, the anterior cerebellum is phylogenetically older than the posterior cerebellum, suggesting that the predictive nature in understanding another's mental states and

emotions evolved from predicting another's actions and intentions behind those actions (Van Overwalle et al., 2020).

When presented with the visual stimulus of artwork, this predictive mechanistic role of the cerebellum may be essential to the predictive processes that mediate pleasure and engagement throughout aesthetic experience (Kesner et al., 2014; Sararsso et al., 2020; Van de Cruys, 2017; Van de Cruys & Wagemans, 2011). Indeed, the cerebellum has been posited to play an essential role in aesthetic experience, based within its functional and anatomical connections reaching far throughout the cerebrum (please see Adamaszek et al., 2023). In addition to the aforementioned networks involved in aesthetic experience, the aesthetic evaluation of visual art, yet not their non-artistic counterparts, has been coupled with cerebellar activation (Di Dio et al. 2007; 2011; Lutz et al. 2013; Mizokami et al. 2014). Moreso, the beauty (Ishizu & Zeki, 2013) and sublimity (Ishizu & Zeki 2014) of visual artwork has shown to recruit the posterior cerebellum with it further being implicated in experiencing beauty differing in valence, such as joy or sorrow (Ishizu & Zeki 2017).

Considering the cerebellum's generation and updating of internal models to make sense of social interactions by understanding another's actions, beliefs, intentions, and emotions, the cerebellum may call on emotional, cognitive, and motor efferent copies via functional connections with subcortical, limbic, associative cortical areas that are subsequently utilized throughout aesthetic engagement to solve an artwork's perceptual salience. In hand with the neural networks based within aesthetic experience, the cerebellum may promote peak aesthetic experiences, such as chills or feeling moved, that concur with instances of high perceptual learning via self-referential processes (Pelowski et al., 2015; 2017; Sarasso et al., 2020), perhaps reflecting empathic processes that underly the meaningfulness and appreciation obtained throughout aesthetic experience (Pelowski et al., 2018; Schoeller et al., 2018). In this case, pleasure arises from the journey of solving an

artwork's ambiguity (Sarasso et al., 2020; Van de Cruys et al., 2023), explaining how moving aesthetic experiences can occur from artwork of both sad and joyful origin (e.g., Menninghaus et al., 2015).

5. Feeling Moved

Given the presumed predictive processes underlying aesthetic experience within a social and empathic context, feeling moved occurs towards a plethora of different scenarios across an individual's lifespan, yet in particular to social events that provoke a form of self-relevance towards past memorable experiences (Menninghaus et al., 2015; Hänninen & Koski-Jännes, 2023). Moving events stem from ethical or moral deeds, strengthening social relationships, empathizing with another's sorrow or joy, promoting achievement and social values, finding an abstract or concrete entity touching, alongside beauty within art and nature (Landmann et al., 2019; Hänninen & Koski-Jännes, 2023). Moreover, physiological sensations co-develop within the feeling moved, such as goosebumps, warmth and tears (Benedek & Kaernbach, 2011; Schubert et al., 2018; Seibt et al., 2018), and these sensations may stem from prosocial and empathic occurrences that make meaning, such as social bonding and social closeness (Schubert et al., 2018; Menninghaus et al., 2015) across cultures (Zickfeld et al., 2019). These incidents of feeling moved have been shown to span across own-life events, media represented real-events, alongside fictional events, such as visual art (Hänninen & Koski-Jännes, 2023; Menninghaus et al., 2015; Schindler et al., 2022). Of importance, being moved has been presumed to be a mixed emotion that is characterized by both positive and negative affect (Cova & Deonna, 2013; Menninghaus et al., 2015; Schindler et al., 2022; Seibt et al., 2018), and a distinction may be made in feeling joyfully and sadly moved. Both cases of joy and sadness within feeling moved are suggested to stem from similar social circumstances, such as prosociality and social connectedness, yet respectively in relation to the moving

experience's negative or positive salience, such as weddings and funerals. The strong salience of such events alongside their self-relevance may provoke a meaningfulness that is acquired through social and cognitive processes (Hänninen & Koski-Jännes, 2023; Landmann et al., 2019; Menninghaus et al., 2015; Schindler et al., 2022; Seibt et al., 2018; Zickfeld et al., 2019). Thus, feeling moved may transpire from experiencing personal attachment to an emotional scenario in hand, extending from explicit social scenarios to abstract scenarios, such as artwork (Hänninen & Koski-Jännes, 2023; Schindler et al., 2022; Schubert et al., 2018).

Hence, visual artwork or films denote one of the frequent experiences in feeling moved; however, they are generally within the realm of negative content (Menninghaus et al., 2015). Indeed, the enjoyment of films and music depicting sadness was coupled by feeling moved (Hanich et al., 2014; Wassiliwizky et al., 2015) alongside being moderated by one's empathic ability (Eerola et al., 2016), while sad stories were shown to make meaning within one's life (Cova et al., 2017). Within visual art, the notion of crying has been posited to related to self-relational processing to provide meaning and is further related to the experienced beauty and goodness of artwork (Pelowski, 2015; Sawada et al., 2024). Thus, feeling moved by artwork seems to be of a specific affective signature that contains both joy and sadness, which is impacted by how art resonates and provides meaning to the viewer (Cova & Deonna, 2013; Menninghaus et al., 2015; Schindler et al., 2022). Indeed, feeling sadly and joyfully moved by fictional events was associated with experiences depicting both pleasant and unpleasant content, while feeling sadly and joyfully moved by real-life events were respectively associated with experiences either depicting pleasant and unpleasant content (Menninghaus et al., 2015; Schindler et al., 2022). Regardless, feeling moved seems to have an overall positive signature, in that both joyful sadly moving experiences provide a subjectively pleasant experience, regardless of the content (Hannien & Kosel-Jannes, 2023;

Meninghaus et al., 2015; Schindler et al., 2022; Schubert et al., 2018; Seibt et al., 2018; Zickfeld et al., 2019). This may be based within the meaningfulness that feeling moved provides, which perhaps stems from a sustained motivated engagement with the scenario in hand that provides novelty concerning impactful life occurrences (e.g., Cova et al., 2017). Within the notion of predictive processing for an aesthetic context, feeling moved may highlight the general attainment of novel experiences that provide meaningfulness and making sense of the world around us based within its contextual saliency of self-relevance (Sarasso et al., 2020; Van de Cruys et al., 2023). Of interest, moving experiences seemed to have been within the negative domain, especially for artistic (i.e., fictional) content versus real-life content (Mennignhaus et al., 2015; Schindler et al., 2022). This may be based within the psychological distance employed throughout aesthetic engagement, especially so within the realm of negative artistic content (Menninghaus et al., 2017).

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6. Philosophical considerations

Deemed the Pleasure of Weeping, current philosophical debate over the aesthetic experience concerns the enjoyment and pleasure of negatively emotional artwork, such as those depicting pain, sadness, and tragedy (for a recent inquiry please see Mazzocut-Mis, 2021). As a viewer, the individual observes, from a *distance*, the negatively emotional content depicted within artwork, such as the cannibalism depicted within Goya's *Saturn Devouring One of his Sons* (1820-1823). This argument complements the Distancing–Embracing model of the enjoyment of negative emotions in art reception (Menninghaus et al., 2017), which states that the interplay of distancing and embracing with negatively emotional artwork lies within schematic representations facilitating the viewer's understanding that they are, indeed, not experiencing real–life events but artworks depicting negatively emotional content. As mentioned previously, "feeling into" is commonly conceptualized as empathy; however, it

can be further classified as aesthetic empathy, explicitly "feeling into" human artefacts (i.e., paintings), and interpersonal empathy, explicitly "feeling into" real–life situations (Ganczarek et al., 2018; Vischer 1873/1994). Through distance, viewers may positively embrace such negatively emotional content via an aesthetic empathetic engagement (Freedberg & Gallese, 2007; Ganczarek et al., 2018; Vischer 1873/1994), which leads to the pleasurable aesthetic experience of artworks depicting negative emotions, and further, basing how an individual may feel moved by an artwork depicting negative content.

Ther

efore, the aesthetic experience of negatively emotional artwork is not of experiencing tragic or negative events firsthand; it is a quasi–experience by experiencing these depicted events through a secondary source (i.e., a painting), which further classifies the emotions from the aesthetic experience as quasi–emotions (Mazzocut-Mis, 2021; Rozzoni, 2021). Accordingly, genuine emotions come from real situations, while quasi–emotions come from situations in fictional (i.e., phantasical) contexts. Although presented only according to the scope of this introduction, this calls the question of the image (Husserl, 1898-1925/2005; Rozzoni, 2020), which is never perceived in the present as it is a fabrication of an illusory object. Thus, the *image thing* may be seen as a physical image, such as a canvas, while the *image object*, also known as the representing image, represents and depicts the object on the physical image, such as the painting on the canvas. Thus, the *image object does not exist* and will never exist as it comes from imagination. Accordingly, the *image subject*, what is represented and depicted by the image object (i.e., a fish being represented by the painted image of a fish) *can exist*, yet this depends whether the image subject is real or phantasical (i.e., a fish from imagination or a fish that has been present on earth). Therefore, image subjects are not present in real life but are *presentified* within the physical image. However, persons can believe in the subject presentified within the image, and in these instances, the distance

between the viewer and the image object may at times be too little to positively embrace negative emotional artwork.

Acco

rdingly, the experience of quasi–emotions depends on either being aware or not aware of the *illusion as not being real* (Mazzocut-Mis, 2021). A cyclic notion between illusion and awareness allows the viewer to experience the emotion of the depicted image, such as visual artwork. Being unaware of and believing in the illusion mediates the emotional experience; however, being aware of and not believing in the illusion distances the viewer and allows the acceptance of experienced emotions as quasi–emotions. This interplay can be further explained by the doubling of ego (Rozzoni, 2021). The real ego is the perception of the present, the real world, while the phantasy ego is the perception of the presentified, the imaginary world. Like the cyclic notion of illusion and awareness, the real ego grounds the viewer within the real world, while the phantasy ego facilitates the viewer's experience of the presentified imaginary world. Without awareness and the real ego, the viewer may become entirely immersed in the artwork's depicted illusion by completely experiencing such through the phantasy ego, which results in the belief that the experienced emotions are real. Conversely, without the illusion and phantasy ego, a viewer would not be able to embrace and experience the emotions depicted by the artwork. Through the communication of these egos modulating the awareness of the illusion, viewers may become immersed, yet not completely, in the image depicted by artwork and experience the associated quasi–emotions.

Hence, empathy may imply that viewers are not explicitly experiencing the emotions *themselves*, but they are *also* recognizing and understanding, or "feeling into", *another's* emotion. In this vein, aesthetic empathy may reflect a viewer's engagement with an artwork as *not* an illusion via the real ego, while interpersonal empathy may reflect the viewer's engagement with an artwork as an illusion via the phantasy ego. As such, aesthetic empathy

may mediate the viewer's understanding that they are engaging with another thing (i.e., the presentified) by not being submerged within the illusion via the real ego. Yet, interpersonal empathy may mediate the submersion of the viewer within the illusion, which leads to the viewer's believing that the presentified is real via the phantasy ego. Notably within an explicit aesthetic context, these concepts may also be further explained within the constructs of mentalizing and emotional empathy, respectively representing aesthetic empathy and interpersonal empathy. The experience of quasi–emotions during aesthetic engagement may be delegated by aesthetic (i.e., mentalizing) and interpersonal (i.e., emotional) empathy, which represent the communication of egos underlying the awareness of the illusion. Therefore, the MNS, alongside neural systems underlying mentalizing and emotional empathy, may promote an empathic-motor resonance for the inward imitation of the actions and emotions depicted within artwork (Freedberg & Gallese, 2007; Gallese et al., 2017). This may in part reflect the viewer's recognition and understanding that they are not solely engaging with an artwork as a human artefact but that they are also engaging with an artwork as a real–life event.

Moreover, the induction of the phantasy ego gives the viewer novel perspectives, and in effect, new variations of the real ego, as these two egos are *not severed* and *consistently interplay* throughout the aesthetic experience (Rozzoni, 2021), which may reflect the interplay of neural systems commonly revealed across aesthetic experience, perhaps in part orchestrated by the cerebellum. Through the inductions of new variations of the real ego from this interplay, the viewer may take novel perspectives, which may allow the viewer to be open to new values and meanings. This gives reason for the transformative capabilities of the aesthetic experience, which may be due to the updating of schematic representations (Kesner, 2014; Van de Cruys, 2017; Van de Cruys & Wagemans, 2011) via top–down and bottom–up effects employed during art engagement (e.g., Pelowski et al., 2017). The outcome of such

experiences within an aesthetic context may underly the notion feeling moved by an artwork (Hänninen & Koski-Jännes, 2023; Landmann et al., 2019; Menninghaus et al., 2015; Schindler et al., 2022). Moreover, humans desire novelty, and in the case of negatively emotional artwork, the experience of the novel immorality, such as a another's painful experience, is in itself desirable as it gives viewers knowledge and experiences that are normally not experienced firsthand (Mazzocut-Mis, 2021). However, if negatively emotional artwork is experienced too closely, not at a distance, then the pleasure diminishes, and negativity dominates the aesthetic experience (Mazzocut-Mis, 2021; Meninghaus et al., 2017; Pelowski et al., 2017). Hence, the common occurrence of being moved by artwork within a negative context (Cova et al., 2017; Hanich et al., 2014; Eerola et al., 2016; Meninghaus et al., 2015; Pelowski, 2015; Pelowski et al., 2017; Schindler et al., 2022; Wassiliwizky et al., 2015) may be based in experiences that are not feasible on a firsthand basis. Through the partial orchestration of the cerebellum, both aesthetic and interpersonal empathy may be attributed to the recruitment of the mirror neuron and social systems throughout the aesthetic experience (Freedberg & Gallese, 2007; Gallese, 2017; 2019), which, alongside the induction of other neural systems underlying self-referential and attentional processing, such as the DMN and ECN (Belfi et al., 2019; Cela-Conde et al., 2009, 2013; Vessel et al., 2019), provides a sense of congruency (i.e., updating of prediction errors) between the artwork and the viewer's schematic representations (Kesner, 2014; Sarasso et al., 2020; Van de Cruys, 2017; Van de Cruys, et al., 2023; Van de Cruys & Wagemans, 2011) via the psychological distance (Menninghaus et al., 2017) mediated by the doubling of ego (Rozzoni, 2021) and the cyclic notion of illusion and awareness (Mazzocut-Mis, 2021). Viewers gain pleasure via this distanced mechanism (e.g., Avenanti et al., 2006; Menninghaus et al., 2017), and, under some circumstances, they may feel moved, even in the case of negatively emotional artwork. In line with the coactivation of neural areas associated with emotion and reward during the

aesthetic experience of visual artwork (i.e., Cupchik et al., 2009; Di Dio et al., 2007, 2011, 2016; Ishizu & Zeki, 2013; Jacobs et al., 2012; Lacey et al., 2011; Osaka et al. 2012; Vartanian & Goel, 2004; Vessel et al., 2012), pleasure may be derived from (quasi) emotions in that artworks depicting all sorts of emotions may be appreciated in part by the employment of empathetic processes.

7. Implications

Neural underpinnings of the visual aesthetic experience have grounded the aesthetic judgment of beauty, aesthetic appreciation, and emotional appraisal of visual artworks within distinct neural networks and their respective nodes. Nonetheless, the interplay of bottom–up and top–down effects attributed to the neurological findings behind the aesthetic experience may facilitate predictive processes modulating the experienced reward and emotion during the observation of visual artwork. Moreover, embodied cognitive processes associated with empathy have been shown to play a pivotal role in the aesthetic experience. As such, the viewer may employ motor-empathic processes to feel into an artwork and experience their depicted emotions; moreover, this indicates an experience of quasi–emotions during the observation of artwork in that the viewer is not experiencing emotions solely on a firsthand basis. Therefore, an emotional experience from artwork may come from aesthetically engaging with an artwork from a distance, all the while, fostering pleasure and reward within the viewer. This distance behind the experience of emotion may be mediated by the doubling of real and phantasy egos, which facilitates the cyclic notion of illusion and awareness. Through distance via the doubling of egos, aesthetic (i.e., emotional) and interpersonal (i.e., mentalizing) empathy may allow the viewer to experience artwork themselves and as another thing, which may be mediated by the neural networks and their nodes underlying predictive processing and social systems throughout the aesthetic experience. Although recent research

within neuroaesthetics has progressed in the following direction (e.g., Ardizzi et al., 2021; Vessel et al., 2019), future research should move away from the outputs of aesthetic appreciation and the aesthetic judgement of beauty and move towards the types of emotions felt by the viewer while engaging with a range artwork depicting different emotional content (e.g., happiness, sadness) or even of peak aesthetic experiences, such as feeling moved. This investigation may be further catered to uncovering neural correlates of aesthetic experience within a negative context. Given the employment of empathetic processes during aesthetic experience, research should also investigate the recruitment of social neural systems underlying empathy. In brief, the emotions felt by the viewer and empathetic processes present during the aesthetic experience should be strongly considered to promote the unification of accounts across a wide breadth of disciplines.

8. Research Questions and Endeavors

In light of investigating negative emotion across aesthetic experience alongside the implication of empathic and social processes within aesthetic experience, the second chapter of this dissertation aims to answer the research question: what are the neural correlates underlying the aesthetic experience associated with negative emotion? Moreover, are these neural correlates similar or different than those experiences associated with social negative stimuli or negative stimuli in general?

Hence, the first meta-analysis on the neural correlates associated with negative *visual* aesthetic experience was conducted in comparison to visual experiences within a social and general context to reveal *how* an individual engages with artwork pertaining negative affect and content. Findings demonstrate an orchestration of neural networks underlying motor-empathic resonance towards sharing and understanding another's emotion across stimuli, suggesting a common involvement of empathic processes across negative stimuli.

Interestingly, meta-analytic results revealed the secondary visual cortex to be particularly recruited within negative visual aesthetic experience, which may indicate that the context of experience, such as aesthetic, may subserve a moderation of the type of engagement a viewer undergoes.

Grounded within functional and anatomical connections throughout the cerebrum, the posterior cerebellum may be a predictive machine to promote navigation throughout one's environment within a social, motor, and affective context, particularly towards negative stimuli; likewise, motor-empathic resonance has been posited to lay within the core of aesthetic experience. Perceptual learning to compare incoming sensory information (e.g., a painting) with previous knowledge may explain the aesthetic experience in hand. Implicit learning may base feeling moved, which may result from an eventual coherency between the self and the artwork via empathic processes alongside experience with the arts. Therefore, the third chapter of this dissertation aims to answer: what is the role of the posterior cerebellum in feeling moved by visual artwork differing in negative and positive emotion? Is this based within individual differences of empathy or past knowledge within the arts?

Accordingly, transcranial direct current stimulation over the right posterior cerebellum (ctDCS) was utilized to investigate its role in feeling moved by visual artwork relating to individual differences in empathy and art experience. Findings revealed that participants with stronger empathic abilities generally felt more moved by negative artwork, while anodal ctDCS reduced feeling moved in those individuals with stronger empathic abilities or higher art experience. Hence, negative artwork may provide novel and meaningful experiences to be learned that are not necessarily present within an individual's real world context. Moreover, anodal ctDCS may have hampered a procession of internal models employed by individuals with more concrete routes in aesthetic engagement, which underly modes of implicit learning within an aesthetic context.

In brief, the fourth and final chapter of this dissertation concludes with summary remarks on the implications in how and why an individual engages with negative artwork within an interdisciplinary perspective encompassing the domains of neuroscience, philosophy, and psychology.

Dana Schutz. *Sneeze*. 2001.

Neural Correlates of Negative Emotion in Visual Artistic versus Social and Non-Artistic Stimuli: A Neuroimaging Meta-Analysis

1. Introduction

Aesthetic experience has been a marvel of human existence since prehistoric times (e.g., Aubert et al., 2019). Although debated heavily in its phenomenology and meaning, a classic example of aesthetic experience is in relation to visual artwork, where the viewer's liking or appreciation of, say, a painting may derive from felt emotions, ranging from ordinary emotions, such as happiness and sadness, to aesthetic feelings, such as the feeling of beauty or ugliness (Kant, 2001; Menninghaus et al., 2019). Therefore, emotion may be associated with the hedonic value derived from the sensation of looking at a painting (Skov & Nadal, 2021; Ureña & Nadal, 2023), and hence, with the recruited neural circuitry underlying the perception of visual artwork. Indeed, neuroscientific models explaining the visual aesthetic experience (henceforth aesthetic experience) generally propose that an interplay between different neural systems associated with sensation, reward, emotion, and cognition engenders top-down and bottom-up processes to entrain aesthetic engagement (Chatterjee & Vartanian, 2014; Pelowski et al., 2016; 2017; but also see Ciricugno et al., 2023). This view has been supported by a plethora of meta-analyses regarding aesthetic experience (e.g., Boccia et al., 2016; Brown et al., 2011; Chuan-Peng et al., 2020; Feng et al., 2021; Sacheli et al., 2022; Vartanian & Skov, 2014). The constructs investigated by these meta-analyses, and likewise by the neuroaesthetic literature, are largely within the domain of positive valence (i.e., positive aesthetic experience), encompassing beauty, pleasantness, pleasure, and aesthetic appreciation. Although right within their investigation of positivity, researchers have generally neglected *negative* aesthetic experience, referring to either repellent (from the artwork's perspective) or disliked (from the observer's perspective) visual artwork. This negligence may be related to the general affiliation

of aesthetics with the concept of beauty, hence the substantial meta-analytical evidence on the neural correlates of positive aesthetic experience.

As portrayed within expressionist movements, negativity has been depicted within valuable works of visual art, such as Francis Bacon's contorted Self Portraits (e.g., 1971) or the visceral disgust within Dana Schutz's Sneeze (2001). Viewers generally chose to actively engage with such paintings that hold negativity at their origin, yet if an artwork's negative content was actually unfolding in front of a viewer's eyes, then the observer may not be so keen to engage. Therefore, the question remains, *how* do persons engage with artwork depicting negativity? The Distancing-Embracing Model of the Enjoyment of Negative Emotions in Art Reception (Menninghaus et al., 2017) posits that the viewers psychologically distance themselves from a negative artwork to appropriately embrace the depicted negative emotions, thus circumventing the insurgence of intense negative emotions within themselves; in hand, this interaction facilitates aesthetic engagement. Likewise in a philosophical inquiry, The Pleasure of Weeping theory (Mazzocut-Mis, 2021) argues that this distance may require the understanding that the depicted subject matter or scenario is not a firsthand experience but a secondhand experience. Therefore, an awareness may persist and wither throughout the viewer's engagement with negative artwork: the awareness that the artwork as a secondary source permits distance while a lack of awareness permits embracement.

Aesthetic experience and the social brain have been posited to share a similar neural infrastructure (van Leeuwen et al., 2022), although the intentions and purpose of these mental faculties differ: engaging with an artwork versus socially interacting with another person. Therefore, distancing and embracement modeled at the neural level may be reflected within the social brain; particularly recruiting the empathy and mentalizing systems. Partial to interoception, the empathy system employs the anterior cingulate cortex (ACC), fronto-insular cortex (Berntson & Khalsa, 2021), and amygdala (Dvash & Shamay-Tsoory, 2014) to

automatically simulate and feel another's emotions (Bernhardt & Singer, 2012; Fallon et al., 2020). The empathy system further overlaps with the salience network, which processes the emotion of salient stimuli (Uddin, 2015; Uddin et al., 2017), such as an artwork's salient perceptual or emotional features (e.g., Cupchik et al., 2009). Mentalizing allows a mental representation of another's mental and affective states (Molenberghs et al., 2016) and recruits a neural system composed by the dorsomedial prefrontal cortex (dmPFC), temporo-parietal junction (TPJ), temporal pole and precuneus (Arioli et al., 2021b). The mentalizing system further overlaps with the default mode network (DMN; Buckner et al., 2008; Raichle & Snyder, 2007), which may facilitate feeling moved by integrating an artwork's content towards the self (Belfi et al., 2019; Cela Conde et al., 2013; Vessel et al., 2012). Comprised of the inferior parietal sulcus, superior temporal sulcus, and premotor cortices, the mirror neuron system (MNS) supports the comprehension of another's actions and motor intentions, alongside the physical imitation of them (Rizzolatti & Craighero, 2004). These systems are suggested to work in parallel to facilitate social interaction (Arioli et al., 2021b; Dvash & Shamay-Tsoory, 2014; Mainieri et al., 2013). Applied to aesthetic experience, *Einfühlung*, translating to "feeling into", posits that viewers may feel into and comprehend a visual artwork by employing empathetic processes via bodily perspective taking (Ganczarek et al., 2018; Vischer, 1873). Likewise, the Embodied Simulation Account for Aesthetic Experience (Freedberg & Gallese, 2007) declares that the MNS is utilized to "feel into" artworks via motor resonance. Hence, a simulation of the sensorimotor correlates behind the actions depicted within a painting, alongside those to produce a painting, may facilitate implicit bodily engagement via the viewer's motor system throughout aesthetic experience (Kirsch et al., 2016; Ticini et al., 2015).

The empathy system shows a particular role in feeling salient negative emotion, such as pain (Ardizzi et al., 2021; Lamm et al., 2011) and disgust (Craig, 2011; Wicker et al., 2003). Likewise, the empathy system has been implicated within viewer engagement towards artwork

depicting sadness (Osaka et al. 2012), ugliness (Ishizu & Zeki, 2011) and pain (Ardizzi et al., 2021) alongside artwork invoking negative emotional experiences of feeling moved (Vessel et al., 2012). The mentalizing system has been recruited across interactions with artistic depictions of mourning (Labek et al., 2018), rejection (Kross et al., 2007) and sorrow (Ishizu & Zeki, 2017), while aesthetically judging artwork as ugly (Di Dio et al., 2007; 2011; Kawabata & Zeki, 2004) revealed the recruitment of motor-related regions spanning across the MNS. Following a training period of art production techniques, a higher corticospinal excitability, an indicator of bodily engagement, predicted *lower* aesthetic ratings, which was mediated by an individual's mentalizing ability (Finisguerra et al., 2021). Importantly, many of these studies revealed neural activation that overlaps across the empathy, mentalizing, and mirror neuron systems (Di Dio et al., 2007; 2011; Ishizu & Zeki, 2011; 2017; Labek et al., 2018; Kross et al., 2007). Therefore, these systems may partly surmise the negative aesthetic experience via a self-other conceptual framework to appropriately interact with *another* based on the cognitive and emotional contexts of the situation (Bonini, 2017; Bonini et al., 2022). Such that feeling and understanding *another person* may stem onto the aesthetic engagement to feel and understand *a visual artwork*; especially so for a painting depicting negative emotion. Partly based within simulating visceromotor correlates of a visual artwork's negative content, the embracement of negative artwork may lie within empathy, a firsthand simulation of the artwork's depicted feelings within oneself, while the employed distance may lie within mentalizing, a secondhand understanding that the negative emotion is occurring within the artwork and not oneself.

Social neuroscientists have focused heavily on the perception and experience of negative emotions (e.g., Arioli et al., 2021a; Chang et al., 2015) while neuroscientists in visual aesthetics have somehow neglected art-related negative emotions. To fill this gap, we aimed for the first meta-analysis on the neural processes associated with negative aesthetic experience. Based on individual studies of visual negative artistic content alongside the neural

interpretation of the Distancing-Embracing Model and Pleasure of Weeping, we expected to find neural activation spanning across the empathy, mentalizing, and mirror neuron networks for the processing of negative visual artistic stimuli. This expectation reflects an even more interesting research question: is negative visual aesthetic experience (VAE) arising from artistic stimuli comparable to the visual processing of general non-artistic images depicting negative emotional content (i.e., negative visual non-artistic experience, VNE)? Given the origins of social cognition within visual aesthetic theory, may VAE neural activation be akin to the neural correlates of negative social stimuli, such as non-artistic images solely depicting human content (negative visual social experience, VSE)?

To understand the overlapping and specific brain regions between these different negatively based visual experiences, we compared at the meta-analytic level three different experiences: VAE, VNE and VSE. We expected to find a general negative experience system common to all meta-analyses, involving the empathy system to process the feeling and recognition of negative emotion alongside the MNS to evoke the visceromotor correlates associated with such negative emotion. However, we expected to find specific brain activity for the VAE, such as further recruitment of the mentalizing network to facilitate the distance between an artwork and the viewer, and that this activation will be more akin to the neural activation as revealed by VSE.

2. Method

2.1 Rationale of Meta-analytic approach

By utilizing the activation likelihood estimation (ALE) meta-analytical approach (Muller et al., 2018), we investigated the neural basis of negative visual aesthetic experience (VAE) alongside the general negative visual non-artistic experience (VNE) and the negative visual social experience (VSE). The methodology of individual neuroimaging experiments can be affected

by researcher bias and paradigm limitations (Carp, 2012; Radua and Mataix-Cols, 2012); therefore, meta-analyses offer an overarching insight into the neural mechanisms involved at large across a plethora of studies (Turkeltaub et al., 2002). Accordingly, the ALE's statistical approach combines and analyzes coordinates from published neuroimaging studies. Of interest, we conducted three individual meta-analyses: VAE, VNE, and VSE. We further conducted two comparisons at the meta-analytic level, which contrasted VAE with VNE and VAE with VSE; given the nature of our design, VNE and VSE could not be contrasted as the VSE study data was inherent to VNE. Moreover, the stimuli sample within many VE studies included a mix of social (i.e., human) and non-social stimuli (i.e., non-human, for example landscapes; see Table S1); thus, we were not able to investigate specifically a non-social visual experience, because we could not retrieve enough studies using only non-social stimuli. Social stimuli were also predominant across VAE studies, with 72.73% of them using artistic stimuli featuring human figures.

We aimed to specify brain activations particular to visual aesthetic experience and social cognition, regardless of the type of visual stimulus used (e.g., paintings or sculptures for VAE and photos or images for VNE and VSE) and tasks employed (e.g., aesthetic judgement or passive viewing). The inclusion and exclusion criteria were defined in a meeting by all authors before continuing with the literature search and study selection. The literature search and study selection were made by two independent evaluators (RJS and MA) and finally approved by the other authors.

2.2 Literature search and study selection

The selection of literature was initiated by using keyword strings on Pubmed (https:// www.ncbi.nlm.nih.gov/pubmed/; date: June 1, 2022; see Figures 1 and 2 for an overview of study selection). For VAE, we searched for studies by using the following keyword strings:

“aesthetic experience fMRI”, “aesthetics fMRI”, “artwork fMRI”, “beauty fMRI”, “dance fMRI”, “neuroaesthetics fMRI”, “paintings fMRI”, “pleasantness fMRI”, “portrait fMRI”, “ugly fMRI”, and “visual art fMRI.” For VE and VNE we searched for studies by using the following keyword strings: “Empathy fMRI”, “IAPS fMRI”, “negative affect fMRI”, “negative emotion fMRI”, and “negative valence fMRI.” After duplicate removal, the search strings revealed 2872 studies for the VAE and 7833 studies for VNE/VSE; these studies were further assessed for inclusion based on the following criteria:

1. Studies published in English.
2. Empirical studies using functional magnetic resonance imaging (fMRI) and a sample size of at least 7 participants (Tahmasian et al., 2019).
3. Healthy and non-clinical adult populations between the ages of 18 and 65.
4. Studies reporting MNI or Talairach coordinates from whole-brain analyses, while excluding studies that reported only analyses restricted to region of interest (ROIs) or small volume correction (SVC) analyses, as these can skew ALE results towards an unrepresentative fashion (Muller et al., 2018).
5. Studies using visual stimuli only.

   Specific to the VAE search, studies investigating visual art-based stimuli, such as images of paintings, sculptures, drawings, photographs, pictographs, buildings, and videos of dance without audio, were included. Specific to the VNE search, studies investigating non-artistic visual stimuli, such as images of humans, landscapes, objects, and videos of such without audio, were included. Specific to the VSE search, studies investigating non-artistic visual stimuli of humans, such as images of faces, bodies, or body parts, alongside videos of such without audio, were included.
6. Studies using visual processing task.

We selected studies using tasks visual in nature (e.g., visual discrimination, passive viewing, ratings of emotional intensity). Studies reporting results from only non-visual tasks, such as attentional (e.g., Stroop) or memory-based tasks (i.e., hits vs. misses), were excluded. Also, studies investigating aesthetic judgements of non-artistic visual stimuli (e.g., faces and landscapes) were excluded, because it was not possible to clearly classify them in VAE or VNE/VSE. Indeed, the contextual effects of artwork status (e.g., Kirk et al., 2009) and aesthetic judgement (e.g., Ishizu & Zeki, 2013) have been shown to recruit different neural systems, with aesthetic judgements even occurring towards everyday objects (Yeh & Peng, 2019). Moreover, the notion of beauty has been coupled with hedonic appraisal (Skov & Nadal, 2021), with negative emotions predicting negative aesthetic evaluations, such as liking (Dorado et al. 2022) and ugliness (Klebl et al 2020). Therefore, we were particularity interested to the emotional aspects of non-artistic and artistic visual stimuli, with aesthetic judgement/ratings being reserved solely for art-based stimuli within the negative VAE search. As such, the associated tasks included those of negative aesthetic judgements or ratings (e.g., ugliness and dislike) alongside the viewing of art-based stimuli varying in degrees across aesthetic dimensions (e.g., beauty, liking, or emotional valence).

7. Studies using specific contrasts.

   Specific to the negative VAE search, contrasts generally assessed negative VAE versus neutral and/or positive VAE (e.g., ugly versus neutral, ugly versus beautiful). Specific to the negative VNE search, contrasts assessed negative versus neutral/positive emotional images of non-artistic stimuli, while specific to the negative VSE search, contrasts assessed negative versus neutral/positive emotional images of non-artistic stimuli depicting *human content*.

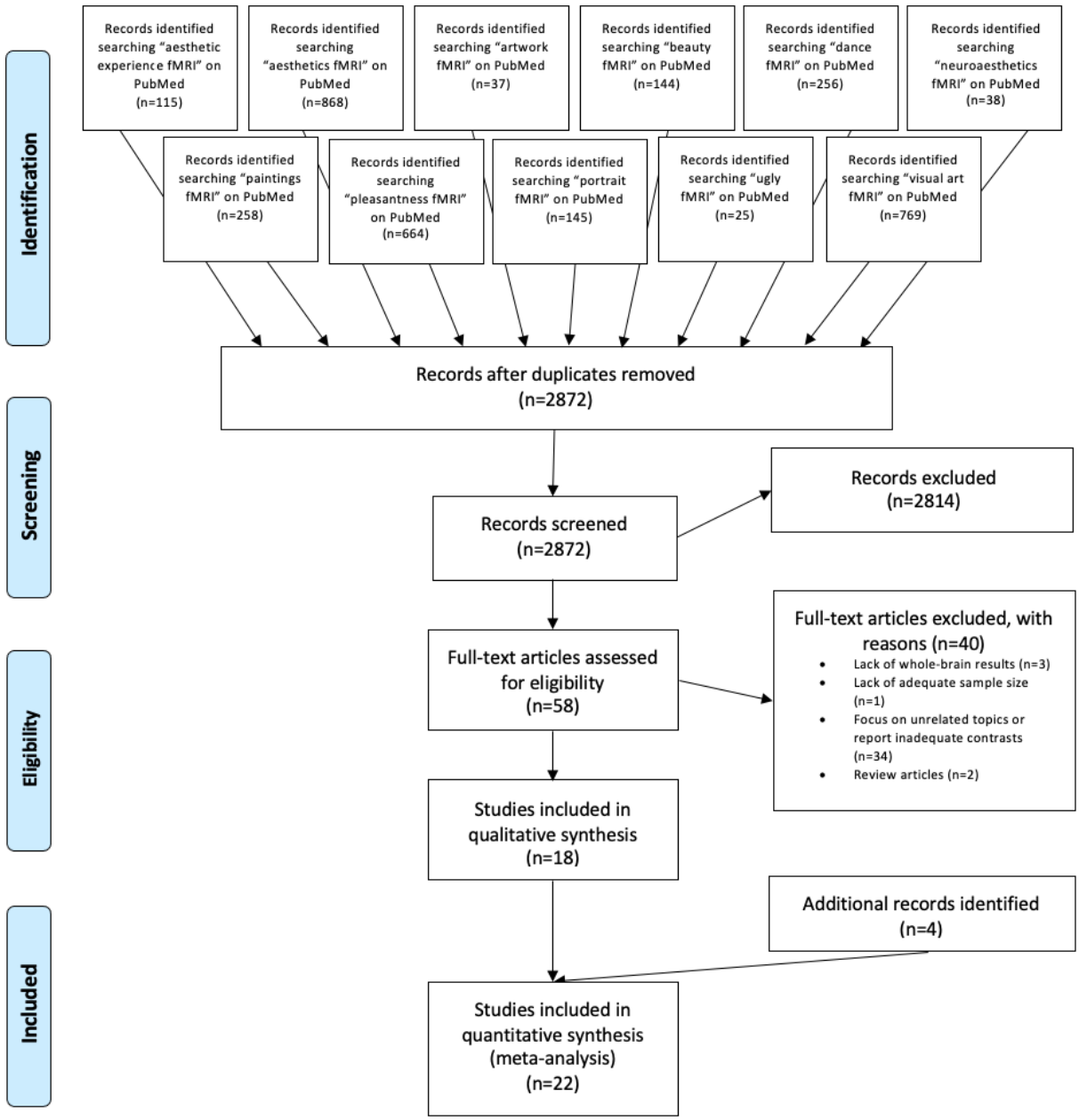
For VAE (Figure 1), we excluded 2814 studies from screening the titles and abstracts. Inspection of the full text, including supplementary materials, of the remaining 58 articles lead to the further exclusion of studies that lacked whole brain results (n=3), had a lack of adequate sample size (n = 1), focused on unrelated topics/reported inadequate contrasts (n = 30), or were review articles (n = 2). After contacting 6 authors for unreported results, 2 studies were further included into the VAE study pool. 18 studies in total fulfilled the above specified VAE criteria. Moreover, we ensured the inclusion of compatible studies that may have fell outside our initial literature search by screening studies referenced by the included studies alongside review articles and meta-analyses focused on aesthetic experience (Boccia et al., 2016; Brown et al., 2011; Chuan-Peng et al., 2020; Feng et al., 2021; Sacheli et al., 2022; Vartanian & Skov, 2014). Accordingly, 4 additional studies met our inclusion criteria and yielded our final number of included studies to 22 with an overall 413 subjects and 179 foci (see Table S1 for an overview of the included studies).

For VNE and VSE (Figure 2), we excluded 7584 studies from screening the titles and abstract for VE. Further inspection of the full text and supplementary materials of the remaining 249 articles resulted in the further exclusion of studies that lacked whole brain results (n = 34), lacked an adequate sample size (n = 9), did not use fMRI data (n= 5), focused on unrelated topics/reported inadequate contrasts (n = 103), or were review articles (n = 1). After contacting 24 authors for unreported results, 4 studies were further included into the VNE/VSE study pool. 77 studies fulfilled the inclusion criteria, and following the same fashion as the VAE, 20 studies were further included yielding a final number of 97 included studies with 4192 subjects and 1412 foci (see Table S2 for an overview of the included studies). Those studies that reported using only human stimuli (faces, bodies, and body parts) were further pulled from the pool of the included VE studies to construct the VSE pool of studies, which

resulted in a total of 45 studies with 1455 subjects and 680 foci (see Table S2 for an overview of the included studies).

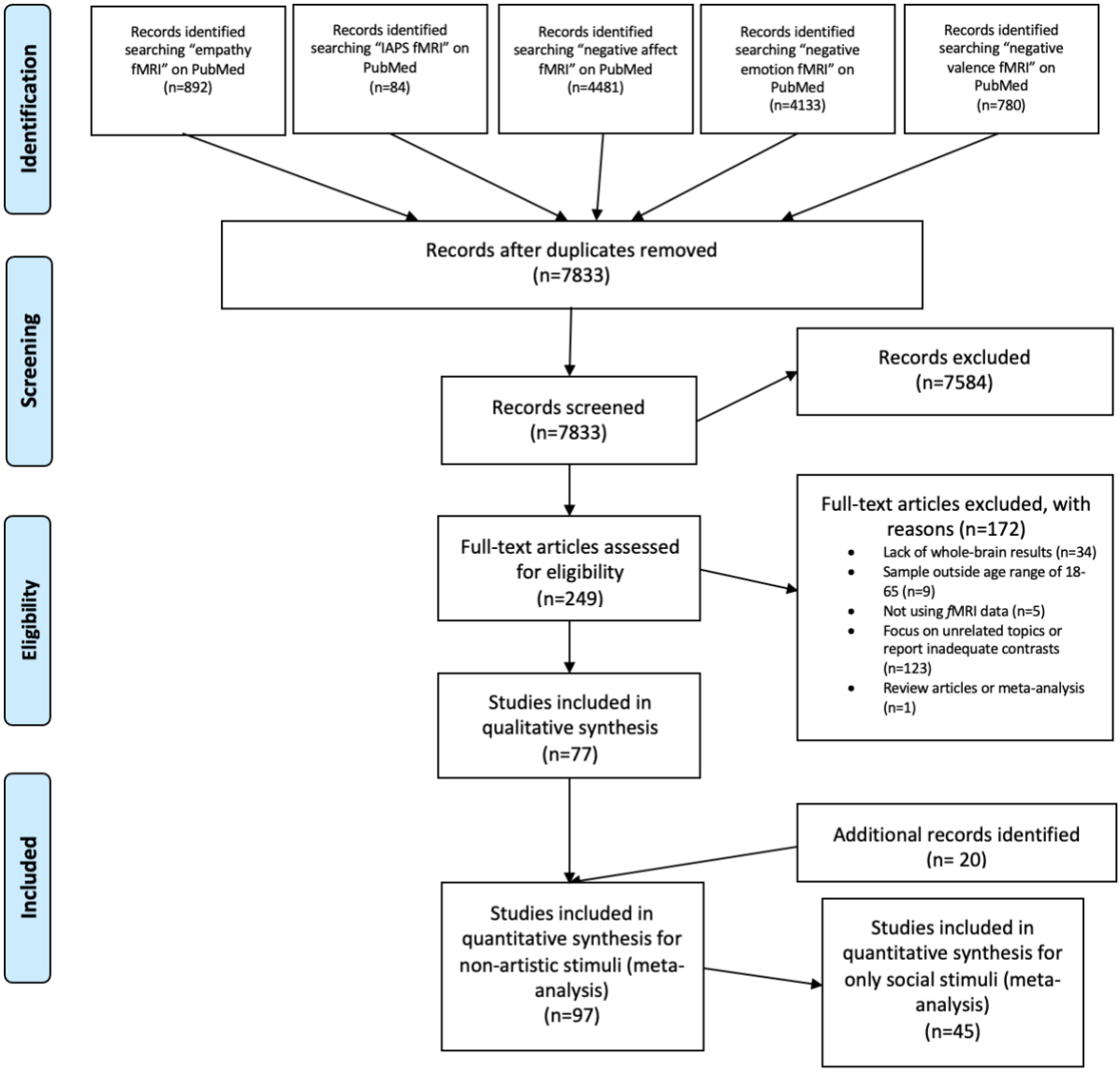
A pressing methodological issue concerns the presence of multiple experiments using the same participants in one study. Therefore, all coordinates from studies using the same participants throughout multiple experiments were coded as single experiments. This resulted in the provision of 22 studies and 23 experiments for VAE, 97 studies and 98 experiments for VNE, and 45 studies and 45 experiments for VSE. Importantly, each of our meta-analyses exceeded the minimum suggested inclusion of 17/20 experiments per ALE meta-analysis as any less may produce false negatives due to a lack of power and false positives due to an overrepresentation of one experiment within the meta-analysis (Muller et al., 2018).

Figure 1: PRISMA Outline for the Negative Visual Aesthetic Experience.



Note: additional records identified by screening studies referenced by the included studies alongside review articles and meta-analyses on aesthetic experience.

Figure 2: PRISMA Outline for the Negative Visual Non-Artistic Experience and the Negative Visual Social Experience.



Note: additional records identified by screening studies referenced by the included studies.

2.3 Activation Likelihood Estimation

GingerALE software 3.0.2 was utilized to conduct ALE analyses to specify neural correlates associated within and between the VAE, VNE, and VSE via the method recommended by Eickhoff and colleagues (2012).

In each meta-analysis, all coordinates were reported or transformed to MNI space via the provided automatic routine within in GingerALE. From the VAE study pool, 7 experiments were converted to MNI space; while from the VNE/VSE study pool, 26 experiments were converted to MNI space. Afterwards, activation foci were interpreted as the central points of three-dimensional Gaussian probability distributions, capturing the spatial uncertainty associated with each specific coordinate. These three-dimensional probabilities representing activation foci in each experiment were combined to construct modeled activation maps (MA), which were combined to produce the ALE scores that represented the convergence across all included experiments in each brain voxel (Turkeltaub et al., 2002). ALE scores were then contrasted with an empirically defined null distribution to determine true convergence from random convergence (i.e., noise; Eickhoff et al., 2012). Accordingly, the null distribution represented the random spatial association between experiments, while the ALE scores represented the fixed distribution of foci within experiments. The application of this random-effects inference demonstrated the above-chance convergence between experiments and not on the clustering of foci within experiments. Therefore, each MA had a random voxel sampled and the union of resulting values were calculated and recorded and the derived "random" ALE scores were retained to provide a sufficient sample of the ALE null distribution. To further correct for multiple comparisons and reduce the chance of reporting false positives, the true ALE scores were tested against the random ALE scores at a conventional threshold of $P < 0.05$, corrected for cluster-level family-wise error, and at a conservative cluster-level threshold of P

< 0.001 with 1,000 permutations to appropriately reveal each analysis's above-chance convergence (Eickhoff et al., 2012).

The resulting significance maps of ALE scores represented the individual activation maps of foci for VAE, VNE, and VSE. These maps were further used for direct comparisons and conjunction analyses to reveal the common and specific neural correlates for (i) VAE and VNE and (ii) VAE and VSE. In the same exact methodological fashion for the generation of individual meta-analytic maps (e.g., VAE), a conjunction image was generated for each comparison via the application of the voxel wise minimum value across ALE images (e.g., VAE & VNE) to reveal common brain activations within the two groups (Eickhoff et al., 2011). For specific neural correlates, two ALE contrasts were created and subsequently subtracted from one another (e.g., VAE > VNE; VAE < VNE). To correct for study size, two random groups of equivalent size were respectively generated for each ALE contrast. In a similar fashion for the application of null distribution to individual meta-analytic activation maps, a random permutation was iterated 1000 times, with each time subtracting the ALE scores from the random groups. Afterwards, the true ALE contrasts were compared with the random ALE contrasts at each voxel, and the resulting subtraction scores were transformed into Z scores to simplify the interpretation of results. Contrast analyses adopted a threshold of $P < 0.05$ with a minimum cluster volume size of $20m^3$ and 1,000 permutations (as in Sacheli et al., 2022).

GingerALE produces anatomical labeling of all clusters alongside peak voxels and the associated statistical scores. Furthermore, Statistical Parametric Mapping Anatomy Toolbox (v.2.2c; Eickhoff *et al.*, 2005), alongside the AAL template (as implemented in MRIcron; https://www.nitrc.org/projects/mricron) and Neurosynth (https://www.neurosynth.org/locations/), were utilized to confirm GingerALE's localizations.

3. Results

3.1 Negative Visual Aesthetic Experience (VAE)

Negative VAE solely recruited the left inferior occipital gyrus encompassing the fusiform gyrus within the secondary visual cortex (area V2; Table 1A, Figure 3A).

3.2 Negative Visual Non-Artistic Experience (VNE)

The negative VNE was shown to recruit the bilateral inferior and middle temporal gyri extending into the middle and inferior occipital gyri and fusiform gyrus within the left hemisphere (Table 1B, Figure 3B). The bilateral inferior parietal lobe was recruited as well as the supramarginal gyrus extending to the TPJ. Negative VNE also recruited the bilateral inferior frontal gyri (IFG), with meta-activation extending into the left insula and into the right ventral premotor cortex. In addition, meta-activations included the dmPFC alongside the middle and anterior cingulate cortex (M/ACC), as well as the supplemental motor area (SMA). Sub-cortical meta-activation was found within the right thalamus extending into the pallidum as well as in the bilateral amygdala and parahippocampal gyri. Lastly, we found involvement of the right anterior cerebellum.

3.3 Negative Visual Social Experience (VSE)

For the negative VSE, meta-activations were found within the left inferior occipital and left middle temporal gyrus (Table 1C, Figure 3C). Likewise, the right inferior temporal and middle occipital gyri were recruited. The supramarginal gyrus extending into the TPJ was also involved. Meta-activations were also found in the left IFG, extending into the left insula and left ventral premotor cortex. Furthermore, negative VSE recruited the medial SMA extending into the M/ACC and the superior medial frontal gyrus encroaching the dmPFC. Subcortically, a cluster was found within the left hemisphere that encompasses basal ganglia and subcortical

structures, including the left pallidum, thalamus, and the dorsal striatum, caudate and putamen as well as the amygdala.

Table 1. Results of individual meta-analyses on Negative Visual Aesthetic Experience (VAE), Visual Experience (VE), and Visual Social Experience (VSE).

Cluster #	Cluster Size mm^3	x	y	z	Brain Region
A: VAE					
1	1080	-28	-94	-10	Left Inferior Occipital Gyrus
B: VNE					
1	11088	49	-63	-4	Right Inferior Temporal Gyrus
		54	-64	4	Right Middle Temporal Gyrus
		52	-74	2	Right Inferior Temporal Gyrus/Middle Temporal Gyrus
		44	-48	-22	Right Anterior Cerebellum
		38	-86	4	Right Middle Occipital Gyrus
2	7080	-47.2	-70	-1	Left Middle/Inferior Occipital Gyrus
		-46	-66	-8	Left Fusiform Gyrus/Inferior Temporal Gyrus
		-46	-72	-4	Left Inferior Occipital Gyrus
		-50	-62	8	Left Middle Temporal Gyrus
3	5428	-23	-5	-16	Left Amygdala
		-20	-6	-16	Left Parahippocampal Gyrus
4	4384	-36	24	-7	Left Inferior Frontal Gyrus (Orbitalis)
		-32	24	-4	Left Insula
		-34	22	-16	Left Inferior Frontal Gyrus (Orbitalis)
		-44	20	-20	Left Inferior Frontal Gyrus / Superior Temporal Lobe
5	4312	24	-5	-16	Right Parahippocampal Gryus /Amygdala
		26	-6	-16	Right Parahippocampal Gyrus / Hippocampus
6	2920	3	17	54	Medial Supplementary Motor Area
		4	18	52	Medial Superior Frontal Gyrus/ Supplementary Motor Area
		8	10	68	Right Superior Frontal Gyrus/ Supplementary Motor Area
		-4	24	40	Medial Cingulate Gyrus/ Superior Medial Frontal Lobe
7	2896	44	11	26	Right Inferior Frontal Gyrus (Opercularis)
		44	8	28	Right Frontal Precentral Gyrus/ Inferior Frontal Gyrus (Opercularis)
8	2440	53	29	7	Right Inferior Frontal Gyrus (Triangularis)
		54	30	4	Right Inferior Frontal Gyrus (Triangularis)

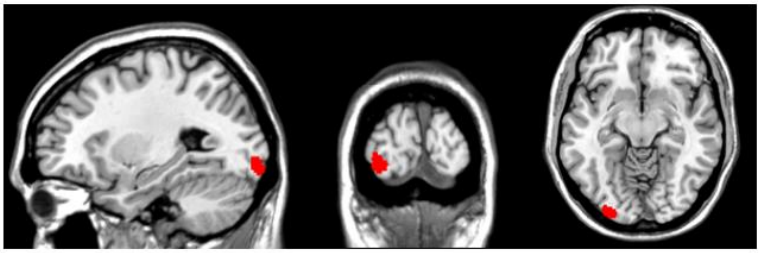
9	1864	61	-21	34	Right Supramarginal Gyrus
		62	-20	34	Right Inferior Parietal Lobule/ Supramarginal Gyrus
10	1560	-61	-23	33	Left Supramarginal Gyrus
		-60	-22	32	Left Inferior Parietal Lobule / Supramarginal Gyrus
11	1472	-41	-45	-18	Left Fusiform Gyrus
		-40	-44	-18	Left Fusiform Gyrus
12	1432	4	55	33	Medial Superior Medial Frontal Gyrus
		6	58	38	Right Superior Medial Frontal Gyrus
		4	52	36	Medial Superior Medial Frontal Gyrus
		6	58	26	Right Superior Medial Frontal Gyrus
13	1296	-46	5	28	Left Inferior Frontal Gyrus (Opercularis)
		-44	6	28	Left Inferior Frontal Gyrus (Opercularis)
14	1136	12	-8	8	Right Thalamus
		14	4	4	Right Globus Pallidus/ Thalamus
C: VSE					
1	3064	-47	-70	-4	Left Occipital Inferior Gyrus
		-44	-70	-4	Left Inferior Temporal Gyrus / Left Inferior Occipital Gyrus
		-54	-62	8	Left Middle Temporal Gyrus
2	2328	-36	23	-5	Left Insula / Inferior Frontal Gyrus (Orbitalis)
		-32	26	-8	Left Insula / Inferior Frontal Gyrus (Orbitalis)
		-40	22	-4	Left Insula / Inferior Frontal Gyrus Orbitalis
		-34	22	-20	Left Inferior Frontal Gyrus (Orbitalis)
		-38	28	2	Left Inferior Frontal Gyrus (Triangularis)
3	2032	52	-64	-5	Right Inferior Temporal Gyrus
		52	-66	-6	Right Middle Occipital Gyrus/ Inferior Temporal Gyrus
		54	-74	4	Right Middle Occipital Gyrus
4	1976	62	-21	34	Right Supramarginal Gyrus
		62	-20	34	Right Inferior Parietal Lobule / Supramarginal Gyrus
5	1448	-1	21	45	Medial Supplemental Motor Area
		-6	24	38	Left Cingulate Gyrus / Anterior/ Middle Cingulate Gyrus
		0	20	52	Medial Superior Frontal Gyrus / Supplemental Motor Area
		6	24	40	Right Cingulate Gyrus/ Anterior / Middle Cingulate Gyrus
6	1296	-15	8	3	Left Pallidum
		-12	14	4	Left Caudate/ Paracentral Lobe
		-20	8	2	Left Putamen
		-10	-2	6	Left Thalamus
7	1176	36	-83	5	Right Middle Occipital Gyrus
		36	-86	4	Right Middle Occipital Gyrus
8	1176	-59	-23	33	Left Supramarginal Gyrus

		-60	-22	32	Left Inferior Parietal Lobule
9	992	-21	-5	-14	Left Amygdala
		-22	-6	-16	Left Parahippocampal Gyrus/ Amygdala
		-16	-4	-10	Left Globus Pallidus
		-8	-6	-10	Left Hypothalamus
10	984	-52	13	7	Left Inferior Frontal Gyrus Opercularis
		-52	12	6	Left Frontal Precentral Gyrus / Inferior Frontal Gyrus (Opercularis)

Note: Coordinates are reported within MNI space.

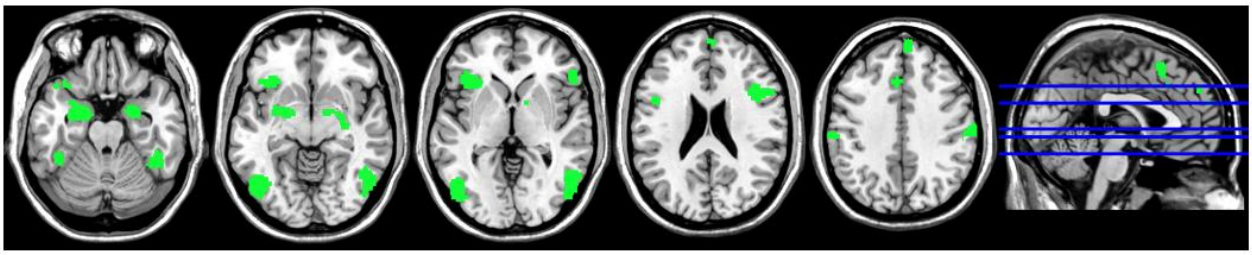
Figure 3. Individual ALE analyses for Negative Visual Experiences.

A) Visual Aesthetic Experience:



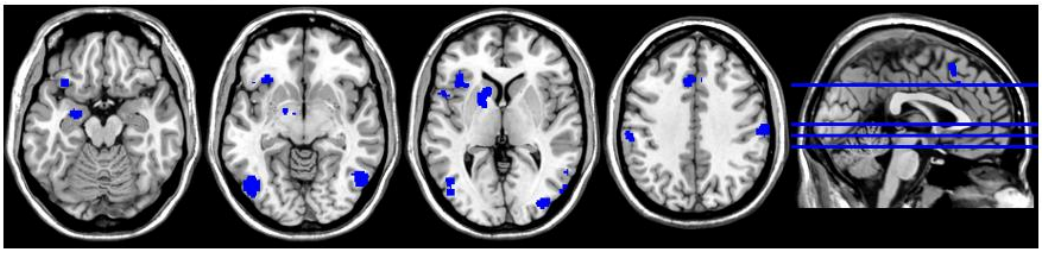
x = -28 y = -94 z = -10

B) Visual Non-Artistic Experience:



z = -22 z = -7 z = 0 z = 23 z = 38

C) Visual Social Experience:



z = -17 z = -7 z = 3 z = 38

Note: Individual meta-activations as assessed by Activation Likelihood Estimation (ALE) analyses across visual experiences. A) Clusters colored red represent neural correlates as revealed by the individual ALE analysis assessing negative Visual Aesthetic Experience (VAE). B) Clusters colored green represent neural correlates as revealed by the individual ALE analysis assessing negative Visual Non-Artistic Experience (VNE). C) Clusters colored blue represent neural correlates as revealed by the individual ALE analysis assessing negative Visual Social Experience (VSE).

3.4 Negative Visual Aesthetic Experience (VAE) & Negative Visual Non-Artistic Experience (VNE)

The conjunction analysis of negative VAE and VNE (Table 2A, Figure 4A) revealed meta-activations in the bilateral inferior and middle occipital and bilateral fusiform gyrus, bilateral supramarginal gyrus/TPJ, bilateral IFG extending into the bilateral insula, right ventral premotor cortex, and superior temporal gyrus. Furthermore, the medial SMA, dmPFC, and left amygdala were also recruited.

3.5 Negative Visual Aesthetic Experience (VAE) > Negative Visual Non-Artistic Experience (VNE)

The contrast of negative VAE versus VNE revealed one small cluster within the left inferior occipital gyrus within area V2 encroaching the fusiform gyrus (Table 2B, Figure 4A).

3.6 Negative Visual Non-Artistic Experience (VNE) > Negative Visual Aesthetic Experience (VAE)

The contrast of the negative VNE versus VAE (Table 2C, Figure 4A) revealed meta-activation within the left fusiform gyrus and the right inferior and middle temporal gyri, as well as the left superior temporal pole. The thalamus, hippocampus and pallidum were also involved.

Table 2. Results of the comparisons between Negative Visual Aesthetic Experience (VAE) and Negative Visual Non-Artistic Experience (VNE).

Cluster #	Cluster Size mm^3	x	y	z	Brain Region
A: VAE & VNE (conjunction meta-analysis)					
1	12312	48	-63	-5	Right Inferior Temporal Gyrus
		54	-64	4	Right Middle Temporal Gyrus
		52	-74	2	Right Inferior Temporal Gyrus / Middle Temporal Gyrus
		44	-48	-20	Right Fusiform Gyrus
		38	-86	6	Right Middle Occipital Gyrus
2	8936	-46	-65	-5	Left Inferior Temporal Gyrus
		-40	-44	-18	Left Fusiform Gyrus
		-46	-66	-8	Left Fusiform Gyrus / Inferior Temporal Gyrus
		-46	-72	-4	Left Inferior Occipital Gyrus
		-50	-62	8	Left Middle Temporal Gyrus
3	5376	-36	25	-5	Left Inferior Frontal Gyrus (Orbitalis)
		-32	24	-4	Left Insula
		-40	22	-4	Left Insula / Inferior Frontal Gyrus (Orbitalis)
		-44	36	4	Left Inferior Frontal Gyrus (Triangularis)
		-44	20	-20	Left Inferior Frontal Gyrus / Superior Temporal Pole/Gyrus
		-44	42	10	Left Middle Frontal Gyrus /Inferior Frontal Gyrus (Triangularis)
4	5264	-22	-5	-17	Left Amygdala
		-20	-6	-16	Left Amygdala
5	4816	27	-5	-15	Right Amygdala
		26	-6	-16	Right Amygdala / Hippocampus
		40	-4	-6	Right Claustrum/ Insula
6	3552	45	11	27	Right Inferior Frontal Gyrus (Opercularis)
		44	8	28	Right Precentral Gyrus / Inferior Frontal Gyrus (Opercularis)
7	3248	3	17	53	Medial Supplemental Motor Area
		4	18	52	Medial Superior Frontal Gyrus / Supplemental Motor Area
		8	10	68	Right Superior Frontal Gyrus / Supplemental Motor Area
		-4	24	40	Medial Cingulate Gyrus / Superior Medial Frontal Gyrus (dmPFC)
8	2936	53	29	8	Right Inferior Frontal Gyrus (Triangularis)
		54	30	4	Right Inferior Frontal Gyrus (Triangularis)
		54	26	10	Right Inferior Frontal Gyrus (Triangularis)
9	2008	61	-21	35	Right Supramarginal Gyrus
		62	-20	34	Right Inferior Parietal Lobule/ Supramarginal Gyrus

10	1784	-31	-90	0	Left Middle Occipital Gyrus
		-30	-90	-4	Left Inferior Occipital Gyrus / Middle Occipital Gyrus
		-32	-88	8	Left Middle Occipital Gyrus
11	1632	-45	5	28	Left Inferior Frontal Gyrus (Opercularis)
		-44	6	28	Left Inferior Frontal Gyrus (Opercularis)
12	1592	5	56	32	Medial Superior Medial Frontal Gyrus
		6	58	38	Right Medial Frontal Gyrus / Superior Medial Frontal Gyrus
		6	58	28	Right Superior Frontal Gyrus / Superior Medial Frontal Gyrus
13	1496	-61	-23	33	Left Supramarginal Gyrus
		-60	-22	32	Left Inferior Parietal Lobule / Supramarginal Gyrus
14	1304	37	25	-4	Right Insula
		34	26	-2	Right Insula
		42	22	-6	Right Insula
15	1096	4	-28	-6	Midbrain Red Nucleus
B: VAE > VNE					
1	48	-29	-97	-11	Left Inferior Occipital Gyrus
C: VNE > VAE					
1	1952	19	-4	-16	Right Parahippocampal / Right Hippocampus (center)
		24	-7	-8	Right Globus Pallidus
2	1424	-48	-67	-3	Left Inferior Occipital Gyrus
		-48	-66	-2	Left Inferior Temporal Gyrus/ Inferior Occipital Gyrus
		-46	-70	-13	Left Fusiform Gyrus / Inferior Occipital Gyrus
3	1384	53	-58	1	Right Middle Temporal Gyrus
		54	-58	1	Right Inferior Temporal Gyrus / Middle Temporal Gyrus
		55	-60	7	Right Middle Temporal Gyrus
4	408	-32	-2	-11	Left Claustrum (center)
5	112	15	-10	7	Right Thalamus
		15	-10	8	Right Thalamus
		10	-10	6	Right Thalamus
6	48	-30	8	-18	Left Superior Temporal Pole
		-31	5	-18	Left Superior Temporal Pole

Note: Coordinates are reported within MNI space.

3.7 Negative Visual Aesthetic Experience (VAE) & Negative Visual Social Experience (VSE)

The conjunction analysis of the negative VAE and VSE (Table 3A, Figure 4B) revealed meta-activations in the right middle occipital gyrus and the right fusiform gyrus. Moreover, meta-activations were found within the bilateral supramarginal gyrus/TPJ, left IFG extending into the insula bilaterally, and the left premotor cortex. Further meta-activations were found within the medial SMA and superior medial frontal gyrus extending into the M/ACC, encompassing the dmPFC. Lastly, the contrast showed recruitment of the left caudate, amygdala, hippocampus, and pallidum.

3.8 Negative Visual Aesthetic Experience (VAE) > Negative Visual Social Experience (VSE)

The negative VAE versus VSE contrast analysis revealed no significant activations (Table 3B).

3.9 Negative Visual Social Experience (VSE) > Negative Visual Aesthetic Experience (VAE)

The contrast of the negative VSE versus negative VAE revealed meta-activation within the right inferior and middle temporal gyri, alongside the left inferior occipital gyrus, extending into the fusiform gyrus (Table 3C, Figure 4B).

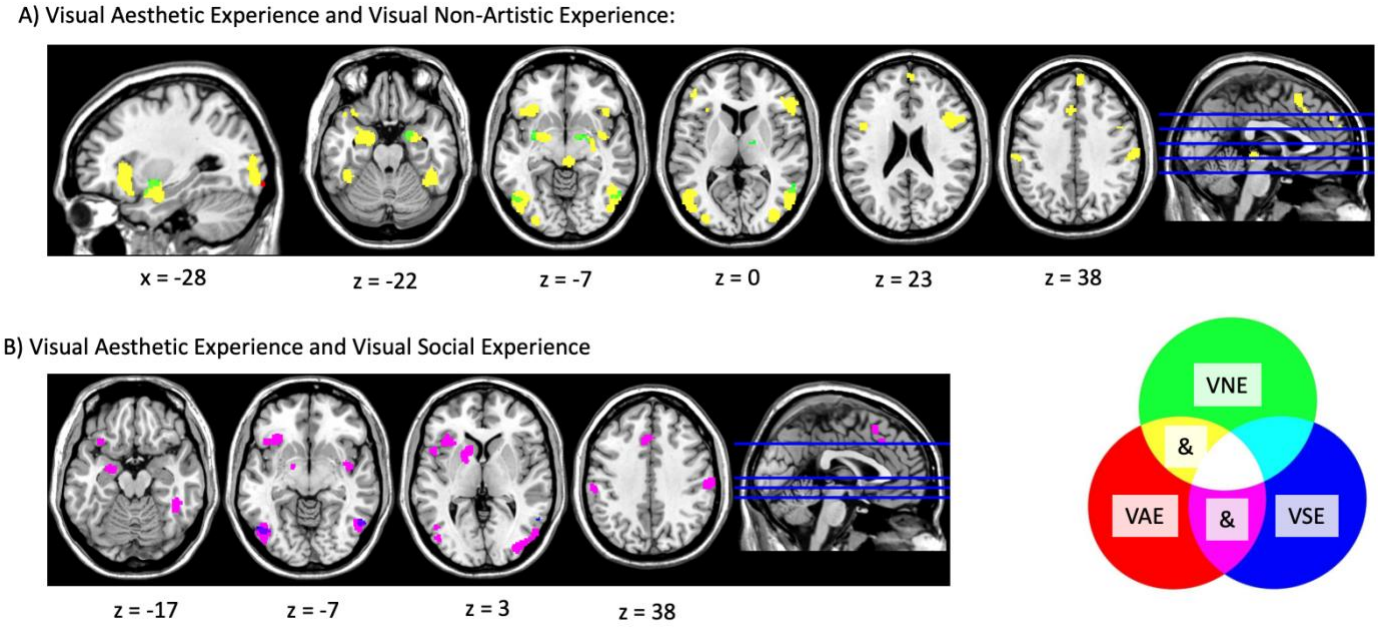
Table 3. Results of the comparisons between Negative Visual Aesthetic Experience (VAE) and Negative Visual Social Experience (VSE).

Cluster #	**Cluster Size**	**x**	**y**	**z**	**Brain Region**
A: VAE & VSE (conjunction meta-analysis)					
1	4040	44	-76	0	Right Inferior Occipital Gyrus
		36	-86	4	Right Middle Occipital Gyrus
		52	-66	-4	Right Inferior Temporal Gyrus
		54	-72	4	Right Inferior / Middle Temporal Gyrus
		46	-80	0	Right Inferior Occipital Gyrus
2	3128	-35	23	-5	Left Insula

		-32	26	-8	Left Insula / Inferior Frontal Gyrus (Orbitalis)
		-42	22	-4	Left Insula/ Inferior Frontal Gyrus
		-34	22	-18	Left Inferior Frontal Gyrus (Orbitalis)
3	2648	-46	-72	-5	Left Inferior Occipital Gyrus
		-44	-70	-4	Left Inferior Temporal Gyrus/ Inferior Occipital Gyrus
4	2152	61	-22	36	Right Supramarginal Gyrus
		62	-20	34	Right Inferior Parietal Lobule / Supramarginal Gyrus
5	2144	2	19	46	Medial Supplemental Motor Area
		-4	24	40	Medial Cingulate Gyrus / Superior Medial Frontal Gyrus
		6	14	50	Right Superior Frontal Gyrus/ Supplementary Motor Area
		2	18	52	Medial Superior Frontal Gyrus/ Supplementary Motor Area
6	1408	-22	-6	-16	Left Amygdala
		-18	-4	-12	Left Globus Pallidus / Hippocampus
7	1200	-15	10	3	Left Pallidum
		-12	14	2	Left Caudate
8	1176	43	-44	-19	Right Fusiform Gyrus
		44	-42	-18	Right Fusiform Gyrus/ Inferior Temporal Gyrus
9	1096	-52	14	6	Left Inferior Frontal Gyrus (Opercularis)
		-52	12	6	Left Precentral Gyrus / Inferior Frontal Gyrus (Opercularis)
10	1032	-59	-23	33	Left Supramarginal Gyrus
		-60	-22	32	Left Inferior Parietal Lobule/ Supramarginal Gyrus
11	920	41	-3	-5	Right Insula
		42	-4	-6	Right Claustrum / Insula
B: VAE > VSE					
No Significant results					
C: VSE > VAE					
1	584	53	-61	-7	Right Inferior Temporal Gyrus
	584	54	-58	-1	Right Inferior Temporal Gyrus/ Middle temporal Gyrus
	584	53	-62	-9	Right Middle Occipital Gyrus/ Inferior Temporal Gyrus
2	504	-47	-69	-8	Left Fusiform Gyrus / Inferior Occipital Gyrus

Note: Coordinates are reported within MNI space.

Figure 4. Conjunction and Contrast ALE analyses for Negative Visual Experiences.



Note: Meta-activations across visual experiences compared against and within one another via contrast and conjunctions Activation Likelihood Estimation (ALE) analyses; A) Clusters colored red represent neural correlates as revealed by the contrast ALE of Visual Aesthetic Experience (VAE) against Visual Non-Artistic Experience (VNE), while clusters colored green represent neural correlates as revealed by the contrast ALE analysis of VNE against VAE. Clusters colored yellow represent shared neural correlates across the VAE and VNE as revealed by their conjunction ALE analysis; B) No clusters shown as none survived the contrast ALE analysis of VAE against VSE, yet clusters colored blue represent neural correlates as revealed by the contrast ALE analysis of VSE against VAE. Clusters colored purple represent shared neural correlates across the VAE and VSE as revealed by their conjunction ALE analysis.

4. Discussion

Given the plethora of research concerning the neural correlates of negative emotion within non-artistic visual stimuli, such as the International Affective Picture System (IAPS; Lang et al., 2005) and human stimuli, alongside the interest in exploring aesthetic experience of visual artwork depicting negativity, we conducted a meta-analysis to evaluate the neural similarities and differences within the negative visual experience of non-artistic (VNE), social (VSE), and artistic stimuli (VAE).

4.1 Activations within the Visual System

Outside our scope of main hypotheses, our meta-analytic results revealed broad neural activation within the visual network across visual experiences. Regarding the negative VAE, our results surprisingly showed sole activation within the midst of area V2, which is associated with early visual perception. Study contributors of VAE's V2 cluster explored the ugliness of paintings (Ishizu & Zeki, 2011), artistic facial expressions of pain (Ardizzi et al., 2021), and ugly Chinese pictographs (Zhang et al., 2016; 2017). Authors of the contributing studies explain these results as the generation of an early negative impression to avert away from negative artwork (Höfel & Jacobsen, 2007; Zhang et al., 2016) and as the execution of visual analysis towards stimulus content (Ardizzi et al., 2021).

Although these interpretations are sound, our results may entail a different story. Indeed, area V2 acts as the initial node within the ventral visual processing stream for object recognition (Arcaro et al., 2009; Bo et al., 2021). It further demonstrated a stronger response to statistical dependencies representing natural textures, while the primary visual cortex (area V1) showed no response (Freeman et al., 2013). This suggests that the cascade of visual information from areas V1 to V2 falls within representations of our naturalistic world. Moreover, functional connections between area V2 and the amygdala may subserve affective processing, especially so for negative emotion (Pessoa & Aldophs, 2010). Accordingly, top-down feedback loops from affective subcortical structures onto the early visual cortex may modulate the processing of salient stimuli (Lang and Bradley 2010; Sabatinelli et al. 2005), while the visual cortex itself has been posited to play a role in affective coding (Miskovic & Anderson, 2018). Early visual areas, such as areas V1 and V2, have been implicated to represent both the novelty (Bradley et al. 2012) and intrinsic stimulus properties of affective stimuli (McTeague et al., 2015). The processing of unpleasant scene perception was associated

with top-down effects from the amygdala and right temporal cortex on the early visual cortex (encompassing the V2), which further demonstrated a distinct multivariate pattern of activation towards unpleasantness (Bo et al., 2021). Although these results lie outside our main hypotheses, the recognition of a visual stimulus as an artwork may engender occipital patterns within the early visual cortex that propagate cascading effects to aesthetically engage with an artwork's negative content.

Contrary to the negative VAE, our meta-analyses revealed that the negative VNE and VSE recruited various visual sensory areas spanning across the bilateral temporal and occipital gyri, largely encompassing the ventral visual pathway (Arcaro et al., 2009). In a similar vein as VAE, this may reflect the synthetization of visual information with associative semantic stores to facilitate the recognition and inference of visual emotional stimuli (Bo et al., 2021; Pessoa & Aldophs, 2010). Moreover, the contrast of the negative VAE versus VNE showed the survival of the VAE analysis's V2 cluster, yet this cluster did not survive the VAE versus VSE contrast. On the other hand, the reverse contrasts (i.e., VNE > VAE; VSE > VAE) showed a general recruitment of higher order visual association areas strongly associated with later visual processes (Aminoff et al., 2013; Arcaro et al., 2009) suggesting that the discrimination between types of visual stimuli is evident. Therefore, a commonality in the processing of social and artistic stimuli may partly lie within the affective functionality of area V2 (Bo et al., 2021), and further supports the notion of similar brain systems in both aesthetic experience and social cognition (van Leeuwen et al., 2022). The employment of visual systems behind the visual experience of negative emotion may aid in assigning a visual stimulus's appropriate hedonic value (Ureña & Nadal, 2023; Skov & Nadal 2021), yet the context of these experiences, such as visual artwork versus war scenes, may be pivotal towards the type of engagement one undergoes.

4.2 Activations across Empathy, Mirror Neuron, and Mentalizing Systems

The individual negative VAE meta-analysis reported no neural activation within social systems of interest; in contrast, the VSE and VNE showed a recruitment of nodes within the MNS (Bonini, 2017; Bonini et al., 2022) alongside the empathy and mentalizing systems (Arioli et al, 2021a; Dvash & Shamay-Tsoory, 2014). Conjunction meta-analyses of the negative VAE with VSE and VNE generally replicated individual analyses of the VNE and VSE, and studies from the negative VAE contributed to almost every cluster across conjunction analyses. Therefore, common involvement of social systems may be present across all investigated visual experiences, yet these findings may be limited due to power issues (please see Limitations).

Concerning the empathy system, the VNE and VSE showed activation of the left anterior IFG and insula (Bernhardt & Singer, 2012; Seeley et al., 2007), which promote interoception (Berntson & Khalsa, 2021) of objective and subjective feelings (Craig, 2011; Fallon et al., 2020), particularly within the negative domain (Uddin, 2015; Uddin et al., 2017). The VNE and VSE showed recruitment of the MNS, notably the bilateral inferior parietal lobe alongside the posterior IFG extending into ventral premotor cortices, which suggests a component of visceromotor resonance across negative visual experiences (Ardizzi et al., 2021; Nummenmaa et al., 2008). The negative VNE and VSE further revealed clusters within the dorsal ACC (dACC) and the MCC extending into premotor cortices (e.g., SMA), and these areas have been associated with the firsthand experience of pain, an empathetic response towards pain (Botvinick et al., 2005; Lamm et al., 2011), as well as the processing of negative social situations (Eisenberger, 2015; Ricciardi et al., 2013). These results may stem from functional connections between the cingulate and medial frontal cortices to compute the degree of stimuli's unpleasantness (Hsu et al., 2020; Rolls et al., 2019; 2020) and between the cingulate and premotor cortices to regulate bodily action within space (Rolls et al., 2019). As the MNS and social brain may work in tandem for social and emotional communication (Chang

et al., 2015; Mainieri et al., 2013), our reported activation may underly visceromotor correlates basing empathic motor resonance to share and feel another's negative emotions. Given the replication of results across conjunction analyses, the notion of feeling into artwork via bodily empathic processes (Freedberg & Gallese, 2007; Ganczarek et al., 2018; Vischer, 1873) may reflect such empathic motor resonance to embrace an artwork's negative emotion as a firsthand experience (Mazzocut-Mis, 2021; Menninghaus et al., 2017; please see also Ardizzi et al., 2021).

VNE

's and VSE's recruitment of the mentalizing system was strongly represented by activation of the DMN, yet only its subsystems. Activation was found within the dmPFC encroaching the dACC, the medial temporal lobe (MTL) consisting of the amygdala, hippocampus, and parahippocampal gyrus, alongside the supramarginal gyrus housing the TPJ (Buckner et al., 2008; Raichle & Snyder, 2007). The dmPFC is reciprocally connected to the MTL, which facilitates affective coding (Wang et al., 2017), autobiographical and spatial memory (Bird & Burgess, 2008), alongside contextual associations (Aminoff et al., 2013; Ruiz-Rizzo et al. 2020). The dmPFC further promotes other-related cognition via functional connections with the TPJ (Bzdok et al., 2013; Buckner et al., 2008), which is presumed to hold representations of abstract emotions (Lettieri et al., 2019) alongside actions via the MNS (Rizzolati & Craighero, 2004). Our results support the role of the TPJ possibly holding salient representations of negative emotion (Berntson & Khalsa, 2021) to be concurrently utilized to understand and share another's negative emotion. Therefore, the mentalizing system may integrate the components of emotion, memory, and context necessary to perceive and engage with the negative stimulus in question. Given again the similar recruitment across conjunction analyses, the mentalizing system may promote the distance to appropriately engage with a negative artwork as a secondhand experience (Mazzocut-Mis, 2021; Menninghaus et al., 2017).

Notably, studies from the negative VAE contributed to every single cluster outside the left TPJ across conjunction analyses and only contributed to right TPJ (rTPJ) activation within the VSE; studies included those investigating artwork depicting ugliness (Di Dio et al., 2011) and mourning (Labek et al., 2018). The rTPJ may distinguish between representations of one's own and another's affective states (Lamm et al., 2019; Preckel et al., 2018; Saxe & Wexler, 2005; Steinbeis, 2016) across body and space (Bardi et al., 2017; Blanke et al., 2005; Tsakiris et al., 2007). Unlike the sole VSE and VNE analyses, the conjunction analyses further reported a bold inclusion of the right insula, which engenders empathic motor resonance towards negative emotion (Craig, 2011; Fan et al., 2016; Liakakis et al., 2011). The right insula is further coupled with the right TPJ to engage with novel and salient stimuli (Fox et al., 2006; Menon & Uddin, 2010; Uddin, 2015). As the rTPJ was particular to the VSE conjunction analysis, engaging with negative visual art may predominately recruit social processes to appropriately assign negative affective states within a self-other representational framework, which may allow the sharing and feeling of visceral emotions from negative artwork (Ardizzi et al., 2021)**.**

This is further supported by the lack of activation of the DMN's main system in all analyses. The DMN's main system codes and integrates affective and hedonic *self-related information* across action and space (Buckner et al., 2008; Raichle & Snyder, 2007; Rolls et al., 2019; 2022); it has been associated with aesthetic appeal and feeling moved, possibly through a mechanism of self-relevance (Belfi et al., 2019; Vessel et al., 2019; Vessel et al., 2012). Therefore, activation of the mentalizing system (i.e., DMN subsystems) may underly *other-related* cognition to understand and share another's negative emotion, while the lack of activation within the DMN main system may reflect a disengagement of self-related cognition to attenuate a complete immersion within another's negative emotional experience. In that, mentalizing stems from empathy, yet, for the case of negative emotion, may preserve a distance

via the lack of self-relational yet employment of other-related processes. Given the negative VAE's broad contribution to clusters and further induction of the empathy system's right insula across VAE & VSE conjunction analyses, this combined augmentation of feeling and distance may be a cornerstone for negative aesthetic experience. The understanding that artwork wades outside reality via the contextual affordances of the visual system may facilitate engagement with a visual artwork's negative emotion. Therefore, our results suggest that the social systems at play for non-artistic stimuli likewise demonstrate an important role in feeling and understanding a visual artwork's negative emotion.

4.3 Subcortical Activations

The VAE and VSE conjunction analysis showed a recruitment of subcortical structures, including the pallidum and thalamus, whose activation was further revealed by the individual VNE and VSE analyses. The pallidum houses a cold spot of pleasure for unpleasant experiences, such as disgust, which may arise via its inhibitory tone on reward circuitry (Berridge & Kringelbach, 2015; Sesack & Grace, 2010). Moreover, the thalamus acts as an information relay center (Min, 2010; Redinbaugh et al., 2020) via cortico-basal ganglia-thalamo-cortical loops that integrate motor and sensory information to effectively direct action within one's environment (Sesack & Grace, 2010; Yin et al., 2008). Concerning the basal ganglia of this loop, the individual VSE and its VAE conjunction analysis showed a further recruitment of the dorsal striatum, which has been implicated within reward seeking behavior (Russo & Nestler, 2019; Yin et al., 2008) alongside social interaction, learning, and reward (Báez-Mendoza & Schultz, 2013). Moreover, the conjunction of the negative VNE and VAE led to a further activation within the midbrain's red nucleus, which, as a key node within the cortico-basal ganglia-thalamo-cortical loops (Habas et al., 2009), plays a central role in motor and sensory function alongside pain perception (please see Basile et al., 2021). A commonality

between these visual experiences depicting negative emotion may lie within relay centers distributing affective and bodily information across functional networks to hedonically code the visceral emotionality of a negative visual stimulus; yet, the presence of a negative human stimulus or artwork may evoke a further component of learning versus general negative stimuli (please see Sarasso et al., 2020).

4.4. Theoretical Implications across Positive and Negative Aesthetic Experience

As suggested by our results, the recognition and perception of a visual artwork modulates the systems underlying aesthetic engagement. Prior research has shown that patterns in occipital activity in conjunction with the orbitofrontal cortex (OFC) are reflected within judging a painting's beauty (Ishizu and Zeki 2011; Feng et al., 2021) yet also ugliness (Rasche et al., 2023), which may be particular to more lateral portions of the OFC (Munar et al., 2012). However, this neurofunctional hedonic coding may occur during the initial interaction with an artwork (Cela-Conde et al., 2013). Therefore, the assignment of hedonic value, of either negative or positive affect, towards visual artwork is suggested to recruit similar neural systems associated within hedonic value and the visual perception, yet the differences in positive and negative aesthetic experience may rely on a differing engagement of neural systems after coding the artwork's hedonic value.

Hence, the executive control network (ECN), characterized by the dorsolateral prefrontal cortex (DLPFC) and posterior parietal cortex, bases executive function alongside external cognition (Corbetta & Shulman, 2002; Menon & Uddin, 2010; Shen et al., 2020), and may prolong and evaluate a pleasurable aesthetic experience (Belfi et al., 2019; Cattaneo et al., 2014; Cela Conde et al., 2004; Kirsch et al., 2016). Notably, there was no prominent recruitment of the ECN for all analyses; the DLPFC has been indicated within positive mood (Piretti et al., 2022), and emotional regulation (Peña-Gómez et al., 2011) alongside supporting

positive affect throughout executive function (Boggio et al., 2009; Trémolière et al., 2018). Likewise, the ECN may direct engagement externally to interact with positive artwork (Belfi et al., 2019; Cela-Conde et al., 2004; 2013) alongside artwork that persons have a preexisting general preference for (Cattaneo et al., 2014). Functional coupling between reward circuitry and the DLPFC facilitates learning and executive functioning (Berridge & Kringelbach, 2015; Sesack & Grace, 2010; Morris et al., 2016; Russo & Nestler, 2013; Sesack & Grace, 2010) and has been implicated in engaging with artwork within an aesthetic context (Lacey et al., 2011). Therefore, the ECN may be geared towards sustaining external cognition within a positive emotional light to entrain learning and reward throughout aesthetic engagement (Sarasso et al., 2020).

Likewise, the empathy system has also been implicated within the positive aesthetic experience (Boccia et al., 2016; Feng et al., 2021; Vartanian & Skov 2014; Sachelli et al., 2022), the general positive appeal of stimuli across sensory domains (Brown et al., 2011), and intentionally engaging with a painting's mood and emotions (Cupchik et al., 2009). Therefore, the specificity of the empathy system in *feeling* emotion is not specific to negative visual experience but may be more implicated within general aesthetic experience. Respectively representing self-relational processing and mentalizing, the DMN's main and sub-systems have been involved within the positive aesthetic experience (Boccia et al., 2016; Sachelli et al., 2022; Vartanian & Skov, 2014). Self-relevance may foster aesthetic engagement by integrating past experiences to promote a sense a congruency between an artwork and the viewer; this empathic interaction may make meaning and provide a transformational experience (Pelowski et al., 2017; 2018a, b). The embodied simulation account for aesthetic experience (Freedberg & Gallese, 2007) further spans into the positive domain (Kirsch et al., 2016; Sachelli et al., 2022), and the status of an artwork shows the recruitment of various nodes across the MNS (Di Dio et al., 2007; 2011; Lutz et al., 2013), alongside higher bodily engagement (Battaglia et al.,

2011). These neural networks may converge to understand and make sense of the artwork from both a cognitive and bodily approach that relates the artwork to the self and promotes emotions felt throughout aesthetic engagement (see Sarasso et al., 2020).

Importantly, our meta-analysis mainly pulled brain coordinates that contrasted negative versus positive aesthetic experience. As represented by the occipital activation reported within the negative VAE's individual and contrast analyses, the classification of the negative visual stimulus as an artwork deems significant, as this presents a schematic basis to interact with the artwork in a distant yet aesthetic manner (Menninghaus et al., 2017) and may promote awareness that the artwork's content stems from a secondhand experience versus a firsthand experience (Mazzocut-Mis, 2021). Thus, the empathy and mirror neuron systems may employ empathic motor resonance to embrace and feel an artwork's visceral negative emotion (please see Ardizzi et a., 2021), while the mentalizing system may be employed to psychologically distance and experience the artwork as another. These results do not posit that the negative aesthetic experience engages these neural systems while the positive aesthetic experience does not; more so, these neural systems may be more distinctly engaged within negative aesthetic experience. Thus, the classification and hedonic coding of an artwork may appropriately engender the recruitment of neural systems surmising *how* an individual engages with an artwork.

4.5 Limitations

Importantly, power limitations inherent to our meta-analysis asks the reader to take our results with caution. Indeed, the VNE versus VAE contrast showed a further recruitment of the right MTL, extending into the globus pallidus, left putamen, right thalamus, and left superior temporal pole. These results may suggest that negative VNE recruits cognitive processes associated with reward and emotional memory; however, the negative VNE has more power

than the negative VAE. Nonetheless, it is of extreme interest that the V2 cluster survived the VAE versus VE contrast, suggesting that even in the face of power from negative VNE, the negative VAE shows a significant difference in activation within the early visual cortex. Conversely, most of the VAE result interpretation stems from the conjunction analyses, suggesting that additional studies for the individual negative VAE may have revealed further nodes akin to its conjunction analyses. Moreover, negative VNE included both social and non-social visual stimuli, which makes it difficult to disentangle differences between general and social negative experiences. Although we have considered differences within an explicit social context, our results concerning negative VNE further allude to social cognition; however, we demonstrated within a more ecological perspective the general applicability of the negative visual experience across contexts. It would have been interesting to assess a non-social visual experience, yet the found studies were too low (N = 2), suggesting a tightened focus on negative visual experiences strictly outside the social domain. Another limitation lies within our included studies as brain contrasts assessed stimuli decided a-priori and/or by participant ratings to be of negative origin, especially so for negative VAE. Therefore, we have assessed the neural correlates that are based within a person's subjectivity alongside validated stimuli sets (i.e., IAPS). Finally, we did not pursue a meta-analysis investigating positive aesthetic experience, which would have been fruitful in disentangling the neural underpinnings of negative aesthetic experience. However, our meta-analysis on negative aesthetic experience alongside meta-analyses on positive aesthetic experience (Boccia et al., 2016; Brown et al., 2011; Chuan-Peng et al., 2020; Feng et al., 2021; Sacheli et al., 2022; Vartanian & Skov, 2014). allow a qualitive assessment for future research exploring intricacies between the two.

5. Conclusions

Across negative visual experiences of artistic and non-artistic content, our results posit that the empathy and mirror neuron systems contribute to the sharing and feeling of another's negative emotion while the mentalizing system promotes understanding another's affective state. In particular to negative aesthetic experience, the identification of an artwork may employ very similar processes as the other negative visual, especially social, experiences; however, the schematic basis as artwork may promote top-down processes that engender an embracement of the associated emotion at a psychological distance, perhaps more so than non-artistic negative visual experiences.

Considerable research exploring the neural correlates of the positive aesthetic experience has been established, yet our lack of power in the negative VAE, and consequently the reported results, lies within the general lack of interest towards the neural correlates underlying the aesthetic experience of negative artwork. Therefore, researchers within neuroaesthetics should be moved to expand their focus towards other aspects of aesthetic experience, such as artwork depicting negativity which has been shown time and time again to have a lasting effect on both viewers and artists alike.

Kim, Wihro. *A body that did once existed*. 2019.

The Posterior Cerebellum's Role in Feeling Moved by Visual Artwork: A Transcranial Direct Current Stimulation Approach

1. Introduction

Feeling moved, a particularly intense emotional experience, transpires across an individual's lifespan, especially within a social context, such as empathizing with another's struggles or achievements. Generally, these moving experiences are situated within self-relevance, provoking the emergence of past memorable experiences (Hänninen & Koski-Jännes, 2023; Landmann et al., 2019; Menninghaus et al., 2015; Schindler et al., 2022). Characterized as a mixed emotion incasing both positive and negative affect, feeling moved generally provides pleasantness to the individual, even under the circumstances of joy and sadness (Cova & Deonna, 2013; Menninghaus et al., 2015; Schindler et al., 2022; Seibt et al., 2018), yet in relation to the affectual salience of such events, such as giving birth or losing a loved one. Goosebumps, warmth and tears occur across experiences of feeling moved (Benedek & Kaernbach, 2011; Schubert et al., 2018; Seibt et al., 2018), suggesting that feeling moved evokes both affectual and bodily engagement within a social context. Prosociality and empathy may base feeling moved that makes meaning via self-relevance towards the strongly salient context of the moving experience in question, encompassing explicit social scenarios and abstract scenarios, such as artwork (Hänninen & Koski-Jännes, 2023; Landmann et al., 2019; Menninghaus et al., 2015; Schindler et al., 2022; Schubert et al., 2018; Seibt et al., 2018; Zickfeld et al., 2019).

Aesthetic experience is commonly reported to evoke feeling moved; however, it is generally reported more within the realm of negative content in comparison to real-life experiences (Meninghaus et al., 2015; 2017; Schindler et al., 2022), spanning across films (Hanich et al., 2014; Wassiliwizky et al., 2015), music (Eerola et al., 2016), stories (Cova et

al., 2017), and visual art (Pelowski et al., 2015; Sawada et al., 2024). As extensively discussed within the previous chapter of this dissertation, this may be based within the employed social and empathic processes denoting psychological distance to feel, share, and understand another's emotions throughout aesthetic engagement, especially so within the realm of negative artistic content (Menninghaus et al., 2017; Mazzocut-Mis, 2021). Thus, feeling moved by artwork seems to be impacted by how art resonates with and provides meaning to the viewer, which may cater to the novel and salient content of the artwork in question (Cova & Deonna, 2013; Menninghaus et al., 2015; Schindler et al., 2022). In consideration of its social and bodily roots, feeling moved by artwork may provide meaningfulness via self-relevance within a social and empathic context across bodily engagement (Pelowski, 2015; Pelowski et al., 2017; 2018a, b; Sarasso et al., 2020; Schoeller et al., 2018).

Accordingly, an individual may "feel into" and comprehend a visual artwork by employing motor empathetic processes via bodily perspective taking (Ganczarek et al., 2018; Vischer, 1873). This may reflect the recruitment of sensorimotor and empathic neural systems to "feel into" artwork via motor-empathic resonance (Freedberg & Gallese, 2007; Gallese 2017; 2019; Kirsch et al., 2016). Therefore, individuals may empathetically engage with artwork through an inward imitation of the actions and emotions depicted within artwork, which may occur through the activation of a viewer's internal schematic representations as supported by neural systems underlying empathic-motor resonance (Freedberg & Gallese, 2007; Gallese, 2019). On the other hand, the predictive processing account for aesthetic experience (catered to visual artwork) claims that the brain actively works as a predictive machine by comparing an artwork's incoming sensory information with previous knowledge (e.g., schematic representations) to explain the aesthetic experience in hand. Mismatches between these comparisons are deemed prediction errors, which occurs

when an artwork presents salient (e.g., novel) content that is not initially represented by previous knowledge (Kesner et al., 2014; Sarasso et al., 2020; Van de Cruys, 2017; Van de Cruys et al., 2023 2017; Van de Cruys & Wagemans, 2011), as often seen within the case of artwork depicting negative content (Menninghaus et al., 2017; Mazzocut-Mis, 2021). Therefore, prediction errors mark perceptual or contextual saliency, which is consequentially reduced by updating previous knowledge via predictive feedback loops. The induction of prediction errors is deemed to be a negative affective experience, while the solving of prediction errors provides a positive affective experience. Therefore, the solving of prediction errors, or implicit learning, allows an individual to make sense of or gain meaning from visual artwork within a pleasurable framework (Kesner et al., 2014; Sarasso et al., 2020; Van de Cruys, 2017; Van de Cruys et al., 2023 2017; Van de Cruys & Wagemans, 2011).

Of high interest, the cerebellum has been posited to work as a predictive machine by integrating both bottom-up and top-down processes to navigate one's environment across social, affective, and motor domains (Adamaszek et al., 2017; Cattaneo et al 2022; Van Overwalle, 2020). Indeed, the cerebellum orchestrates the call of internal models represented within limbic, subcortical, and associative cortical areas via functional and anatomical connections situated within cerebellar-thalamo-cortical loops (Buckner et al., 2011; Habas et al., 2009; Palesi et al., 2020). In particular to its posterior portions, the posterior cerebellum exhibits a medial to lateral functional gradient: medial portions are associated with sensorimotor and emotional empathic processes via functional connectivity with the salience and sensorimotor networks, while lateral portions (i.e., Crus I/II) are associated with higher social and affective functions, such as emotional evaluation and cognitive empathy, via functional connections with the executive control and default mode networks (Adamaszek et al., 2017; Cattaneo et al., 2022; Guell et al., 2018; Klein et al., 2016; Van Overwalle, 2020). The predictive nature of the cerebellum may utilize affective, cognitive, and motor faculties

to make sense and effectively learn about one's environment within a social context (Adamaszek et al., 2017; Cattaneo et al., 2022; Timmann et al., 2010; Van Overwalle et al., 2020).

Therefore, the cerebellum may be essential to the predictive processes that mediate aesthetic pleasure and engagement (Adamaszek et al., 2023; Kesner et al., 2014; Sararsso et al., 2020; Van de Cruys, 2017; Van de Cruys & Wagemans, 2011). The aesthetic evaluation of visual art, yet not their non-artistic counterparts, has been coupled with cerebellar activation (Di Dio et al. 2007; 2011; Lutz et al. 2013; Mizokami et al. 2014). Moreso, the beauty (Ishizu & Zeki, 2013) and sublimity (Ishizu & Zeki 2014) of visual artwork has been shown to recruit the posterior cerebellum with it further being implicated in experiencing beauty differing in valence, such as joy or sorrow (Ishizu & Zeki 2017). Of interest, the default mode network (DMN), consisting mainly of limbic and cortical midline structures, is associated with self-referential processing and cognitive empathy, the attribution of another's mental state (Buckner et al., 2008; Raichle & Snyder, 2007). Heightened recruitment of the DMN was found in feeling moved by artwork (Belfi et al., 2019; Vessel et al., 2012; 2019; but also see Cela-Conde et al., 2013), which may reflect a utilization of self-referential processing within an empathic context. Moreover, an individual's tendency to experience aesthetic chills was coupled by increased cerebellar resting network functional connectivity with the DMN (Williams et al., 2018). In consideration of the cognitive, empathic and bodily processes present within aesthetic experience, the cerebellum may call on emotional, cognitive, and motor efferent copies that are subsequently utilized throughout aesthetic engagement to make meaning of an artwork partly within a motor-empathic context. Thus, the cerebellum may promote feeling moved, which concurs with instances of implicit learning via self-referential processes (Pelowski, 2015; Pelowski et al., 2017; Sarasso et al., 2020), perhaps reflecting empathic processes that underly the meaningfulness and

appreciation obtained throughout aesthetic experience (Pelowski et al., 2018, b; Schoeller et al., 2018).

Non-invasive brain stimulation (NIBs) research has provided causal evidence on the neural underpinnings of aesthetic experience, across various neural areas reaching far throughout the cortex (for a review please see Ciricugno & Slaby et al., 2023). Transcranial magnetic stimulation (TMS) induces a transitory electric current to modulate action potentials or produce virtual lesions within the targeted neural areas (Pascual-Leone, 1999); transcranial direct current stimulation (tDCS) modulates a neural resting state's subthreshold potential by delivering a low-voltage current through a pair of bipolar electrodes, with anodal stimulation boosting neural firing rate and cathodal stimulation reducing neural firing rate (Jacobsen et al., 2012). The general mechanism of the cerebellum is based within the inherent nature of Purkinjee cells that exert an inhibitory tone on the cortex via deep cerebellar nuclei on the thalamus, which regulates subcortical and cortical activity towards the situation on hand. Termed cerebellar inhibition (CBI), the inhibitory tone of the cerebellum has been shown to extend to the motor cortex, such that increased cerebellar activity is associated with reduced activity within the motor cortices (Batsikadze et al., 2019; Calzolari et al., 2023; Galea et al., 2009; Grimaldi et al., 2016; Jackman et al., 2020). CBI has been investigated through the utilization of NIBs: following the application of TMS or tDCS over the posterior cerebellum, corticospinal excitability (CSE) may be measured through single-pulse TMS over the primary motor cortex and used as a measurement of motor-induced CBI (Batsikadze et al., 2019; Galea et al., 2009).

Accordingly, right posterior cerebellar-tDCS (ctDCS) induces plastic changes on resting CSE, with cathodal ctDCS increasing CSE (i.e., reducing CBI) and anodal tDCS decreasing CSE (i.e., increasing CBI; Calzolari et al., 2023; Galea et al., 2009); however, these opposing polarity effects are inconsistent, with both cathodal and anodal ctDCS

decreasing CBI (Batsikadze et al., 2019). Variation in results may be dependent on the static and dynamic ctDCS effects on functional connectivity between motor and thalamic regions (Calzolari et al., 2023). Moreover, ctDCS may induce changes on functional connectivity throughout the cerebellar-cortical networks, such as the DMN (Grami et al., 2021a), recruited for the task on hand (Grami et al., 2021b; Maldonado et al., 2023), explaining opposing yet complementary polarity effects of right-posterior ctDCS on motor excitability (Calzolari et al., 2023), action generation (Aloi et al., 2022), motor imagery (Grami et al., 2021b), motor learning (Galea et al., 2011; Takano et al., 2022), and working memory (Maldonado et al., 2023).

Cerebellar neuromodulation has been expanded towards the social and affective domains based within empathic processes (for a review, please see Cattaneo et al., 2022). Medial-posterior ctDCS (Ferrucci et al., 2012) and disruptive TMS over various regions of the posterior cerebellum hindered the recognition of negative emotions from holistic human stimuli (Ferrari et al., 2018; Ferrari et al., 2019), perhaps through a reduced CBI (Ferrari et al., 2021). The cerebellum may be employed to detect, feel, and engage with negative stimuli and their situational contexts (Habas, 2018; Habas et al., 2009; Schutter et al., 2012; Seeley et al., 2007). The denate nucleus, the main output channel of the cerebellum, is implicated in emotional processing via functional connections with the salience network (Adamaszek et al., 2017; Allen et al., 2005), which is particular for the detection of negative emotion (Uddin, 2015; Uddin et al., 2017). This may stem towards the cerebellum's evolutionary nature to promote well-being and survivability (Adamaszek et al., 2017; Van Overwalle et al., 2020), classified as hallmarks within the evolutionary prospects of feeling moved (Hannien & Kosel-Jannes, 2023; Vingerhoets, 2013).

Deemed the "stopping for knowledge" account for aesthetic experience (for a discussion, please see Sarasso et al., 2020), a reduction of motor output may allow a

cognitive modification of internal representations that generates intrinsic reward from aesthetic experience. Following an art production learning paradigm, a higher empathic disposition mediated the inverse relationship between aesthetic appreciation and CSE, suggesting that a higher motor inhibition was characterized by a stronger individual empathic ability for aesthetic appreciation (Finisguera et al., 2021). While physically imitating frowning, a person's a higher empathic disposition positively correlated with aesthetic judgments of beauty of negative facial expression taken from paintings (Ardizzi et al., 2020). Thus, motor inhibition (such as represented by employing a congruent motor program throughout aesthetic engagement) may generate intrinsic reward by allocating attentional resources towards the artwork in question alongside employing implicit empathic and mirroring mechanisms to make sense of an artwork (Gallese et al., 2017; 2019; Sarasso et al., 2020). As such, aesthetic experience may be a self-referential process situated within empathic-motor resonance to reduce saliency through the updating of prior knowledge (please see further Sachelli et al., 2022). Therefore, the neuromodulatory impact of increasing CBI may induce motor inhibition that facilitates an implicit learning approach to feel moved by an artwork via an induction of empathic and predictive processes.

Hence, higher instances of saliency and uncertainty may be more demanding and employ the cerebellum more to learn from one's environment. Medial-posterior ctDCS was shown to affect the learning of social action sequences, with cathodal ctDCS hindering the learning of moderately salient sequences and anodal ctDCS boosting the learning of highly salient sequences (Oldrati et al., 2021; please see further Oldrati et al., 2024). Through the intricate cerebellar-cortical circuitry, these effects may entail that more demanding social and affective tasks may benefit from anodal ctDCS, perhaps through a promotion of cortical resources denoting motor-empathic and predictive processes (i.e., Timmann et al., 2010). In contrast, more automatic processes may be hindered by anodal ctDCS, through impairing the

cerebellum's regulatory role in motor-empathic and predictive processes via an overcompensation of cortical resources; opposing effects on learning may occur from cathodal ctDCS (please see Maldonado et al., 2023). Artwork exhibiting negative emotion, and in hand higher novelty or saliency (Meninghaus et al., 2017; Mazzocut-Mis, 2021), may allow instances of implicit learning associated with peak aesthetic experiences (Kesner et al., 2014; Sarasso et al., 2020; Van de Cruys et al., 2017; Van de Cruys & Wagemans, 2011), such as feeling moved, more so than for artwork exhibiting positive emotion (Menninghaus et al., 2015). Moreover, those individuals with higher empathic ability or previous knowledge (i.e., art experience) may pose more of an ease within implicit learning via the promotion of updating prior knowledge to impose a self-relevant congruency with an artwork's content via a predictive fashion (Freedberg & Gallese, 2007; Gallese 2017; 2019; Ganczarek et al., 2018; Kirsch et al., 2016; Kesner et al., 2014; Pelowski, 2015; Pelowski et al., 2017; 2018ab; Van de Cruys, 2017; Van de Cruys & Wagemans, 2011; Sarasso et al., 2020; Schoeller et al., 2018; Specker et al., 2024; Vischer 1873/1994). Given the cerebellum's specificity within empathic processes and predictive processing, these aspects within aesthetic experience were investigated within a causal manner through ctDCS.

Therefore, the cerebellum may be employed as a regulator within the implicit learning of moving aesthetic experiences by orchestrating the neural network dynamics surmising the motor, emotional, and cognitive functions to appreciate visual art. To our current knowledge, no study has investigated the role of the posterior cerebellum within aesthetic experience. Therefore, we aimed to explore the construct of feeling moved as delegated by the cerebellum. Given the particularity of feeling moved by artwork depicting negative content, we hypothesized that participants would feel more moved by negative artwork versus positive artwork, and further given the notions of empathy and previous knowledge propagating aesthetic experience, we hypothesized that feeling moved would be positively

impacted by individual differences in trait empathy and art experience. Given the particularity of the right-posterior cerebellum within motor-induced CBI alongside the affective and social domains, ctDCS was utilized over the right posterior cerebellum to assess how much individuals felt moved from artwork differing in emotional valence. Within the perspective of opposing ctDCS effects, it was hypothesized that anodal ctDCS over the right posterior cerebellum will boost feeling moved by artwork as CBI promotes motor inhibition, which may concur with a promotion of cortical resources that engender attentional and empathic processes for implicit learning throughout aesthetic experience. Conversely, hindering CBI via cathodal ctDCS may impair feeling moved by increasing motor excitability and impairing implicit learning via a lack of promotion to cortical resources. This may be particular to individuals with low empathic abilities or art experience, denoting difficulties in implicit learning throughout aesthetic experience. On the other hand, the promotion of cortical resources following anodal ctDCS may hinder feeling moved for individuals with high empathic abilities or art experience, who demonstrate greater automaticity and ease in implicit learning throughout aesthetic experience. Given the predominance of feeling moved towards artwork of negative content, we expected ctDCS effects to be the strongest in relation to feeling moved by negative artwork. As the nature of the aesthetic evaluation task set no time constraint in response and the subjectivity in response time (RT) in feeling moved (e.g., Belfi et al., 2019), all analyses considering RT were exploratory.

2. Method

2.1 Participants

We recruited 48 Italian participants predominantly from the University of Milano-Bicocca's undergraduate and graduate psychology population. Participants were split between anodal and cathodal ctDCS montage conditions, resulting in 24 participants per ctDCS stimulation montage (please see Table 1 for participant descriptives). Further in line with past studies applying tDCS over the cerebellum or for investigating aesthetic experience (e.g., Cattaneo et al., 2020; Ferrari et al., 2015; Oldrati et al., 2021; please see further Oldrati & Schutter et al., 2017), our sample size for each ctDCS condition was assessed a-priori through G-power to ensure a statistical power of 80% and an alpha level of 0.05 for a medium-low effect size (f = 0.25). All participants provided written informed consent and privacy of data usage statements alongside screening questionnaires, which evaluated their eligibility to undergo non-invasive brain stimulation; no participant reported neurological or psychological disorders, brain trauma, or a family history of epilepsy. All participants were right-handed as assessed by the Edinburgh Handedness Inventory (Oldefield, 1971) and had normal or corrected to normal vision. These questionnaires were respectively completed in chronological order before moving forward within the experiment. The protocol was approved by the local ethical committee, and participants were treated in accordance with the Declaration of Helsinki.

2.2 Self-Report Questionnaires for Individual Differences

The Art Experience Questionnaire (AEQ; Chatterjee et al., 2010) is an 8 item-self report questionnaire that asked participants to indicate their level of experience with art-related activities, such as formal education, visiting galleries or museums, and art-engagement. Our sample generally reported to not be experts in art by generally falling below the flexible cut-

off of 14; however, 3 anodal and 4 cathodal participants fell above the flexible cut-off, which may be due to differences in the European and American Education Systems (please see Ticini et al., 2014); nonetheless, no participant identified as art professionals or indicated any pursuit of a career within the arts.

The Interpersonal Reactivity Index (IRI) is a 28-item self-report questionnaire that measures an individual's empathic traits via four subscales on a 5-point Likert-like rating scale (Davis, 1983). Perspective Taking (PT) measures an individual's ability to undertake another's cognitive perspective, while Empathic Concern (EC) measures an individual's feeling of concern or sympathy for persons in need. Personal Distress (PD) measures an individual's tendency to experience negative self-oriented feelings, such as anxiety, when presented with another's unease. Fantasy (FN) measures an individual's ability to become absorbed by the feelings and actions of characters within an imaginary context. Although the verdict is not out concerning the validity of the IRI in appropriately measuring emotional and cognitive empathy (e.g., mentalizing), the construct validity of the IRI in emotional and cognitive empathy have generally surmised that EC and PT may respectively represent emotional and cognitive empathy, with the total of these two subscales representing an individual's general empathic ability (Murphy et al., 2020; Wang et al., 2020a). While PD could be a better indicator of emotional empathy when combined with EC (Wang et al., 2020), PD may better represent negative emotionality, such as interpersonal malignancy (Murphy et al., 2020). Moreover, FN seems to better represent trait absorption rather than empathy *per se* (Murphy et al., 2020). Therefore, we comprised the following constructs to investigate the role of empathy on aesthetic experience: PT representing cognitive empathy (i.e., mentalizing), EC representing emotional empathy, and EC + PT representing general empathy.

Table 1. Participant Descriptives Age and Measures of Individual Differences across ctDCS participant samples.

Measure	Statistic	Total (N = 48, 12M)	Anodal ctDCS (N = 24, 6M)	Cathodal ctDCS (N = 24, 6M)
Age	Mean (SD)	25.6 (3.72)	25.5 (3.41)	25.7 (4.08)
	Min - Max	19 - 37	20 - 32	19 - 37
Perspective Taking	Mean (SD)	20.0 (3.61)	19.3 (3.53)	20.8 (3.61)
	Min - Max	12 - 27	12 - 26	14 - 27
Empathic Concern	Mean (SD)	20.6 (4.20)	20.7 (4.19)	20.5 (4.29)
	Min - Max	12 - 28	13 - 28	12 - 28
General Empathy	Mean (SD)	20.3 (3.36)	20.0 (3.34)	20.6 (3.43)
	Min - Max	12.5 - 26.5	12.5 - 26.0	14.5 - 26.5
Art Experience	Mean (SD)	8.79 (4.77)	8.54 (4.38)	9.04 (5.21)
	Min - Max	2 - 22	2 - 18	2 - 22

Note: SD = standard deviation

2.3 Stimuli Acquisition and Validation

All stimuli were figurative paintings of scenes obtained from the Vienna Art Picture System (VAPS; Fekete et al., 2022), a database of paintings validated on as battery of aesthetics ratings via a 7-point rating scale (emotional arousal, emotional valence, familiarity, liking, and visual complexity). Accordingly, 120 unfamiliar paintings (< 3.5 on the 7-point scale) were selected from the VAPS database and were split between two stimuli sets of 60 paintings each (A and B). The sets was further equally split by valence, constituting 30 positive (> 4.0) and 30 negative (< 3.0) paintings each. Two-way ANOVAs (set: A, B) x (valence: positive, negative) revealed no main effect of set across all variables: emotional valence ($F(1, 116) = .311$, $p = 0.578$), emotional arousal ($F(1, 116) = .026$, $p = 0.873$), liking ($F(1, 116) = .292$, $p = 0.590$), familiarity ($F(1, 116) = .524$, $p = 0.471$), visual complexity ($F(1, 116) = .025$, $p = 0.874$) alongside absolute value of valence ($F(1, 116) = .092$, $p = 0.762$). Likewise, *no main effect of valence* was revealed for visual complexity ($F(1, 116) =$

.1.941, p = 0.166), familiarity (F(1, 116) = 3.355, p = 0.070) and absolute value of valance (F(1, 116) = 3.736, p = 0.56). However, a main effect of valence was revealed for emotional valence (F(1, 116) = 1418.279, p < 0.001, ηp2 = .924), emotional arousal (F(1, 116) = 87.07, p < 0.001, ηp2 = .429) and liking (F(1, 116) = 54.670, p < 0.001, ηp2 = .432), yet this was expected as emotional valence was strongly related with the dimensions of liking and emotional arousal within the VAPS database.

Replicating main effects, Tukey-Kramer post-hoc analyses revealed no interaction effects for different sets of the same valence. Accordingly, set A's positive valence group did not differ from set B's positive valence group for all aesthetic ratings (emotional valence (t(116) = -0.180, p = 0.998), emotional arousal (t(116) = -.254, p = 0.994), liking (t(1, 116) = 0.631, p = 0.992), familiarity (t(116) = 1.198, p = 0.629), visual complexity (t(116) = -.111, p = 1.000), and absolute value of valence (F(1, 116) = -.180, p = 0.998)), with the same results being revealed for each set's negative valence counterparts (emotional valence (t(1, 116) = -0.609, p = 0.929), emotional arousal (t(1, 116) = 0.481 p = 0.963), liking (t(1, 116) = 0.133, p = 0.999), familiarity (t(1, 116) = -0.174, p = 0.998), visual complexity (t(116) = -0.144, p = 0.999), and absolute value of valence (F(1, 116) = 0.609, p = 0.929)). Therefore, painting sets were found to be comparable within and between sets across all aesthetic dimensions, yet positive paintings were liked more and were less emotionally arousing than negative paintings (Table 2).

Table 2. Descriptives of Artwork Stimuli Sets.

	Set	Valence	N	Mean	SD	Minimum	Maximum
Emotional Valence	A	NEG	30	2.516	0.308	1.80	2.95
		POS	30	4.558	0.292	4.20	5.25
	B	NEG	30	2.562	0.316	1.85	3.00
		POS	30	4.572	0.259	4.21	5.25
Emotional Arousal	A	NEG	30	4.824	0.653	2.75	5.80
		POS	30	3.838	0.605	2.70	5.40
	B	NEG	30	4.756	0.387	4.15	5.60
		POS	30	3.874	0.508	3.10	4.80
Familiarity	A	NEG	30	1.683	0.527	1.10	3.45
		POS	30	1.952	0.556	1.05	3.25
	B	NEG	30	1.706	0.512	1.05	2.88
		POS	30	1.789	0.506	1.15	3.35
Liking	A	NEG	30	3.486	0.632	2.55	5.30
		POS	30	4.322	0.501	3.50	5.35
	B	NEG	30	3.466	0.695	2.40	5.35
		POS	30	4.225	0.512	2.90	5.25
Visual Complexity	A	NEG	30	4.455	0.779	2.45	5.70
		POS	30	4.280	0.692	2.70	5.85
	B	NEG	30	4.475	0.675	3.00	6.20
		POS	30	4.300	0.599	3.40	5.60
Absolute Value of Valence	A	NEG	30	0.984	0.309	0.55	1.70
		POS	30	1.058	0.292	0.70	1.75
	B	NEG	30	0.938	0.316	0.50	1.65
		POS	30	1.072	0.259	0.71	1.75

Note: NEG = negative; POS= positive; SD = standard deviation; Set= painting set for experimental session.

2.4 Procedure

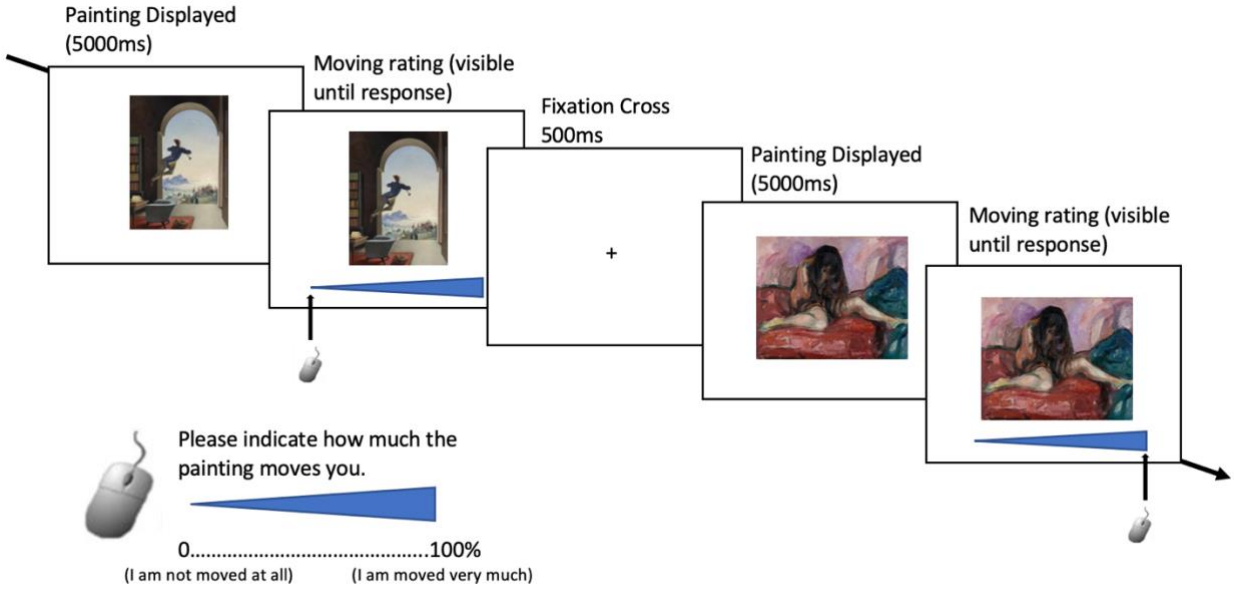
The experiment was composed in a single-blind, within-subjects design. The whole experiment was situated within the same physical setting across all participants and consisted of two experimental sessions, one session for real ctDCS and one session for sham ctDCS. Participants were asked to perform an aesthetic evaluation task before and after ctDCS. Generally, sessions were separated by 5-15 days (mean days (SD): anodal ctDCS= 10.04 (6.03); cathodal ctDCS= 8.52 (3.63)) and occurred within the same time of day (i.e.,

morning: 9:00 – 1:00; afternoon: 14:00 - 18:00; mean hour difference between sessions (SD): anodal ctDCS= 0.88 (1.09); cathodal ctDCS = 0.63 (0.91)). Before beginning the first session, participants completed the AEQ and IRI in a counterbalanced fashion on a 2019 MacBook Air.

For each session, participants were seated approximately 60cm in front of a 17-inch monitor (refresh frequency, 60 Hz; resolution 1366 × 768) on a Windows Laptop. The computer was equipped with a mouse, and the monitor was positioned/tilted to each participant's viewing preference. Each session started with a short practice block to familiarize the participants with the aesthetic evaluation task. The practice block consisted of two negative and two positive paintings taken from the VAPS and was the same across all sessions. The aesthetic evaluation task (Figure 1) asked participants to indicate *quanto il dipinto ti emoziona,* the appropriate Italian translation for *how much does this painting move you* in an aesthetic context. Unlike past studies exploring being moved by visual artwork (e.g., Vessel et al., 2012), we chose this simple question due to an individual's inherent semantic understanding of feeling moved, which encompasses both sad and joyful emotional events with a moderately arousing and positively affective signature (Menninghaus et al., 2015; Schindler 2022). Accordingly, participants were asked to indicate with the mouse on a visual analogue scale (VAS) from 0 on the left (*non mi emoziona per niente; it does not move me at not at all)* to 100 on the right (*mi emoziona moltissimo; it moves me very muc*h). Participants were asked to use the entire scale and were blind to the numerical value of the scale. For each trial, a fixation cross was presented on the screen for 500ms followed by a painting for five seconds; then the VAS appeared below the painting and remained until the participants provided a response. Five seconds was chosen to allot the appropriate time for participants to aesthetically engage and consequently feel moved by the paintings (please see Belfi et al., 2019). All paintings were presented in random order.

After the practice block, the ctDCS montage was administered onto the participant's head by strapping ctDCS electrodes into place with belt-like rubber bands. Administering the ctDCS montage before versus after the first aesthetic evaluation block controlled for confounds associated with sensations induced by the physicality of the ctDCS montage within participants alongside differences in time to administer the ctDCS montage across participants. Following, participants were asked to complete the first aesthetic evaluation task block, which consisted of one validated painting set (A or B) and was designed in the same exact fashion as the practice block. Participants were reminded about the dimensionality of the VAS to indicate how much they felt moved by each painting. Promptly after the completing the first aesthetic evaluation block, participants underwent the 20 minutes of ctDCS positioned over the right posterior cerebellum. During ctDCS, participants were instructed to relax and keep still, unless they needed to correct their posture to ensure comfortability. Every couple of minutes throughout ctDCS, the researcher checked on participants' comfortability towards ctDCS and informed participants how much time has passed. Two minutes before the end of ctDCS, participants were informed that the second aesthetic evaluation block was about to begin and were once again reminded about the dimensionality of the VAS to indicate how moved they felt by each painting. The second aesthetic evaluation block utilized the same validated painting set as the first aesthetic evaluation block (e.g., A and A) to control for the effect of aesthetic experience in feeling moved akin to the contextual elements of each painting set and to allow the appropriate comparison of aesthetic ratings obtained pre- and post-stimulation.

Figure 1. Aesthetic Evaluation Task.



Note: Schematic overview of experimental trials within the aesthetic evaluation task. Each trial started with a fixation cross screen, after which a painting was presented. Participants were asked to rate how moved they felt by the painting by a mouse. The mouse cursor was presented an equal number of times at the left and right extremity of the line. From left to right, the paintings shown are, firstly, *Evening Song (*Franz Sedlacek, 1938*)* and, secondly, *Weeping Nude* (Edvard Much, 1914), respectively representing the most positively and negatively a-priorly rated artworks within our stimuli sets. All paintings shown in this figure are in the public domain.

At the end of each session, participants completed a discomfort questionnaire that assessed their level of discomfort experienced from ctDCS (such as sensations of itch, pain, and burning) alongside being provided supplies to clean any residue post ctDCS. While being blind to the numerical value, participants indicated how much they experienced each sensation on a series of 8 VAS scales spanning from 0 on the left (*per niente; not at all*) to 100 on the right (*moltissimo*; *a lot*). Paired sample t-tests indicated that the total level of discomfort summed across all 8 scales for each stimulation type was not significantly different (anodal ctDCS: $t(23) = .950$, $p = .348$; cathodal ctDCS $t(23) = .769$, $p = .450$) between real (anodal ctDCS: mean (SD)= 96.4 (80.3); cathodal ctDCS: mean (SD)= 89.0 (80.3)) and sham stimulation (anodal ctDCS: mean (SD) = 81.3 (59.0); cathodal ctDCS:

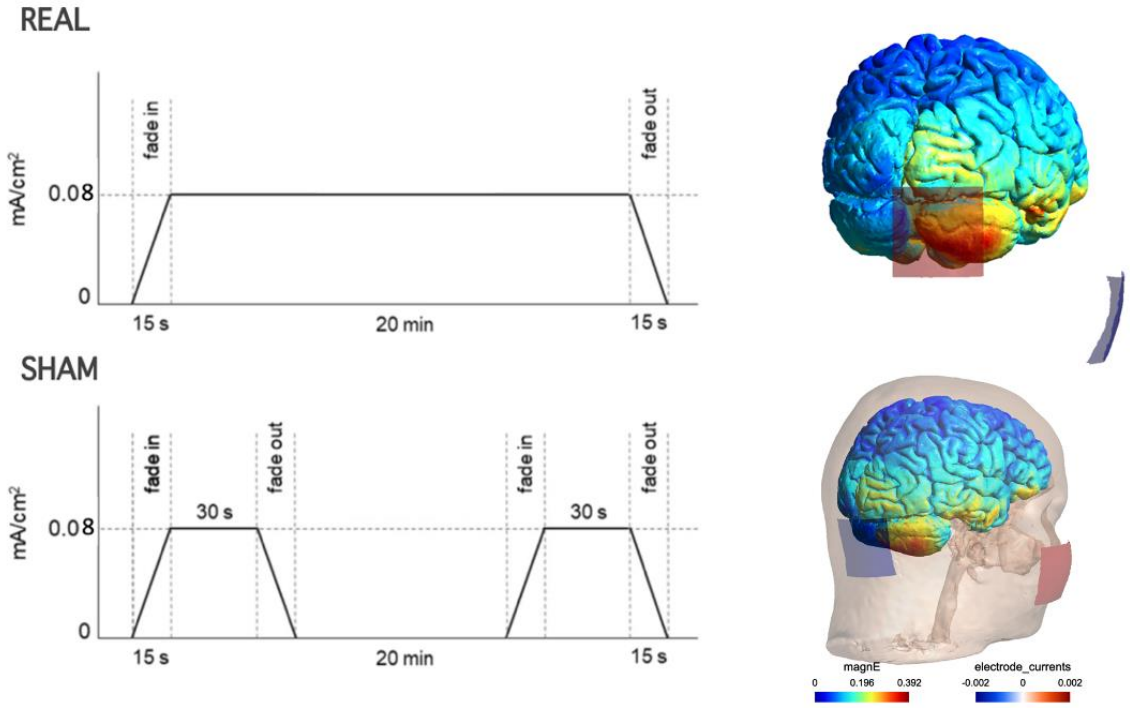
mean (SD) = 78.5 (55.4)), and independent sample t-tests showed that the level of discomfort between anodal and cathodal stimulation did not significantly differ for real ($t(46) = 0.296$, $p = .769$) and sham stimulation ($t(46) = 0.166$, $p = 0.869$). These results imply that the confound of discomfort did not impair our results and that participants were blind to stimulation type, regardless of it being anodal or cathodal ctDCS. Importantly, painting sets and type of ctDCS were counterbalanced across the two experimental sessions. Such that, sham ctDCS occurred in the first session for half of the participants, and painting set A was used in half of the sham and real ctDCS sessions. Qualtrics was used to collect data from self-report questionnaires, while E-Prime 2 software (Psychology Software Tools, Inc., Pittsburgh, PA, USA) was used for the presentation of measures, stimuli, and data collection from the aesthetic evaluation tasks.

2.5 ctDCS Administration

ctDCS was delivered via a battery-driven constant DC current stimulator (BrainSTIM, EMS s.r.l., Bologna) through a pair of saline-soaked sponge electrodes (5x5cm) coated with electrocurrent gel. The current intensity was set at a low 2 mA allotting a current density of 0.08 mA/cm^2. Participants were assigned to one of the two real ctDCS conditions (anodal or cathodal) and a sham condition, whose ctDCS montage replicated the participant's real ctDCS condition (Figure 2). The ctDCS montage in each condition targeted the right posterior cerebellum. In respect to the anodal montage, the anode was positioned 1 cm below and 3 cm lateral to the inion, orientated parallel to the midline, while the cathode was positioned over the right buccinator muscle; the cathodal montage had the reverse anodal and cathodal placement. In comparison to other possible ctDCS montages, our ctDCS montage has been shown to be affective in adequately modulating electric field strength across the right cerebellum with minimal spreading onto the frontal and occipital cortices (Razaee &

Dutta, 2019), whose modulation has been implicated within aesthetic experience (Cattaneo et al., 2020) and could had potentially construed the comprehension of our results. Moreover, this montage has been applied to investigate network effects following ctDCS (Aloi et al., 2022; Calzolari et al., 2023; but also see Liao et al., 2022) alongside CBI (Batsikadze et al., 2019; Gallea et al., 2009; 2011). By utilizing SimNIBS (Thielscher et al., 2015), we further ran simulation models of the applied montages (anodal and cathodal) that displayed their generated electric field distribution and magnitude using standard conductivity values. Both the real and sham ctDCS sessions lasted for a total of 20 minutes and began with a ramp-up period of 15 seconds to incrementally achieve maximum stimulation intensity. For the real tDCS session, the stimulation intensity continued throughout the 20-minute period with the last 15 seconds ramping stimulation down to 0 mA. For the sham ctDCS session, the stimulation continued for 30 seconds and was then ramped back down to 0mA; ramping up and down occurred both at the beginning and end of the sham ctDCS session to induce a placebo of physical sensations akin to real ctDCS (please see Oldrati et al., 2021).

Figure 2. ctDCS stimulation parameters and ctDCS Montage and Electric Field Magnitude from SimNIBS 4.0.



Note: Left: a graphic illustration of cerebellar transcranial direct current stimulation (ctDCS) parameters (in mA/cm^2) across time within real (top) and sham (bottom) experimental sessions. Right: an illustration of electric field magnitude and distribution (in V/m) of anodal (top) and cathodal (bottom) ctDCS montages via SimNIBs (v4.1.0) original *Ernie* head model. The red electrode denotes placement of the anode and the blue electrode denotes placement of the cathode; the dominant electrode (e.g., anode in the anodal montage) is positioned 1cm below and 3 cm to the right of the inion over the right cerebellum and subordinate electrode is placed over the right buccinator muscle.

2.6 Data Pre-processing

Across both ctDCS montages (anodal and cathodal), data was preprocessed in respect to response time. Accordingly, 4 participants accidentally proceeded with the 2nd aesthetic evaluation task that followed ctDCS stimulation before the stimulation period ended, resulting in the removal of the first trial of these blocks per participant. Subsequently within each block per each individual participant, responses were filtered to account for outliers by computing responses that fell outside the 3 standard deviations from their mean response time. This process resulted in the removal of 219 trials. Furthermore, 32 trials in which the

participant response occurred below 500ms were removed from the dataset. In total, 255 trials were removed from the raw dataset of 11520 trials; the final dataset consisted of 11,265 trials representing of 97.79% of the raw dataset. For feeling moved, the position of the mouse cursor along the bar was automatically converted by E-Prime software to percentage rating scores, where a 0% score corresponded to the mouse cursor positioned at the left end of the VAS and a 100% score corresponded to the mouse cursor positioned at the right end of the VAS. From the final dataset, mean response time (RT; in milliseconds (ms)) and mean percent in feeling moved were calculated per each participant across experimental blocks (i.e., Pre-ctDCS and Post-ctDCS). Moreover, mean change scores for feeling moved and RT were computed by subtracting their respective mean scores acquired before ctDCS (pre-ctDCS) from after ctDCS (post-ctDCS) across experimental sessions.

2.7 Baseline Statistical Analyses

All statistical analyses were performed with Jamovi, an R-based scripting platform for statistical analyses (The jamovi project, 2023; R Core Team, 2022). To investigate differences in feeling moved on different experimental sessions before ctDCS stimulation, a Linear Mixed Model (LMM) was carried out separately on pre-ctDCS scores of feeling moved and RT with experimental session (1 and 2), valence (positive and negative), and stimulation (real and sham) as the within-subjects factors that were allowed to interact. To appropriately represent a baseline in line with subsequent analyses, data was nested within participants, who were coded as the cluster and random intercept, and stimulation was coded as the random slope within participants (for LMM specifics and reasoning, please see *ctDCS analyses*). Two-sided Pearson Correlations were carried out to examine the relation of individual differences (Perspective Taking, Empathic Concern, General Empathy, and Art Experience) to mean scores of feeling moved and RT before ctDCS during the first aesthetic

evaluation block (i.e., pre-ctDCS scores) across experimental sessions (1 and 2). Feeling moved and RT was further collapsed across (positive and negative) and split between (positive or negative) artwork differing in valence.

2.8 ctDCS Statistical Analyses

All LMMs were employed through Jamovi's General Analyses for Linear Models module that estimates models using Restricted Maximum Likelihood (REML) and employs Satterthwaite's method to generate degrees of freedom and p-values (Gallucci, 2019); this approach has been demonstrated to reduce Type-1 error, especially in the face of small sample size (Luke et al., 2017). Moreover, LMMs have been shown to be substantially robust, even if distributional assumptions are violated (Schielzeth et al., 2020). To initially explore the effects of Stimulation on response to feeling moved yet also reducing the complexity of the models, LMMs were employed on the mean change scores in feeling moved and RT separately for each ctDCS montage (anodal or cathodal). Stimulation type (real vs. sham), artwork valence (positive vs. negative), and measures of individual differences (Perspective Taking, Empathic Concern, General Empathy, and Art Experience) were coded as independent variables. Accordingly, stimulation type and artwork valence were coded as fixed effects as they do not vary across participants. Given our interest in the effect of individual differences, measures of individual differences were coded as covariates, which respectively assigned scores of individual differences to each participant. As such, the interaction effects were included as following: stimulation x valence; stimulation x individual differences; valence x individual differences; stimulation x valence x individual differences.

Regarding random effects, models were compared to one another with differing random effects, which account for each participant's variability in response to feeling moved by an artwork. Accordingly, the random intercept assigns each participant a unique baseline

value of the dependent variable representing their change in feeling moved. Random slopes allow the relationship (i.e., slopes) between the independent and dependent variables to differ between participants; we further allowed random effects to be correlated (Brown, 2021). The coding of random effects in LMMs have been up to debate. Some argue to keep the model 'maximum,' to include all possible random effects within random intercepts and slopes to ensure a reduction of type-1 error (i.e., false positives; e.g., Bar et al., 2013), while others insist on comparing the parsimony of models in light of reducing complexity that may result in an overfit of the data (Matuschek et al., 2017; Park et al., 2020). As such, the Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) are two indicators for measuring a model's goodness of fit based on the inclusion of parameters (e.g., random intercepts and/or random slopes), with BIC being the most conservative for goodness of fit by penalizing a model's fit with each additional parameter (Cavanaugh et al., 2019; Sutherland et al., 2007). Moreover, log-likelihood indicates the degree in which a model may explain data, with a higher (or less negative) log-likelihood indicating a better fit of data. Following a chi square distribution, the likelihood ratio test (LRT) compares the log-likelihood scores of two models and indicates a significant improvement of a model's fit with and without additional parameters (i.e., random slopes). Models can be compared by nesting them within one another, such that one model contains every parameter as its complementary plus more. Therefore, a model's goodness of fit can be explored by comparing the removal or inclusion of parameters (Brown et al., 2021). To find a balance for the most parsimonious model without overfitting the data, we first fitted the model to include a random intercept and slope, and we compared this more maximum model to a nested simpler model that included only a random intercept.

Accordingly, the subjectivity in feeling moved may vary from person to person; therefore, participants were coded as the cluster variable and were included as the random

intercept (Intercept | Participant). This allowed mean change scores to be respectively nested within each participant and to vary across participants. Moreover, ctDCS effects have been demonstrated to be influenced by interindividual differences, stemming from physiology (e.g., skin-cerebellum distance) and susceptibility to tDCS (Maas et al., 2023; Vergallito et al., 2022). Therefore, ctDCS stimulation (real vs. sham) was coded as the random slope. This resulted in fitting two potential models for each individual difference across ctDCS montages: Model 1 accounted for both random intercepts and slopes (MeanMoveChange ~ 1 + Stimulation + Valence + Individual Difference + Stimulation:Valence + Stimulation:Individudal Difference + Stimulation:Valence:Individual Difference (1+ Stimulation | Participant)), while Model 2 accounted for only random intercepts (MeanMoveChange ~ 1 + Stimulation + Valence + Individual Difference + Stimulation:Valence + Stimulation:Indivudal Difference + Stimulation:Valence:Individual Difference (Intercept | Participant)). For mean change in RT to indicate feeling moved, the same models were employed with the only difference being a respective replacement of the dependent variable. We compared model fits by nesting Model 2 within Model 1 and selected the best fit model for further analyses. These comparisons also included comparing such models to their marginal forms, which were fitted without any random effects. Model selection led to Model 1 being employed across all LMMs for mean change in feeling moved and RT, except the LMM assessing Anodal ctDCS on the mean change in feeling moved related to Art Experience, which utilized Model 2 (please see the appendix for Model Selection).

After selecting the best fit model, the employed LMMs were designed to test the effects of stimulation type (real vs. sham) on response to feeling moved by artworks differing in valence (positive vs. negative) across participants on an individual level, which further took measures of individual differences in empathy and art experience into consideration.

This occurred for both the dependent variables of change in feeling moved and change in RT. For each dependent variable, we carried out LMMs for each measure of individual differences (Perspective Taking, Empathic Concern, General Empathy, and Art Experience) for each stimulation montage (anodal and cathodal). Tukey Kramer post hoc tests were utilized for investigating significant results involving nominal fixed effects (i.e., valence). For the interpretation of significant LMM results that included measures of individual differences, simple slope analyses were performed with denoting individual differences at +/- 1 SD as the moderator (please see Liu et al., 2017), and their respective plots were generated for visual inspection. Moreover, significant results were further inquired by employing LMMs that adopted the random effects of parent models to reveal underlying effects that may had been concealed by employing the initial robust models. The specifics of such are detailed throughout the results.

3. Results

3.1 Baseline Scores

The LMM on pre-ctDCS Mean move scores (Table 3) revealed a main effect of valence (b = 16.873, t(46) = 13.6876, $p < .001$, 95% CI = [14.44, 19.306]) indicating that participants felt more moved by negative paintings than positive paintings across experimental sessions (1 and 2) and stimulation conditions (real and sham) before ctDCS. No other main effect or interactions were revealed for pre-ctDCS mean move scores (all ps > 0.168).

Moreover, cluster nested residual-predicted plots generated from the LMM modeling pre-ctDCS RT scores flagged a participant belonging to the anodal ctDCS montage to be an extreme outlier, who demonstrated mean RTs (14489- 17552ms) lying more than 3 SD (5904ms) outside the mean RT composed from all participants (2677ms), and outside 3 SD + 1.5 x the interquartile range of the third quartile (7934ms). Experimenters noted that this participant did not have any difficulties in completing the task; however, they took much

longer across the experimental sessions to respond in how much they felt moved. Therefore, this participant was removed from all analyses considering RT yet kept for all analyses concerning mean percent in feeling moved. Accordingly, the LMM on pre-ctDCS RT scores (Table 3) revealed a main effect of valence (b = 204.4, t(90) = 3.329, p = .001, 95% CI = [83.2, 325.5]) and experimental session (b = -581.5, t(45) = -2.510, p = .016, 95% CI = [-1038.7, -124.3]) indicating that participants were slower to respond to negative paintings in feeling moved and faster to respond on the second day of experimental session. No other main effect or interactions were revealed for pre-ctDCS mean move RT scores (ps> 0.124).

Taken together, these results suggest that the baseline for participants' response in feeling moved were similar between experimental session and ctDCS stimulation. However, participants generally felt more moved by and were slower to respond to negative paintings, and they may have become acclimated to the task after the first experimental session (please see Figure 3).

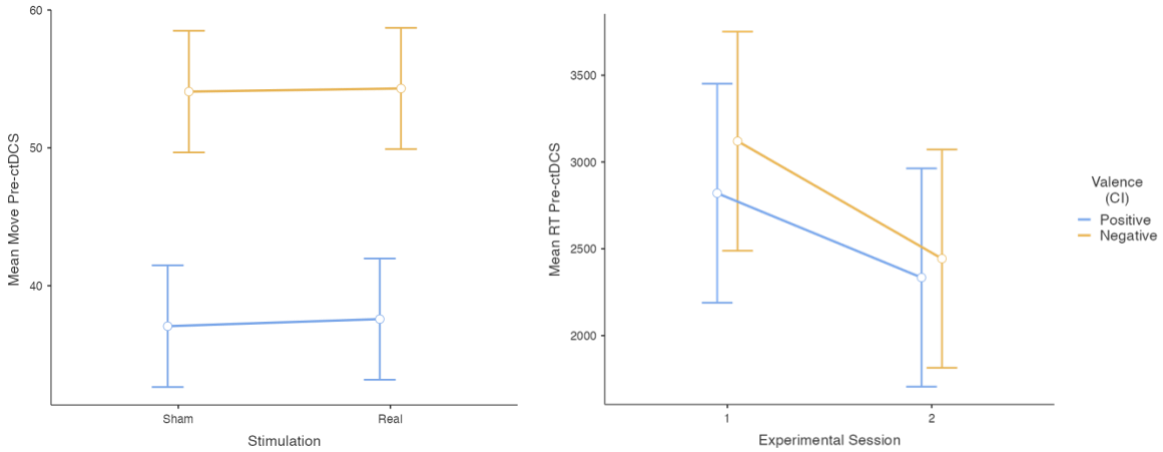
Table 3. Parameter Estimates from Before Stimulation on Response to Feeling Moved Across Participants.

Measure	Names	Effect	Estimate	SE	Lower	Upper	df	t	p
Pre-ctDCS Mean move scores	(Intercept)	(Intercept)	45.758	1.93	41.95	49.565	46.0	23.7203	< .001
	Valence	Negative - Positive	16.873	1.23	14.44	19.306	138.0	13.6876	< .001
	Stimulation	Real - Sham	0.371	1.23	-2.06	2.803	138.0	0.3006	0.764
	Experimental Session	2 - 1	-1.603	1.23	-4.04	0.830	138.0	-1.3000	0.196
	Valence ✻ Stimulation	(Negative - Positive) ✻ (Real - Sham)	-0.286	2.47	-5.15	4.578	138.0	-0.1162	0.908
	Valence ✻ Experimental Session	(Negative - Positive) ✻ (2 - 1)	-2.971	2.47	-7.84	1.894	138.0	-1.2049	0.230
	Stimulation ✻ Experimental Session	(Real - Sham) ✻ (2 - 1)	-10.816	7.72	-26.04	4.411	46.0	-1.4016	0.168

Measure	Names	Effect	Estimate	SE	Lower	Upper	df	t	p
	Valence ✻ Stimulation ✻ Experimental Session	(Negative - Positive) ✻ (Real - Sham) ✻ (2 - 1)	-0.361	4.93	-10.09	9.368	138.0	-0.0733	0.942
Pre-ctDCS Mean RT scores	(Intercept)	(Intercept)	2679.5	289.6	2108.0	3251.1	45.0	9.252	< .001
	Valence	Negative - Positive	204.4	61.4	83.2	325.5	90.0	3.329	0.001
	Stimulation	Real - Sham	-45.8	231.7	-503.0	411.4	45.0	-0.197	0.844
	Experimental Session	2 - 1	-581.5	231.7	-1038.7	-124.3	45.0	-2.510	0.016
	Valence ✻ Stimulation	(Negative - Positive) ✻ (Real - Sham)	33.0	122.8	-209.3	275.3	90.0	0.269	0.789
	Valence ✻ Experimental Session	(Negative - Positive) ✻ (2 - 1)	-190.8	122.8	-433.1	51.5	90.0	-1.554	0.124
	Stimulation ✻ Experimental Session	(Real - Sham) ✻ (2 - 1)	547.5	1158.5	-1738.7	2833.8	45.0	0.473	0.639
	Valence ✻ Stimulation ✻ Experimental Session	(Negative - Positive) ✻ (Real - Sham) ✻ (2 - 1)	149.5	245.6	-335.1	634.1	90.0	0.609	0.544

Note: SE = standard error; df = degrees of freedom.

Figure 3. Plot of Marginal Means for Response to Feeling Moved by Artwork from the First Aesthetic Evaluation Task Before ctDCS Stimulation.



Note: Left: Mean move scores split by valence for each stimulation type; Right: Mean RT scores split by valence across for each experimental session; Error Bars denote 95% Confidence Intervals.

Two-sided correlations (Table 4) showed that feeling moved across (positive and negative) and within artworks differing in valence positively correlated with one another, and in the same fashion, RT across and within artworks differing in valence positively correlated with one another. In addition to individual differences in trait empathy correlating with one another, general empathy and empathic concern positively correlated with feeling moved across artworks and by negative artwork yet not positive artwork. Art experience did not correlate with any measure of interest.

Table 4. Descriptives and Two-sided Pearson Correlations for Individual Differences and Feeling Moved in the First Aesthetic Evaluation Block before ctDCS Stimulation.

Measure	N	Mean	SD	1	2	3	4	5	6	7	8	9	10
1. Mean Move Pre-ctDCS	48	45.76	13.50	—									
2. Mean RT Pre-ctDCS	47	2676.63	1968.24	0.178 (0.231)	—								
3. Negative Mean Move Pre-ctDCS	48	54.19	14.89	0.919 (< .001) ***	0.132 (0.377)	—							
4. Negative Mean RT Pre-ctDCS	47	2778.41	2111.78	0.168 (0.260)	0.995 (< .001) ***	0.125 (0.404)	—						
5. Positive Mean Move Pre-ctDCS	48	37.32	14.57	0.915 (< .001) ***	0.195 (0.189)	0.681 (< .001) ***	0.183 (0.217)	—					
6. Positive Mean RT Pre-ctDCS	47	2574.85	1847.66	0.187 (0.207)	0.993 (< .001) ***	0.139 (0.353)	0.977 (< .001) ***	0.205 (0.166)	—				
7. Perspective Taking	48	20.04	3.61	0.051 (0.733)	0.108 (0.468)	0.129 (0.381)	0.118 (0.431)	-0.039 (0.795)	0.097 (0.518)	—			
8. Empathic Concern	48	20.56	4.20	0.307 (0.034) *	0.025 (0.865)	0.364 (0.011) *	0.050 (0.737)	0.198 (0.177)	-0.003 (0.983)	0.480 (< .001) ***	—		
9. General Empathy	48	20.30	3.36	0.219 (0.135)	0.074 (0.620)	0.297 (0.041) *	0.094 (0.528)	0.103 (0.486)	0.050 (0.738)	0.837 (< .001) ***	0.882 (< .001) ***	—	
10. Art Experience	48	8.79	4.77	0.173 (0.240)	-0.022 (0.881)	0.153 (0.300)	-0.020 (0.892)	0.164 (0.264)	-0.024 (0.871)	-0.016 (0.916)	0.199 (0.174)	0.116 (0.432)	—

Note: Each cell within the correlational matrix contains the Pearson's r value followed by the p-value in parentheses; SD = Standard Deviation; RT = Response Time; *p < .05; **p < .01; ***p < .001.

3.2 Cathodal ctDCS

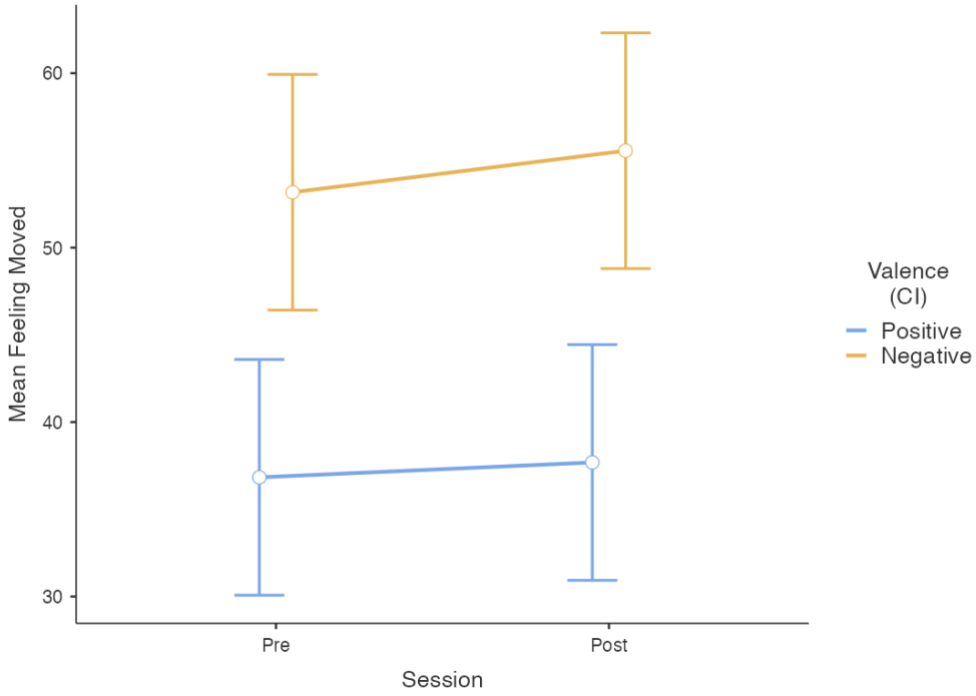
3.2.1 Mean Change in Feeling Moved within Cathodal ctDCS

Table 5 reports a detailed overview of statistics and results for all employed LMMs on mean change in feeling moved by cathodal ctDCS. The LMM on mean change in feeling moved to artwork outside individual differences revealed a main effect of valence (b = 1.527, SE = .739, t(23) = 2.067, p = 0.044, 95% CI = [0.0585, 3.00]) with all other main effects and interactions being non-significant (all ps> 0.349). To explore this general relation of feeling moved between valence before and after ctDCS stimulation (Real and Sham) outside individual differences, we employed an LMM on mean percent scores in feeling moved to paintings with Valence (Negative vs. Positive), Stimulation (Real vs. Sham), and Session (Post-ctDCS vs. Pre-ctDCS) coded as fixed factors that were allowed to interact; this LMM adopted the same random effects structure as the Parent LMM (Model 1), with Participants and Stimulation as the random-intercept and random-slope, respectively. Outside valence (b = 17.107, SE= 1.33, t (138) = 12.8468, p < .001, 95% CI = [14.48, 19.73]), no significant main effects or interactions were observed (all ps > .227), suggesting that participants felt similarly more moved by negative paintings than positive paintings both before and after ctDCS stimulation (Figure 4).

To understand the specificity of feeling moved within artworks of different valence as revealed by the previous LMM, we performed separate LMMs individually for positive and negative artworks following cathodal ctDCS. These LMMs coded Stimulation and Session (Post-ctDCS vs. Pre-ctDCS) as fixed factors that were allowed to interact, and the LMMs adopted the same random effects structure as the Parent LMM (Model 1). The LMM catered to negative artwork revealed a main effect of Session (Post-ctDCS – Pre-ctDCS; b= 2.380, SE = 0.815, t (46) = 2.922, p = .005, 95% CI = [0.761, 4.00]) yet no other main effects or interactions (all ps > 0.540); this result indicates that participants felt more moved within the

second session by negative paintings than within the first session. The LMM catered to positive artwork revealed no main effects or interactions (all *p*s > 0.390).

Figure 4. Feeling Moved by Artwork of Different Valence before and after both Sham and Real ctDCS for Participants within the Cathodal Condition.



Note: Negative artwork was more moving than positive artwork, and negative artwork showed to be more moving in the second aesthetic evaluation block; Error Bars denote 95% Confidence Intervals.

Taken together, results across LMMs outside individual differences indicate that participants felt more moved by negative paintings in comparison to baseline and that this change was not apparent within positive paintings. Likewise, LMMs that assessed change in feeling moved revealed a significant main effect of Valence across all individual differences (Perspective Taking, Empathic Concern, General Empathy, and Art Experience; Table 5), indicating a higher change in feeling moved by negative paintings compared to positive paintings. Specifically, the coefficients for Valence were consistent across all individual differences (*b* = 1.527, SE= 0.732- 0.737, t(22) = 2.073 - 2.086, *p* = 0.043 - 0.044, 95% CI =

[.0621, 2.992] - [.0710, 2.985]). No other significant main effects or interactions were observed (*p*s > 0.106) across all individual differences.

Table 5. Parameter Estimates from Cathodal Stimulation on Change Scores in Feeling Moved per Each Individual Difference.

Individual Difference	Parameters	Effect	Estimate	SE	95% CI Lower	95% CI Upper	df	t	*p*
N/A	(Intercept)	(Intercept)	1.617	0.853	-0.0774	3.31	23.0	1.897	0.071
	Stimulation	Real - Sham	0.307	1.254	-2.1846	2.80	23.0	0.245	0.809
	Valence	Negative - Positive	1.527	0.739	0.0585	3.00	46.0	2.067	0.044
	Stimulation ✻ Valence	(Real - Sham) ✻ (Negative - Positive)	1.399	1.478	-1.5377	4.34	46.0	0.947	0.349
Perspective Taking	(Intercept)	(Intercept)	1.6169	0.870	-0.1140	3.348	22.0	1.858	0.077
	Stimulation	Real - Sham	0.3068	1.209	-2.0973	2.711	22.0	0.254	0.802
	Valence	Negative - Positive	1.5271	0.737	0.0621	2.992	44.0	2.073	0.044
	Perspective Taking	Perspective Taking	0.0628	0.246	-0.4263	0.552	22.0	0.255	0.801
	Stimulation ✻ Valence	(Real - Sham) ✻ (Negative - Positive)	1.3995	1.473	-1.5307	4.330	44.0	0.950	0.347
	Stimulation ✻ Perspective Taking	(Real - Sham) ✻ Perspective Taking	-0.5649	0.342	-1.2443	0.114	22.0	-1.654	0.112
	Valence ✻ Perspective Taking	(Negative - Positive) ✻ Perspective Taking	0.1255	0.208	-0.2885	0.540	44.0	0.603	0.550
	Stimulation ✻ Valence ✻ Perspective Taking	(Real - Sham) ✻ (Negative - Positive) ✻ Perspective Taking	-0.5767	0.416	-1.4048	0.251	44.0	-1.385	0.173
Empathic Concern	(Intercept)	(Intercept)	1.617	0.859	-0.0917	3.325	22.0	1.882	0.073
	Stimulation	Real - Sham	0.307	1.265	-2.2089	2.822	22.0	0.242	0.811
	Valence	Negative - Positive	1.527	0.732	0.0710	2.983	44.0	2.086	0.043
	Empathic Concern	Empathic Concern	0.164	0.204	-0.2422	0.571	22.0	0.804	0.430
	Stimulation ✻ Valence	(Real - Sham) ✻ (Negative - Positive)	1.399	1.464	-1.5128	4.312	44.0	0.956	0.344
	Stimulation ✻ Empathic Concern	(Real - Sham) ✻ Empathic Concern	-0.231	0.301	-0.8294	0.368	22.0	-0.767	0.451
	Valence ✻ Empathic Concern	(Negative - Positive) ✻ Empathic Concern	0.288	0.174	-0.0587	0.634	44.0	1.652	0.106
	Stimulation ✻ Valence ✻ Empathic Concern	(Real - Sham) ✻ (Negative - Positive) ✻ Empathic Concern	-0.122	0.348	-0.8145	0.571	44.0	-0.349	0.729
General Empathy	(Intercept)	(Intercept)	1.617	0.864	-0.1008	3.335	22.0	1.872	0.075
	Stimulation	Real - Sham	0.307	1.232	-2.1429	2.756	22.0	0.249	0.806
	Valence	Negative - Positive	1.527	0.733	0.0692	2.985	44.0	2.083	0.043
	General Empathy	General Empathy	0.164	0.258	-0.3481	0.676	22.0	0.637	0.531

Individual Difference	Parameters	Effect	Estimate	SE	95% CI Lower	95% CI Upper	df	t	*p*
	Stimulation ✻ Valence	(Real - Sham) ✻ (Negative - Positive)	1.399	1.466	-1.5163	4.315	44.0	0.954	0.345
	Stimulation ✻ General Empathy	(Real - Sham) ✻ General Empathy	-0.496	0.367	-1.2260	0.235	22.0	-1.349	0.191
	Valence ✻ General Empathy	(Negative - Positive) ✻ General Empathy	0.296	0.219	-0.1388	0.730	44.0	1.353	0.183
	Stimulation ✻ Valence ✻ General Empathy	(Real - Sham) ✻ (Negative - Positive) ✻ General Empathy	-0.416	0.437	-1.2857	0.453	44.0	-0.953	0.346
Art Experience	(Intercept)	(Intercept)	1.6169	0.867	-0.1073	3.341	22.0	1.865	0.076
	Stimulation	Real - Sham	0.3068	1.265	-2.2080	2.821	22.0	0.243	0.811
	Valence	Negative - Positive	1.5271	0.733	0.0691	2.985	44.0	2.083	0.043
	Art Experience	Art Experience	-0.0828	0.170	-0.4207	0.255	22.0	-0.487	0.631
	Stimulation ✻ Valence	(Real - Sham) ✻ (Negative - Positive)	1.3995	1.466	-1.5167	4.316	44.0	0.954	0.345
	Stimulation ✻ Art Experience	(Real - Sham) ✻ Art Experience	-0.1927	0.248	-0.6855	0.300	22.0	-0.778	0.445
	Valence ✻ Art Experience	(Negative - Positive) ✻ Art Experience	0.1812	0.144	-0.1046	0.467	44.0	1.261	0.214
	Stimulation ✻ Valence ✻ Art Experience	(Real - Sham) ✻ (Negative - Positive) ✻ Art Experience	0.3065	0.287	-0.2650	0.878	44.0	1.067	0.292

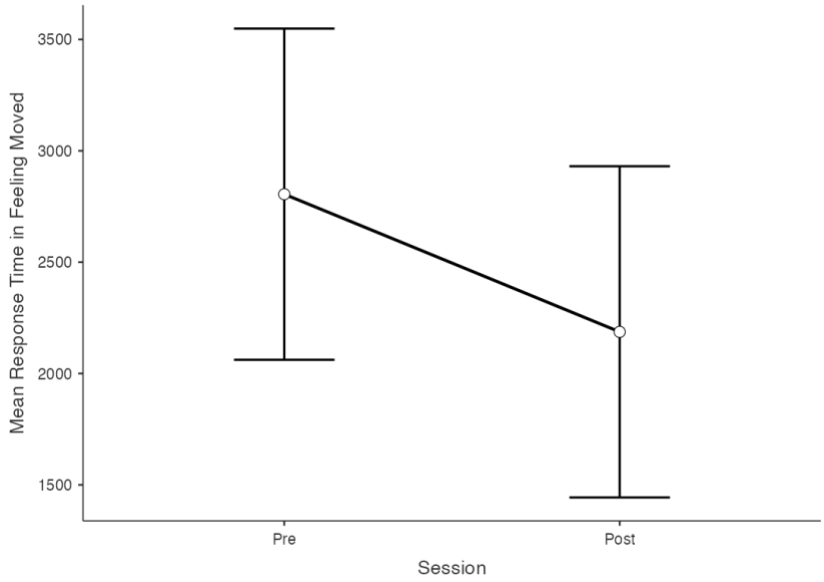
Note: SE = standard error; df = degrees of freedom.

3.2.2 Mean Change in RT within Cathodal ctDCS

Visual inspection of data plots indicated a potential outlier within the real stimulation experimental session for RT. This participant demonstrated a mean change (Post ctDCS– Pre ctDCS) in RT (-5404.08ms) that fell outside 3 SD (3294ms) from the sample mean (-601ms), yet still within 3 SD + 1.5 x the interquartile range of the first quartile (-5466ms). Moreover, cluster nested residual-predicted plots across all LMMs assessing mean change RT to indicate feeling moved did not flag the participant as an extreme outlier; the participant was kept within all analyses.

All LMMs revealed a significant intercept (Table 6; all *p*s < .001), indicating that participants were faster in response after versus before ctDCS stimulation (Figure 5).

Figure 5. Response Time in Feeling Moved by Artwork before and after both Sham and Real ctDCS for Participants within the Cathodal Condition.



Note: Participants were slower to respond in feeling moved by artwork in the first aesthetic evaluation block versus the second aesthetic evaluation block; Error Bars denote 95% Confidence Intervals.

The LMM assessing change in RT to indicate feeling moved outside individual differences revealed no further significant main effects or interactions (all *p*s > .198). For Perspective taking, the LMM revealed a significant interaction of Stimulation (Real- Sham) by Perspective Taking (b = 203.58, t(44) = 3.120, p = 0.024, 95% CI = [37.1, 370.0]), indicating that as a participant's Perspective Taking increased, they exhibited a slower RT in feeling moved following real ctDCS versus sham ctDCS. However, a simple slopes analysis revealed no differences for Stimulation (Real - Sham) by Perspective Taking on the change in RT in feeling moved (*p*s > .098). No additional significant main effects or interactions were revealed from the LMM assessing Perspective taking (all *ps*> .163), and no significant main effects or interactions were observed across other individual differences (Table 6; all *p*s > 0.077).

Table 6. Parameter Estimates from Cathodal Stimulation on Change Scores in Response Time in Feeling Moved per Each Individual Difference.

Individual Difference	Parameter	Effect	Estimate	SE	Lower	Upper	df	t	*p*
N/A	(Intercept)	(Intercept)	-618.12	140	-896	-340.4	23.0	-4.42384	< .001
	Stimulation	Real - Sham	2.27	326	-646	650.7	23.0	0.00695	0.995
	Valence	Negative - Positive	-137.03	105	-346	71.6	46.0	-1.30545	0.198
	Stimulation ✻ Valence	(Real - Sham) ✻ (Negative - Positive)	-116.53	210	-534	300.7	46.0	-0.55009	0.582
Perspective Taking	(Intercept)	(Intercept)	-618.12	138.5	-893.5	-342.7	22.0	-4.46340	< .001
	Stimulation	Real - Sham	2.27	296.2	-586.7	591.2	22.0	0.00766	0.994
	Valence	Negative - Positive	-137.03	104.7	-345.2	71.2	44.0	-1.30880	0.197
	Perspective Taking	Perspective Taking	46.53	39.1	-31.3	124.4	22.0	1.18880	0.247
	Stimulation ✻ Valence	(Real - Sham) ✻ (Negative - Positive)	-116.53	209.4	-532.9	299.9	44.0	-0.55652	0.581
	Stimulation ✻ Perspective Taking	(Real - Sham) ✻ Perspective Taking	203.58	83.7	37.1	370.0	22.0	2.43227	0.024
	Valence ✻ Perspective Taking	(Negative - Positive) ✻ Perspective Taking	-14.03	29.6	-72.9	44.8	44.0	-0.47425	0.638
	Stimulation ✻ Valence ✻ Perspective Taking	(Real - Sham) ✻ (Negative - Positive) ✻ Perspective Taking	83.94	59.2	-33.7	201.6	44.0	1.41839	0.163
Empathic Concern	(Intercept)	(Intercept)	-618.12	136.9	-890.5	-345.79	22.0	-4.51364	< .001
	Stimulation	Real - Sham	2.27	333.6	-661.2	665.70	22.0	0.00680	0.995
	Valence	Negative - Positive	-137.03	101.4	-338.7	64.66	44.0	-1.35106	0.184
	Empathic Concern	Empathic Concern	45.42	32.6	-19.4	110.22	22.0	1.39401	0.177
	Stimulation ✻ Valence	(Real - Sham) ✻ (Negative - Positive)	-116.53	202.8	-519.9	286.85	44.0	-0.57449	0.569
	Stimulation ✻ Empathic Concern	(Real - Sham) ✻ Empathic Concern	1.65	79.4	-156.2	159.50	22.0	0.02081	0.984
	Valence ✻ Empathic Concern	(Negative - Positive) ✻ Empathic Concern	-38.07	24.1	-86.1	9.92	44.0	-1.57755	0.122
	Stimulation ✻ Valence ✻ Empathic Concern	(Real - Sham) ✻ (Negative - Positive) ✻ Empathic Concern	80.50	48.3	-15.5	176.47	44.0	1.66795	0.102

Individual Difference	Parameter	Effect	Estimate	SE	Lower	Upper	df	t	*p*
General Empathy	(Intercept)	(Intercept)	-618.12	135.9	-888.4	-347.8	22.0	-4.54783	< .001
	General Empathy	General Empathy	61.55	40.5	-19.0	142.1	22.0	1.51899	0.143
	Stimulation	Real - Sham	2.27	323.4	-640.8	645.4	22.0	0.00701	0.994
	Valence	Negative - Positive	-137.03	101.9	-339.7	65.6	44.0	-1.34476	0.186
	Stimulation ✻ Valence	(Real - Sham) ✻ (Negative - Positive)	-116.53	203.8	-521.8	288.7	44.0	-0.57180	0.570
	General Empathy ✻ Stimulation	General Empathy ✻ (Real - Sham)	114.59	96.4	-77.2	306.3	22.0	1.18842	0.247
	General Empathy ✻ Valence	General Empathy ✻ (Negative - Positive)	-37.70	30.4	-98.1	22.7	44.0	-1.24084	0.221
	General Empathy ✻ Stimulation ✻ Valence	General Empathy ✻ (Real - Sham) ✻ (Negative - Positive)	109.91	60.8	-10.9	230.7	44.0	1.80893	0.077
Art Experience	(Intercept)	(Intercept)	-618.12	142.8	-902.0	-334.2	22.0	-4.32974	< .001
	Valence	Negative - Positive	-137.03	107.1	-349.9	75.9	44.0	-1.27984	0.207
	Stimulation	Real - Sham	2.27	331.2	-656.4	661.0	22.0	0.00684	0.995
	Art Experience	Art Experience	5.01	28.0	-50.6	60.6	22.0	0.17891	0.860
	Valence ✻ Stimulation	(Negative - Positive) ✻ (Real - Sham)	-116.53	214.1	-542.4	309.3	44.0	-0.54420	0.589
	Stimulation ✻ Art Experience	(Real - Sham) ✻ Art Experience	-36.63	64.9	-165.7	92.5	22.0	-0.56432	0.578
	Valence ✻ Art Experience	(Negative - Positive) ✻ Art Experience	-4.48	21.0	-46.2	37.2	44.0	-0.21369	0.832
	Valence ✻ Stimulation ✻ Art Experience	(Negative - Positive) ✻ (Real - Sham) ✻ Art Experience	-17.16	42.0	-100.6	66.3	44.0	-0.40898	0.685

Note: SE = standard error; df = degrees of freedom.

3.3 Anodal ctDCS

3.3.1 Mean Change in Feeling Moved within Anodal ctDCS

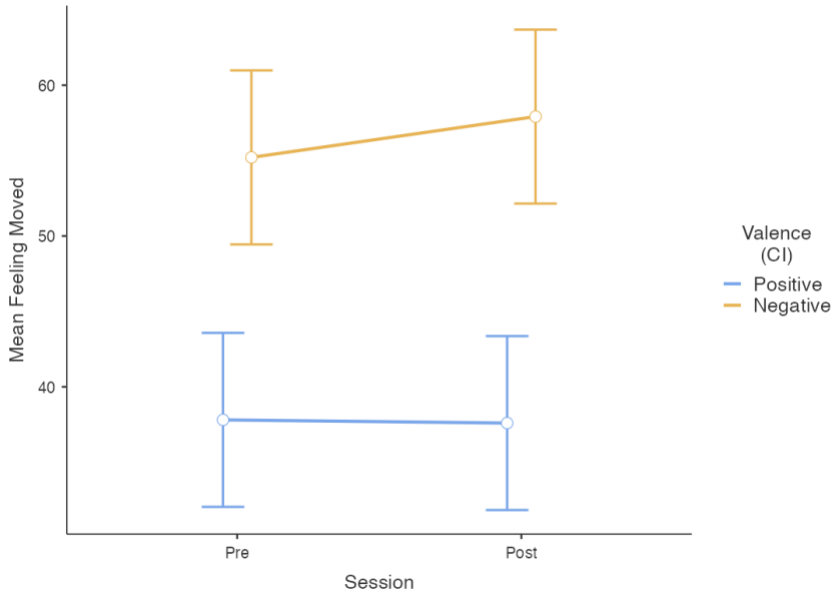
Table 7 reports a detailed overview of statistics and results for all employed LMMs on mean change in feeling moved by anodal ctDCS. Outside individual differences, the LMM on mean change in feeling moved to paintings revealed a main effect of valence (b = 2.916, SE = .973, t(23) = 2.996, p = 0.004, 95% CI = [0.982, 4.85]) with all other main effects and interactions being non-significant (all ps> 0.591), indicating that participants felt an increased change in feeling moved by negative versus positive artworks.

To explore the general relation of feeling moved between valence before and after ctDCS outside individual differences, we employed an LMM on mean percent scores in feeling moved to paintings with Valence (Negative vs. Positive), Stimulation (Real vs. Sham), and Session (Post-ctDCS vs. Pre-ctDCS) coded as fixed factors that were allowed to interact; this LMM adopted the same random effects structure as the Parent LMM (Model 1), with Participants and Stimulation as the random-intercept and random-slope, respectively. Outside valence (b = 18.861, SE= 1.1158, t (138) = 16.994, p < .001, 95% CI = [16.671, 21.05]), no significant main effects or interactions were observed (all ps > .191), suggesting that participants felt similarly more moved by negative paintings than positive paintings both before and after anodal ctDCS.

To understand the specificity of feeling moved within artworks of different valence as revealed by the previous LMM, we performed separate LMMs individually for positive and negative artworks. These LMMs coded Stimulation and Session (Post-ctDCS vs. Pre-ctDCS) as fixed factors that were allowed to interact, and once again adopted the same random effects structure as the Parent LMM (Model 1). The LMM catered to negative artwork revealed a main effect of Session (Post-ctDCS – Pre-ctDCS; b= 2.7043, SE = 0.981, t (46) = 2.757, p = .008, 95% CI = [0.755, 4.65]) yet no other main effects or interactions (all ps >

0.451); replicating results from our sample within the cathodal stimulation, this result indicates that participants felt more moved within the second session by negative paintings than within the first session (see Figure 6). The LMM catered to positive artwork revealed no main effects or interactions (all *p*s > 0.529). Across LMMs outside individual differences, results indicate that participants felt more moved by negative paintings in comparison to baseline scores and that this change was not apparent within positive paintings. Likewise, LMMs that assessed change in feeling moved revealed a significant main effect of Valence across all individual differences (Perspective Taking, Empathic Concern, General Empathy, and Art Experience; Table 7), indicating a higher change in feeling moved by negative paintings compared to positive paintings. Specifically, the coefficients for Valence were consistent across all individual differences (*b* = 2.916, SE= t(22) = 2.073 - 2.086, *p* = 0.043 - 0.044, 95% CI = [.0621, 2.992] - [.0710, 2.985]).

Figure 6. Feeling Moved by Artwork of Different Valence before and after both Sham and Real ctDCS for Participants within the Anodal Condition.



Note: Negative artwork was more moving than positive artwork, and negative artwork showed to be more moving in the second aesthetic evaluation block; Error Bars denote 95% Confidence Intervals.

3.3.1.1 Perspective Taking

Outside Valence, the LMM that assessed change in feeling moved revealed no other significant main effects or interactions were observed (all *p*s > 0.106).

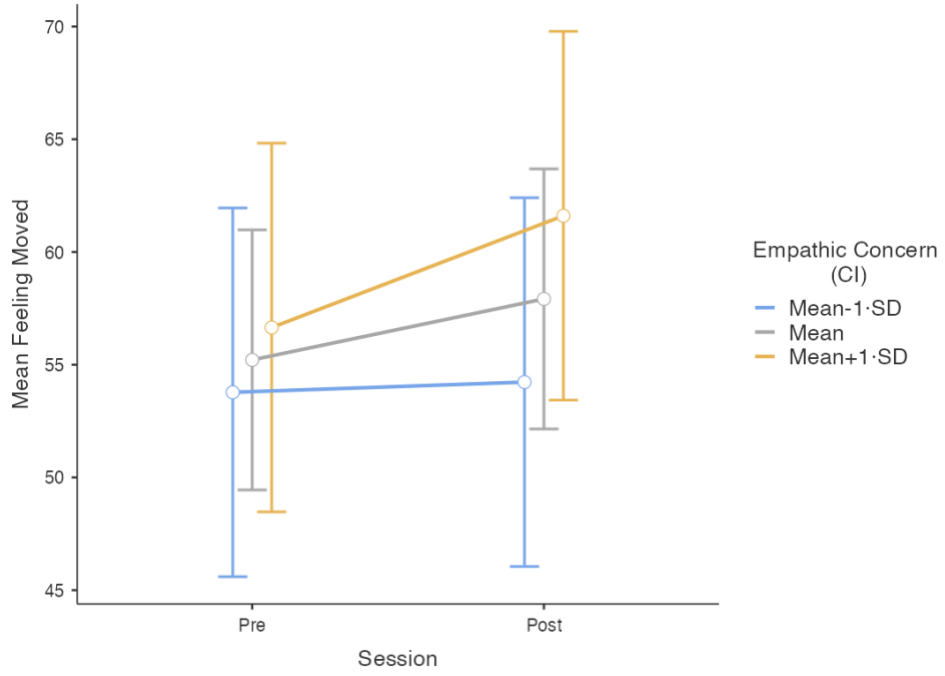
3.3.1.2 Empathic Concern

The LMM that assessed change in feeling moved further revealed a significant interaction of Valence (Negative - Positive) by Empathic Concern (*b* = .668, t(44) = 3.120, *p* = 0.003, 95% CI = [.242, 1.094]), indicating that as a participant's Empathic Concern increases, they felt a higher change in feeling moved by negative paintings versus positive paintings. To further explore the significant interaction of Valence by Empathic Concern (+/-1 SD) on the change in feeling moved, we conducted a simple slopes analysis. The analysis revealed that at moderate (Mean (0 SD); b = 2.916, SE = 0.878, t(44) = 3.321, p = .002, 95% CI = [1.15, 4.69]) and high levels of Empathic Concern (+1 SD; b = 5.670, SE = 1.245, t (44) = 4.554, p < .001, 95% CI = [3.16, 8.18]), participants felt a change in feeling more moved by negative artwork than positive artwork, while there was no significant effect for participants with low levels of Empathic Concern (-1 SD; b = 0.162, SE = 1.245, t (44) = 0.130, p = .897, 95% CI = [-2.35, 2.67]).

To further assess the relation of feeling moved within artworks of negative valence by Empathic Concern, we performed a LMM individually for negative artworks on mean percent scores in feeling moved before and after ctDCS. These LMMs coded Stimulation (Real vs. Sham) and Session (Post-ctDCS vs. Pre-ctDCS) as fixed factors alongside Empathic Concern as a covariate that were all allowed to interact; they adopted the same random effects structure as the Parent LMM (Model 1). In addition to the main effect of session (*b= 2.7043* t (44) = 2.8678, p = .006, 95% CI = [0.8290, 4.580]), the LMM modeled within

negative artwork revealed a main interaction between session (Post-ctDCS – Pre-ctDCS) and Empathic Concern (*b*= *.5465* t (44) = 2.3758, p = .022, 95% CI = [0.0891, 1.004]); no other main effects or interactions were revealed (all *p*s > 0.364). A simple slopes analysis exploring the significant interaction of Session by Empathic Concern (+/-1 SD) on feeling moved by negative artworks revealed that at moderate (Mean (0 SD); b = 2.704, SE = 0.943, t(44) = 2.868, p = .006, 95% CI = [0.804, 4.60]) and high levels of Empathic Concern (+1 SD; b = 4.956, SE = 1.337, t (44) = 3.707, p < .001, 95% CI = [2.262, 7.65]), participants felt more moved after ctDCS than before ctDCS, while there was no significant effect for participants with low levels of Empathic Concern (-1 SD; b = 0.452, SE = 1.337, t (44) = 0.338, p = .737, 95% CI = [-2.243,3.15]). These results suggest that participants felt more moved within the second session by negative paintings than within the first session, and that this was particular to individuals with higher Empathic Concern (Figure 7).

Figure 7. Feeling Moved by Negative Artwork before and after both Sham and Real ctDCS in Relation to Individual Differences in Empathic Concern for Participants within the Anodal Condition.



Note: SD = standard deviation; participants with moderate (mean) and high (+1 SD) levels of empathic concern felt more moved by negative artwork in the second aesthetic evaluation block versus the first aesthetic evaluation block; Error Bars denote 95% Confidence Intervals.

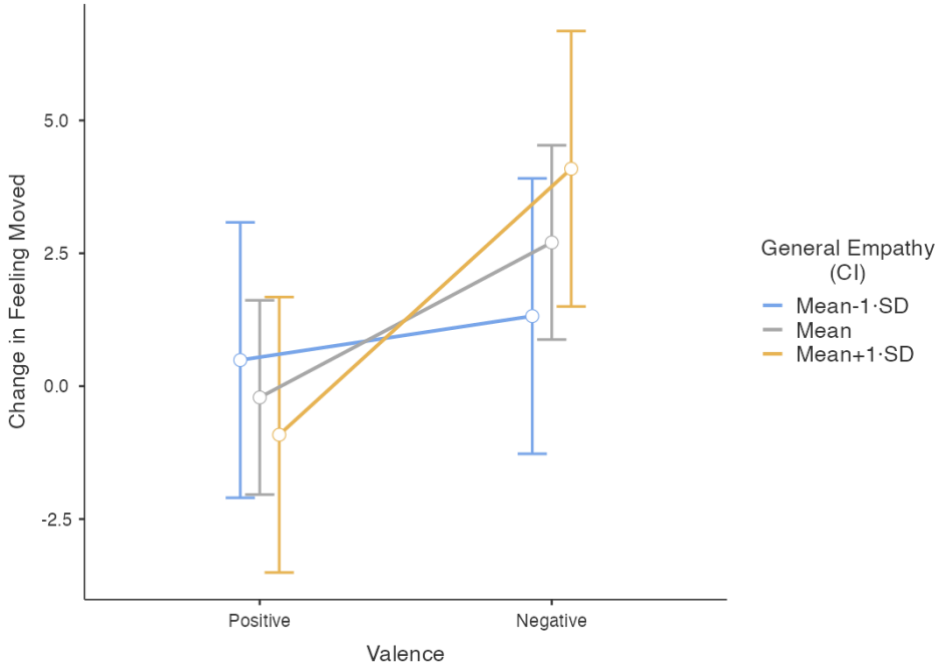
3.3.1.3 General Empathy

The LMM assessing change in feeling moved revealed a significant interaction of Valence by General Empathy (b = .636, t(44) = 2.297, p = 0.026, 95% CI = [.0854, 1.186]) and a trend towards significance for the interaction of Valence by General Empathy by Stimulation (b = 1.104, t(44) = 1.994, p = 0.052, 95% CI = [.000321, 2.204]). No other significant main effects or interactions were observed within the LMM assessing change in feeling moved within General Empathy (ps > .129).

The interaction of Valence by General Empathy indicates that as a participant's General Empathy increases, they felt a higher change in feeling moved by negative paintings versus positive paintings. A simple slopes analysis showed that at moderate (Mean (0 SD); b = 2.916, SE = 0.905, t(44) = 3.224, p = .002, 95% CI = [1.09, 4.74]) and high levels of General Empathy (+ 1 SD; b = 5.005, SE = 1.283, t (44) = 3.902, p = .002, 95% CI = [2.42, 7.59]), participants felt a change in feeling more moved by negative artwork than by positive artwork, while there was no significant effect for participants with low levels of General Empathy (-1 SD; b = 0.827, SE = 1.283, t (44) = 0.645, p = .522, 95% CI = [-1.76, 3.41]).

To further examine this interaction between General Empathy and feeling moved by negative artworks, we performed a LMM separately for negative artworks on mean percent scores in feeling moved before and after ctDCS. The LMM coded Stimulation and Session (Post-ctDCS vs. Pre-ctDCS) as fixed factors alongside General Empathy as a covariate that were all allowed to interact; they adopted the same random effects structure as the Parent LMM (Model 1). The LMM revealed only a main effect of session (*b*= 2.7043, SE= 0.981, t (44) = 2.7573, p = .008, 95% CI = [0.754, 4.65]) and no other main effects or interactions were revealed (all *p*s > 0.167). These results suggest that the significant increase in the change in feeling moved by negative artwork in those individuals with moderate and high levels of General Empathy versus those with low or moderate levels of General Empathy is only in comparison to feeling moved by positive artwork (Figure 8).

Figure 8. Change in Feeling Moved by Artwork of Different Valance before and after both Sham and Real ctDCS in Relation to Individual Differences in General Empathy for Participants within the Anodal Condition.



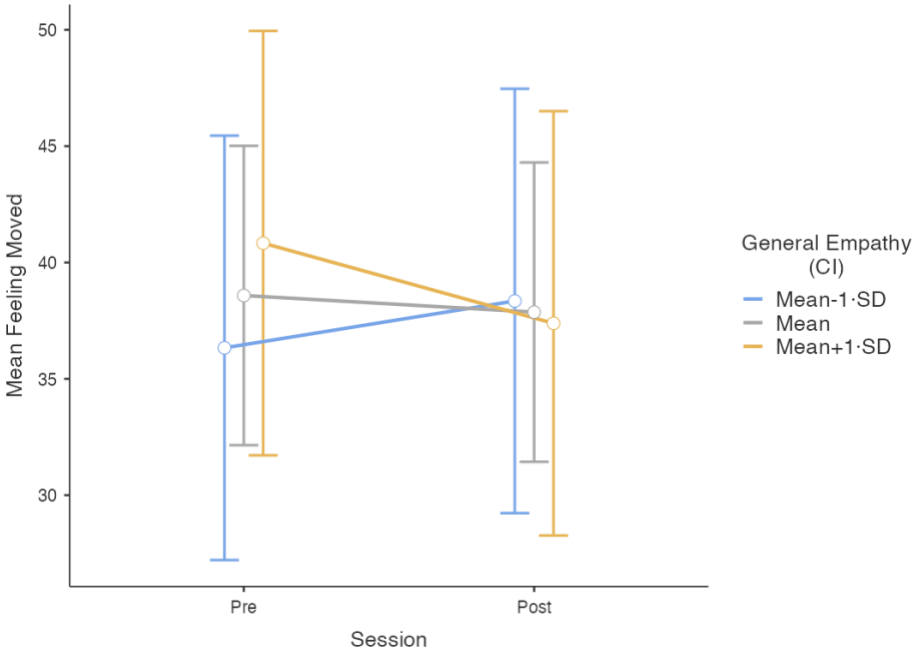
Note: SD = standard deviation; participants with moderate (mean) and high (+1 SD) levels of general empathy felt more moved by negative artwork versus positive artwork; Error Bars denote 95% Confidence Intervals.

As revealed by the LMM assessing change in feeling moved, the trending interaction of Valence by General Empathy by Stimulation was further indicated to be of significant interest as the confidence intervals laid outside 0 (95% CI = [.000321, 2.204]). To further explore this interaction, we performed simple interactions separately for positive and negative artworks. Accordingly, the interaction of Stimulation (Real- Sham) by General Empathy within positive artworks showed significance (b = -1.234, SE = 0.514, t (40.3) = -2.402, p = 0.021, 95% CI = [-2.27, -0.196]), while the interaction of Stimulation (Real-Sham) by General Empathy within negative artworks showed no significance (b = -0.130, SE = 0.514, t (40.3) = -0.254, p = 0.801, 95% CI = [0.908, 0.254]). These results indicate that as

a participant's General Empathy increases, they felt less moved by positive artworks following real ctDCS in comparison to sham ctDCS; however, this association was not found within negative artwork. Accordingly, simple slopes analysis of the interaction of Stimulation by General Empathy within positive artworks revealed that at high levels of General Empathy (+ 1 SD; b = 5.0636, SE = 2.38, t (40.3) = -2.126, p = .040, 95% CI = [-9.87, -0.255]), participants felt a stronger change in feeling less moved by positive artwork following real ctDCS, while there was no significant effect at low (-1 SD; b = 3.0470, SE = 2.38, t (40.3) = 1.279, p = 0.208, 95% CI = [-1.76, 7.85]) or moderate (Mean (0 SD); b = -1.0083, SE = 1.68, t (44) = -0.6004, p = .522, 95% CI = [-4.40, 2.385]) levels of General Empathy.

To further examine this interaction based within positive artworks, we employed an LMM on mean percent in feeling moved to positive artworks with Stimulation, Session (Post-ctDCS vs. Pre-ctDCS), and General Empathy coded as fixed factors that were allowed to interact; this LMM adopted the same random effects structure as the Parent LMM (Model 1), with Participants and Stimulation as the random-intercept and random-slope, respectively. Accordingly, only the interaction of Stimulation by Session by General Empathy was significant (b = -1.2341, SE = 0.456, t (44) = -2.704, p = 0.010, 95% CI = [-2.142, -0.326]). A simple slopes analysis revealed that participants with high levels of General Empathy felt less moved after real ctDCS versus before real ctDCS (+1 SD; b = -3.446, SE = 1.50, t (44) = -2.304, p = 0.026, 95% CI = [-6.46, -0.431]), with no other effects reaching significance (*p*s > 0.185). These results indicate that anodal ctDCS reduced feeling moved by positive paintings for participants as their General Empathy increased, particularly to those persons with high levels of General Empathy (Figure 9).

Figure 9. Change in Feeling Moved by Positive Artwork before and after Real ctDCS in Relation to Individual Differences in General Empathy for Participants within the Anodal Condition.



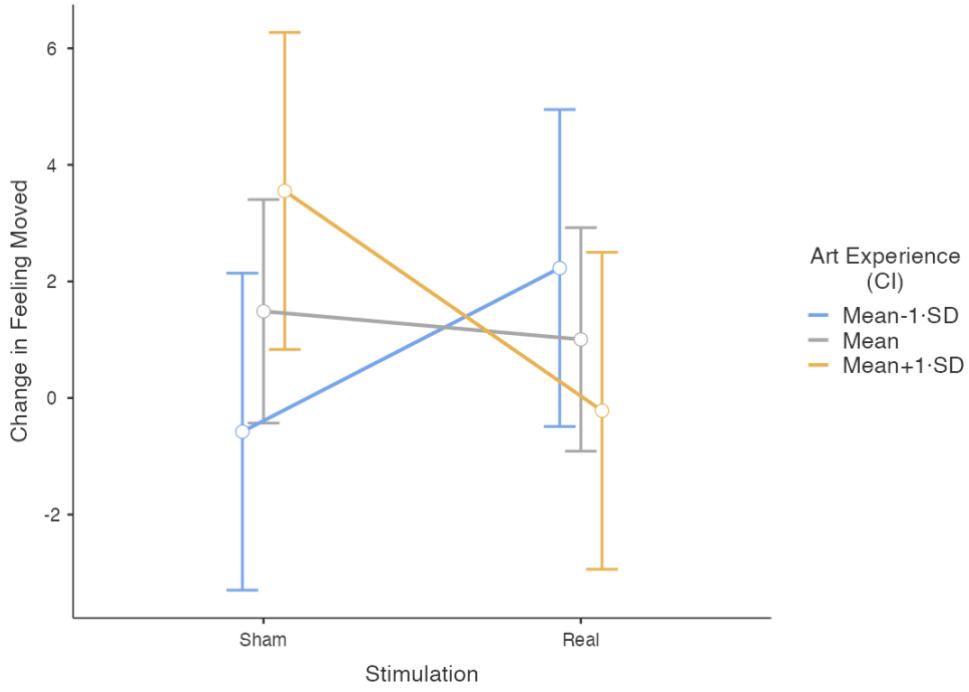
Note: SD = standard deviation; participants with high (+1 SD) levels of general empathy felt less moved by positive artwork; Error Bars denote 95% Confidence Intervals.

3.3.1.4 Art Experience

A significant interaction of Stimulation (Real – Sham) by Art Experience was revealed (b = -0.7624, SE = 0.256, t (66) = 2.982, p = 0.004, 95% CI = [-1.271, -0.254]), suggesting that as a person's Art Experience increases, they feel less of a change in feeling moved by artwork following real ctDCS in comparison to sham ctDCS. A simple slopes analysis revealed that at high levels of Art Experience (+1 SD; b = -3.771, SE = 1.56, t(66) = -2.424, p = .018, 95% CI = [-6.877, -0.665]), participants felt a change in feeling less moved from real ctDCS, while there was no significant effect for participants with low (-1 SD; b = 2.807, SE = 1.56, t (66) = 0.1.805, p = 0.076, 95% CI = [-0.299, 5.913]) or moderate (Mean (0 SD); b = -0.482,

SE = 1.10, t (66) = -0.439, p = .662, 95% CI = [-2.672, 1.709]) levels of Art Experience. These results indicate that participants with higher Art Experience felt less moved from real ctDCS versus sham ctDCS (Figure 10). No other significant main effects or interactions were observed (*p*s > .507).

Figure 10. Change in Feeling Moved by Artwork across Sham and Real ctDCS in Relation to Individual Differences in Art Experience for Participants within the Anodal Condition.



Note: SD = standard deviation; participants with high (+1 SD) levels of art experience felt less moved by artwork; Error Bars denote 95% Confidence Intervals.

Table 7. Parameter Estimates from Anodal Stimulation on Change Scores in Feeling Moved per Each Individual Difference.

Individual Differences	Parameter	Effect	Estimate	SE	Lower	Upper	df	t	p
N/A	(Intercept)	(Intercept)	1.246	0.766	-0.277	2.77	23.0	1.626	0.118
	Stimulation	Real - Sham	-0.482	1.460	-3.383	2.42	23.0	-0.330	0.744
	Valence	Negative - Positive	2.916	0.973	0.982	4.85	46.0	2.996	0.004
	Stimulation ✻ Valence	(Real - Sham) ✻ (Negative - Positive)	1.053	1.947	-2.815	4.92	46.0	0.541	0.591
Perspective Taking	(Intercept)	(Intercept)	1.246	0.779	-0.303	2.796	22.0	1.599	0.124
	Stimulation	Real - Sham	-0.482	1.451	-3.368	2.404	22.0	-0.332	0.743
	Valence	Negative - Positive	2.916	0.957	1.013	4.819	44.0	3.047	0.004
	Perspective Taking	Perspective Taking	-0.112	0.225	-0.560	0.335	22.0	-0.499	0.623
	Stimulation ✻ Valence	(Real - Sham) ✻ (Negative - Positive)	1.053	1.914	-2.754	4.860	44.0	0.550	0.585
	Stimulation ✻ Perspective Taking	(Real - Sham) ✻ Perspective Taking	-0.473	0.419	-1.307	0.361	22.0	-1.128	0.271
	Valence ✻ Perspective Taking	(Negative - Positive) ✻ Perspective Taking	0.197	0.277	-0.353	0.747	44.0	0.711	0.481
	Stimulation ✻ Valence ✻ Perspective	(Real - Sham) ✻ (Negative - Positive) ✻ Perspective	0.968	0.553	-0.133	2.068	44.0	1.749	0.087
Empathic Concern	(Intercept)	(Intercept)	1.246	0.761	-0.268	2.761	22.0	1.637	0.116
	Stimulation	Real - Sham	-0.482	1.419	-3.303	2.339	22.0	-0.340	0.737
	Valence	Negative - Positive	2.916	0.878	1.170	4.662	44.0	3.321	0.002
	Empathic Concern	Empathic Concern	0.212	0.186	-0.157	0.582	22.0	1.143	0.265
	Stimulation ✻ Valence	(Real - Sham) ✻ (Negative - Positive)	1.053	1.756	-2.439	4.545	44.0	0.600	0.552
	Stimulation ✻ Empathic Concern	(Real - Sham) ✻ Empathic Concern	-0.531	0.346	-1.219	0.157	22.0	-1.534	0.139
	Valence ✻ Empathic Concern	(Negative - Positive) ✻ Empathic Concern	0.668	0.214	0.242	1.094	44.0	3.120	0.003
	Stimulation ✻ Valence ✻ Empathic	(Real - Sham) ✻ (Negative - Positive) ✻ Empathic	0.714	0.428	-0.137	1.566	44.0	1.668	0.102
General Empathy	(Intercept)	(Intercept)	1.246	0.780	-0.30548	2.798	22.0	1.597	0.124
	Stimulation	Real - Sham	-0.482	1.415	-3.29544	2.332	22.0	-0.341	0.737
	Valence	Negative - Positive	2.916	0.905	1.11712	4.715	44.0	3.224	0.002
	General Empathy	General Empathy	0.104	0.239	-0.37070	0.579	22.0	0.436	0.667
	Stimulation ✻ Valence	(Real - Sham) ✻ (Negative - Positive)	1.053	1.809	-2.54471	4.651	44.0	0.582	0.564

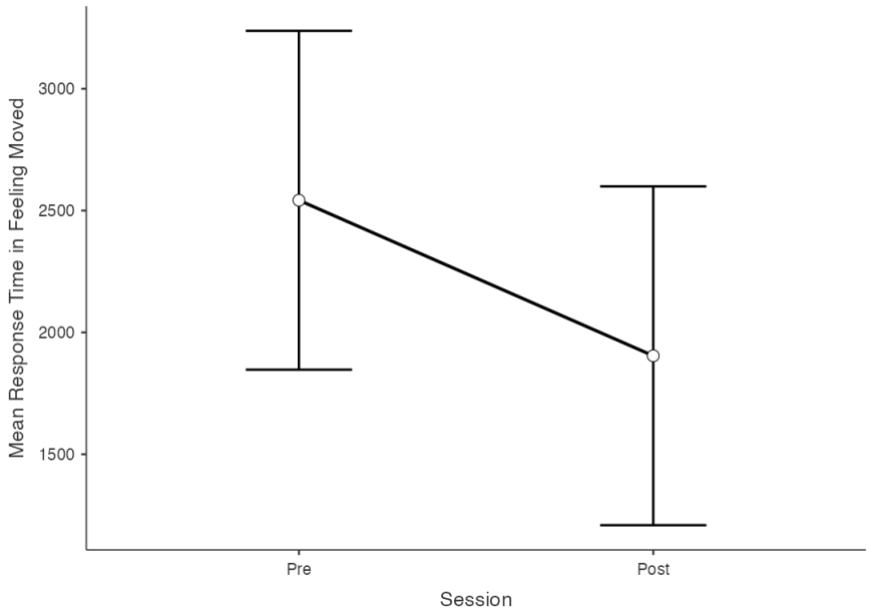
Individual Differences	Parameter	Effect	Estimate	SE	Lower	Upper	df	t	p
	Stimulation ✻ General Empathy	(Real - Sham) ✻ General Empathy	-0.682	0.433	-1.54290	0.178	22.0	-1.576	0.129
	Valence ✻ General Empathy	(Negative - Positive) ✻ General Empathy	0.636	0.277	0.08538	1.186	44.0	2.297	0.026
	Stimulation ✻ Valence ✻ General	(Real - Sham) ✻ (Negative - Positive) ✻ General Empathy	1.104	0.553	0.00321	2.204	44.0	1.994	0.052
Art Experience	(Intercept)	(Intercept)	1.2463	0.779	-0.302	2.794	22.0	1.601	0.124
	Stimulation	Real - Sham	-0.4818	1.097	-2.663	1.699	66.0	-0.439	0.662
	Valence	Negative - Positive	2.9160	1.097	0.735	5.097	66.0	2.658	0.010
	Art Experience	Art Experience	0.0974	0.181	-0.263	0.458	22.0	0.537	0.597
	Stimulation ✻ Valence	(Real - Sham) ✻ (Negative - Positive)	1.0530	2.194	-3.309	5.415	66.0	0.480	0.633
	Stimulation ✻ Art Experience	(Real - Sham) ✻ Art Experience	-0.7624	0.256	-1.271	-0.254	66.0	-2.982	0.004
	Valence ✻ Art Experience	(Negative - Positive) ✻ Art Experience	0.3344	0.256	-0.174	0.843	66.0	1.308	0.195
	Stimulation ✻ Valence ✻ Art	(Real - Sham) ✻ (Negative - Positive) ✻ Art Experience	0.2918	0.511	-0.725	1.308	66.0	0.571	0.570

Note: SE = standard error; df = degrees of freedom.

3.3.2 Mean Change in RT within Anodal ctDCS

Across and outside individual differences, the LMMs revealed the intercept to be significant, indicating that participants were faster after than before ctDCS (Figure 11), replicating results from our participant sample within the cathodal condition; however, all LMMs revealed no significant main effects or interactions (Table 8, all *p*s > 0.106).

Figure 11. Response Time in Feeling Moved by Artwork before and after both Sham and Real ctDCS for Participants within the Anodal Condition.



Note: Participants were slower to respond in feeling moved by artwork in the first aesthetic evaluation block versus the second aesthetic evaluation block; Error Bars denote 95% Confidence Intervals.

Table 8. Parameter Estimates from Anodal Stimulation on Change Scores in RT per Each Individual Difference.

Individual Difference	Parameter	Effect	Estimate	SE	Lower	Upper	df	t	p
N/A	(Intercept)	(Intercept)	-638	262.8	-1161	-115.7	22.0	-2.429	0.024
	Stimulation	Real - Sham	216	270.8	-322	754-7	22.0	0.799	0.433
	Valence	Negative - Positive	-110	85.5	-280	60.2	44.0	-1.284	0.206
	Stimulation ✻ Valence	(Real - Sham) ✻ (Negative - Positive)	133	170.9	-207	472-7	44.0	0.777	0.441
Perspective Taking	(Intercept)	(Intercept)	-638.202	269.0	-1173.4	-103.0	21.0	-2.37290	0.027
	Stimulation	Real - Sham	216.288	277.1	-335.2	767.8	21.0	0.78047	0.444
	Valence	Negative - Positive	-109.652	87.4	-283.5	64.2	42.0	-1.25512	0.216
	Perspective Taking	Perspective Taking	-7.039	76.1	-158.5	144.4	21.0	-0.09248	0.927
	Stimulation ✻ Valence	(Real - Sham) ✻ (Negative - Positive)	132.889	174.7	-214.8	480.6	42.0	0.76056	0.451
	Stimulation ✻ Perspective Taking	(Real - Sham) ✻ Perspective Taking	-0.212	78.4	-156.3	155.9	21.0	-0.00270	0.998

Individual Difference	Parameter	Effect	Estimate	SE	Lower	Upper	df	t	p
	Valence ✻ Perspective Taking	(Negative - Positive) ✻ Perspective Taking	-6.950	24.7	-56.1	42.2	42.0	-0.28113	0.780
	Stimulation ✻ Valence ✻ Perspective Taking	(Real - Sham) ✻ (Negative - Positive) ✻ Perspective Taking	-6.928	49.4	-105.3	91.5	42.0	-0.14011	0.889
Empathic Concern	(Intercept)	(Intercept)	-636.34	269.6	-1172.8	-99.9	21.0	-2.360	0.028
	Stimulation	Real - Sham	192.51	267.5	-339.8	724.9	21.0	0.720	0.480
	Valence	Negative - Positive	-116.18	86.1	-287.5	55.1	42.0	-1.350	0.184
	Empathic Concern	Empathic Concern	7.13	67.8	-127.9	142.1	21.0	0.105	0.917
	Stimulation ✻ Valence	(Real - Sham) ✻ (Negative - Positive)	140.41	172.2	-202.2	483.0	42.0	0.816	0.419
	Stimulation ✻ Empathic Concern	(Real - Sham) ✻ Empathic Concern	-86.35	67.3	-220.3	47.6	21.0	-1.283	0.214
	Valence ✻ Empathic Concern	(Negative - Positive) ✻ Empathic Concern	-23.34	21.7	-66.5	19.8	42.0	-1.078	0.287
	Stimulation ✻ Valence ✻ Empathic Concern	(Real - Sham) ✻ (Negative - Positive) ✻ Empathic Concern	27.67	43.3	-58.5	113.9	42.0	0.639	0.526
General Empathy	(Intercept)	(Intercept)	-638.16	269.2	-1173.9	-102.4	21.0	-2.3704	0.027
	Stimulation	Real - Sham	208.03	273.6	-336.5	752.5	21.0	0.7603	0.456
	Valence	Negative - Positive	-112.51	86.8	-285.2	60.2	42.0	-1.2964	0.202
	General Empathy	General Empathy	1.13	82.1	-162.2	164.4	21.0	0.0137	0.989
	Stimulation ✻ Valence	(Real - Sham) ✻ (Negative - Positive)	134.90	173.6	-210.5	480.3	42.0	0.7773	0.441
	Stimulation ✻ General Empathy	(Real - Sham) ✻ General Empathy	-63.28	83.4	-229.3	102.7	21.0	-0.7587	0.456
	Valence ✻ General Empathy	(Negative - Positive) ✻ General Empathy	-21.11	26.5	-73.8	31.5	42.0	-0.7981	0.429
	Stimulation ✻ Valence ✻ General Empathy	(Real - Sham) ✻ (Negative - Positive) ✻ General Empathy	16.21	52.9	-89.1	121.5	42.0	0.3064	0.761
Art Experience	(Intercept)	(Intercept)	-660.52	266.5	-1190.9	-130.1	21.0	-2.4781	0.022
	Stimulation	Real - Sham	202.58	277.2	-349.1	754.2	21.0	0.7308	0.473
	Valence	Negative - Positive	-110.31	87.8	-284.9	64.3	42.0	-1.2570	0.216
	Art Experience	Art Experience	-54.02	68.1	-189.5	81.5	21.0	-0.7934	0.436
	Stimulation ✻ Valence	(Real - Sham) ✻ (Negative - Positive)	140.79	175.5	-208.5	490.1	42.0	0.8022	0.427
	Stimulation ✻ Art Experience	(Real - Sham) ✻ Art Experience	-33.32	70.8	-174.2	107.6	21.0	-0.4705	0.643

Individual Difference	Parameter	Effect	Estimate	SE	Lower	Upper	df	t	p
	Valence ⁎ Art Experience	(Negative - Positive) ⁎ Art Experience	-1.35	22.4	-46.0	43.3	42.0	-0.0602	0.952
	Stimulation ⁎ Valence ⁎ Art Experience	(Real - Sham) ⁎ (Negative - Positive) ⁎ Art Experience	19.45	44.8	-69.8	108.7	42.0	0.4339	0.667

Note: SE = standard error; df = degrees of freedom.

4. Discussion

The purpose of this study was to examine the role of the posterior cerebellum in feeling moved by artwork, across negative and positive valence. The posterior cerebellum has shown a particular role within social and affective cognition; this may stem from its predictive functionality to promote navigation and make sense of one's environment within a social and affective space (Adamaszek et al., 2017; Cattaneo et al., 2022; Guell et al., 2018; Klein et al., 2016; Van Overwalle, 2020). In the context of artwork, empathic processes alongside previous experience with the arts may serve as vehicles to promote aesthetic engagement and, subsequently, feeling moved (Eerola et al., 2016; Hänninen & Koski-Jännes, 2023; Landmann et al., 2019; Menninghaus et al., 2015; Pelowski, 2015; Pelowski et al., 2017; 2018a,b; Sarasso et al., 2020; Schindler et al., 2022; Schoeller et al., 2018). Therefore, we were further interested in individual differences spanning across cognitive and emotional empathic ability.

4.1 Baseline Results

Our analyses on feeling moved before ctDCS (i.e.,pre-ctDCS scores) across stimulation montages (anodal and cathodal) revealed that participants felt more moved and took longer to respond to feeling moved by negative artwork than positive artwork (Figure 3). The frequency of moving occurrences towards negative content resides more within a fictional

versus real-life context (Meninghaus et al., 2015; Schindler et al., 2022), reflecting how our participants were highly moved by negative artwork, while they were lowly moved by positive artwork. Additionally, artwork depicting negative content has been shown to receive higher appreciation and evaluation (Eerola et al., 2016; Gerger et al., 2014; Meninghaus et al., 2017; Pelowski et al., 2015; Specker et al., 2024); this may occur through a distanced empathic mechanism to entrain aesthetic engagement (e.g., Eerola et al., 2016; Menninghaus et al., 2017), which may explain our participants' longer response time to indicate feeling moved by negative artwork versus positive artwork. Both positive and negative emotional content may provide moving experiences, yet the aesthetic context may facilitate self-referential processes that allows an adoption of new experiences retaining negative content within an aesthetic context, as demonstrated by the pleasantry and frequency within feeling moved across multiple channels of negative fictional content (Cova et al., 2017; Hanich et al., 2014; Eerola et al., 2016; Meninghaus et al., 2015; 2017; Schindler et al., 2022).

Empathic concern (i.e., emotional empathy) and general empathy (Davis, 1983; Murphy et al., 2020; Wang et al., 2020a) were positively related to feeling moved by artwork, especially so for negative artwork (Table 3). Feeling moved has been prominently shown to occur across social events, yet often from a third person perspective across aesthetic contexts (Menninghaus et al., 2015; Schindler et al., 2022). Therefore, an empathic psychological distance may promote an appropriate secondhand engagement with negative artwork versus real-life contexts; this allows engagement with negative content outside an immediate proximity as brought forth by a first-hand experience (Menninghaus et al., 2017; Mazzocut-Mis, 2021; Pelowski, 2015; Pelowski et al., 2018a, b), which may provoke a negativity and threat towards an individual (Pelowski et al., 2017). Our results suggest that an individual's ability to empathize with another, on both a general and emotional level, may subserve the ability to feel moved by an artwork depicting negative content (Ardizzi et al., 2020; 2021;

Avenanti et al., 2006; Eerola et al., 2016; Freedberg & Gallese, 2007; Gallese 2017; 2019; Kirsch et al., 2016). Therefore, the notion of feeling moved by visual artwork (e.g., Pelowski et al., 2015) may span on the employment of social and empathic processes to share, feel, and understand a negative artwork's novel and emotional content, which ultimately provides meaning to a viewer by adopting new experiences that may had not been possible within a real-life context (Cova & Deonna, 2013; Mazocut-mis, 2021; Menninghaus et al., 2015; 2017; Schindler et al., 2022).

4.2 Change in Feeling Moved

Moreover, these results within negative artwork are further reflected within our participants' change in feeling moved (Figures 4 & 6), which sought to reveal an increase or decrease in feeling moved in comparison to baseline (i.e., Post-ctDCS – Pre-ctDCS). Across stimulation montages (cathodal and anodal) and conditions (real and sham), participants felt more moved by negative artwork than positive artwork after versus before ctDCS, suggesting that the second exposure to negative artwork facilitated a stronger moving experience. Deemed the mere exposure effect, repeated exposure, even just for a second occurrence (Montoya et al., 2017), results in an increased preference towards stimuli (Zajonc, 1968), including visual art (Cutting et al., 2003) and particuarily complex stimuli (Berlyne, 1970). The underlying mechanism may lie within recognition and familiarity (Montoya et al., 2017), which are hallmarks in defining processing fluency, a subjective ease associated with mental processing that is commonly achieved by repeated exposure (Graf et al., 2018; Popescu & Holeman, 2024). Processing fluency may result from perceiver-driven fluency (i.e., subjective fluency), such as intrinsic motivation to engage with an artwork, or stimulus-driven fluency (i.e., objective fluency), such an ease to perceive the objective features of an artwork (i.e., Graf & Landwehr, 2015). Both accounts of processing fluency have been shown within aesthetic

experience, with higher processing fluency generally being associated with higher appreciation and evaluation towards artwork (Mayer & Landwehr et al., 2018; Vissers & Wagemans, 2023).

These constructs of processing fluency are not outside the mechanisms behind feeling moved. Indeed, a sense of familiarity, representing self-relevancy, lies at the core in moving experiences (Hannien & Kosel-Jannes, 2023; Landmann et al., 2019; Menninghaus et al., 2015; Schindler et al., 2022), suggesting that a secondary exposure may allow a further engagement and coherency with an artwork that was not initially incurred. Respective to experimental session, participants were presented with the same artwork sets before and after ctDCS stimulation; thus, the initial exposure to artwork across valence may have allowed individuals to adopt the content and update previous knowledge to provide a pleasurable experience, as supported by the predictive processing account (Kesner et al., 2014; Nanay, 2017; Van de Cruys, 2017; Van de Cruys & Wagemans, 2011; Sarasso et al., 2020). However, the construct of feeling moved has been shown to occur predominantly for negative versus positive artwork (Menninghaus et al., 2015; Schindler et al., 2022), and our results show that negative artwork highly moved our participants while positive artwork did not. Perhaps through an implicit learning and self-relevant mechanism, novel experiences presented by positive artwork may had been adequately obtained by initial exposure or they may have already been previously experienced within a real-life context (Cova & Deonna, 2013; Hänninen & Koski-Jännes, 2023; Landmann et al., 2019; Menninghaus et al., 2015; Sarasso et al., 2020; Schindler et al., 2022). Yet within the case of negative artwork, its secondary exposure may have facilitated feeling moved by further fostering an adoption of the negative content in question, that our participants may have internalized during the initial exposure (please see Berlyne, 1970).

Notably, processing fluency within the subjective versus objective standard seems to be more effective in propagating aesthetic appreciation (Belke et al., 2010; 2015; Commare et al., 2018; Forster et al., 2013; Reber et al., 1998; 2004; Specker et al., 2024). Indeed, subjectively felt fluency (e.g., self-report in ease; Forster et al., 2013), conceptual (real versus fake titles; Belke et al., 2010), art interest (Specker et al., 2024), art experience (Commare et al., 2018), and trait empathy (Ardizzi et al., 2020; 2021; Finisguerra et al., 2021) have been reported to positively impact aesthetic evaluations. Feeling moved assumes a social empathic foundation alongside bodily engagement (Benedek & Kaernbach, 2011; Schubert et al., 2018; Seibt et al., 2018); this parallels the notion of "feeling into" an artwork (Ganczarek et al., 2018; Vischer 1873/1994), which presumes an employment of neural systems underlying empathic-motor resonance to facilitate art engagement (Gallese et al., 2017; 2019; Sarasso et al., 2020), especially within the negative domain (Ardizzi et al., 2020; 2021, but see also Finisguerra et al., 2021). Although particular to our anodal group, we show that generally those individuals with moderate or high empathic or general empathy felt a stronger change in feeling moved by negative artwork in comparison to those with low levels of empathic or general empathy (Figures 7 & 8). Therefore, our results posit that feeling moved by negative artwork employs routes of processing fluency, such as one's empathic ability (Ardizzi et al., 2020; 2021; Eerola et al., 2016), that provide an ease to appreciate, make sense of, and provide meaning to the viewer (Cova et al., 2017; Mazzocut-Mis, 2021; Menninghaus et al., 2015; 2017; Pelowski, 2015; Pelowski et al., 2017; 2018a,b; Schindler et al., 2022).

Indeed, a forced attentive paradigm towards the objective features of artistic photographs, aiming to establish subjective fluency, found that more complex artistic photographs were preferred, while passive viewing was associated with higher preferences towards more simple artistic photos (i.e., objective fluency; Visser & Wagemans, 2023). Thus, an ease of processing (i.e., a reduction of cognitive load) within aesthetic engagement

results in a more intense and pleasurable aesthetic experience (please see Brielmann & Pelli, 2017a). This is further seen with ambiguous or challenging artworks that are generally shown to provide meaning to a viewer (Muth et al., 2015), yet this may be based on one's ability to engage and understand the artwork in question (Belke, 2015; Rui & Xiangping, 2011). This evidence may be based within predictive processing underlying aesthetic engagement: an artwork that provides too many prediction errors may deter a viewer's engagement and results in a unpleasurable experience (Kesner et al., 2014; Sararsso et al., 2020; Van de Cruys, 2017; Van de Cruys & Wagemans, 2011), yet individuals with motivated engagement, facilitated by subjective fluency (Belke et al., 2015; Forster et al., 2013; Reber et al., 1998; 2004; Specker et al., 2024; Visser & Wagemans, 2023), may continue to work through prediction errors, update previous knowledge, and find meaning from aesthetic experience (e.g., Pelowski et al., 2017). Therefore, routes of processing to appropriately engage with an artwork's negative content may be characterized by a viewer's art interest (Specker et al., 2024) and empathic ability (Ardizzi et al., 2020; 2021; Menninghaus et al., 2017; Pelowski, 2015; Pelowski et al., 2017; 2018a, b; Schoeller et al., 2018); an empathic relation between our internal representations and those poised by an artwork may allow the building of a shared conceptual space (Van de Cruys et al., 2017), based within social interactions to understand another (Friston & Frith, 2015). As characterized by a mixed emotion within a broad social context (Hannien & Kosel-Jannes, 2023; Landmann et al., 2019; Menninghaus et al., 2015; Schindler et al., 2022; Schubert et al., 2018), feeling moved may denote the throe of solving prediction errors based within a self-relevancy via empathic processes (Kesner et al., 2014; Pelowski et al., 2015; 2017; 2018; Van de Cruys, 2017; Van de Cruys & Wagemans, 2011; Sarasso et al., 2020; Schoeller et al., 2018), and thus may intrinsically occur towards negative artwork across an aesthetically situated social affective space (Cova et al., 2017; Hanich et al., 2014; Eerola et al., 2016; Meninghaus et al., 2015; 2017; Schindler

et al., 2022). Although feeling moved by positive artwork is possible, the affordances of negative artwork may provide more meaning and subsequently move the individual more.

4.3 Effects of Cerebellar Transcranial Direct Current Stimulation

Concerning the ctDCS effects on feeling moved, our results show that anodal ctDCS over the right posterior cerebellum reduced feeling moved by positive paintings, yet only within individuals with higher levels of general empathy (encompassing both emotional and cognitive empathy; Figure 9). On the other hand, anodal ctDCS over the right posterior cerebellum reduced feeling moved by all paintings (both negative and positive), yet only for those individuals with moderate and higher levels of art experience (Figure 10).

The bilateral posterior cerebellum has generally been associated with social cognition within an emotional and cognitive empathic framework, such as emotional evaluation and understanding another's intentions and mental states, yet strongly implicated within the realm of negative affect (Adamaszek et al., 2017; Cattaneo et al., 2022; Habas, 2018; Habas et al., 2009; Schutter et al., 2012; Timmann et al., 2010; Van Overwalle et al., 2020). Accordingly, both anodal and cathodal ctDCS over the medial posterior cerebellum has shown to impair the recognition of negative facial expressions (Ferrucci et al., 2012), while anodal ctDCS, yet not cathodal ctDCS over the same region, improved the recognition of another's emotions through eye-reading, perhaps reflecting different capabilities of the medial posterior cerebellum in affect attribution (Clausi et al., 2022). Moreover, online rTMS over the left posterior cerebellum disrupted the emotional recognition of faces (Ferrari et al., 2018) and negatively valanced bodies (Ferrari et al., 2019). These results were further expanded on with disruptive TMS over the medial and left posterior cerebellum impaired biological motion discrimination (Ferrari et al., 2021). The medial cerebellum has been further implicated within mood regulation, with disruption of the cerebellum via low frequency TMS leading to

an increase in self-reported negative mood after viewing stimuli depicting aversive scenes (Schutter & Van Honk, 2009).

The general interpretation of these findings suggests that the evolutionary nature of the cerebellum to detect salient and negative content promotes social interaction and functioning to both understand another person and share their emotions within a cognitive and affective space (Adamaszek et al., 2017; Cattaneo et al., 2022; Van Overwalle et al., 2020). Although this presumed functionality of the cerebellum spans across all posterior regions, these studies targeted the medial and left lateral portions of posterior cerebellum, while our study specifically targeted the right posterior cerebellum. To theoretically investigate the right posterior cerebellum's modulatory effects of CBI on the motor cortex (Batsikadze et al., 2019; Calzolari et al., 2023; Galea et al., 2009; Grimaldi et al., 2016; Jackman et al., 2020), this location was chosen to specifically investigate the role of motor inhibition within aesthetic experience, doubly inquiring into the role of motor-empathic resonance to "feel into" artwork (Ardizzi et al., 2020; 2021; Freedberg & Gallese, 2007; Gallese 2017; 2019; Ganczarek et al., 2018; Kirsch et al., 2016; Vischer 1873/1994) and the stopping for knowledge account to appreciate artwork (Sarasso et al., 2020).

Accordingly, tDCS over the right posterior cerebellum has shown to induce plastic changes on CSE, with cathodal tDCS increasing CSE (decreasing CBI) and anodal tDCS decreasing CSE (increasing CBI; e.g., Galea et al., 2009). These CBI effects may be situated within connections between the cerebellum, thalamus, motor and premotor regions; hence, anodal ctDCS over the right posterior cerebellum leads to an inhibition of the contralateral premotor and primary cortices via a promotion of thalamic inhibition while cathodal ctDCS imposes opposite effects (Calzolari et al., 2023). Indeed, ctDCS over the right posterior cerebellum are strong enough to ameliorate plastic changes on CSE commonly induced by TMS (Liao et al., 2022). Importantly, evidence suggests that the opposing polarity effects on

the CBI following ctDCS over the right posterior cerebellum are not necessarily consistent (Batsikadze et al., 2019). Of note, both cathodal and anodal ctDCS have been suggested to have similar effects on motor and cognitive task performance, with anodal ctDCS generally demonstrating a stronger impact than cathodal ctDCS (Oldrati & Schutter, 2018), perhaps explaining the general lack of cathodal ctDCS effects on feeling moved across our analyses.

Nonetheless, the implications of opposing ctDCS network effects have been shown across learning paradigms, largely within the motor and social domains. Anodal ctDCS over the right cerebellum demonstrated an incremental reduction in simple motor skill acquisition, which was accompanied by an increase of CBI (Takano et al., 2022); in contrast, anodal ctDCS over the right posterior cerebellum resulted in enhanced skill acquisition in a much more demanding visuomotor task (Galea et al., 2011). Moreover, ctDCS showed a modulation of CBI throughout the generation of motor commands, with anodal ctDCS over the right cerebellum leading to greater motor inhibition via thalamo-motor coupling for motor commands, while opposite effects occurred for cathodal ctDCS (Aloi et al., 2022). Likewise, cathodal ctDCS over the right cerebellum improved reaction times in a simple motor sequencing task, while anodal ctDCS resulted in reduced accuracy; this was reflected by cathodal ctDCS reducing the recruitment of neural regions associated with motor learning, while anodal ctDCS showed an increased recruitment of various neural networks underlying attentional control and motor learning (Maldonado et al., 2023). Therefore, ctDCS effects may modulate motor-based learning: anodal ctDCS may facilitate the provision of associative cortices to beneficially compensate for difficult motor learning, yet this compensation may impair more automatic or simple tasks, with ctDCS imposing opposite effects (please see Maldonado et al., 2023).

The posterior cerebellum's role towards the gravity of task difficulty has also been investigated within social learning paradigms. ctDCS over the medial posterior cerebellum

was shown to affect the implicit learning of novel social action (i.e., human action) sequences: cathodal ctDCS hindered the implicit learning of highly informative sequences (i.e., simple learning), and anodal ctDCS boosted the implicit learning for moderately informative sequences (i.e., difficult learning; Oldrati et al., 2021). These results were expanded upon with anodal ctDCS, which demonstrated that after learning social action sequences, medial posterior anodal ctDCS improved the prediction of moderately informative sequences, yet not highly informative sequences, suggesting that the posterior cerebellum utilizes previously established knowledge (i.e., internal models), to predict the environment at hand (Oldrati et al., 2024). Within both a motoric and social context, anodal ctDCS may improve implicit learning towards more difficult instances yet may impair more simple instances of implicit learning, with opposite effects occurring from cathodal ctDCS.

Moreover, the call of internal models to promote implicit learning may be based within functional networks associated with the task at hand. Following anodal ctDCS over the right posterior cerebellum, motor imagery and motor execution tasks demonstrated mostly positive functional connectivity changes between the cerebellum its associated networks. In the lateral comparisons of these tasks with one another, motor execution tasks did not recruit the posterior DMN that is implicated in attributing another's state (i.e., cognitive empathy), while motor imagery did not recruit the sensorimotor anterior cerebellum nor the anterior DMN that is implicated in self-referential processing (Grami et al., 2021a). This evidence is further compounded by anodal ctDCS over the right posterior cerebellum increasing resting-state connectivity both within and between the cerebellum and cerebral functional networks (Grami et al., 2021b), perhaps reflecting modulation of network connectivity that is associated with an increased CBI alongside a promotion of cortical resources (e.g., Sarasso et al., 2020). Alongside its coupling with the cerebellum to promote peak aesthetic experiences (Williams et al., 2018), increased recruitment of the DMN has

been shown to propagate feelings of being moved by artwork, suggesting an increased engagement of self-referential processing throughout pleasurable aesthetic experiences (Belfi et al., 2019; Cela-Conde et al., 2013; Vessel et al., 2012; 2019).

In all, the posterior cerebellum has been shown to be involved within implicit learning via a call of internal models to predict actions across motor and social domains alongside being implicated within an empathic affective space. These functionalities mirror the components underlying feeling moved, which may be defined as a bodily (Benedek & Kaernbach, 2011; Schubert et al., 2018; Seibt et al., 2018), empathic and social emotion noting a promotion a new experience through a self-relevant mechanism (Hannien & Kosel-Jannes, 2023; Landmann et al., 2019; Menninghaus et al., 2015; Pelowski et al., 2015; 2017; 2018; Schindler et al., 2022; Schubert et al., 2018; Seibt et al., 2018; Zickfeld et al., 2019). Although our participants felt more moved by negative artwork than positive artwork, anodal ctDCS showed a reduction in feeling moved by positive artwork, yet only for those individuals with higher levels of general empathy. Firstly, the lack of feeling moved by positive artwork may suggest that positive artwork is predictable, such as being easily understood and simply liked more than negative artwork (Specker et al., 2024; Visser & Wagemans, 2023). The self-relevancy behind feeling moved by positive artwork may be present, yet unlike negative artwork, positive artwork's lack of novelty may hamper an update of previous knowledge to make meaning (Kesner et al., 2014; Pelowski et al., 2017; Sarasso et al., 2020; Specker et al., 2024; Van de Cruys, 2017; Van de Cruys & Wagemans, 2011; Van de Cruys, et al., 2023). Therefore, positive artwork may represent more simple implicit learning, while negative artwork may represent difficult implicit learning. This may explain the lack of change in feeling moved by positive artwork, in that, the generality of the depicted content may have already been experienced by the viewer across different

modalities, such as within real-life events or aesthetic contexts (Berlyne, 1970; Menninghaus et al., 2015; 2017; Schindler et al., 2022).

Secondly, general empathy may promote a sharing, feeling, and understanding of another's emotional and mental states (Arioli et al., 2021b; Bernhardt & Singer, 2012; Dvash & Shamay-Tsoory, 2014; Fallon et al., 2020; Mainieri et al., 2013; Molenberghs et al., 2016) alongside being implicated as a route of subjective processing fluency within aesthetic experience (Ardizzi et al., 2020; 2021; Finnesguara et al., 2021; Pelowski, 2015; Pelowski et al., 2017; 2018a, b; Schoeller et al., 2018). As in line with our behavioral results and further supported by past research investigating feeling moved across negative aesthetic experiences (Cova et al., 2017; Eerola et al., 2016; Hanich et al., 2014; Hannien & Kosel-Jannes, 2023; Menninghaus et al., 2015; 2017; Schindler et al., 2022;), general empathy may be employed across aesthetic engagement to make meaning from a negative artwork's novelty and emotional saliency, underlying routes of subjective processing fluency to call forth internal models via empathic-motor resonance throughout aesthetic engagement. Notably, general empathy was not associated with feeling moved by positive artwork, perhaps reflecting that positive artwork is simply moving; therefore, positive artwork may be inherently dull, characterized by lack of prediction errors and their throes, which results in an unnecessity to call forth internal models via empathic processes to "feel into" a painting (Freedberg & Gallese, 2007; Gallese 2017; 2019; Ganczarek et al., 2018; Kirsch et al., 2016; Kesner et al., 2014; Pelowski et al., 2015; 2017; 2018; Van de Cruys, 2017; Van de Cruys & Wagemans, 2011; Sarasso et al., 2020; Schoeller et al., 2018; Vischer 1873/1994).

Therefore, anodal ctDCS's call of internal models within an implicit learning perspective across motor and social contexts (Aloi et al., 2022; Galea et al., 2011; Maldonado et al., 2023; Oldrati et al., 2021; 2024; Takano et al., 2022) may impair the simple implicit learning of feeling moved by positive artwork; however, this may occur only for those

individuals with a stronger subjective processing fluency to engage with more difficult or challenging instances of implicit learning within an aesthetic context (Belke et al., 2015; Forster et al., 2013; Muth et al., 2015; Reber et al., 1998; 2004; Rui & Xiangping, 2011; Specker et al., 2024; Visser & Wagemans, 2023): this may be characterized by individual's with a higher empathic ability to feel moved by negative artwork, a potential case of higher implicit learning. Stopping for knowledge (i.e., motor inhibition) may promote appreciation within instances of aesthetic experience that provide novelty and saliency (Sarasso et al., 2020), implicating difficult implicit learning. Given the general increment of CBI following anodal ctDCS over the right posterior cerebellum (Calzolari et al., 2023; Galea et al., 2009; Ul-Ain et al., 2024), anodal ctDCS may deteriorate moving experiences by instigating a fairly predictable aesthetic experience, such as in the case of more simple aesthetic experiences that do not need to call forth internal models to appreciate artwork nor an induction of motor inhibition. In hand, a stronger subjective ease in engaging with an artwork may propagate these anodal ctDCS effects, such as feeling into an artwork via empathic processes.

Of interest, anodal ctDCS reduced feeling moved across all paintings; however, this was found only within our participants showing moderate to higher levels of art experience (Figure 11). These results suggest that an individual with higher art experience generally felt less moved by both positive and negative artwork after anodal ctDCS. This may be based within an individual's previous knowledge within the arts, denoting subjective processing fluency affecting aesthetic engagement. In comparison to art laypersons, art-experts show a higher subjective fluency within the appreciation of art (Bimler et at., 2015; Else et al., 2015; Fudali-Czyż et al., 2018). Accordingly, art-experts perceive abstract and representational artworks more similarly (Bimler et al., 2015) and show higher engagement of attentional and visual processing streams throughout aesthetic engagement (Else et al., 2015; Fudali-Czyż et al., 2018). Ambiguous or challenging artworks may provide meaning

(Muth et al., 2015), yet this depends on one's subjective processing fluency to engage with such artwork (Belke, 2015; Rui & Xiangping, 2011; Visser & Wagemans, 2023). Indeed, higher art experience was associated with a simplicity in processing an artwork (Commare et al., 2018) alongside finding meaning within artwork (Bauer & Schwan, 2018). Although art-interest showed positive impacts on appreciating, understanding, and gaining value from negative artwork versus positive artwork, art interest may note an intrinsic motivation behind aesthetic engagement, while art experience may note a subjective processing fluency characterized by gained art knowledge (please see Specker et al., 2024). In consideration of our results, art experience may result in a main effect across implicit learning within an aesthetic context, both towards simple and difficult implicit learning. Therefore, anodal ctDCS's call of internal models within feeling moved by artwork of both positive and negative valence may result in an unfavorable promotion of previous knowledge that results in a less predictable, and hence, less moving aesthetic experience.

4.4 Limitations

Nonetheless, this study poses several limitations. As indicated by the response time results, participants generally showed faster responses within the second aesthetic evaluation block (i.e., after both sham and real ctDCS; Figures 5 & 11) and further showed faster responses within the second experimental session. As the same artwork was used set across blocks within each experimental session, the second exposure may indicate that participants based their responses in accordance with their previous response alongside becoming acclimated to the task at hand. However, the subjectivity behind feeling moved varies greatly by the individual (e.g., Schindler et al., 2022); therefore, there participants were deliberately presented with the same artwork set before and after ctDCS to provide a contextual baseline across analyses assessing change in feeling moved after ctDCS. Our results showed that

participants with higher perspective taking took longer to respond to feeling moved after cathodal ctDCS. However, a post-hoc simple slopes analysis indicated no differences between different levels of perspective taking (i.e., cognitive empathy; Davis, 1983; Murphy et al., 2020; Wang et al., 2020), and baseline analyses indicated no relation between cognitive empathy and feeling moved (Table 3). Indeed, response time was indicated to have no relation to magnitude of pleasurable aesthetic experiences across multiple facets of stimuli (Brielmann & Pelli, 2017b) alongside participants showing large variability within their response time to feeling moved, perhaps stemming from the high-level construct in question (e.g., Belfi et al., 2019). In all, results concerning response time should be taken with extreme caution.

Although participant samples demonstrated similar levels of empathy and art experience (Table 1), a lack of replication between the change in feeling moved and individual differences of empathy was shown across participant samples assigned to anodal and cathodal ctDCS montages. As feeling moved is inherently personal and subjective, this may imply that the artwork used was not adequately touching on processing routes of empathy with the participant sample assigned within the cathodal ctDCS montage; regardless, the lack of replication should be known when interpreting the results. Sample sizes were assumed through a power analysis, yet a larger sample size may have revealed more appropriate effects. Lastly, we did not systematically assess motor-induced CBI via single-pulse TMS over the primary cortex (Batsikadze et al., 2019; Galea et al., 2009); therefore, the interpretation of results on motor inhibition should be within a more theoretical perspective, and future research may directly assess the role of motor-induced CBI in relation to feeling moved and aesthetic appreciation.

5. Conclusions

Feeling moved is posited to be an intense social emotion based within self-relevancy and bodily engagement and may provide instances of implicit learning to make meaning. Within an aesthetic context, an individual's empathic ability may facilitate feeling moved, yet predominately towards artwork depicting negative content, an instance of high implicit learning. The social and affective cerebellum's role in predictive and bodily processes may be utilized in feeling moved by calling forth internal models based in past experience, yet in association with an individual's subjective ease to engage with an artwork, such as through empathy and art experience. Hence, anodal ctDCS over the right posterior cerebellum may call forth internal models that hampered feeling moved within those individuals with a higher subjective ease to engage with artwork.

Diego Rivera. *Two Women*, 1914.

Concluding Remarks

This dissertation has aimed at uncovering the shared neural underpinnings between the aesthetic and social brain with a particular focus on visual aesthetic experiences with negativity at their origin (i.e., negative aesthetic experience). Routes of empathy, such as emotional empathy and mentalizing (i.e., cognitive empathy) have been posited to be employed within aesthetic experience; "feeling into" argues that viewers may feel and comprehend a visual artwork by employing motor-empathetic processes (Freedberg & Gallese, 2007; Gallese, 2017; 2019; Ganczarek et al., 2018; Kirsch et al., 2016; Vischer, 1873). Indeed, emotional empathy is associated with sharing and feeling another's emotions (Bernhardt & Singer, 2012; Dvash & Shamay-Tsoory, 2014; Fallon et al., 2020), while mentalizing deems the adoption and attribution of another's mental state, such as their emotions, intentions and beliefs (Arioli et al., 2021; Buckner et al., 2008; Raichle & Snyder, 2007). These constructs have been implicated within functional neural systems to share, feel, and understand another's negative emotion in both a social (Chang et al., 2015; Botvinick et al., 2005; Lamm et al., 2011) and aesthetic context (Di Dio et al., 2007; 2011; Ishizu & Zeki, 2011; 2017; Labek et al., 2018; Kross et al., 2007).

Current psychological and philosophical debate partially lies within explaining a viewer's enjoyment of negative visual artwork. To facilitate aesthetic engagement, a viewer's employment of psychological distance towards a negative artwork may allow an embracement of the depicted negative content notwithstanding an intense evocation of negative emotion within themself (Menninghaus et al., 2017). In hand, an ebb and flow of awareness may denote this psychological distance to appropriately engage with a negative artwork: the awareness that the depicted subject matter or scenario is a secondhand experience permits distance, while a lack of awareness permits embracement (Mazzocut-Mis, 2021). Hence, emotional empathy may represent the embracement of negative artwork, while

mentalizing may represent the distance; within a philosophical lens, these notions may respectively reflect aesthetic empathy, an adoption of the emotional and cognitive state of an artwork, and interpersonal empathy, to share and feel an artwork's emotions within a real-life context (Ganczarek et al., 2018; Vischer 1873/1994). Therefore, engaging with negative content within an aesthetic context may recruit similar systems as the social brain to, feel, understand, and share the emotions of another. Hence, the second chapter of dissertation aimed to uncover the neural underpinnings surmising negative emotion within visual experiences towards artistic (VAE),non-artistic (VNE), and social (VSE) stimuli through a neuroimaging meta-analysis.

The individual analyses revealed that the negative VAE solely recruited the early visual cortex, perhaps reflecting an affectively situated coding of negativity (Bo et al., 2021; Pessoa & Aldophs, 2010) within an aesthetic context (Ureña & Nadal, 2023; Skov & Nadal, 2021). On the other hand, broad activation across neural systems within empathy, mentalizing, and bodily engagement were revealed for the VNE and VSE, and these activations were replicated by their respective conjunction analyses with the VAE. Therefore, the negative visual experiences of interest suggesting that visual stimuli depicting negative emotion tap into neural networks surmising empathy and bodily function, echoing motor-empathic resonance, to feel and share another's negative emotion alongside mentalizing to attribute such negative emotion to another. Of note, the lack of neural systems associated with the affective and hedonic coding of self-related information may further note a lack of complete immersion within visual experience at hand. Therefore, empathic processes to feel, understand, and share another's negative emotions may preserve a distance via the lack of self-relational yet employment of other-related processes.

The contrast analyses suggest that these negative visual experiences differ within their visual contexts. Indeed, the contrast of the negative VAE versus VNE showed the survival of

the early visual cortex cluster as revealed by the sole VAE analysis; yet this cluster did not survive the VAE versus VSE contrast. Given the conjunction analyses' results, the conception of interacting with social and aesthetic stimuli on a visual level may signal common neural substrates to appropriately engage within a social or aesthetic manner (please see van Leeuwen et al., 2022). Therefore, the employment of neural systems situated within mentalizing, emotional empathy, and bodily engagement towards visual experiences of negative emotion may be commonly employed to generate the appropriate hedonic value (Ureña & Nadal, 2023; Skov & Nadal, 2021), yet the context of these experiences, such as visual artwork versus war scenes, may be pivotal towards the type of engagement one undergoes. Hence, the psychological distance and embracement to share feel and understand another's negative emotion may occur across various contexts, yet *how* and individual engages depends on the context in question (i.e., aesthetic).

Yet, the question remains, of *why* do persons engage with artwork depicting negative content? An empathically-based distancing and embracing, rooting engagement artwork depicting negative content, may allow the viewer to experience situations that they morally or feasibly cannot experience within real life (Meninghaus et al., 2017; Mazzocut-mis, 2021; Pelowski et al., 2015; 2017), such as the cannibalism as depicted within Francisco Goya's Saturn Devouring his Sons (1820/23). Feeling moved has been posited to be an intense, yet pleasant, emotional and bodily experience that emerges from prosociality to empathize with another through a self-relevant mechanism (Hannien & Kosel-Jannes, 2023; Landmann et al., 2019; Menninghaus et al., 2015; Schindler et al., 2022; Schubert et al., 2018; Seibt et al., 2018; Zickfeld et al., 2019); notably, feeling moved within an aesthetic versus a real-life context transpires more towards negative content (Cova et al., 2017; Eerola et al., 2016; Hanich et al., 2014; Meninghaus et al., 2015; 2017; Pelowski et al., 2015; Schindler et al., 2022).

Moreover, predictive processing claims that an individual updates previous knowledge within an affectual space to progress throughout and make sense of their world; in the perspective of aesthetic experience, an individual compares an artwork's salient and novel content with previous knowledge to engender aesthetic appreciation within an implicit learning framework (Kesner et al., 2014; Van de Cruys, 2017; Van de Cruys & Wagemans, 2011), perhaps through a reduction of explicit bodily engagement to allocate resources towards neural systems of need (Sarasso et al., 2020). Therefore, feeling moved may underly instances of high implicit learning based within a progressed coherency between the self and the artwork, which results in the adoption new meaningful experiences (Cova & Deonna, 2013; Menninghaus et al., 2015; Schindler et al., 2022). Given the empathic, social and bodily components of feeling moved by negative artwork alongside the mirroring of such neural systems within negative aesthetic experience, feeling moved by negative artwork may denote higher instances of implicit learning based within an individual's empathic ability and previous knowledge with the arts.

In parallel, the cerebellum may integrate bottom-up and top-down processes to predict one's environment within a social, affective, and motoric fashion (Adamaszek et al., 2017; Cattaneo et al 2022; Van Overwalle, 2020), through a call of internal models across various neural systems, including those implicated within bodily engagement, emotional empathy, and mentalizing (Buckner et al., 2011; Grami et al., 2021a,b; Habas et al., 2009; Palesi et al., 2020; Williams et al., 2018), and has been further associated with aesthetic experience (please see Adamaszek et al., 2023). The cerebellum, especially its posterior portions, has shown to be involved in empathic engagement with negative stimuli (Ferrucci et al., 2012; Ferrari et al., 2018; 2019; 2020; 2021; Schutter & Van Honk, 2009) alongside functionalities within implicit learning across the social (Oldrati et al., 2021; 2024) and motor domains (Aloi et al., 2022; Galea et al., 2011; Maldonado et al., 2023; Takano et al., 2022), perhaps in part

through its inhibitory tone on the motor cortex (Batsikadze et al., 2019; Calzolari et al., 2023; Galea et al., 2009; Grimaldi et al., 2016; Jackman et al., 2020). Therefore, the cerebellum may direct the call and updating of internal models propagating onto the empathic-motor resonance and previous knowledge in feeling moved by artwork, especially those of negative origin.

Accordingly, the third chapter of this dissertation showed that individuals felt more moved by negative artwork than positive artwork, and that this was positively impacted by an individual's empathic ability. Therefore, negative artwork may provide may novel experiences that are subjectively pleasant to the individual via self-relevant mechanism across a social, bodily and affective space (Cova et al., 2017; Hanich et al., 2014; Eerola et al., 2016; Meninghaus et al., 2015; 2017; Pelowski et al., 2015 ;2017; 2018; Schindler et al., 2022); hence, negative artwork may provide instances of higher implicit learning (e.g., Van de Cruys, 2017) by providing meaning and novelty to the viewer outside a real-life context (Cova & Deonna, 2013; Mazzocut-Mis, 2021; Menninghaus et al., 2015; 2017; Schindler et al., 2022). Moreover, feeling moved by negative artwork was positively impacted by an individual's empathic ability, suggesting that an empathic-motor resonance alongside attributing the artwork as another (Ardizzi et al., 2020; 2021; Avenanti et al., 2006 ; Freedberg & Gallese, 2007; Gallese 2017; 2019; Kirsch et al., 2016) may propagate an individual's ability to distantly embrace the negative content in question (Menninghaus et al., 2017; Mazzocut-Mis, 2021).

Following anodal cerebellar transcranial direct current stimulation (ctDCS) over the right posterior cerebellum, participants felt less moved, yet in particular to individual differences. Those individuals with higher level of empathy felt less moved by positive artwork, and those individuals with higher levels of art experience felt less moved by artwork across valance. Anodal ctDCS over the medial and right posterior cerebellum has been

suggested to call forth internal models to be employed for implicit learning (Aloi et al., 2022; Galea et al., 2011; Maldonado et al., 2023; Oldrati et al., 2021; 2024; Takano et al., 2022) and reduce explicit bodily engagement (Calzolari et al., 2023; Galea et al., 2009). Alongside a reallocation of cortical resources from explicit motor engagement (Sarasso et al., 2020), an individual's subjective ease in aesthetic engagement, as characterized by empathy and art experience, may foster aesthetic engagement (Bauer & Schwan, 2018; Belke et al., 2010; 2015; Commare et al., 2018; Forster et al., 2013; Muth et al., 2015; Reber et al., 1998; 2004; Rui & Xiangping, 2011; Specker et al., 2024; Visser & Wagemans, 2023). Unlike negative artwork, positive artwork was not generally moving nor associated with empathic ability; it may be simply moving and does not necessitate a call of internal models via empathic processes. Perhaps for those persons that show a greater ease in feeling moved by higher instances of implicit learning within an empathic framework, such as towards negative artwork, anodal ctDCS's promotion of implicit learning may make positive artwork even more simple and predictable. For the case of art experience, the call of internal models associated with general art knowledge may have led to an impairment in feeling moved; therefore, both negative and positive artwork become more predictable to those with higher art experience. In all, anodal ctDCS over the right posterior cerebellum may impair feeling moved by artwork; however, this may occur only for those individuals with a stronger ease towards implicit learning within an aesthetic context.

All in all, this dissertation has explored the reasons of *how* and *why* an individual may engage with artwork within a negative affectual and contextual realm. Through the induction of neural systems functionally poised within bodily, empathic, and social processes, aesthetic engagement with negative artwork may induce a motor-empathic resonance to embracement of an artwork's emotions, alongside fostering a distance through the attribution of such to another. Moreover, negative artwork may lead to higher instances of feeling moved, an

emotionally intense and socially rooted experience that indicates a discovery of meaning via a self-relevant mechanism, and an individual's tendency to employ empathic processes may foster feeling moved. The posterior cerebellum may propagate meaningful aesthetic experiences through an induction of internal models to make sense of the artwork in hand, yet this may be based within an individual's subjective ease in aesthetic engagement. In all, empathic and social processes may partly underly an individual's engagement with negative artwork, which promotes an attainment of new meaningful experiences that they may have otherwise not been to experience within their real world.

Paul Cezanne. *Bathers, 1890*.

Bibliography

Adamaszek, M., Cattaneo, Z., Ciricugno, A., & Chatterjee, A. (2022). The Cerebellum and Beauty: The Impact of the Cerebellum in Art Experience and Creativity. *Advances in experimental medicine and biology*, *1378*, 213–233. https://doi.org/10.1007/978-3-030-99550-8_14

Adamaszek, M., D'Agata, F., Ferrucci, R., Habas, C., Keulen, S., Kirkby, K. C., Leggio, M., Mariën, P., Molinari, M., Moulton, E., Orsi, L., Van Overwalle, F., Papadelis, C., Priori, A., Sacchetti, B., Schutter, D. J., Styliadis, C., & Verhoeven, J. (2017). Consensus Paper: Cerebellum and Emotion. *Cerebellum (London, England)*, *16*(2), 552–576. https://doi.org/10.1007/s12311-016-0815-8

Allen, G., McColl, R., Barnard, H., Ringe, W. K., Fleckenstein, J., & Cullum, C. M. (2005). Magnetic resonance imaging of cerebellar-prefrontal and cerebellar-parietal functional connectivity. *NeuroImage*, *28*(1), 39–48. https://doi.org/10.1016/j.neuroimage.2005.06.013

Aloi, D., Jalali, R., Tilsley, P., Miall, R. C., & Fernández-Espejo, D. (2022). tDCS modulates effective connectivity during motor command following; a potential therapeutic target for disorders of consciousness. *NeuroImage*, *247*, 118781. https://doi.org/10.1016/j.neuroimage.2021.118781

Aminoff, E. M., Kveraga, K., & Bar, M. (2013). The role of the parahippocampal cortex in cognition. *Trends in cognitive sciences*, *17*(8), 379–390. https://doi.org/10.1016/j.tics.2013.06.009

Apps, M. A., & Ramnani, N. (2014). The anterior cingulate gyrus signals the net value of others' rewards. *The Journal of neuroscience : the official journal of the Society for Neuroscience*, *34*(18), 6190–6200. https://doi.org/10.1523/JNEUROSCI.2701-13.2014

Arcaro, M. J., McMains, S. A., Singer, B. D., & Kastner, S. (2009). Retinotopic organization of human ventral visual cortex. *The Journal of neuroscience : the official journal of the Society for Neuroscience*, *29*(34), 10638–10652. https://doi.org/10.1523/JNEUROSCI.2807-09.2009

Ardizzi, M., Ferroni, F., Siri, F., Umiltà, M. A., Cotti, A., Calbi, M., Fadda, E., Freedberg, D., & Gallese, V. (2020). Beholders' sensorimotor engagement enhances aesthetic rating of pictorial facial expressions of pain. *Psychological Research*, *84*(2), 370–379.

Ardizzi, M., Ferroni, F., Umiltà, M. A., Pinardi, C., Errante, A., Ferri, F., Fadda, E., & Gallese, V. (2021). Visceromotor roots of aesthetic evaluation of pain in art: an fMRI study. *Social cognitive and affective neuroscience*, *16*(11), 1113–1122. https://doi.org/10.1093/scan/nsab066

Arioli, M., Basso, G., Carne, I., Poggi, P., & Canessa, N. (2021a). Increased pSTS activity and decreased pSTS-mPFC connectivity when processing negative social interactions. Behavioural Brain Research, 399, 113027. https://doi.org/10.1016/j.bbr.2020.113027

Arioli, M., Cattaneo, Z., Ricciardi, E., & Canessa, N. (2021b). Overlapping and specific neural correlates for empathizing, affective mentalizing, and cognitive mentalizing: A

coordinate-based meta-analytic study. *Human brain mapping*, *42*(14), 4777–4804. https://doi.org/10.1002/hbm.25570

Aubert, M., Lebe, R., Oktaviana, A. A., Tang, M., Burhan, B., Hamrullah, ... & Brumm, A. (2019). Earliest hunting scene in prehistoric art. Nature, 576(7787), 442-445.

Avenanti, A., Minio-Paluello, I., Bufalari, I., & Aglioti, S. M. (2006). Stimulus-driven modulation of motor-evoked potentials during observation of others' pain. *NeuroImage*, *32*(1), 316–324.

Bacon, F. (1971). *Autoportrait.* Centre Pompidou, Musée national d'art modern-Centre de création industrielle, Paris.

Báez-Mendoza, R., & Schultz, W. (2013). The role of the striatum in social behavior. *Frontiers in neuroscience*, *7*, 233. https://doi.org/10.3389/fnins.2013.00233

Bardi, L., Gheza, D., & Brass, M. (2017). TPJ-M1 interaction in the control of shared representations: New insights from tDCS and TMS combined. *NeuroImage, 146*, 734–740. https://doi.org/10.1016/j.neuroimage.2016.10.050

Barr, D. J., Levy, R., Scheepers, C., & Tily, H. J. (2013). Random effects structure for confirmatory hypothesis testing: Keep it maximal. *Journal of memory and language*, *68*(3), 10.1016/j.jml.2012.11.001. https://doi.org/10.1016/j.jml.2012.11.001

Basile, G. A., Quartu, M., Bertino, S., Serra, M. P., Boi, M., Bramanti, A., Anastasi, G. P., Milardi, D., & Cacciola, A. (2021). Red nucleus structure and function: from anatomy to clinical neurosciences. *Brain structure & function*, *226*(1), 69–91. https://doi.org/10.1007/s00429-020-02171-x

Batsikadze, G., Rezaee, Z., Chang, D. I., Gerwig, M., Herlitze, S., Dutta, A., Nitsche, M. A., & Timmann, D. (2019). Effects of cerebellar transcranial direct current stimulation on cerebellar-brain inhibition in humans: A systematic evaluation. *Brain stimulation*, *12*(5), 1177–1186. https://doi.org/10.1016/j.brs.2019.04.010

Battaglia, F., Lisanby, S. H., & Freedberg, D. (2011). Corticomotor Excitability during Observation and Imagination of a Work of Art. *Frontiers in human neuroscience*, *5*, 79. https://doi.org/10.3389/fnhum.2011.00079

Belfi, A. M., Vessel, E. A., Brielmann, A., Isik, A. I., Chatterjee, A., Leder, H., Pelli, D. G., & Starr, G. G. (2019). Dynamics of aesthetic experience are reflected in the default-mode network. *NeuroImage*, *188*, 584–597.

Belfi, A. M., Vessel, E. A., Brielmann, A., Isik, A. I., Chatterjee, A., Leder, H., Pelli, D. G., & Starr, G. G. (2019). Dynamics of aesthetic experience are reflected in the default-mode network. NeuroImage, 188, 584–597. https://doi.org/10.1016/j.neuroimage.2018.12.017

Belke, B., Leder, H., & Carbon, C. C. (2015). When challenging art gets liked: Evidences for a dual preference formation process for fluent and non-fluent portraits. *PLoS ONE*, *10*(8), Article e0131796. https://doi.org/10.1371/journal.pone.0131796

Belke, B., Leder, H., Strobach, T., & Carbon, C.-C. (2010). Cognitive fluency: High-level processing dynamics in art appreciation. *Psychology of Aesthetics, Creativity, and the Arts*, *4*(4), 214–222. https://doi.org/10.1037/a0019648

Benedek, M., & Kaernbach, C. (2011). Physiological correlates and emotional specificity of human piloerection. *Biological Psychology*, *86*(3), 320–329. https://doi.org/10.1016/j.biopsycho.2010.12.012

Berlyne, D. E. (1970). Novelty, complexity, and hedonic value. *Perception & Psychophysics*, *8*(5-A), 279–286. https://doi.org/10.3758/BF03212593

Bernhardt, B. C., & Singer, T. (2012). The neural basis of empathy. Annual Review of Neuroscience, 35, 1–23. https://doi.org/10.1146/annurev- neuro-062111-150536

Berntson, G. G., & Khalsa, S. S. (2021). Neural circuits of Interoception. Trends in Neurosciences, 44(1), 17–28. https://doi.org/10.1016/j.tins. 2020.09.011

Berridge, K. C., & Kringelbach, M. L. (2015). Pleasure systems in the brain. *Neuron*, *86*(3), 646–664. https://doi.org/10.1016/j.neuron.2015.02.018

Bindemann, M., Burton, A. M., Langton, S. R. H., Schweinberger, S. R., & Doherty, M. J. (2007). The control of attention to faces. *Journal of Vision*, *7*(10), 1–8. https://doi.org/10.1167/7.10.15

Bird, C. M., & Burgess, N. (2008). The hippocampus and memory: insights from spatial processing. *Nature reviews. Neuroscience*, *9*(3), 182–194. https://doi.org/10.1038/nrn2335

Blanke, O., Mohr, C., Michel, C. M., Pascual-Leone, A., Brugger, P., Seeck, M., Landis, T., & Thut, G. (2005). Linking out-of-body experience and self processing to mental own-body imagery at the temporoparietal junction. *The Journal of neuroscience : the official journal of the Society for Neuroscience*, *25*(3), 550–557. https://doi.org/10.1523/JNEUROSCI.2612-04.2005

Bo, K., Yin, S., Liu, Y., Hu, Z., Meyyappan, S., Kim, S., Keil, A., & Ding, M. (2021). Decoding Neural Representations of Affective Scenes in Retinotopic Visual Cortex. Cerebral cortex (New York, N.Y. : 1991), 31(6), 3047–3063. https://doi.org/10.1093/cercor/bhaa411

Boccia, M., Barbetti, S., Piccardi, L., Guariglia, C., Ferlazzo, F., Giannini, A. M., & Zaidel, D. W. (2016). Where does brain neural activation in aesthetic responses to visual art occur? Meta-analytic evidence from neuroimaging studies. *Neuroscience and biobehavioral reviews*, *60*, 65–71.

Boggio, P. S., Zaghi, S., & Fregni, F. (2009). Modulation of emotions associated with images of human pain using anodal transcranial direct current stimulation (tDCS). *Neuropsychologia*, *47*(1), 212–217. https://doi.org/10.1016/j.neuropsychologia.2008.07.022

Bonini L. (2017). The Extended Mirror Neuron Network: Anatomy, Origin, and Functions. The Neuroscientist : a review journal bringing neurobiology, neurology and psychiatry, 23(1), 56–67. https://doi.org/10.1177/1073858415626400

Bonini, L., Rotunno, C., Arcuri, E., & Gallese, V. (2022). Mirror neurons 30 years later: implications and applications. *Trends in cognitive sciences*, *26*(9), 767–781. https://doi.org/10.1016/j.tics.2022.06.003

Boot, N., Baas, M., van Gaal, S., Cools, R., & De Dreu, C. (2017). Creative cognition and dopaminergic modulation of fronto-striatal networks: Integrative review and research agenda. *Neuroscience and biobehavioral reviews*, *78*, 13–23.

Botvinick, M., Jha, A.P., Bylsma, L.M., et al. (2005). Viewing facial expressions of pain engages cortical areas involved in the direct experience of pain. NeuroImage, 25, 312–9.

Bradley, M. M., Keil, A., & Lang, P. J. (2012). Orienting and emotional perception: facilitation, attenuation, and interference. *Frontiers in psychology*, *3*, 493. https://doi.org/10.3389/fpsyg.2012.00493

Brielmann, A. A., & Pelli, D. G. (2017a). Beauty Requires Thought. *Current biology : CB*, *27*(10), 1506–1513.e3. https://doi.org/10.1016/j.cub.2017.04.018

Brielmann, A. A., Vale, L., & Pelli, D. G. (2017b). Beauty at a glance: The feeling of beauty and the amplitude of pleasure are independent of stimulus duration. *Journal of vision*, *17*(14), 9. https://doi.org/10.1167/17.14.9

Brown, S., Gao, X., Tisdelle, L., Eickhoff, S. B., & Liotti, M. (2011). Naturalizing aesthetics: brain areas for aesthetic appraisal across sensory modalities. *NeuroImage*, *58*(1), 250–258. https://doi.org/10.1016/j.neuroimage.2011.06.012

Brown, V. A. (2021). An introduction to linear mixed-effects modeling in R. *Advances in Methods and Practices in Psychological Science*, *4*(1), 2515245920960351.

Buckner, R. L., Andrews-Hanna, J. R., & Schacter, D. L. (2008). The brain's default network: anatomy, function, and relevance to disease. *Annals of the New York Academy of Sciences*, *1124*, 1–38. https://doi.org/10.1196/annals.1440.011

Buckner, R. L., Krienen, F. M., Castellanos, A., Diaz, J. C., & Yeo, B. T. (2011). The organization of the human cerebellum estimated by intrinsic functional connectivity. *Journal of neurophysiology*, *106*(5), 2322–2345. https://doi.org/10.1152/jn.00339.2011

Bzdok, D., Langner, R., Schilbach, L., Engemann, D. A., Laird, A. R., Fox, P. T., & Eickhoff, S. B. (2013). Segregation of the human medial prefrontal cortex in social cognition. *Frontiers in human neuroscience*, *7*, 232. https://doi.org/10.3389/fnhum.2013.00232

Calzolari, S., Jalali, R., & Fernández-Espejo, D. (2023). Characterising stationary and dynamic effective connectivity changes in the motor network during and after tDCS. *NeuroImage*, *269*, 119915. https://doi.org/10.1016/j.neuroimage.2023.119915

Carp, J. (2012). On the plurality of (methodological) worlds: estimating the analytic flexibility of FMRI experiments. Frontiers in Neuroscience, 6, 149.

Cattaneo, Z. (2020). Neural correlates of visual aesthetic appreciation: insights from non-invasive brain stimulation. *Experimental brain research*, *238*(1), 1-16.

Cattaneo, Z., Ferrari, C., Ciricugno, A., Heleven, E., Schutter, D. J. L. G., Manto, M., & Van Overwalle, F. (2022). New Horizons on Non-invasive Brain Stimulation of the Social and Affective Cerebellum. *Cerebellum (London, England)*, *21*(3), 482–496. https://doi.org/10.1007/s12311-021-01300-4

Cattaneo, Z., Ferrari, C., Schiavi, S., Alekseichuk, I., Antal, A., & Nadal, M. (2020). Medial prefrontal cortex involvement in aesthetic appreciation of paintings: a tDCS study. *Cognitive processing*, *21*(1), 65–76. https://doi.org/10.1007/s10339-019-00936-9

Cattaneo, Z., Lega, C., Ferrari, C., Vecchi, T., Cela-Conde, C. J., Silvanto, J., & Nadal, M. (2015). The role of the lateral occipital cortex in aesthetic appreciation of representational and abstract paintings: a TMS study. *Brain and Cognition*, *95*, 44–53.

Cattaneo, Z., Lega, C., Flexas, A., Nadal, M., Munar, E., & Cela-Conde, C. J. (2014a). The world can look better: enhancing beauty experience with brain stimulation. *Social Cognitive and Affective Neuroscience*, *9*(11), 1713–1721.

Cattaneo, Z., Lega, C., Gardelli, C., Merabet, L. B., Cela-Conde, C. J., & Nadal, M. (2014b). The role of prefrontal and parietal cortices in esthetic appreciation of representational and abstract art: A TMS study. *NeuroImage*, *99*, 443–450.

Cattaneo, Z., Lega, C., Gardelli, C., Merabet, L. B., Cela-Conde, C. J., & Nadal, M. (2014). The role of prefrontal and parietal cortices in esthetic appreciation of representational and abstract art: a TMS study. *NeuroImage*, *99*, 443–450. https://doi.org/10.1016/j.neuroimage.2014.05.037

Cavanaugh, J. E., & Neath, A. A. (2019). The Akaike information criterion: Background, derivation, properties, application, interpretation, and refinements. *Wiley Interdisciplinary Reviews: Computational Statistics*, *11*(3), e1460. https://doi.org/10.1002/wics.1460

Cela-Conde, C. J., Ayala, F. J., Munar, E., Maestú, F., Nadal, M., Capó, M. A., del Río, D., López-Ibor, J. J., Ortiz, T., Mirasso, C., & Marty, G. (2009). Sex-related similarities and differences in the neural correlates of beauty. *Proceedings of the National Academy of Sciences of the United States of America*, *106*(10), 3847–3852.

Cela-Conde, C. J., García-Prieto, J., Ramasco, J. J., Mirasso, C. R., Bajo, R., Munar, E., Flexas, A., del-Pozo, F., & Maestú, F. (2013). Dynamics of brain networks in the aesthetic appreciation. Proceedings of the National Academy of Sciences of the United States of America, 110 Suppl 2(Suppl 2), 10454–10461. https://doi.org/10.1073/pnas.1302855110

Cela-Conde, C. J., Marty, G., Maestú, F., Ortiz, T., Munar, E., Fernández, A., Roca, M., Rosselló, J., & Quesney, F. (2004). Activation of the prefrontal cortex in the human visual aesthetic perception. *Proceedings of the National Academy of Sciences of the United States of America*, *101*(16), 6321–6325. https://doi.org/10.1073/pnas.0401427101

Chang, L. J., Gianaros, P. J., Manuck, S. B., Krishnan, A., & Wager, T. D. (2015). A Sensitive and Specific Neural Signature for Picture-Induced Negative Affect. *PLoS biology*, *13*(6), e1002180. https://doi.org/10.1371/journal.pbio.1002180

Chatterjee, A. (2003). Prospects for a cognitive neuroscience of visual aesthetics. *Bull. Psychol. Art* 4, 55–60.

Chatterjee, A., Widick, P., Sternschein, R., Smith, W. B., & Bromberger, B. (2010). The Assessment of Art Attributes. Empirical Studies of the Arts, 28(2), 207-222. https://doi.org/10.2190/EM.28.2.f

Chatterjee, A., & Vartanian, O. (2014). Neuroaesthetics. *Trends in cognitive sciences*, *18*(7), 370–375. https://doi.org/10.1016/j.tics.2014.03.003

Chuan-Peng, H., Huang, Y., Eickhoff, S. B., Peng, K., & Sui, J. (2020). Seeking the "Beauty Center" in the Brain: A Meta-Analysis of fMRI Studies of Beautiful Human Faces and Visual Art. *Cognitive, affective & behavioral neuroscience*, *20*(6), 1200–1215. https://doi.org/10.3758/s13415-020-00827-z

Ciricugno, A., Slaby, R. J., Benedek, M., & Cattaneo, Z. (2023). The Contribution of Non-invasive Brain Stimulation to the Study of the Neural Bases of Creativity and Aesthetic Experience. In: Richard, A., Pelowski, M., Spee, B. T. (eds) Art and Neurological Disorders - Illuminating the Intersection of Creativity and the Changing Brain. Humana, Cham, 163-196

Clausi, S., Lupo, M., Funghi, G., Mammone, A., & Leggio, M. (2022). Modulating mental state recognition by anodal tDCS over the cerebellum. *Scientific reports*, *12*(1), 22616. https://doi.org/10.1038/s41598-022-26914-4

Clos, M., Amunts, K., Laird, A. R., Fox, P. T., & Eickhoff, S. B. (2013). Tackling the multifunctional nature of Broca's region meta-analytically: co-activation-based parcellation of area 44. *NeuroImage*, *83*, 174–188. https://doi.org/10.1016/j.neuroimage.2013.06.041

Commare, L., Rosenberg, R., & Leder, H. (2018). More than the sum of its parts: Perceiving complexity in painting. *Psychology of Aesthetics, Creativity, and the Arts*, *12*(4), 380–391. https://doi.org/10.1037/aca0000186

Cova, F., & Deonna, J. A. (2014). Being moved. *Philosophical Studies*, *169*, 447–466. https://doi.org/10.1007/s11098-013-0192-9

Cova, F., Deonna, J., & Sander, D. (2017). “That’s deep!” The role of being moved and profundity on the appreciation of serious narratives. In T. Blake & D. Wehrs (Eds.), *Palgrave handbook of affect studies and textual criticism* (pp. 347–369). Palgrave McMillan

Corbetta, M., & Shulman, G. L. (2002). Control of goal-directed and stimulus-driven attention in the brain. *Nature reviews. Neuroscience*, *3*(3), 201–215. https://doi.org/10.1038/nrn755

Craig A. D. (2011). Significance of the insula for the evolution of human awareness of feelings from the body. *Annals of the New York Academy of Sciences*, *1225*, 72–82. https://doi.org/10.1111/j.1749-6632.2011.05990.x

Cupchik, G. C., Vartanian, O., Crawley, A., & Mikulis, D. J. (2009). Viewing artworks: contributions of cognitive control and perceptual facilitation to aesthetic experience. *Brain and cognition*, *70*(1), 84–91. https://doi.org/10.1016/j.bandc.2009.01.003

Cutting, J. E. (2003). Gustave Caillebotte, French Impressionism, and mere exposure. *Psychonomic Bulletin & Review, 10*, 319–343. https://doi.org/10.3758/BF03196493

Davis, M. H. (1983). Measuring individual differences in empathy: Evidence for a multidimensional approach. Journal of Personality and Social Psychology, 44, 113-126.

de Goya, F. (1820-1823). *Saturn Devouring One of his Sons*. [mural painting transferred to canvas]. Museo del Prado, Madrid, Spain.

Di Dio, C., Ardizzi, M., Massaro, D., Di Cesare, G., Gilli, G., Marchetti, A., & Gallese, V. (2016). Human, Nature, Dynamism: The Effects of Content and Movement Perception on Brain Activations during the Aesthetic Judgment of Representational Paintings. *Frontiers in human neuroscience*, *9*, 705.

Di Dio, C., Canessa, N., Cappa, S. F., & Rizzolatti, G. (2011). Specificity of esthetic experience for artworks: an FMRI study. Frontiers in human neuroscience, 5, 139. https://doi.org/10.3389/fnhum.2011.00139

Di Dio, C., Macaluso, E., & Rizzolatti, G. (2007). The golden beauty: brain response to classical and renaissance sculptures. *PloS one*, *2*(11), e1201. https://doi.org/10.1371/journal.pone.0001201

Dorado, A., Skov, M., Rosselló, J., & Nadal, M. (2023). Defensive emotions and evaluative judgements: Sensitivity to anger and fear predicts moral judgements, whereas sensitivity to disgust predicts aesthetic judgements. British journal of psychology (London, England : 1953), 114(1), 1–20. https://doi.org/10.1111/bjop.12590

Eerola, T., Vuoskoski, J. K., & Kautiainen, H. (2016). Being Moved by Unfamiliar Sad Music Is Associated with High Empathy. *Frontiers in psychology*, *7*, 1176. https://doi.org/10.3389/fpsyg.2016.01176

Eickhoff, S.B., Bzdok, D., Laird, A.R., et al. (2011). Co-activation patterns distinguish cortical modules, their connectivity and functional differentiation. NeuroImage, 57(3), 938–49.

Eickhoff, S.B., Bzdok, D., Laird, A.R., Kurth, F., Fox, P.T. (2012). Acti- vation likelihood estimation meta-analysis revisited. NeuroImage, 59(3), 2349–61.

Eickhoff, S.B., Laird, A.R., Grefkes, C., Wang, L.E., Zilles, K., Fox, P.T. (2009). Coordinate-based activation likelihood estimation meta- analysis of neuroimaging data: a random-effects approach based on empirical estimates of spatial uncertainty. Human Brain Map- ping, 30(9), 2907–26.

Eickhoff, S.B., Nichols, T.E., Laird, A.R., et al. (2016). Behavior, sensitivity, and power of activation likelihood estimation characterized by massive empirical simulation. NeuroImage, 137, 70–85.

Eickhoff, S.B., Stephan, K.E., Mohlberg, H., et al. (2005). A new SPM toolbox for combining probabilistic cytoarchitectonic maps and functional imaging data. NeuroImage, 25(4), 1325–35.

Eisenberger, N. I. (2015). Meta-analytic evidence for the role of the ante- rior cingulate cortex in social pain. Social Cognitive and Affective Neuro- science, 10(1), 1–2. https://doi.org/10.1093/scan/nsu120

Eklund, A., Nichols, T.E., Knutsson, H. (2016). Cluster failure: why fMRI inferences for spatial extent have inflated false-positive rates. Proceedings of the National Academy of Sciences, 113(28), 7900–5.

Fairhall, S. L., & Ishai, A. (2008). Neural correlates of object indeterminacy in art compositions. *Consciousness and Cognition: An International Journal, 17*(3), 923–932. https://doi.org/10.1016/j.concog.2007.07.005

Fallon, N., Roberts, C., & Stancak, A. (2020). Shared and distinct functional networks for empathy and pain processing: a systematic review and meta-analysis of fMRI studies. *Social cognitive and affective neuroscience*, *15*(7), 709–723. https://doi.org/10.1093/scan/nsaa090

Fan, Y., Duncan, N. W., de Greck, M., & Northoff, G. (2011). Is there a core neural network in empathy? An fMRI based quantitative meta-analysis. *Neuroscience and biobehavioral reviews*, *35*(3), 903–911. https://doi.org/10.1016/j.neubiorev.2010.10.009

Fekete, A., Pelowski, M., Specker, E., Brieber, D., Rosenberg, R., & Leder, H. (2023). The vienna art picture system (vaps): a data set of 999 paintings and subjective ratings for art and aesthetics research. Psychology of Aesthetics, Creativity, and the Arts, 17(5), 660–671.

Feng, X., Gan, J., Huang, X., and Luo, S. (2021). Neural representations of visual aesthetic experience (VAE): a meta-analysis. *Cult. Brain*. doi: 10.1007/s40167-021-00102-z

Ferrari, C., Ciricugno, A., Urgesi, C., & Cattaneo, Z. (2019). Cerebellar contribution to emotional body language perception: a TMS study. *Social cognitive and affective neuroscience*, nsz074. Advance online publication.

Ferrari, C., Fiori, F., Suchan, B., Plow, E. B., & Cattaneo, Z. (2021). TMS over the posterior cerebellum modulates motor cortical excitability in response to facial emotional expressions. *The European journal of neuroscience*, *53*(4), 1029–1039.

Ferrari, C., Lega, C., Tamietto, M., Nadal, M., & Cattaneo, Z. (2015). I find you more attractive … after (prefrontal cortex) stimulation. *Neuropsychologia*, *72*, 87–93. https://doi.org/10.1016/j.neuropsychologia.2015.04.024

Ferrari, C., Oldrati, V., Gallucci, M., Vecchi, T., & Cattaneo, Z. (2018). The role of the cerebellum in explicit and incidental processing of facial emotional expressions: A study with transcranial magnetic stimulation. *Neuroimage, 169*, 256-264.

Ferrucci, R., Giannicola, G., Rosa, M., Fumagalli, M., Boggio, P. S., Hallett, M., Zago, S., & Priori, A. (2012). Cerebellum and processing of negative facial emotions: cerebellar transcranial DC stimulation specifically enhances the emotional recognition of facial anger and sadness. *Cognition & emotion*, *26*(5), 786–799. https://doi.org/10.1080/02699931.2011.619520

Finisguerra, A., Ticini, L. F., Kirsch, L. P., Cross, E. S., Kotz, S. A., & Urgesi, C. (2021). Dissociating embodiment and emotional reactivity in motor responses to artworks. Cognition, 212, 104663. https://doi.org/10.1016/j.cognition.2021.104663

Flexas, A., Rosselló, J., Christensen, J. F., Nadal, M., Olivera La Rosa, A., & Munar, E. (2013). Affective priming using facial expressions modulates liking for abstract art. *PloS one*, *8*(11), e80154.

Forster, M., Fabi, W., & Leder, H. (2015). Do I really feel it? The contributions of subjective fluency and compatibility in low-level effects on aesthetic appreciation. *Frontiers in Human Neuroscience, 9.* https://doi.org/10.3389/fnhum.2015.00373

Fox, M. D., Corbetta, M., Snyder, A. Z., Vincent, J. L., & Raichle, M. E. (2006). Spontaneous neuronal activity distinguishes human dorsal and ventral attention systems. *Proceedings of the National Academy of Sciences of the United States of America*, *103*(26), 10046–10051. https://doi.org/10.1073/pnas.0604187103

Freedberg, D., & Gallese, V. (2007). Motion, emotion and empathy in esthetic experience. *Trends in cognitive sciences*, *11*(5), 197–203. https://doi.org/10.1016/j.tics.2007.02.003

Freeman, J., Ziemba, C. M., Heeger, D. J., Simoncelli, E. P., & Movshon, J. A. (2013). A functional and perceptual signature of the second visual area in primates. *Nature neuroscience*, *16*(7), 974–981. https://doi.org/10.1038/nn.3402

Galea, J. M., Jayaram, G., Ajagbe, L., & Celnik, P. (2009). Modulation of cerebellar excitability by polarity-specific noninvasive direct current stimulation. *The Journal of neuroscience : the official journal of the Society for Neuroscience*, *29*(28), 9115–9122. https://doi.org/10.1523/JNEUROSCI.2184-09.2009

Galea, J. M., Vazquez, A., Pasricha, N., de Xivry, J. J., & Celnik, P. (2011). Dissociating the roles of the cerebellum and motor cortex during adaptive learning: the motor cortex retains what the cerebellum learns. *Cerebral cortex (New York, N.Y. : 1991)*, *21*(8), 1761–1770. https://doi.org/10.1093/cercor/bhq246

Gallese, V. (2017). Mirroring, a liberated embodied simulation and aesthetic experience. Mirror Images. Reflections Art Med.

Gallese, V. (2019). Embodied Simulation. Its Bearing on Aesthetic Experience and the Dialogue Between Neuroscience and the Humanities. *Gestalt theory*, 41(2) 113-127.

Gallucci, M. (2019). GAMLj: General analyses for linear models. [jamovi module]. Retrieved from https://gamlj.github.io/.

Gamond, L., Ferrari, C., La Rocca, S., & Cattaneo, Z. (2017). Dorsomedial prefrontal cortex and cerebellar contribution to in-group attitudes: a transcranial magnetic stimulation study. *The European journal of neuroscience*, *45*(7), 932–939. https://doi.org/10.1111/ejn.13529

Ganczarek, J., Hünefeldt, T., & Olivetti Belardinelli, M. (2018). From "Einfühlung" to empathy: exploring the relationship between aesthetic and interpersonal experience. *Cognitive processing*, *19*(2), 141–145. https://doi.org/10.1007/s10339-018-0861-x

Gough, P. M., Campione, G. C., & Buccino, G. (2013). Fine tuned modulation of the motor system by adjectives expressing positive and negative properties. *Brain and language*, *125*(1), 54–59.

Graf LK, Landwehr JR. A dual-process perspective on fluency-based aesthetics: the pleasure-interest model of aesthetic liking. Pers Soc Psychol Rev. 2015 Nov;19(4):395-410. doi: 10.1177/1088868315574978. Epub 2015 Mar 5. PMID: 25742990.

Graf, L. K. M., Mayer, S., & Landwehr, J. R. (2018). Measuring processing fluency: One versus five items. *Journal of Consumer Psychology*, *28*(3), 393–411. https://doi.org/10.1002/jcpy.1021

Grami, F., de Marco, G., Bodranghien, F., Manto, M., & Habas, C. (2021a). Cerebellar transcranial direct current stimulation reconfigurates static and dynamic functional connectivity of the resting-state networks. Cerebellum & ataxias, 8(1), 7. https://doi.org/10.1186/s40673-021-00132-6

Grami, F., de Marco, G., Bodranghien, F., Manto, M., & Habas, C. (2022b). Cerebellar Transcranial Direct Current Stimulation Reconfigures Brain Networks Involved in Motor Execution and Mental Imagery. *Cerebellum (London, England)*, *21*(4), 665–680. https://doi.org/10.1007/s12311-021-01322-y

Grimaldi, G., Argyropoulos, G. P., Bastian, A., Cortes, M., Davis, N. J., Edwards, D. J., Ferrucci, R., Fregni, F., Galea, J. M., Hamada, M., Manto, M., Miall, R. C., Morales-Quezada, L., Pope, P. A., Priori, A., Rothwell, J., Tomlinson, S. P., & Celnik, P. (2016). Cerebellar Transcranial Direct Current Stimulation (ctDCS): A Novel Approach to Understanding Cerebellar Function in Health and Disease. *The Neuroscientist : a review journal bringing neurobiology, neurology and psychiatry*, *22*(1), 83–97. https://doi.org/10.1177/1073858414559409

Guell, X., Gabrieli, J. D. E., & Schmahmann, J. D. (2018). Triple representation of language, working memory, social and emotion processing in the cerebellum: convergent evidence from task and seed-based resting-state fMRI analyses in a single large cohort. *NeuroImage*, *172*, 437–449. https://doi.org/10.1016/j.neuroimage.2018.01.082

Habas C. (2018). Research note: a resting-state, cerebello-amygdaloid intrinsically connected network. *Cerebellum & ataxias*, *5*, 4. https://doi.org/10.1186/s40673-018-0083-0

Habas, C., Kamdar, N., Nguyen, D., Prater, K., Beckmann, C. F., Menon, V., & Greicius, M. D. (2009). Distinct cerebellar contributions to intrinsic connectivity networks. *The Journal of neuroscience : the official journal of the Society for Neuroscience*, *29*(26), 8586–8594. https://doi.org/10.1523/JNEUROSCI.1868-09.2009

Hanich, J., Wagner, V., Shah, M., Jacobsen, T., & Menninghaus, W. (2014). Why we like to watch sad films. The pleasure of being moved in aesthetic experiences. *Psychology of Aesthetics, Creativity, and the Arts*, *8*(2), 130–143. https://doi.org/10.1037/a0035690

Hänninen, V., & Koski-Jännes, A. (2023). Being moved: A meaningful but enigmatic emotional experience. *Human Arenas.* https://doi.org/10.1007/s42087-023-00340-y

Hartwigsen, G., Neef, N. E., Camilleri, J. A., Margulies, D. S., & Eickhoff, S. B. (2019). Functional Segregation of the Right Inferior Frontal Gyrus: Evidence From Coactivation-Based Parcellation. *Cerebral cortex (New York, N.Y. : 1991)*, *29*(4), 1532–1546. https://doi.org/10.1093/cercor/bhy049

Heleven, E., van Dun, K., De Witte, S., Baeken, C., & Van Overwalle, F. (2021). The Role of the Cerebellum in Social and Non-Social Action Sequences: A Preliminary LF-rTMS Study. *Frontiers in human neuroscience*, *15*, 593821. https://doi.org/10.3389/fnhum.2021.593821

Höfel, L., & Jacobsen, T. (2007). Electrophysiological indices of processing aesthetics: Spontaneous or intentional processes?. *International journal of psychophysiology : official journal of the International Organization of Psychophysiology*, *65*(1), 20–31. https://doi.org/10.1016/j.ijpsycho.2007.02.007

Höge, H. (1984). The emotional impact on aesthetic judgments: An exper- imental investigation of a time-honored hypothesis. *Visual Arts Research*, 10, 37–48.

Hsu, C. C. H., Rolls, E. T., Huang, C. C., Chong, S. T., Zac Lo, C. Y., Feng, J., & Lin, C. P. (2020). Connections of the Human Orbitofrontal Cortex and Inferior Frontal Gyrus. *Cerebral cortex (New York, N.Y. : 1991)*, *30*(11), 5830–5843. https://doi.org/10.1093/cercor/bhaa160

Husserl, E. (2005). Phantasy, Image Consciousness, and Memory (1898-1925). Dordrecht, The Netherlands: Springer. (Originally published 1898-1925).

Ishizu, T., & Zeki, S. (2011). Toward a brain-based theory of beauty. PloS one, 6(7), e21852. https://doi.org/10.1371/journal.pone.0021852

Ishizu, T., & Zeki, S. (2013). The brain's specialized systems for aesthetic and perceptual judgment. The European journal of neuroscience, 37(9), 1413–1420. https://doi.org/10.1111/ejn.12135

Ishizu, T., & Zeki, S. (2017). The experience of beauty derived from sorrow. *Human brain mapping*, *38*(8), 4185–4200. https://doi.org/10.1002/hbm.23657

Jackman, S. L., Chen, C. H., Offermann, H. L., Drew, I. R., Harrison, B. M., Bowman, A. M., Flick, K. M., Flaquer, I., & Regehr, W. G. (2020). Cerebellar Purkinje cell activity modulates aggressive behavior. *eLife*, *9*, e53229. https://doi.org/10.7554/eLife.53229

Jacobs, R. H., Renken, R., & Cornelissen, F. W. (2012). Neural correlates of visual aesthetics--beauty as the coalescence of stimulus and internal state. *PloS one*, *7*(2), e31248.

Jacobsen, T. (2010). Beauty and the brain: culture, history and individual differences in aesthetic appreciation. *Journal of anatomy*, *216*(2), 184–191.

Jacobsen, T., Schubotz, R. I., Höfel, L., & Cramon, D. Y. (2006). Brain correlates of aesthetic judgment of beauty. *NeuroImage*, *29*(1), 276–285.

Jacobson, L., Koslowsky, M., & Lavidor, M. (2012). tDCS polarity effects in motor and cognitive domains: a meta-analytical review. Experimental brain research, 216(1), 1-10

Kant, I. (2001). *Critique of the power of judgment* (P. Guyer & E. Matthews, Trans.). United Kingdom: Cambridge University Press. (Original work published 1790)

Kawabata, H., & Zeki, S. (2004). Neural correlates of beauty. *Journal of neurophysiology*, *91*(4), 1699–1705. https://doi.org/10.1152/jn.00696.2003

Kesner, L. (2014). The predictive mind and the experience of visual art work. *Frontiers in psychology*, *5*, 1417.

Kesner, L. (2014). The predictive mind and the experience of visual art work. Frontiers in psychology, 5, 1417.

King, M., Hernandez-Castillo, C. R., Poldrack, R. A., Ivry, R. B., & Diedrichsen, J. (2019). Functional boundaries in the human cerebellum revealed by a multi-domain task battery. *Nature neuroscience*, *22*(8), 1371–1378. https://doi.org/10.1038/s41593-019-0436-x

Kirk, U., Skov, M., Hulme, O., Christensen, M. S., & Zeki, S. (2009). Modulation of aesthetic value by semantic context: an fMRI study. *NeuroImage*, *44*(3), 1125–1132. https://doi.org/10.1016/j.neuroimage.2008.10.009

Kirsch, L. P., Urgesi, C., & Cross, E. S. (2016). Shaping and reshaping the aesthetic brain: Emerging perspectives on the neurobiology of embodied aesthetics. *Neuroscience and biobehavioral reviews*, *62*, 56–68. https://doi.org/10.1016/j.neubiorev.2015.12.005

Klebl, C., Greenaway, K. H., Rhee, J. J., & Bastian, B. (2021). Ugliness Judgments Alert us to Cues of Pathogen Presence. Social Psychological and Personality Science, 12(5), 617-628. https://doi.org/10.1177/1948550620931655

Klein, A. P., Ulmer, J. L., Quinet, S. A., Mathews, V., & Mark, L. P. (2016). Nonmotor Functions of the Cerebellum: An Introduction. *AJNR. American journal of neuroradiology*, *37*(6), 1005–1009. https://doi.org/10.3174/ajnr.A4720

Lacey, S., Hagtvedt, H., Patrick, V. M., Anderson, A., Stilla, R., Deshpande, G., Hu, X., Sato, J. R., Reddy, S., & Sathian, K. (2011). Art for reward's sake: visual art recruits the ventral striatum. *NeuroImage*, *55*(1), 420–433. https://doi.org/10.1016/j.neuroimage.2010.11.027

Lagravinese, G., Bisio, A., De Ferrari, A. R., Pelosin, E., Ruggeri, P., Bove, M., & Avanzino, L. (2017). An Emotion-Enriched Context Influences the Effect of Action Observation on Cortical Excitability. *Frontiers in human neuroscience*, *11*, 504.

Lamm, C., Decety, J., Singer, T. (2011). Meta-analytic evidence for common and distinct neural networks associated with directly experienced pain and empathy for pain. NeuroImage, 54, 2492–502.

Lamm, C., Rütgen, M., & Wagner, I. C. (2019). Imaging empathy and prosocial emotions. *Neuroscience letters*, *693*, 49–53. https://doi.org/10.1016/j.neulet.2017.06.054

Landmann, H., Cova, F., & Hess, U. (2019). Being moved by meaningfulness: appraisals of surpassing internal standards elicit being moved by relationships and

achievements. *Cognition and Emotion*, *33*(7), 1387–1409. https://doi.org/10.1080/02699931.2019.1567463

Lang, P. J., & Bradley, M. M. (2010). Emotion and the motivational brain. *Biological psychology*, *84*(3), 437–450. https://doi.org/10.1016/j.biopsycho.2009.10.007

Leech, R., & Sharp, D. J. (2014). The role of the posterior cingulate cortex in cognition and disease. *Brain : a journal of neurology*, *137*(Pt 1), 12–32. https://doi.org/10.1093/brain/awt162

Lettieri, G., Handjaras, G., Ricciardi, E., Leo, A., Papale, P., Betta, M., Pietrini, P., & Cecchetti, L. (2019). Emotionotopy in the human right temporo-parietal cortex. Nature communications, 10(5568), 1–12.

Liakakis, G., Nickel, J., & Seitz, R. J. (2011). Diversity of the inferior frontal gyrus--a meta-analysis of neuroimaging studies. *Behavioural brain research*, *225*(1), 341–347. https://doi.org/10.1016/j.bbr.2011.06.022

Liao, W. Y., Sasaki, R., Semmler, J. G., & Opie, G. M. (2022). Cerebellar transcranial direct current stimulation disrupts neuroplasticity of intracortical motor circuits. *PloS one*, *17*(7), e0271311. https://doi.org/10.1371/journal.pone.0271311

Liu, Y., West, S. G., Levy, R., & Aiken, L. S. (2017). Tests of Simple Slopes in Multiple Regression Models with an Interaction: Comparison of Four Approaches. *Multivariate behavioral research*, *52*(4), 445–464. https://doi.org/10.1080/00273171.2017.1309261

Locher, P., Overbeeke, K., and Wensveen, S. (2010). Aesthetic interaction: a framework. *Design Issues* 26, 70–79.

Lopez, R. B., Denny, B. T., & Fagundes, C. P. (2018). Neural mechanisms of emotion regulation and their role in endocrine and immune functioning: A review with implications for treatment of affective disorders. *Neuroscience and biobehavioral reviews*, *95*, 508–514. https://doi.org/10.1016/j.neubiorev.2018.10.019

Luke S. G. (2017). Evaluating significance in linear mixed-effects models in R. *Behavior research methods*, *49*(4), 1494–1502. https://doi.org/10.3758/s13428-016-0809-y

Lutz, A., Nassehi, A., Bao, Y., Pöppel, E., Sztrókay, A., Reiser, M., Fehse, K., & Gutyrchik, E. (2013). Neurocognitive processing of body representations in artistic and photographic images. *NeuroImage*, *66*, 288–292. https://doi.org/10.1016/j.neuroimage.2012.10.067

Maas, R. P. P. W. M., Faber, J., van de Warrenburg, B. P. C., & Schutter, D. J. L. G. (2023). Interindividual differences in posterior fossa morphometry affect cerebellar tDCS-induced electric field strength. *Clinical Neurophysiology*, *153*, 152-165. https://doi.org/10.1016/j.clinph.2023.06.019

Mainieri, A. G., Heim, S., Straube, B., Binkofski, F., & Kircher, T. (2013). Differential role of the Mentalizing and the Mirror Neuron system in the imitation of communicative gestures. *NeuroImage*, *81*, 294–305. https://doi.org/10.1016/j.neuroimage.2013.05.021

Maldonado, T., Jackson, T. B., & Bernard, J. A. (2023). Anodal cerebellar stimulation increases cortical activation: Evidence for cerebellar scaffolding of cortical processing. *Human brain mapping*, *44*(4), 1666–1682. https://doi.org/10.1002/hbm.26166

Matuschek, H., Kliegl, R., Vasishth, S., Baayen, H., & Bates, D. (2017). Balancing type I error and power in linear mixed models. *Journal of Memory and Language, 94*, 305–315. https://doi.org/10.1016/j.jml.2017.01.001

Mayer, S., & Landwehr, J. R. (2018). Quantifying visual aesthetics based on processing fluency theory: Four algorithmic measures for antecedents of aesthetic preferences.*Psychology of Aesthetics, Creativity, and the Arts*, *12*(4), 399–431. https://doi.org/10.1037/aca0000187

Mazzocut-Mis, M. (2021). The Pleasure of Weeping: The Novelty of a Research. In: Giacomoni, P., Valentini, N., Dellantonio, S. (eds) The Dark Side: Philosophical Reflections on the "Negative Emotions". Studies in the History of Philosophy of Mind, vol 25. Springer, Cham.

McTeague, L. M., Gruss, L. F., & Keil, A. (2015). Aversive learning shapes neuronal orientation tuning in human visual cortex. *Nature communications*, *6*, 7823. https://doi.org/10.1038/ncomms8823

Menninghaus, W., Wagner, V., Hanich, J., Wassiliwizky, E., Jacobsen, T., & Koelsch, S. (2017). The Distancing-Embracing model of the enjoyment of negative emotions in art reception. *Behavioral and Brain Sciences*, *40*, E347.

Menninghaus, W., Wagner, V., Hanich, J., Wassiliwizky, E., Kuehnast, M., & Jacobsen, T. (2015). Towards a psychological construct of being moved. *PloS one*, *10*(6), e0128451. https://doi.org/10.1371/journal.pone.0128451

Menninghaus, W., Wagner, V., Wassiliwizky, E., Schindler, I., Hanich, J., Jacobsen, T., & Koelsch, S. (2019). What are aesthetic emotions?. *Psychological review*, *126*(2), 171–195.

Menon, V., & Uddin, L. Q. (2010). Saliency, switching, attention and control: a network model of insula function. *Brain structure & function*, *214*(5-6), 655–667. https://doi.org/10.1007/s00429-010-0262-0

Miller, J. G., Xia, G., & Hastings, P. D. (2020). Right Temporoparietal Junction Involvement in Autonomic Responses to the Suffering of Others: A Preliminary Transcranial Magnetic Stimulation Study. *Frontiers in human neuroscience*, *14*, 7. https://doi.org/10.3389/fnhum.2020.00007

Min B. K. (2010). A thalamic reticular networking model of consciousness. *Theoretical biology & medical modelling*, *7*, 10. https://doi.org/10.1186/1742-4682-7-10

Miskovic, V., & Anderson, A. K. (2018). Modality general and modality specific coding of hedonic valence. *Current opinion in behavioral sciences*, *19*, 91–97. https://doi.org/10.1016/j.cobeha.2017.12.012

Mizokami, Y., Terao, T., Hatano, K., Hoaki, N., Kohno, K., Araki, Y., Kodama, K., Makino, M., Izumi, T., Shimomura, T., Fujiki, M., & Kochiyama, T. (2014). Difference in brain activations during appreciating paintings and photographic analogs. *Frontiers in human neuroscience*, *8*, 478. https://doi.org/10.3389/fnhum.2014.00478

Molenberghs, P., Johnson, H., Henry, J. D., & Mattingley, J. B. (2016). Understanding the minds of others: A neuroimaging meta-analysis. Neuroscience and Biobehavioral Reviews, 65, 276–291. https://doi.org/ 10.1016/j.neubiorev.2016.03.020

Montoya, R. M., Horton, R. S., Vevea, J. L., Citkowicz, M., & Lauber, E. A. (2017). A re-examination of the mere exposure effect: The influence of repeated exposure on recognition, familiarity, and liking. Psychological Bulletin, 143(5), 459-498. https://doi.org/10.1037/bul0000085

Morris, L. S., Kundu, P., Dowell, N., Mechelmans, D. J., Favre, P., Irvine, M. A., Robbins, T. W., Daw, N., Bullmore, E. T., Harrison, N. A., & Voon, V. (2016). Fronto-striatal organization: Defining functional and microstructural substrates of behavioural flexibility. *Cortex; a journal devoted to the study of the nervous system and behavior*, *74*, 118–133. https://doi.org/10.1016/j.cortex.2015.11.004

Müller, V.I., Cieslik, E.C., Laird, A.R., et al. (2018). Ten simple rules for neuroimaging meta-analysis. Neuroscience and Biobehavioral Reviews, 84, 151–61.

Munar, E., Nadal, M., Rosselló, J., Flexas, A., Moratti, S., Maestú, F., Marty, G., & Cela-Conde, C. J. (2012). Lateral orbitofrontal cortex involvement in initial negative aesthetic impression formation. *PloS one*, *7*(6), e38152. https://doi.org/10.1371/journal.pone.0038152

Murphy, B. A., Costello, T. H., Watts, A. L., Cheong, Y. F., Berg, J. M., & Lilienfeld, S. O. (2020). Strengths and Weaknesses of Two Empathy Measures: A Comparison of the Measurement Precision, Construct Validity, and Incremental Validity of Two Multidimensional Indices. *Assessment*, *27*(2), 246–260. https://doi.org/10.1177/1073191118777636

Muth, C., Hesslinger, V. M., & Carbon, C.-C. (2015). The appeal of challenge in the perception of art: How ambiguity, solvability of ambiguity, and the opportunity for insight affect appreciation. *Psychology of Aesthetics, Creativity, and the Arts*, *9*(3), 206–216. https://doi.org/10.1037/a0038814

Nakabayashi, K., & Liu, C. H. (2014). Development of holistic vs. featural processing in face recognition. *Frontiers in human neuroscience*, *8*, 831. https://doi.org/10.3389/fnhum.2014.00831

Nakamura, K., & Kawabata, H. (2015). Transcranial Direct Current Stimulation over the Medial Prefrontal Cortex and Left Primary Motor Cortex (mPFC-lPMC) Affects Subjective Beauty but Not Ugliness. *Frontiers in human neuroscience*, *9*, 654.

Nanay, B. (2017). Perceptual learning, the mere exposure effect, and aesthetic antirealism. *Leonardo*, *50*(1), 58–63. https://doi.org/10.1162/LEON_a_0130

Newstead, S., Young, H., Benton, D., Jiga-Boy, G., Andrade Sienz, M. L., Clement, R. M., & Boy, F. (2018). Acute and repetitive fronto-cerebellar tDCS stimulation improves mood in non-depressed participants. *Experimental brain research*, *236*(1), 83–97. https://doi.org/10.1007/s00221-017-5109-y

Nummenmaa, L., Hirvonen, J., Parkkola, R., & Hietanen, J. K. (2008). Is emotional contagion special? An fMRI study on neural systems for affective and cognitive empathy. NeuroImage, 43(3), 571–580. https://doi.org/10.1016/j.neuroimage.2008.08.014

Oathes, D. J., & Ray, W. J. (2006). Depressed mood, index finger force and motor cortex stimulation: a transcranial magnetic stimulation (TMS) study. *Biological psychology*, *72*(3), 271–277.

Oldfield R. C. (1971). The assessment and analysis of handedness: the Edinburgh inventory. *Neuropsychologia*, *9*(1), 97–113. https://doi.org/10.1016/0028-3932(71)90067-4

Oldrati, V., Butti, N., Ferrari, E., Cattaneo, Z., Urgesi, C., & Finisguerra, A. (2024). Excitatory cerebellar transcranial direct current stimulation boosts the leverage of prior knowledge for predicting actions. *Social Cognitive and Affective Neuroscience*, *19*(1), nsae019. https://doi.org/10.1093/scan/nsae019

Oldrati, V., & Schutter, D. J. L. G. (2018). Targeting the Human Cerebellum with Transcranial Direct Current Stimulation to Modulate Behavior: a Meta-Analysis. *Cerebellum (London, England)*, *17*(2), 228–236. https://doi.org/10.1007/s12311-017-0877-2

Oldrati, V., Ferrari, E., Butti, N., Cattaneo, Z., Borgatti, R., Urgesi, C., & Finisguerra, A. (2021). How social is the cerebellum? Exploring the effects of cerebellar transcranial direct current stimulation on the prediction of social and physical events. *Brain structure & function*, *226*(3), 671–684. https://doi.org/10.1007/s00429-020-02198-0

Osaka, N., Minamoto, T., Yaoi, K., & Osaka, M. (2012). Neural Correlates of Delicate Sadness: An FMRI Study Based on the Neuroaesthetics of Noh Masks. *NeuroReport.* 23 (1): 26–29.

Palesi, F., Lorenzi, R. M., Casellato, C., Ritter, P., Jirsa, V., Gandini Wheeler-Kingshott, C. A. M., & D'Angelo, E. (2020). The Importance of Cerebellar Connectivity on Simulated Brain Dynamics. *Frontiers in cellular neuroscience*, *14*, 240. https://doi.org/10.3389/fncel.2020.00240

Palomero-Gallagher, N., & Amunts, K. (2022). A short review on emotion processing: a lateralized network of neuronal networks. *Brain structure & function*, *227*(2), 673–684. https://doi.org/10.1007/s00429-021-02331-7

Park, J., Cardwell, R., & Yu, H.-T. (2020). Specifying the random effect structure in linear mixed effect models for analyzing psycholinguistic data. *Methodology*, *16*(2), 92–111. https://doi.org/10.5964/meth.2809

Pascual-Leone, A. (1999). Transcranial magnetic stimulation: studying the brain--behaviour relationship by induction of 'virtual lesions'. *Philosophical Transactions of the Royal Society of London. Series B: Biological Sciences*, *354*(1387), 1229-1238.

Pelowski, M. (2015). Tears and transformation: Feeling like crying as an indicator of insightful or “aesthetic” experience with art. *Frontiers in Psychology, 6,* Article 1006. https://doi.org/10.3389/fpsyg.2015.01006

Pelowski, M., Ishizu, T., & Leder, H. (2018a). Sadness and beauty in art-Do they really coincide in the brain?: Comment on "An integrative review of the enjoyment of sadness associated with music" by Eerola et al. *Physics of life reviews*, *25*, 124–127. https://doi.org/10.1016/j.plrev.2018.03.013

Pelowski, M., Markey, P. S., Forster, M., Gerger, G., & Leder, H. (2017). Move me, astonish me… delight my eyes and brain: The Vienna Integrated Model of top-down and bottom-up processes in Art Perception (VIMAP) and corresponding affective, evaluative, and neurophysiological correlates. *Physics of life reviews*, *21*, 80–125.

Pelowski, M., Markey, P. S., Lauring, J. O., & Leder, H. (2016). Visualizing the impact of art: An update and comparison of current psychological models of art experience. *Frontiers in Human Neuroscience, 10,* Article 160. https://doi.org/10.3389/fnhum.2016.00160

Pelowski, M., Markey, P. S., Lauring, J. O., & Leder, H. (2016). Visualizing the impact of art: An update and comparison of current psychological models of art experience. *Frontiers in Human Neuroscience, 10,* Article 160. https://doi.org/10.3389/fnhum.2016.00160

Pelowski, M., Markey, P., & Leder, H. (2018b). Chills, aesthetic experience, and new versus old knowledge - What do chills actually portend?: Comment on "Physics of mind: Experimental confirmations of theoretical predictions" by Schoeller et al. *Physics of life reviews*, *25*, 83–87. https://doi.org/10.1016/j.plrev.2018.03.014

Peña-Gómez, C., Vidal-Piñeiro, D., Clemente, I. C., Pascual-Leone, Á., & Bartrés-Faz, D. (2011). Down-regulation of negative emotional processing by transcranial direct current stimulation: effects of personality characteristics. *PloS one*, *6*(7), e22812. https://doi.org/10.1371/journal.pone.0022812

Pessoa, L., & Adolphs, R. (2010). Emotion processing and the amygdala: from a 'low road' to 'many roads' of evaluating biological significance. Nature reviews. Neuroscience, 11(11), 773–783. https://doi.org/10.1038/nrn2920

Piretti, L., Pappaianni, E., Gobbo, S., Rumiati, R. I., Job, R., & Grecucci, A. (2022). Dissociating the role of dACC and dlPFC for emotion appraisal and mood regulation using cathodal tDCS. *Cognitive, affective & behavioral neuroscience*, *22*(2), 304–315. https://doi.org/10.3758/s13415-021-00952-3

Popescu, A., & Holman, A. C. (2024). Loop and Enjoy: A Scoping Review of the Research on the Effects of Processing Fluency on Aesthetic Reactions to Auditory Stimuli. Psychological Reports, 0(0). https://doi.org/10.1177/00332941241277474

Preckel, K., Kanske, P., & Singer, T. (2018). On the interaction of social affect and cognition: Empathy, compassion and theory of mind. *Current Opinion in Behavioral Sciences*, *19,* 1–6. https://doi.org/10.1016/j.cobeha.2017.07.010

R Core Team (2022). R: A Language and environment for statistical computing. (Version 4.1) [Computer software]. Retrieved from https://cran.r-project.org. (R packages retrieved from CRAN snapshot 2023-04-07).

Radua, J., Mataix-Cols, D., 2012. Meta-analytic methods for neuroimaging data explained. Biol. Mood Anxiety Disord. 2, 6. https://doi.org/10.1186/2045-5380-2-6.

Raichle, M. E., & Snyder, A. Z. (2007). A default mode of brain function: a brief history of an evolving idea. *NeuroImage*, *37*(4), 1083–1099. https://doi.org/10.1016/j.neuroimage.2007.02.041

Rasche, S. E., Beyh, A., Paolini, M., & Zeki, S. (2023). The neural determinants of abstract beauty. The European journal of neuroscience, 57(4), 633–645. https://doi.org/10.1111/ejn.15912

Reber, R., Schwarz, N., & Winkielman, P. (2004). Processing Fluency and Aesthetic Pleasure: Is Beauty in the Perceiver's Processing Experience? Personality and Social Psychology Review, 8(4), 364-382. https://doi.org/10.1207/s15327957pspr0804_3

Reber, R., Winkielman, P., & Schwarz, N. (1998). Effects of perceptual fluency on affective judgments. *Psychological Science*, *9*(1), 45–48. https://doi.org/10.1111/1467-9280.00009

Redinbaugh, M. J., Phillips, J. M., Kambi, N. A., Mohanta, S., Andryk, S., Dooley, G. L., Afrasiabi, M., Raz, A., & Saalmann, Y. B. (2020). Thalamus Modulates Consciousness via Layer-Specific Control of Cortex. *Neuron*, *106*(1), 66–75.e12. https://doi.org/10.1016/j.neuron.2020.01.005

Ricciardi, E., Rota, G., Sani, L., Gentili, C., Gaglianese, A., Guazzelli, M., & Pietrini, P. (2013). How the brain heals emotional wounds: The functional neuroanatomy of forgiveness. Frontiers in Human Neuroscience, 7, 839. https://doi.org/10.3389/fnhum.2013.00839

Rui, C., & Xiangping, G. (2011). The more fluent, the more beautiful?—An exploration of abstract art aesthetic processing. *Psychological Science (China)*, *34*(3), 565–570.

Rizzolatti, G., & Craighero, L. (2004). The mirror-neuron system. *Annual review of neuroscience*, *27*, 169–192. https://doi.org/10.1146/annurev.neuro.27.070203.144230

Rolls E. T. (2019). The cingulate cortex and limbic systems for emotion, action, and memory. *Brain structure & function*, *224*(9), 3001–3018. https://doi.org/10.1007/s00429-019-01945-2

Rolls, E. T., Cheng, W., & Feng, J. (2020). The orbitofrontal cortex: reward, emotion and depression. *Brain communications*, *2*(2), fcaa196. https://doi.org/10.1093/braincomms/fcaa196

Rolls, E. T., Deco, G., Huang, C. C., & Feng, J. (2022). The human orbitofrontal cortex, vmPFC, and anterior cingulate cortex effective connectome: emotion, memory, and action. *Cerebral cortex (New York, N.Y. : 1991)*, *33*(2), 330–356. https://doi.org/10.1093/cercor/bhac070

Rozzoni, C. (2020). Seeing the unreal: Husserlian Insights into the Nature of Images. *Kunstiteaduslikke Uurimusi*, 29(3–4), 57-70.

Rozzoni, C. (2021). Am I Truly Feeling This? Quasi-Emotions and Quasi-Values in Cinematic Experience. In Press.

Ruiz-Rizzo, A. L., Beissner, F., Finke, K., Müller, H. J., Zimmer, C., Pasquini, L., & Sorg, C. (2020). Human subsystems of medial temporal lobes extend locally to amygdala nuclei and globally to an allostatic-interoceptive system. *NeuroImage*, *207*, 116404. https://doi.org/10.1016/j.neuroimage.2019.116404

Russo, S. J., & Nestler, E. J. (2013). The brain reward circuitry in mood disorders. *Nature reviews. Neuroscience*, *14*(9), 609–625. https://doi.org/10.1038/nrn3381

Sabatinelli, D., Lang, P. J., Bradley, M. M., Costa, V. D., & Keil, A. (2009). The timing of emotional discrimination in human amygdala and ventral visual cortex. *The Journal of neuroscience : the official journal of the Society for Neuroscience*, *29*(47), 14864–14868. https://doi.org/10.1523/JNEUROSCI.3278-09.2009

Sacheli, L. M., Tomasetig, G., Musco, M. A., Pizzi, S., Bottini, G., Pizzamiglio, L., & Paulesu, E. (2022). The unexplored link between aesthetic perception and creativity: A theory-driven meta-analysis of fMRI studies in the visual domain. *Neuroscience and biobehavioral reviews*, *140*, 104768. https://doi.org/10.1016/j.neubiorev.2022.104768

Sarasso, P., Neppi-Modona, M., Sacco, K., & Ronga, I. (2020). "Stopping for knowledge": The sense of beauty in the perception-action cycle. *Neuroscience and biobehavioral reviews*, *118*, 723–738. https://doi.org/10.1016/j.neubiorev.2020.09.004

Sawada, K., Koike, H., Murayama, A., Nishida, H., & Nomura, M. (2024). Appreciation processing evoking feelings of being moved and inspiration: Awe and meaning-making. *Journal of Creativity*, *34*(1), 100076. https://doi.org/10.1016/j.yjoc.2024.100076

Saxe, R., & Wexler, A. (2005). Making sense of another mind: the role of the right temporo-parietal junction. *Neuropsychologia*, *43*(10), 1391–1399. https://doi.org/10.1016/j.neuropsychologia.2005.02.013

Schielzeth, H., Dingemanse, N. J., Nakagawa, S., Westneat, D. F., Allegue, H., Teplitsky, C., ... & Araya-Ajoy, Y. G. (2020). Robustness of linear mixed-effects models to violations of distributional assumptions. *Methods in ecology and evolution*, *11*(9), 1141-1152.

Schindler, I., Wagner, V., Jacobsen, T., & Menninghaus, W. (2022). Lay conceptions of "being moved" ("bewegt sein") include a joyful and a sad type: Implications for theory and research. *PLoS ONE, 17*(10), e0276808. https://doi.org/10.1371/journal.pone.0276808

Schino, G., van Klaveren, L.-M., Gallegos González, H. G., & Cox, R. F. A. (2021). Applying bodily sensation maps to art-elicited emotions: An explorative study. *Psychology of Aesthetics, Creativity, and the Arts.* Advance online publication.

Schoeller, F., Perlovsky, L., & Arseniev, D. (2018). Physics of mind: Experimental confirmations of theoretical predictions. *Physics of life reviews*, *25*, 45–68. https://doi.org/10.1016/j.plrev.2017.11.021

Schubert, T. W., Zickfeld, J. H., Seibt, B., & Fiske, A. P. (2018). Moment-to-moment changes in feeling moved match changes in closeness, tears, goosebumps, and warmth: time series analyses. *Cognition & emotion*, *32*(1), 174–184. https://doi.org/10.1080/02699931.2016.1268998

Schutter D. J. (2012). The cerebello-hypothalamic-pituitary-adrenal axis dysregulation hypothesis in depressive disorder. *Medical hypotheses*, *79*(6), 779–783. https://doi.org/10.1016/j.mehy.2012.08.027

Schutter D. J. (2020). The cerebellum in emotions and psychopathology. London: Taylor & Francis; 2020.

Schutter D. J. L. G. (2016). A Cerebellar Framework for Predictive Coding and Homeostatic Regulation in Depressive Disorder. *Cerebellum (London, England)*, *15*(1), 30–33. https://doi.org/10.1007/s12311-015-0708-2

Schutter, D. J., & Van Honk, J. (2009). The cerebellum in emotion regulation: a repetitive transcranial magnetic stimulation study. *Cerebellum (London, England)*, *8*(1), 28–34. https://doi.org/10.1007/s12311-008-0056-6

Schutter, D. J., Enter, D., & Hoppenbrouwers, S. S. (2009). High-frequency repetitive transcranial magnetic stimulation to the cerebellum and implicit processing of happy facial expressions. *Journal of psychiatry & neuroscience : JPN*, *34*(1), 60–65.

Schutter, D. J., Hofman, D., & Van Honk, J. (2008). Fearful faces selectively increase corticospinal motor tract excitability: a transcranial magnetic stimulation study. *Psychophysiology*, *45*(3), 345–348.

Schutz, D. (2001). *Sneeze*.

Seeley, W. W., Menon, V., Schatzberg, A. F., Keller, J., Glover, G. H., Kenna, H., Reiss, A. L., & Greicius, M. D. (2007). Dissociable intrinsic connectivity networks for salience processing and executive control. *The Journal of neuroscience : the official journal of the Society for Neuroscience*, *27*(9), 2349–2356. https://doi.org/10.1523/JNEUROSCI.5587-06.2007

Seeley, W. W., Menon, V., Schatzberg, A. F., Keller, J., Glover, G. H., Kenna, H., Reiss, A. L., & Greicius, M. D. (2007). Dissociable intrinsic connectivity networks for salience processing and executive control. *The Journal of neuroscience : the official journal of the Society for Neuroscience*, *27*(9), 2349–2356. https://doi.org/10.1523/JNEUROSCI.5587-06.2007

Seibt, B., Schubert, W., Zickfeld, J., Zhu, L., Arriaga, P., Simão, C., Nussinson, R., & Fiske, A. P. (2018). Kama muta: Similar emotional responses to touching videos across the United States, Norway, China, Israel, and Portugal. *Journal of Cross-Cultural Psychology*, *49*(3), 418–435.

Sesack, S. R., & Grace, A. A. (2010). Cortico-Basal Ganglia reward network: microcircuitry. *Neuropsychopharmacology : official publication of the American College of Neuropsychopharmacology*, *35*(1), 27–47. https://doi.org/10.1038/npp.2009.93

Shen, K. K., Welton, T., Lyon, M., McCorkindale, A. N., Sutherland, G. T., Burnham, S., Fripp, J., Martins, R., & Grieve, S. M. (2020). Structural core of the executive control network: A high angular resolution diffusion MRI study. *Human brain mapping*, *41*(5), 1226–1236. https://doi.org/10.1002/hbm.24870

Silvia, P. J., & Brown, E. M. (2007). Anger, disgust, and the negative aesthetic emotions: expanding an appraisal model of aesthetic experience. *Psychology of Aesthetics, Creativity, and the Arts*, 1, 100–106.

Skov, M., & Nadal, M. (2021). The nature of beauty: behavior, cognition, and neurobiology. *Annals of the New York Academy of Sciences*, *1488*(1), 44–55. https://doi.org/10.1111/nyas.14524

Specker, E., Douda, M., & Leder, H. (2024). How do we understand artworks? Exploring the role of artwork inherent features in art processing. *Empirical Studies of the Arts*, *42*(2), 469–497. https://doi.org/10.1177/02762374231201074

Steinbeis N. (2016). The role of self-other distinction in understanding others' mental and emotional states: neurocognitive mechanisms in children and adults. *Philosophical transactions of the Royal Society of London. Series B, Biological sciences*, *371*(1686), 20150074. https://doi.org/10.1098/rstb.2015.0074

Sutherland, C., Hare, D., Johnson, P. J., Linden, D. W., Montgomery, R. A., & Droge, E. (2023). Practical advice on variable selection and reporting using Akaike information criterion. *Proceedings. Biological sciences*, *290*(2007), 20231261. https://doi.org/10.1098/rspb.2023.1261

Tahmasian, M., Sepehry, A. A., Samea, F., Khodadadifar, T., Soltaninejad, Z., Javaheripour, N., Khazaie, H., Zarei, M., Eickhoff, S. B., & Eickhoff, C. R. (2019). Practical recommendations to conduct a neuroimaging meta-analysis for neuropsychiatric disorders. Human Brain Mapping, 40(17), 5142–5154.

Takano, K., Katagiri, N., Sato, T., Jin, M., Koseki, T., Kudo, D., Yoshida, K., Tanabe, S., Tsujikawa, M., Kondo, K., & Yamaguchi, T. (2023). Changes in Corticospinal Excitability and Motor Control During Cerebellar Transcranial Direct Current Stimulation in Healthy Individuals. *Cerebellum (London, England)*, *22*(5), 905–914. https://doi.org/10.1007/s12311-022-01469-2

Teufel, C., & Nanay, B. (2017). How to (and how not to) think about top-down influences on visual perception. *Consciousness and cognition*, *47*, 17–25.

The jamovi project (2023). jamovi. (Version 2.4) [Computer Software]. Retrieved from https://www.jamovi.org.

Thielscher, A., Antunes, A., & Saturnino, G. B. (2015). Field modeling for transcranial magnetic stimulation: A useful tool to understand the physiological effects of TMS?. *Annual*

International Conference of the IEEE Engineering in Medicine and Biology Society. IEEE Engineering in Medicine and Biology Society. Annual International Conference, *2015*, 222–225. https://doi.org/10.1109/EMBC.2015.7318340

Thompson, N. M., Uusberg, A., Gross, J. J., & Chakrabarti, B. (2019). Empathy and emotion regulation: an integrative account. *Progress in Brain Research*, *247*, 273–304.

Ticini, L. F., Rachman, L., Pelletier, J., & Dubal, S. (2014). Enhancing aesthetic appreciation by priming canvases with actions that match the artist's painting style. *Frontiers in Human Neuroscience, 8.* https://doi.org/10.3389/fnhum.2014.00391

Ticini, L.F., Urgesi, C., Calvo-Merino, B. (2015). Embodied Aesthetics: Insight from Cognitive Neuroscience of Performing Arts. In: Scarinzi, A. (eds) Aesthetics and the Embodied Mind: Beyond Art Theory and the Cartesian Mind-Body Dichotomy. Contributions To Phenomenology, vol 73. Springer, Dordrecht. https://doi.org/10.1007/978-94-017-9379-7_7

Timmann, D., Drepper, J., Frings, M., Maschke, M., Richter, S., Gerwig, M., & Kolb, F. P. (2010). The human cerebellum contributes to motor, emotional and cognitive associative learning. A review. *Cortex; a journal devoted to the study of the nervous system and behavior*, *46*(7), 845–857. https://doi.org/10.1016/j.cortex.2009.06.009

Trémolière, B., Maheux-Caron, V., Lepage, J. F., & Blanchette, I. (2018). tDCS Stimulation of the dlPFC Selectively Moderates the Detrimental Impact of Emotion on Analytical Reasoning. *Frontiers in psychology*, *9*, 568. https://doi.org/10.3389/fpsyg.2018.00568

Tsakiris, M., Costantini, M., & Haggard, P. (2008). The role of the right temporo-parietal junction in maintaining a coherent sense of one's body. *Neuropsychologia*, *46*(12), 3014–3018. https://doi.org/10.1016/j.neuropsychologia.2008.06.004

Turkeltaub, P.E., Eden, G.F., Jones, K.M., Zeffiro, T.A. (2002). Meta- analysis of the functional neuroanatomy of single-word reading: method and validation. NeuroImage, 16(3), 765–80.

Uddin L. Q. (2015). Salience processing and insular cortical function and dysfunction. *Nature reviews. Neuroscience*, *16*(1), 55–61. https://doi.org/10.1038/nrn3857

Uddin, L. Q., Nomi, J. S., Hébert-Seropian, B., Ghaziri, J., & Boucher, O. (2017). Structure and Function of the Human Insula. *Journal of clinical neurophysiology : official publication of the American Electroencephalographic Society*, *34*(4), 300–306. https://doi.org/10.1097/WNP.0000000000000377

Ul-Ain, Q., Ilyas, S., Ali, H., Ali, I., Ullah, R., Arshad, H., Khalid, S., Azim, M. E., Liu, T., & Wang, J. (2024). Exploring the Differential Effects of Transcranial Direct Current Stimulation: A Comparative Analysis of Motor Cortex and Cerebellar Stimulation. *Heliyon*, *10*(6), e26838. https://doi.org/10.1016/j.heliyon.2024.e26838

Ureña, E., & Nadal, M. (2023). The evolution of sensory valuation systems. In M. Skov & M. Nadal (Eds.), *The Routledge international handbook of neuroaesthetics* (pp. 254–291). Routledge.

Van de Cruys, S. (2017). Affective value in the predictive mind. In T. K. Metzinger & W. Wiese, Philosophy and predictive processsing, MIND Group.

Van de Cruys, S., & Wagemans, J. (2011). Putting reward in art: A tentative prediction error account of visual art. *i-Perception*, 2(9), 1035-1062.

Van de Cruys, S., Frascaroli, J., & Friston, K. (2024). Order and change in art: Towards an active inference account of aesthetic experience. *Philosophical Transactions of the Royal Society: Biological Sciences, 379* (20220411). https://doi.org/10.1098/rstb.2022.0411

van Leeuwen, J. E. P., Boomgaard, J., Bzdok, D., Crutch, S. J., & Warren, J. D. (2022). More Than Meets the Eye: Art Engages the Social Brain. *Frontiers in neuroscience*, *16*, 738865. https://doi.org/10.3389/fnins.2022.738865

Van Overwalle, F., Baetens, K., Mariën, P., & Vandekerckhove, M. (2014). Social cognition and the cerebellum: a meta-analysis of over 350 fMRI studies. *NeuroImage*, *86*, 554–572. https://doi.org/10.1016/j.neuroimage.2013.09.033

Van Overwalle, F., Manto, M., Cattaneo, Z., Clausi, S., Ferrari, C., Gabrieli, J. D. E., Guell, X., Heleven, E., Lupo, M., Ma, Q., Michelutti, M., Olivito, G., Pu, M., Rice, L. C., Schmahmann, J. D., Siciliano, L., Sokolov, A. A., Stoodley, C. J., van Dun, K., Vandervert, L., … Leggio, M. (2020). Consensus Paper: Cerebellum and Social Cognition. *Cerebellum (London, England)*, *19*(6), 833–868. https://doi.org/10.1007/s12311-020-01155-1

Vartanian, O., & Goel, V. (2004). Neuroanatomical correlates of aesthetic preference for paintings. *Neuroreport*, *15*(5), 893–897.

Vartanian, O., & Skov, M. (2014). Neural correlates of viewing paintings: evidence from a quantitative meta-analysis of functional magnetic resonance imaging data. *Brain and cognition*, *87*, 52–56. https://doi.org/10.1016/j.bandc.2014.03.004

Vergallito, A., Feroldi, S., Pisoni, A., & Romero Lauro, L. J. (2022). Inter-Individual Variability in tDCS Effects: A Narrative Review on the Contribution of Stable, Variable, and Contextual Factors. Brain sciences, 12(5), 522. https://doi.org/10.3390/brainsci12050522

Vessel, E. A., Isik, A. I., Belfi, A. M., Stahl, J. L., & Starr, G. G. (2019). The default-mode network represents aesthetic appeal that generalizes across visual domains. *Proceedings of the National Academy of Sciences of the United States of America*, *116*(38), 19155–19164. https://doi.org/10.1073/pnas.1902650116

Vessel, E. A., Starr, G. G., & Rubin, N. (2012). The brain on art: intense aesthetic experience activates the default mode network. *Frontiers in human neuroscience*, *6*, 66. https://doi.org/10.3389/fnhum.2012.00066

Vicario, C. M., Rafal, R. D., Borgomaneri, S., Paracampo, R., Kritikos, A., & Avenanti, A. (2017). Pictures of disgusting foods and disgusted facial expressions suppress the tongue motor cortex. *Social cognitive and affective neuroscience*, *12*(2), 352–362.

Vischer, R. (1873). On the optical sense of form: a contribution to aesthetics. In: Mallgrave, HF, Ikonomou E (eds) (1994). Empathy, form, and space: problems in german aesthetics, 1873–1893 (pp 89–123). Santa Monica, California: Getty Center for the History of Art and the Humanities

Vischer, R., Mallgrave, H. F., & Ikonomou, E. (1994). Empathy, form, and space: Problems in German aesthetics, 1873-1893. (Original Work published 1873)

Vissers, N., & Wagemans, J. (2023). Processing fluency, processing style, and aesthetic response to artistic photographs. *Psychology of Aesthetics, Creativity, and the Arts*, *17*(3), 338–357. https://doi.org/10.1037/aca0000388

Wang, S., Yu, R., Tyszka, J. M., Zhen, S., Kovach, C., Sun, S., Huang, Y., Hurlemann, R., Ross, I. B., Chung, J. M., Mamelak, A. N., Adolphs, R., & Rutishauser, U. (2017). The human amygdala parametrically encodes the intensity of specific facial emotions and their categorical ambiguity. *Nature communications*, *8*, 14821. https://doi.org/10.1038/ncomms14821

Wang, Y., Li, Y., Xiao, W., Fu, Y., & Jie, J. (2020a). Investigation on the Rationality of the Extant Ways of Scoring the Interpersonal Reactivity Index Based on Confirmatory Factor Analysis. *Frontiers in psychology*, *11*, 1086. https://doi.org/10.3389/fpsyg.2020.01086

Wang, Z. M., Wei, P. H., Shan, Y., Han, M., Zhang, M., Liu, H., Gao, J. H., & Lu, J. (2020b). Identifying and characterizing projections from the subthalamic nucleus to the cerebellum in humans. *NeuroImage*, *210*, 116573. https://doi.org/10.1016/j.neuroimage.2020.116573

Waskom, M. L., Kumaran, D., Gordon, A. M., Rissman, J., & Wagner, A. D. (2014). Frontoparietal representations of task context support the flexible control of goal-directed cognition. *The Journal of neuroscience : the official journal of the Society for Neuroscience*, *34*(32), 10743–10755.

Wassiliwizky, E., Wagner, V., Jacobsen, T., & Menninghaus, W. (2015). Art-elicited chills indicate states of being moved. *Psychology of Aesthetics, Creativity, and the Arts*, *9*(4), 405–416. https://doi.org/10.1037/aca0000023

Wessel, J. R., & Aron, A. R. (2017). On the Globality of Motor Suppression: Unexpected Events and Their Influence on Behavior and Cognition. *Neuron*, *93*(2), 259–280. https://doi.org/10.1016/j.neuron.2016.12.013

Wicker, B., Keysers, C., Plailly, J., Royet, J. P., Gallese, V., & Rizzolatti, G. (2003). Both of us disgusted in My insula: the common neural basis of seeing and feeling disgust. *Neuron*, *40*(3), 655–664. https://doi.org/10.1016/s0896-6273(03)00679-2

Williams, P. G., Johnson, K. T., Curtis, B. J., King, J. B., & Anderson, J. S. (2018). Individual differences in aesthetic engagement are reflected in resting-state fMRI

connectivity: Implications for stress resilience. *NeuroImage, 179*, 156–165. https://doi.org/10.1016/j.neuroimage.2018.06.042

Wittgenstein, L. (1968). *Philosophical investigations: The English text of the third edition*. New York: Macmillan. (Original work published 1958)

Wittgenstein, L., Barrett, C., Smythies, Y., Rhees, R., & Taylor, J. (1987). *Lectures & conversations on aesthetics, psychology and religious belief*. Oxford: Basil Blackwell. (Original work published 1966)

Yeh, Y. C., Lin, C.-W., Hsu, W.-C., Kuo, W.-J., & Chan, Y.-C. (2015). Associated and dissociated neural substrates of aesthetic judgment and aesthetic emotion during the appreciation of everyday designed prod- ucts. *Neuropsychologia, 73*, 151–160. http://dx.doi.org/10.1016/j .neuropsychologia.2015.05.010

Yeh, Y.-C., & Peng, Y.-Y. (2019). The influences of aesthetic life experience and expertise on aesthetic judgement and emotion in mundane arts. International Journal of Art & Design Education, 38*(3), 492–507. https://doi.org/10.1111/jade.12213

Yin, H. H., Ostlund, S. B., & Balleine, B. W. (2008). Reward-guided learning beyond dopamine in the nucleus accumbens: the integrative functions of cortico-basal ganglia networks. *The European journal of neuroscience, 28*(8), 1437–1448. https://doi.org/10.1111/j.1460-9568.2008.06422.x

Zajonc, R. B. (1968). Attitudinal effects of mere exposure. *Journal of Personality and Social Psychology, 9*(2, Pt.2), 1–27. https://doi.org/10.1037/h0025848

Zhang, W., He, X., Lai, S., Wan, J., Lai, S., Zhao, X., & Li, D. (2017). Neural substrates of embodied natural beauty and social endowed beauty: An fMRI study. *Scientific reports, 7*(1), 7125. https://doi.org/10.1038/s41598-017-07608-8

Zhang, W., Lai, S., He, X., Zhao, X., & Lai, S. (2016). Neural correlates for aesthetic appraisal of pictograph and its referent: An fMRI study. *Behavioural brain research, 305*, 229–238. https://doi.org/10.1016/j.bbr.2016.02.029

Zickfeld, J. H., Schubert, T. W., Seibt, B., & Fiske, A. P. (2019). Moving Through the Literature: What Is the Emotion Often Denoted Being Moved? Emotion Review, 11(2), 123-139. https://doi.org/10.1177/1754073918820126

Thiago Boecan. *Limit.* 2018.

Appendix

Table s1: An Overview of the Studies Included in The Meta-Analysis on Negative Visual Aesthetic Experience

N	Author and year	Sample size (mean age of participants)	Stimuli	Task	Contrast	Number of Foci included in ALE
1	Ardizzi et al., 2021	20 (25.15)	Paintings	Evaluation of Pain in Facial Expressions	Art Pain > Art Neutral/No Pain; Art Pain vs. Baseline	53
2	Bachrach et al., 2016	20 (27.65)	Dance Videos	Passive viewing while indicating when there was temporal acceleration of video	Discoherent > Coherent	4
3	Baeken et al., 2012	40 (24.4)	Paintings with emotional primes of baby pictures	Memorize and recognize paintings	Primed Negative > Primed Positive	2
4	Bao et al., 2017	16 (24.45)	Paintings	Passive viewing	Altered Green Paintings > Original Red Paintings by Chinese Artist LaoZhu	3
5	Bermudez et al., 2017	12 (age range: 26-48)	Architectural Spaces	Passive viewing	Ordinary > Baseline; Ordinary (Control) > Contemplative Architecture (Experimental)	16
6	de Gelder et al., 2018	20 (25)	Paintings	Passive viewing	From SI: Women only: Male paintings with arrows vs. Male paintings with no arrows; Men only: Female paintings with arrows vs. female paintings with no arrows	2
7	Di Dio et al., 2007	14 (24.5)	Sculptures	Aesthetic Judgement of Beauty	Ugly > Beautiful (Main effect and interaction for Aesthetic Judgement)	6
8	Di Dio et al., 2011	24 (28.28)	Sculptures	Aesthetic Judgement of Beauty	Modified > Canonical Sculptures	2
9	Di Dio et al., 2016	19 (21.96)	Paintings	Observation (indicate when a red circle appears); Aesthetic Judgement of Beauty; Judgement of Movement	Paintings of Humans > Paintings of Nature (Observation, Aesthetic Judgement, Movement Judgement)	13

10	Flexas et al., 2014	24 (23.54)	Paintings	Aesthetic Judgement of Beauty	Abstract > Representational Paintings	3
11	Ikeda et al., 2015	18 (19-30)	Color combination pairs	Aesthetic Rating of Color Harmony	Disharmony > Neutral and Harmony	1
12	Ishizu et al., 2011	21 (27.5)	Paintings	Aesthetic Judgement of Beauty	Ugly > Beautiful	7
13	Ishizu et al., 2017	21 (28.6)	Photography (professional photographers of national geographic)	Aesthetic Judgement of Beauty	Sorrowful Beauty > Joyful beauty	9
14	Kawabata et al., 2004	10 (20-31)	Paintings	Aesthetic Judgement of Beauty	Ugly > Beautiful	2
15	Kross et al., 2007	20 (24.5)	Paintings	Passive viewing	Paintings displaying rejection > Paintings displaying acceptance	12
16	Labek et al., 2018	17 (22.7	Drawings of Paintings	Passive viewing	Mourning > Control; Mourning > Control Activation over time within block; Mourning > Control Activation over time between blocks	19
17	Thakral et al., 2012	16 (18-65)	Paintings	Aesthetic Judgement of Pleasantness	Unpleasant > Pleasant	8
18	Vartanian et al., 2004	12 (28)	Paintings	Aesthetic Preference	Negative correlation with preference rating	1
19	Vartanian et al., 2015	18 (23.39)	Architectural Spaces	Aesthetic and Approach-Avoidance Judgements	Enclosed Spaces > Open Spaces	1
20	Vessel et al., 2012	16 (27.6)	Paintings	Aesthetic Judgement of Feeling Moved	Correlation of "Negative Emotional" PCA Factor with Whole Brain contrast of Moving > Not Moving	2
21	Zhang et al., 2016	16 (21.29)	Chinese Pictographs	Aesthetic Judgement of Beauty and Judgement of Luminance	Ugly Pictograph > Low Luminance	2
22	Zhang et al., 2017	19 (21.74)	Chinese Pictographs and Oracle Bone Scripts	Aesthetic Judgement of Beauty and Judgement of Luminance	Ugly Pictograph > Low Luminance; Negative Oracle Bone Script > Low Luminance; Negative Oracle Bone Script > Positive Oracle Bone Script	11
Total number of studies: 22		Total number of participants: 413				Total number of foci: 179

Table s2: An Overview of the Studies Included in the Meta-Analysis on Visual Non-Artistic Experience & Visual Social Experience

N	Author and year	Sample size (mean age of participants)	Stimuli	Task	Contrast	Foci included in ALE	BOTH (B); SOCIAL (S); NON SOCIAL (NS)
1	Aldhafeeri et al., 2012	15 (44.5)	IAPS	Passive Viewing	Unpleasant > Baseline	16	B
2	Andreano et al., 2010	17 (20.88)	IAPS	Passive Viewing	Emotional (Negative) > Neutral	8	S
3	Arioli et al., 2021	34 (25.38)	Images of Social Interactions	Passive Viewing	Conflictual > affective; Competitive > cooperative	2	S
4	Ballotta et al., 2018	30 (21.7)	Images of Faces	Passive Viewing and Discrimination of Facial Expressions	Pain > Neutral	2	S
5	Barro´s-Loscertales et al., 2010	45 (21.82)	IAPS	Passive Viewing and Letter Discrimination Task	Aversive > Neutral	18	B
6	Benuzzi et al., 2008	15 (23.5)	Video clips of hands/feet (1 sec)	Passive Viewing followed by pleasantness rating after 10 seconds	Pain > Neutral & Disgust > Neutral	12	S
7	Beraha et al., 2012	36 (36.7)	IAPS	Passive Viewing; half of trials with attentional cues for emotion	Lateralization: Negative > Neutral; Negative > Positive	7	B
8	Bisby et al., 2016	20 (23)	IAPS	Passive Viewing followed by intrascanner indication if the presented two images go well/are plausible together; second memory recognition task	Negative > Neutral (Encoding only)	7	S
9	Blair et al., 2007	22 (27.95)	IAPS and arabic symbols of numbers	Passive Viewing	Negative > Neutral + Positive	6	B
10	Bo et al., 2021	20 (20.4)	IAPS	Passive Viewing	Unpleasant > Pleasant	28	B
11	Botvinick et al., 2005	12 (20-30)	Video clips of faces	Passive Viewing	Pain > Neutral	18	S

			(1.10 seconds)				
12	Nelson et al., 2015	22 (25.2)	Faces	Rate experienced emotion	Maintain Negative > Look Neutral	3	S
13	Canli et al., 1998	8 (25.6 for 14 parts; 18-65)	IAPS	Judgement of arousal and valence	Negative > Positive	5	B
14	Cao et al., 2014	21 (18-65)	Animals and objects with or without human context	Passive Viewing followed by repetition detection task	Negative > Neutral	14	B
15	Chakrabarti et al., 2007	26 (23.4); 1 participant exclude; total = 25	Dynamic videos of faces (3 seconds)	Passive Viewing	Sad; Angry; Disgust > Neutral	27	S
16	Christov-Moore et al, 2019	70 (18-35)	Videos of hands (5 seconds)	Passive Viewing	Needle Penetration > Q-tip Touch	29	S
17	Deuse et al., 2016	42 (23.88)	Images of Scenes (Valence = social; control = non-social)	Judge Pleasantness	Negative > Positive	6	S
18	Diers et al., 2021	46 (18-38)	IAPS, EmoPicS (emotional picture set)	Emotional Regulation (Distance or Permit)	Negative Stimulation Phase > Neutral Stimulation Phase	9	B
19	Dolcos et al., 2020	21 (34.24)	Social Scenes	Viewing with attentional focus cues	Negative Emotional Scene with Foreground > Neutral	24	S
20	Domes et al., 2010	33 (24.89)	IAPS	Passive viewing	Negative > Neutral	24	B
21	Enzi et al., 2016	20 (27)	Primes of faces, painful/not painful stimulus on body	Emotional recognition and empathize	Pain > No Pain	13	S
22	Erk et al., 2006	14 (21-25)	IAPS	Working Memory Task followed by picture presentation	Negative > Neutral for picture presentation	11	B
23	Favre et al., 2021	332 (40.74)	Social Scenes	Viewing: Rate Valence and nervousness of experienced emotions (task evoked valence and anxiety)	Negative > Neutral	22	S

24	Feng et al., 2016	22 (22.23)	Images of Faces	Viewing then rate other's experienced pain	Pain > No Pain	23	S
25	Ferri et al., 2013	41 (22.29)	IAPS	Passive viewing then rate negative emotion	Unpleasant No Focus > Neutral No Focus (both experiments)	25	B
26	Flaisch et al., 2009	30 (19-33)	Images of emotional hand gestures	Passive Viewing	Insult > Point	18	S
27	Gerdes et al., 2010	17 (25.12)	IAPS	Passive viewing then rate pleasantness post-scanning	Unpleasant > Neutral; Pleasant	4	B
28	Grosbras et al., 2006	20 (28.6)	video clips of hand or face in movement (2-5secs)	Passive viewing	Angry Hands > Neutral Hands	16	S
29	Gu et al., 2007	12 (21.9)	Images of hands (pictures and cartoons)	Rate pain intensity or counting number of hands	Pain > No Pain (Pictures only)	6	S
30	Gu et al., 2010	18 (24.8)	Images of hands and feet	Pain Evaluation and Laterality judgment	Pain > No Pain	22	S
31	Gu et al., 2013	18 (25.2)	Images of hands and feet	Judgement of pain, body part, or laterality	Pain > No Pain (Pain judgement, body part, laterality)	72	S
32	Han et al., 2017	33 (22.91)	Video clips of faces (3 secs)	Passive viewing	Pain> No Pain	14	S
33	Hartung et al., 2019	31 (18-35)	Images of disfigured faces before and after treatment	Passive viewing	Disfigured> After Treatment	3	S
34	Heller et al., 2014	26 (21.8)	Emotional images	Passive viewing	Negative > Neutral	24	B
35	Herwig et al., 2007	16 (23-36)	IAPS	Passive viewing after emotional cue	Expectation Negative > Neutral	15	B
36	Iidaka et al., 2001	12 (25.1)	Images of Faces	Viewing and Gender Discrimination	Negative > Neutral; Positive	8	S
37	Iidaka et al., 2002	12 (25.1)	Faces	Gender Discrimination	Negative > Baseline	11	S
38	Ito et al., 2017	19 (24.1)	Faces	Emotional Identification	100% Sad > 100% Happy	2	S

39	Jackson et al., 2005	15 (22)	Images of hands and feet	View then rate other's experienced pain	Pain > No Pain	20	S
40	Jackson et al., 2006	18 (25.2)	images ofhands/feet	View then rate other's experienced pain	Pain > No Pain	14	S
41	Kark et al., 2015	17 (23.9)	IAPS	View and decide to approach or withdrawal from depicted scene; then recognition task	Negative Hits > Neutral Hits	19	B
42	Koenigsberg et al., 2010	16 (31.8)	IAPS-social scenes	Suppress or maintain, then image viewing, then rate emotional reaction in valence	Negative > Neutral	8	S
43	Kolesar & Kornelsen et al., 2016	13 (18-30)	IAPS	Passive Viewing	Negative > Neutral	10	B
44	Koppe et al., 2015	30 (24.2	Faces	Gender Discrimination	Angry > Happy	8	S
45	Kornelsen et al., 2019	20 (22.0)	IAPS	Passive Viewing and rate pain from noxious stimuli on 10th pulse	Negative > Neutral; Positive	12	B
46	Kuniecki et al., 2017	19 (22.9)	IAPS & Nencki Affective Picture System	Passive viewing with attentional check of image being outdoors or indoors	Negative > Neutral (Pupil dilation and Image Noise)	9	B
47	Lamm et al., 2008	18 (23.67)	Images of Hands	Passive viewing with small subset rated for pain intensity	Injection > Control	33	S
48	LeClerc et al., 2008	17 (19-31)	Images of objects	View and indicate if the object would fit in a cabinet drawer	Negative > Neutral (Young adults)	13	NS
49	Lee et al., 2004	10 (29.5)	IAPS	Emotional Intensity	Negative > Neutral	9	B
50	Lee et al., 2010	13 (25-39)	IAPS	Either choose the truth or lie about picture valence	True Negative > True Positive	17	B
51	Lemogne et al., 2011	45 (23.3)	IAPS, EPS (Empathy Picture System), Images of indoors/outdoors	Viewing and Judgement (Valence to the self, Valence in general, control= indoors or outdoors)	Negative > Positive	4	B
52	Loos et al., 2019	1385 (22.38)	IAPS	Picture encoding task (passive viewing then rate valence and arousal)	Negative > Neutral (encoding)	16	B

53	Mataix-Cols et al., 2008	37 (30.7)	IAPS	Imagine self in the situation and then rate anxiety	Disgust > Neutral (positive correlations)	15	B
54	Mériau et al., 2009	23 (27.1)	IAPS	Passive viewing	Aversive > Neutral	8	B
55	Meseguer et al., 2007	14 (28.8)	IAPS	Passive view then letter discrimination task	Negative > Neutral	35	B
56	Moore et al., 2019	22 (18-31)	Shapes stimuli and IAPS distractors	Visual oddball task	Negative Distractors > Neutral Distractors	44	B
57	Morawetz et al., 2016	48 (29.7)	Faces	Watch/Observe	Negative > Neutral	27	S
58	Morrison et al., 2013	14 (23-35)	Pictures of hands with objects	Passive viewing then rate appropriateness of action	Noxious > Neutral (BOLD outside response period)	11	B
59	Nielen et al., 2009	23 (20-25)	IAPS	Stimulus classification (outdoors vs. indoors)	Negative > Positive	18	B
60	Nummenmaa et al., 2008	10 (26)	Scenes	Watch/Passive Viewing	Watch Emotional (Aversive) > Watch Neutral	8	S
61	Ochsner et al., 2009	20 (20.3)	IAPS	View then rate emotion	Increased negative affect rating correlated with activation from Bottom-up Negative > Bottom-up Neutral contrast	2	B
62	Park et al., 2016	19 (25.9)	Faces	Encoding and recognition of Faces	Negative > Neutral	7	S
63	Park et al., 2019	32 (22.19)	Faces	Reward Categorization	Negative Reward > Positive Reward	1	S
64	Pedale et al., 2019	22 (23.6)	IAPS (No Humans)	Passive viewing (Localizer Task)	Negative > Neutral + Positive (1 experiment)	10	NS
65	Pereira et al., 2010	11 (24.8)	Social Scenes	Attend	Unpleasant > Neutral	4	S
66	Preckel et al., 2019	27 (28.78)	Faces, Social Scenes, Non Social	Matching Pictures	Negative > Neutral (Faces, social scenes, non-social scenes); Negative > Positive (Faces, social scenes, non-social scenes)	36	B

67	Preis et al., 2015	62 (23.0)	Images of hands	Induction of touch or pain before MRI; then rate pain of images	Pain > No Pain	7	S
68	Radua et al., 2014	40 (19-59)	IAPS	Look/ Passive viewing	Disgust > Neutral; Fear > Neutral; Sadness > Neutral	9	B
69	Reisch et al., 2020	43 (32.19)	IAPS, FACES database, words	Passive viewing, then at end, rate random selection of 10 items for valence and arousal	Negative > Neutral: 2 analyses for IAPS and FACES	9	B
70	Ren et al., 2022	24 (21.48)	Images of bodies from BEAST (The bodily expressive action stimulus test)	Passive Viewing then Expression Recognition	Whole Body: Fear; Anger > Neutral	2	S
71	Ruckmann et al., 2015	30 (24.5)	Bodies	Passive Viewing, then rate pain after each block	Pain > Neutral	11	S
72	Rymarczyk et al., 2019	46 (23.8)	The Amsterdam Dynamic Facial Expression Set (Dynamic of 6 secs and Static Stimuli used)	Passive Viewing	Negative emotion > Neutral (Dynamic, Static)	66	S
73	Sakaki et al., 2011	19 (21.2; 18-65)- originally 20 removed one participant	Images Pairs of Scenes	Passive Viewing in Initial Learning Phase	Negative > Neutral (first presentation of picture)	3	B
74	Schmitz et al., 2009	16 (22.03)	IAPS	Passive viewing	Negative > Positive	1	S
75	Schurmann et al., 2011	15 (27.1)	Images of hands	Passive Viewing then rate unpleasantness outside scanner	Distorted > Natural	5	S
76	Seara-Cardoso et al., 2016	30 (26.9)	Faces	Empathy for emotional face expressions	Negative > Neutral	1	S
77	Silvers et al., 2015	30 (21.97)	IAPS	View and rate negativity	Look Negative > Look Neutral	32	B
78	Smith et al., 2004	15 (18-32)	IAPS	Recognition of previously seen (hits vs. misses)	Negative > positive (Hits)	8	B

79	Sokołowski et ak., 2022	83 (21.66)	IAPS	Passive Viewing (Look condition in cognitive reappraisal task)	Negative > Neutral; Negative > Positive	33	B
80	Sterpenich et al., 2014	34 (22.15)	IAPS	Viewing then rate for pleasantness after picture disappeared	Negative > Neutral; Positive	23	B
81	Takahashi et al., 2015	38 (18-44)	Images of Faces	View and rate sadness	Sad > Neutral	41	S
82	Thomas et al., 2019	30 (18-65)	IAPS	Watch during scan; rate emotional valence and intensity after scan	Negative > Neutral	32	S
83	Uchida et al., 2015	62 (22.3)	IAPS	Attend and rate the negative emotion experienced	Attend Negative > Attend Neutral	5	B
84	van der Heiden et al., 2013	18 (25.3)	Bodies	View then rate success in emotional perspective taking	View Pain > View No Pain	1	S
85	Van Dillen et al., 2009	17 (20)	IAPS	Passive viewing then arithmetic problem and mood rating	Negative > Fixation	18	B
86	Vermeylen et al., 2020	38 (23.71)	Images of Scenes	Color Circle task	Negative > Positive (Affect in color circle naming task)	3	B
87	Villalta-Gil et al., 2017	32 (23.13)	IAPS	Cued Aversive Picture Task (CAP); Aversive and Erotica Picture Task (AEP)	CAP Negative > Neutral; AEP Negative vs. Neutral	3	B
88	Vistoli et al., 2016	21 (29.2)	Rapid fire 3 image sets of hands	Instruction (self/other), then view then rate pain intensity	Pain > No Pain	11	S
89	Waugh et al., 2014	27 (23.8)	IAPS	Passive Viewing Picture, rate emotional intensity 2nd picture (all same valence)	Negative > Neutral (Non-maintain)	6	B
90	Waugh et al., 2016	47 (27.98)	Images of Scenes	Passive Viewing then rate valence of feeling	Negative > Neutral (Look; Height)	11	B
91	Weierich et al., 2010	15 (22.2)	IAPS	Viewing and Arousal Rating	Negative > Neutral	10	B
92	White et al., 2014	30 (26.0)	Images of faces and objects	Dot Probe Task	Negative > Neutral (Main effect of emotion)	3	B
93	Willinger et al., 2019	33 (27.4)	Radboud face database	Matching Faces	Negative > Neutral; Positive	15	S

94	Wittfoth et al., 2020	17 (23.47)	IAPS	Passive viewing then rate negativity with or without emotional regulation strategy	Fear & Disgust> Neutral	18	B
95	Wrase et al., 2003	20= 10M (43.2); 10F (40); but separately per exp and in data set	IAPS	Passive viewing	Negative > Neutral (Men and Women)	11	B
96	Yoon et al., 2015	30 (23.13)	Primes of Faces and Passive view of Scenes	Passive viewing	(Angry Face Prime & Negative Photo – Angry Face Prime & Neutral Photo) > (Neutral Face prime & Negative Photo – Neutral Face Prime & Neutral Photo)	2	B
97	Zhang et al., 2015	25 (18.61)	IAPS	View then rate arousal	Negative > Neutral	20	B
Total number of studies for B: 50 For S: 45 For NS: 2 For VNE: 97 For VSE: 45		Total number of subjects for B: 2698 For S: 1455 For NS: 39 For VNE: 4192 For VSE: 1455				Total number of foci for B: 719 For S: 680 For NS: 23 For VNE: 1412 For VSE: 680	

*Note: VNE = Visual Negative Experience; VSE = Visual Social Experience.

Bibliography of Included Studies

Aldhafeeri, F. M., Mackenzie, I., Kay, T., Alghamdi, J., & Sluming, V. (2012). Regional brain responses to pleasant and unpleasant IAPS pictures: different networks. *Neuroscience letters*, *512*(2), 94–98. https://doi.org/10.1016/j.neulet.2012.01.064

Andreano, J. M., & Cahill, L. (2010). Menstrual cycle modulation of medial temporal activity evoked by negative emotion. *NeuroImage*, *53*(4), 1286–1293. https://doi.org/10.1016/j.neuroimage.2010.07.011

Ardizzi, M., Ferroni, F., Umiltà, M. A., Pinardi, C., Errante, A., Ferri, F., Fadda, E., & Gallese, V. (2021). Visceromotor roots of aesthetic evaluation of pain in art: an fMRI study. *Social cognitive and affective neuroscience*, *16*(11), 1113–1122. https://doi.org/10.1093/scan/nsab066

Arioli, M., Basso, G., Carne, I., Poggi, P., & Canessa, N. (2021). Increased pSTS activity and decreased pSTS-mPFC connectivity when processing negative social interactions. *Behavioural brain research*, *399*, 113027. https://doi.org/10.1016/j.bbr.2020.113027

Bachrach, A., Jola, C., & Pallier, C. (2016). Neuronal bases of structural coherence in contemporary dance observation. *NeuroImage*, *124*(Pt A), 464–472. https://doi.org/10.1016/j.neuroimage.2015.08.072

Ballotta, D., Lui, F., Porro, C. A., Nichelli, P. F., & Benuzzi, F. (2018). Modulation of neural circuits underlying temporal production by facial expressions of pain. *PloS one*, *13*(2), e0193100. https://doi.org/10.1371/journal.pone.0193100

Bermudez, J., Krizaj, D., Lipschitz, D. L., Bueler, C. E., Rogowska, J., Yurgelun-Todd, D., & Nakamura, Y. (2017). Externally-induced meditative states: An exploratory fMRI study of architects' responses to contemplative architecture. *Frontiers of Architectural Research*, *6*(2), 123-136. https://doi.org/10.1016/j.foar.2017.02.002

Bao, Y., Yang, T., Zhang, J., Zhang, J., Lin, X., Paolini, M., Pöppel, E., & Silveira, S. (2017). The "third abstraction" of the Chinese artist LaoZhu: Neural and behavioral indicators of aesthetic appreciation. *PsyCh journal*, *6*(2), 110–119. https://doi.org/10.1002/pchj.167

Barrós-Loscertales, A., Ventura-Campos, N., Sanjuán-Tomás, A., Belloch, V., Parcet, M. A., & Avila, C. (2010). Behavioral activation system modulation on brain activation during appetitive and aversive stimulus processing. *Social cognitive and affective neuroscience*, *5*(1), 18–28. https://doi.org/10.1093/scan/nsq012

Benuzzi, F., Lui, F., Duzzi, D., Nichelli, P. F., & Porro, C. A. (2008). Does it look painful or disgusting? Ask your parietal and cingulate cortex. *The Journal of neuroscience : the official journal of the Society for Neuroscience*, *28*(4), 923–931. https://doi.org/10.1523/JNEUROSCI.4012-07.2008

Beraha, E., Eggers, J., Hindi Attar, C., Gutwinski, S., Schlagenhauf, F., Stoy, M., Sterzer, P., Kienast, T., Heinz, A., & Bermpohl, F. (2012). Hemispheric asymmetry for affective

stimulus processing in healthy subjects--a fMRI study. *PloS one*, *7*(10), e46931. https://doi.org/10.1371/journal.pone.0046931

Bisby, J. A., Horner, A. J., Hørlyck, L. D., & Burgess, N. (2016). Opposing effects of negative emotion on amygdalar and hippocampal memory for items and associations. *Social cognitive and affective neuroscience*, *11*(6), 981–990. https://doi.org/10.1093/scan/nsw028

Blair, K. S., Smith, B. W., Mitchell, D. G., Morton, J., Vythilingam, M., Pessoa, L., Fridberg, D., Zametkin, A., Sturman, D., Nelson, E. E., Drevets, W. C., Pine, D. S., Martin, A., & Blair, R. J. (2007). Modulation of emotion by cognition and cognition by emotion. *NeuroImage*, *35*(1), 430–440. https://doi.org/10.1016/j.neuroimage.2006.11.048

Bo, K., Yin, S., Liu, Y., Hu, Z., Meyyappan, S., Kim, S., Keil, A., & Ding, M. (2021). Decoding Neural Representations of Affective Scenes in Retinotopic Visual Cortex. *Cerebral cortex (New York, N.Y. : 1991)*, *31*(6), 3047–3063. https://doi.org/10.1093/cercor/bhaa411

Botvinick, M., Jha, A. P., Bylsma, L. M., Fabian, S. A., Solomon, P. E., & Prkachin, K. M. (2005). Viewing facial expressions of pain engages cortical areas involved in the direct experience of pain. *NeuroImage*, *25*(1), 312–319. https://doi.org/10.1016/j.neuroimage.2004.11.043

Canli, T., Desmond, J. E., Zhao, Z., Glover, G., & Gabrieli, J. D. (1998). Hemispheric asymmetry for emotional stimuli detected with fMRI. *Neuroreport*, *9*(14), 3233–3239. https://doi.org/10.1097/00001756-199810050-00019

Cao, Z., Zhao, Y., Tan, T., Chen, G., Ning, X., Zhan, L., & Yang, J. (2014). Distinct brain activity in processing negative pictures of animals and objects - the role of human contexts. *NeuroImage*, *84*, 901–910. https://doi.org/10.1016/j.neuroimage.2013.09.064

Chakrabarti, B., Bullmore, E., & Baron-Cohen, S. (2006). Empathizing with basic emotions: common and discrete neural substrates. *Social neuroscience*, *1*(3-4), 364–384. https://doi.org/10.1080/17470910601041317

Christov-Moore, L., & Iacoboni, M. (2019). Sex differences in somatomotor representations of others' pain: a permutation-based analysis. *Brain structure & function*, *224*(2), 937–947. https://doi.org/10.1007/s00429-018-1814-y

de Gelder, B., Watson, R., Zhan, M., Diano, M., Tamietto, M., & Vaessen, M. J. (2018). Classical paintings may trigger pain and pleasure in the gendered brain. *Cortex; a journal devoted to the study of the nervous system and behavior*, *109*, 171–180. https://doi.org/10.1016/j.cortex.2018.09.011

Deuse, L., Rademacher, L. M., Winkler, L., Schultz, R. T., Gründer, G., & Lammertz, S. E. (2016). Neural correlates of naturalistic social cognition: brain-behavior relationships in healthy adults. *Social cognitive and affective neuroscience*, *11*(11), 1741–1751. https://doi.org/10.1093/scan/nsw094

Di Dio, C., Macaluso, E., & Rizzolatti, G. (2007). The golden beauty: brain response to classical and renaissance sculptures. *PloS one*, *2*(11), e1201. https://doi.org/10.1371/journal.pone.0001201

Di Dio, C., Canessa, N., Cappa, S. F., & Rizzolatti, G. (2011). Specificity of esthetic experience for artworks: an FMRI study. *Frontiers in human neuroscience*, *5*, 139. https://doi.org/10.3389/fnhum.2011.00139

Di Dio, C., Ardizzi, M., Massaro, D., Di Cesare, G., Gilli, G., Marchetti, A., & Gallese, V. (2016). Human, Nature, Dynamism: The Effects of Content and Movement Perception on Brain Activations during the Aesthetic Judgment of Representational Paintings. *Frontiers in human neuroscience*, *9*, 705. https://doi.org/10.3389/fnhum.2015.00705

Diers, K., Dörfel, D., Gärtner, A., Schönfeld, S., Walter, H., Strobel, A., & Brocke, B. (2021). Should we keep some distance from distancing? Regulatory and post-regulatory effects of emotion downregulation. *PloS one*, *16*(9), e0255800. https://doi.org/10.1371/journal.pone.0255800

Dolcos, F., Katsumi, Y., Shen, C., Bogdan, P. C., Jun, S., Larsen, R., Heller, W., Bost, K. F., & Dolcos, S. (2020). The Impact of Focused Attention on Emotional Experience: A Functional MRI Investigation. *Cognitive, affective & behavioral neuroscience*, *20*(5), 1011–1026. https://doi.org/10.3758/s13415-020-00816-2

Domes, G., Schulze, L., Böttger, M., Grossmann, A., Hauenstein, K., Wirtz, P. H., Heinrichs, M., & Herpertz, S. C. (2010). The neural correlates of sex differences in emotional reactivity and emotion regulation. *Human brain mapping*, *31*(5), 758–769. https://doi.org/10.1002/hbm.20903

Enzi, B., Amirie, S., & Brüne, M. (2016). Empathy for pain-related dorsolateral prefrontal activity is modulated by angry face perception. *Experimental brain research*, *234*(11), 3335–3345. https://doi.org/10.1007/s00221-016-4731-4

Erk, S., Abler, B., & Walter, H. (2006). Cognitive modulation of emotion anticipation. *The European journal of neuroscience*, *24*(4), 1227–1236. https://doi.org/10.1111/j.1460-9568.2006.04976.x

Favre, P., Kanske, P., Engen, H., & Singer, T. (2021). Decreased emotional reactivity after 3-month socio-affective but not attention- or meta-cognitive-based mental training: A randomized, controlled, longitudinal fMRI study. *NeuroImage*, *237*, 118132. https://doi.org/10.1016/j.neuroimage.2021.118132

Feng, C., Li, Z., Feng, X., Wang, L., Tian, T., & Luo, Y. J. (2016). Social hierarchy modulates neural responses of empathy for pain. *Social cognitive and affective neuroscience*, *11*(3), 485–495. https://doi.org/10.1093/scan/nsv135

Ferri, J., Schmidt, J., Hajcak, G., & Canli, T. (2013). Neural correlates of attentional deployment within unpleasant pictures. *NeuroImage*, *70*, 268–277. https://doi.org/10.1016/j.neuroimage.2012.12.030

Flaisch, T., Schupp, H. T., Renner, B., & Junghöfer, M. (2009). Neural systems of visual attention responding to emotional gestures. *NeuroImage*, *45*(4), 1339–1346. https://doi.org/10.1016/j.neuroimage.2008.12.073

Flexas, A., Rosselló, J., de Miguel, P., Nadal, M., & Munar, E. (2014). Cognitive control and unusual decisions about beauty: an fMRI study. *Frontiers in human neuroscience*, *8*, 520. https://doi.org/10.3389/fnhum.2014.00520

Gerdes, A. B., Wieser, M. J., Mühlberger, A., Weyers, P., Alpers, G. W., Plichta, M. M., Breuer, F., & Pauli, P. (2010). Brain Activations to Emotional Pictures are Differentially Associated with Valence and Arousal Ratings. *Frontiers in human neuroscience*, *4*, 175. https://doi.org/10.3389/fnhum.2010.00175

Gu, X., & Han, S. (2007). Attention and reality constraints on the neural processes of empathy for pain. *NeuroImage*, *36*(1), 256–267. https://doi.org/10.1016/j.neuroimage.2007.02.025

Gu, X., Liu, X., Guise, K. G., Naidich, T. P., Hof, P. R., & Fan, J. (2010). Functional dissociation of the frontoinsular and anterior cingulate cortices in empathy for pain. *The Journal of neuroscience : the official journal of the Society for Neuroscience*, *30*(10), 3739–3744. https://doi.org/10.1523/JNEUROSCI.4844-09.2010

Gu, X., Liu, X., Van Dam, N. T., Hof, P. R., & Fan, J. (2013). Cognition-emotion integration in the anterior insular cortex. *Cerebral cortex (New York, N.Y. : 1991)*, *23*(1), 20–27. https://doi.org/10.1093/cercor/bhr367

Han, X., He, K., Wu, B., Shi, Z., Liu, Y., Luo, S., Wei, K., Wu, X., & Han, S. (2017). Empathy for pain motivates actions without altruistic effects: evidence of motor dynamics and brain activity. *Social cognitive and affective neuroscience*, *12*(6), 893–901. https://doi.org/10.1093/scan/nsx016

Hartung, F., Jamrozik, A., Rosen, M. E., Aguirre, G., Sarwer, D. B., & Chatterjee, A. (2019). Behavioural and Neural Responses to Facial Disfigurement. *Scientific reports*, *9*(1), 8021. https://doi.org/10.1038/s41598-019-44408-8

Heller, A. S., Lapate, R. C., Mayer, K. E., & Davidson, R. J. (2014). The face of negative affect: trial-by-trial corrugator responses to negative pictures are positively associated with amygdala and negatively associated with ventromedial prefrontal cortex activity. *Journal of cognitive neuroscience*, *26*(9), 2102–2110. https://doi.org/10.1162/jocn_a_00622

Herwig, U., Kaffenberger, T., Baumgartner, T., & Jäncke, L. (2007). Neural correlates of a 'pessimistic' attitude when anticipating events of unknown emotional valence. *NeuroImage*, *34*(2), 848–858. https://doi.org/10.1016/j.neuroimage.2006.09.035

Ikeda, T., Matsuyoshi, D., Sawamoto, N., Fukuyama, H., & Osaka, N. (2015). Color harmony represented by activity in the medial orbitofrontal cortex and amygdala. *Frontiers in human neuroscience*, *9*, 382. https://doi.org/10.3389/fnhum.2015.00382

Iidaka, T., Omori, M., Murata, T., Kosaka, H., Yonekura, Y., Okada, T., & Sadato, N. (2001). Neural interaction of the amygdala with the prefrontal and temporal cortices in the

processing of facial expressions as revealed by fMRI. *Journal of cognitive neuroscience*, *13*(8), 1035–1047. https://doi.org/10.1162/089892901753294338

Iidaka, T., Okada, T., Murata, T., Omori, M., Kosaka, H., Sadato, N., & Yonekura, Y. (2002). Age-related differences in the medial temporal lobe responses to emotional faces as revealed by fMRI. *Hippocampus*, *12*(3), 352–362. https://doi.org/10.1002/hipo.1113

Ishizu, T., & Zeki, S. (2011). Toward a brain-based theory of beauty. *PloS one*, *6*(7), e21852. https://doi.org/10.1371/journal.pone.0021852

Ishizu, T., & Zeki, S. (2017). The experience of beauty derived from sorrow. *Human brain mapping*, *38*(8), 4185–4200. https://doi.org/10.1002/hbm.23657

Ito, T., Yokokawa, K., Yahata, N., Isato, A., Suhara, T., & Yamada, M. (2017). Neural basis of negativity bias in the perception of ambiguous facial expression. *Scientific reports*, *7*(1), 420. https://doi.org/10.1038/s41598-017-00502-3

Jackson, P. L., Meltzoff, A. N., & Decety, J. (2005). How do we perceive the pain of others? A window into the neural processes involved in empathy. *NeuroImage*, *24*(3), 771–779. https://doi.org/10.1016/j.neuroimage.2004.09.006

Jackson, P. L., Brunet, E., Meltzoff, A. N., & Decety, J. (2006). Empathy examined through the neural mechanisms involved in imagining how I feel versus how you feel pain. *Neuropsychologia*, *44*(5), 752–761. https://doi.org/10.1016/j.neuropsychologia.2005.07.015

Kark, S. M., & Kensinger, E. A. (2015). Effect of emotional valence on retrieval-related recapitulation of encoding activity in the ventral visual stream. *Neuropsychologia*, *78*, 221–230. https://doi.org/10.1016/j.neuropsychologia.2015.10.014

Kawabata, H., & Zeki, S. (2004). Neural correlates of beauty. *Journal of neurophysiology*, *91*(4), 1699–1705. https://doi.org/10.1152/jn.00696.2003

Kross, E., Egner, T., Ochsner, K., Hirsch, J., & Downey, G. (2007). Neural dynamics of rejection sensitivity. *Journal of cognitive neuroscience*, *19*(6), 945–956. https://doi.org/10.1162/jocn.2007.19.6.945

Koenigsberg, H. W., Fan, J., Ochsner, K. N., Liu, X., Guise, K., Pizzarello, S., Dorantes, C., Tecuta, L., Guerreri, S., Goodman, M., New, A., Flory, J., & Siever, L. J. (2010). Neural correlates of using distancing to regulate emotional responses to social situations. *Neuropsychologia*, *48*(6), 1813–1822. https://doi.org/10.1016/j.neuropsychologia.2010.03.002

Kolesar, T. A., Kornelsen, J., & Smith, S. D. (2017). Separating neural activity associated with emotion and implied motion: An fMRI study. *Emotion (Washington, D.C.)*, *17*(1), 131–140. https://doi.org/10.1037/emo0000209

Koppe, G., Heidel, A., Sammer, G., Bohus, M., Gallhofer, B., Kirsch, P., & Lis, S. (2015). Temporal unpredictability of a stimulus sequence and the processing of neutral and emotional stimuli. *NeuroImage*, *120*, 214–224. https://doi.org/10.1016/j.neuroimage.2015.06.081

Kornelsen, J., McIver, T. A., & Stroman, P. W. (2019). Unique brain regions involved in positive versus negative emotional modulation of pain. *Scandinavian journal of pain*, *19*(3), 583–596. https://doi.org/10.1515/sjpain-2018-0341

Kuniecki, M., Wołoszyn, K., Domagalik, A., & Pilarczyk, J. (2018). Disentangling brain activity related to the processing of emotional visual information and emotional arousal. *Brain structure & function*, *223*(4), 1589–1597. https://doi.org/10.1007/s00429-017-1576-y

Labek, K., Berger, S., Buchheim, A., Bosch, J., Spohrs, J., Dommes, L., Beschoner, P., Stingl, J. C., & Viviani, R. (2017). The iconography of mourning and its neural correlates: a functional neuroimaging study. *Social cognitive and affective neuroscience*, *12*(8), 1303–1313. https://doi.org/10.1093/scan/nsx058

Lamm, C., & Decety, J. (2008). Is the extrastriate body area (EBA) sensitive to the perception of pain in others?. *Cerebral cortex (New York, N.Y. : 1991)*, *18*(10), 2369–2373. https://doi.org/10.1093/cercor/bhn006

Leclerc, C. M., & Kensinger, E. A. (2008). Age-related differences in medial prefrontal activation in response to emotional images. *Cognitive, affective & behavioral neuroscience*, *8*(2), 153–164. https://doi.org/10.3758/cabn.8.2.153

Lee, G. P., Meador, K. J., Loring, D. W., Allison, J. D., Brown, W. S., Paul, L. K., Pillai, J. J., & Lavin, T. B. (2004). Neural substrates of emotion as revealed by functional magnetic resonance imaging. *Cognitive and behavioral neurology : official journal of the Society for Behavioral and Cognitive Neurology*, *17*(1), 9–17. https://doi.org/10.1097/00146965-200403000-00002

Lee, T. M., Lee, T. M., Raine, A., & Chan, C. C. (2010). Lying about the valence of affective pictures: an fMRI study. *PloS one*, *5*(8), e12291. https://doi.org/10.1371/journal.pone.0012291

Lemogne, C., Gorwood, P., Bergouignan, L., Pélissolo, A., Lehéricy, S., & Fossati, P. (2011). Negative affectivity, self-referential processing and the cortical midline structures. *Social cognitive and affective neuroscience*, *6*(4), 426–433. https://doi.org/10.1093/scan/nsq049

Loos, E., Egli, T., Coynel, D., Fastenrath, M., Freytag, V., Papassotiropoulos, A., de Quervain, D. J., & Milnik, A. (2019). Predicting emotional arousal and emotional memory performance from an identical brain network. *NeuroImage*, *189*, 459–467. https://doi.org/10.1016/j.neuroimage.2019.01.028

Mataix-Cols, D., An, S. K., Lawrence, N. S., Caseras, X., Speckens, A., Giampietro, V., Brammer, M. J., & Phillips, M. L. (2008). Individual differences in disgust sensitivity modulate neural responses to aversive/disgusting stimuli. *The European journal of neuroscience*, *27*(11), 3050–3058. https://doi.org/10.1111/j.1460-9568.2008.06311.x

Mériau, K., Wartenburger, I., Kazzer, P., Prehn, K., Villringer, A., van der Meer, E., & Heekeren, H. R. (2009). Insular activity during passive viewing of aversive stimuli reflects individual differences in state negative affect. *Brain and cognition*, *69*(1), 73–80. https://doi.org/10.1016/j.bandc.2008.05.006

Meseguer, V., Romero, M. J., Barrós-Loscertales, A., Belloch, V., Bosch-Morell, F., Romero, J., & Avila, C. (2007). Mapping the apetitive and aversive systems with emotional pictures using a block-design fMRI procedure. *Psicothema*, *19*(3), 483–488.

Moore, M., Shafer, A. T., Bakhtiari, R., Dolcos, F., & Singhal, A. (2019). Integration of spatio-temporal dynamics in emotion-cognition interactions: A simultaneous fMRI-ERP investigation using the emotional oddball task. *NeuroImage*, *202*, 116078. https://doi.org/10.1016/j.neuroimage.2019.116078

Morawetz, C., Kellermann, T., Kogler, L., Radke, S., Blechert, J., & Derntl, B. (2016). Intrinsic functional connectivity underlying successful emotion regulation of angry faces. *Social cognitive and affective neuroscience*, *11*(12), 1980–1991. https://doi.org/10.1093/scan/nsw107

Morrison, I., Tipper, S. P., Fenton-Adams, W. L., & Bach, P. (2013). "Feeling" others' painful actions: the sensorimotor integration of pain and action information. *Human brain mapping*, *34*(8), 1982–1998. https://doi.org/10.1002/hbm.22040

Nelson, B. D., Fitzgerald, D. A., Klumpp, H., Shankman, S. A., & Phan, K. L. (2015). Prefrontal engagement by cognitive reappraisal of negative faces. *Behavioural brain research*, *279*, 218–225. https://doi.org/10.1016/j.bbr.2014.11.034

Nielen, M. M., Heslenfeld, D. J., Heinen, K., Van Strien, J. W., Witter, M. P., Jonker, C., & Veltman, D. J. (2009). Distinct brain systems underlie the processing of valence and arousal of affective pictures. *Brain and cognition*, *71*(3), 387–396. https://doi.org/10.1016/j.bandc.2009.05.007

Nummenmaa, L., Hirvonen, J., Parkkola, R., & Hietanen, J. K. (2008). Is emotional contagion special? An fMRI study on neural systems for affective and cognitive empathy. *NeuroImage*, *43*(3), 571–580. https://doi.org/10.1016/j.neuroimage.2008.08.014

Ochsner, K. N., Ray, R. R., Hughes, B., McRae, K., Cooper, J. C., Weber, J., Gabrieli, J. D., & Gross, J. J. (2009). Bottom-up and top-down processes in emotion generation: common and distinct neural mechanisms. *Psychological science*, *20*(11), 1322–1331. https://doi.org/10.1111/j.1467-9280.2009.02459.x

Park, C. H., Lee, H. K., Kweon, Y. S., Lee, C. T., Kim, K. T., Kim, Y. J., & Lee, K. U. (2016). Emotion-Induced Topological Changes in Functional Brain Networks. *Brain topography*, *29*(1), 108–117. https://doi.org/10.1007/s10548-015-0449-z

Park, H. R. P., Kostandyan, M., Boehler, C. N., & Krebs, R. M. (2019). Winning smiles: Signalling reward by overlapping and non-overlapping emotional valence differentially affects performance and neural activity. *Neuropsychologia*, *122*, 28–37. https://doi.org/10.1016/j.neuropsychologia.2018.11.018

Pedale, T., Macaluso, E., & Santangelo, V. (2019). Enhanced insular/prefrontal connectivity when resisting from emotional distraction during visual search. *Brain structure & function*, *224*(6), 2009–2026. https://doi.org/10.1007/s00429-019-01873-1

Preckel, K., Trautwein, F. M., Paulus, F. M., Kirsch, P., Krach, S., Singer, T., & Kanske, P. (2019). Neural mechanisms of affective matching across faces and scenes. *Scientific reports*, *9*(1), 1492. https://doi.org/10.1038/s41598-018-37163-9

Preis, M. A., Kröner-Herwig, B., Schmidt-Samoa, C., Dechent, P., & Barke, A. (2015). Neural Correlates of Empathy with Pain Show Habituation Effects. An fMRI Study. *PloS one*, *10*(8), e0137056. https://doi.org/10.1371/journal.pone.0137056

Radua, J., Sarró, S., Vigo, T., Alonso-Lana, S., Bonnín, C. M., Ortiz-Gil, J., Canales-Rodríguez, E. J., Maristany, T., Vieta, E., Mckenna, P. J., Salvador, R., & Pomarol-Clotet, E. (2014). Common and specific brain responses to scenic emotional stimuli. *Brain structure & function*, *219*(4), 1463–1472. https://doi.org/10.1007/s00429-013-0580-0

Reisch, L. M., Wegrzyn, M., Woermann, F. G., Bien, C. G., & Kissler, J. (2020). Negative content enhances stimulus-specific cerebral activity during free viewing of pictures, faces, and words. *Human brain mapping*, *41*(15), 4332–4354. https://doi.org/10.1002/hbm.25128

Ren, J., Ding, R., Li, S., Zhang, M., Wei, D., Feng, C., Xu, P., & Luo, W. (2022). Features and Extra-Striate Body Area Representations of Diagnostic Body Parts in Anger and Fear Perception. *Brain sciences*, *12*(4), 466. https://doi.org/10.3390/brainsci12040466

Ruckmann, J., Bodden, M., Jansen, A., Kircher, T., Dodel, R., & Rief, W. (2015). How pain empathy depends on ingroup/outgroup decisions: A functional magnet resonance imaging study. *Psychiatry research*, *234*(1), 57–65. https://doi.org/10.1016/j.pscychresns.2015.08.006

Rymarczyk, K., Żurawski, Ł., Jankowiak-Siuda, K., & Szatkowska, I. (2019). Empathy in Facial Mimicry of Fear and Disgust: Simultaneous EMG-fMRI Recordings During Observation of Static and Dynamic Facial Expressions. *Frontiers in psychology*, *10*, 701. https://doi.org/10.3389/fpsyg.2019.00701

Sakaki, M., Niki, K., & Mather, M. (2011). Updating existing emotional memories involves the frontopolar/orbito-frontal cortex in ways that acquiring new emotional memories does not. *Journal of cognitive neuroscience*, *23*(11), 3498–3514. https://doi.org/10.1162/jocn_a_00057

Schmitz, T. W., De Rosa, E., & Anderson, A. K. (2009). Opposing influences of affective state valence on visual cortical encoding. *The Journal of neuroscience : the official journal of the Society for Neuroscience*, *29*(22), 7199–7207. https://doi.org/10.1523/JNEUROSCI.5387-08.2009

Schürmann, M., Hlushchuk, Y., & Hari, R. (2011). Embodied visual perception of distorted finger postures. *Human brain mapping*, *32*(4), 612–623. https://doi.org/10.1002/hbm.21049

Seara-Cardoso, A., Sebastian, C. L., Viding, E., & Roiser, J. P. (2016). Affective resonance in response to others' emotional faces varies with affective ratings and psychopathic traits in amygdala and anterior insula. *Social neuroscience*, *11*(2), 140–152. https://doi.org/10.1080/17470919.2015.1044672

Silvers, J. A., Wager, T. D., Weber, J., & Ochsner, K. N. (2015). The neural bases of uninstructed negative emotion modulation. *Social cognitive and affective neuroscience*, *10*(1), 10–18. https://doi.org/10.1093/scan/nsu016

Smith, A. P., Henson, R. N., Dolan, R. J., & Rugg, M. D. (2004). fMRI correlates of the episodic retrieval of emotional contexts. *NeuroImage*, *22*(2), 868–878. https://doi.org/10.1016/j.neuroimage.2004.01.049

Sokołowski, A., Morawetz, C., Folkierska-Żukowska, M., & Łukasz Dragan, W. (2022). Brain activation during cognitive reappraisal depending on regulation goals and stimulus valence. *Social cognitive and affective neuroscience*, *17*(6), 559–570. https://doi.org/10.1093/scan/nsab117

Sterpenich, V., Schwartz, S., Maquet, P., & Desseilles, M. (2014). Ability to maintain internal arousal and motivation modulates brain responses to emotions. *PloS one*, *9*(12), e112999. https://doi.org/10.1371/journal.pone.0112999

Takahashi, H. K., Kitada, R., Sasaki, A. T., Kawamichi, H., Okazaki, S., Kochiyama, T., & Sadato, N. (2015). Brain networks of affective mentalizing revealed by the tear effect: The integrative role of the medial prefrontal cortex and precuneus. *Neuroscience research*, *101*, 32–43. https://doi.org/10.1016/j.neures.2015.07.005

Thakral, P. P., Moo, L. R., & Slotnick, S. D. (2012). A neural mechanism for aesthetic experience. *Neuroreport*, *23*(5), 310–313. https://doi.org/10.1097/WNR.0b013e328351759f

Thomas, M., Gaudeau-Bosma, C., Bouaziz, N., Schenin-King Andrianisaina, P., Benadhira, R., Januel, D., & Moulier, V. (2019). Gender-Related Brain Activations during an Emotional Task: An fMRI Study. *Neuropsychobiology*, *78*(3), 128–135. https://doi.org/10.1159/000499977

Uchida, M., Biederman, J., Gabrieli, J. D., Micco, J., de Los Angeles, C., Brown, A., Kenworthy, T., Kagan, E., & Whitfield-Gabrieli, S. (2015). Emotion regulation ability varies in relation to intrinsic functional brain architecture. *Social cognitive and affective neuroscience*, *10*(12), 1738–1748. https://doi.org/10.1093/scan/nsv059

van der Heiden, L., Scherpiet, S., Konicar, L., Birbaumer, N., & Veit, R. (2013). Inter-individual differences in successful perspective taking during pain perception mediates emotional responsiveness in self and others: an fMRI study. *NeuroImage*, *65*, 387–394. https://doi.org/10.1016/j.neuroimage.2012.10.003

Van Dillen, L. F., Heslenfeld, D. J., & Koole, S. L. (2009). Tuning down the emotional brain: an fMRI study of the effects of cognitive load on the processing of affective images. *NeuroImage*, *45*(4), 1212–1219. https://doi.org/10.1016/j.neuroimage.2009.01.016

Vartanian, O., & Goel, V. (2004). Neuroanatomical correlates of aesthetic preference for paintings. *Neuroreport*, *15*(5), 893–897. https://doi.org/10.1097/00001756-200404090-00032

Vartanian, O., Navarrete, G., Chatterjee, A., Fich, L. B., Gonzalez-Mora, J. L., Leder, H., Modroño, C., Nadal, M., Rostrup, N., & Skov, M. (2015). Architectural design and the brain:

Effects of ceiling height and perceived enclosure on beauty judgments and approach-avoidance decisions. *Journal of Environmental Psychology*, *41*, 10–18. https://doi.org/10.1016/j.jenvp.2014.11.006

Vermeylen, L., Wisniewski, D., González-García, C., Hoofs, V., Notebaert, W., & Braem, S. (2020). Shared Neural Representations of Cognitive Conflict and Negative Affect in the Medial Frontal Cortex. *The Journal of neuroscience : the official journal of the Society for Neuroscience*, *40*(45), 8715–8725. https://doi.org/10.1523/JNEUROSCI.1744-20.2020

Vessel, E. A., Starr, G. G., & Rubin, N. (2012). The brain on art: intense aesthetic experience activates the default mode network. *Frontiers in human neuroscience*, *6*, 66. https://doi.org/10.3389/fnhum.2012.00066

Villalta-Gil, V., Hinton, K. E., Landman, B. A., Yvernault, B. C., Perkins, S. F., Katsantonis, A. S., Sellani, C. L., Lahey, B. B., & Zald, D. H. (2017). Convergent individual differences in visual cortices, but not the amygdala across standard amygdalar fMRI probe tasks. *NeuroImage*, *146*, 312–319. https://doi.org/10.1016/j.neuroimage.2016.11.038

Vistoli, D., Achim, A. M., Lavoie, M. A., & Jackson, P. L. (2016). Changes in visual perspective influence brain activity patterns during cognitive perspective-taking of other people's pain. *Neuropsychologia*, *85*, 327–336. https://doi.org/10.1016/j.neuropsychologia.2016.03.020

Waugh, C. E., Lemus, M. G., & Gotlib, I. H. (2014). The role of the medial frontal cortex in the maintenance of emotional states. *Social cognitive and affective neuroscience*, *9*(12), 2001–2009. https://doi.org/10.1093/scan/nsu011

Waugh, C. E., Zarolia, P., Mauss, I. B., Lumian, D. S., Ford, B. Q., Davis, T. S., Ciesielski, B. G., Sams, K. V., & McRae, K. (2016). Emotion regulation changes the duration of the BOLD response to emotional stimuli. *Social cognitive and affective neuroscience*, *11*(10), 1550–1559. https://doi.org/10.1093/scan/nsw067

Weierich, M. R., Wright, C. I., Negreira, A., Dickerson, B. C., & Barrett, L. F. (2010). Novelty as a dimension in the affective brain. *NeuroImage*, *49*(3), 2871–2878. https://doi.org/10.1016/j.neuroimage.2009.09.047

White, S. F., Adalio, C., Nolan, Z. T., Yang, J., Martin, A., & Blair, J. R. (2014). The amygdala's response to face and emotional information and potential category-specific modulation of temporal cortex as a function of emotion. *Frontiers in human neuroscience*, *8*, 714. https://doi.org/10.3389/fnhum.2014.00714

Willinger, D., Karipidis, I. I., Beltrani, S., Di Pietro, S. V., Sladky, R., Walitza, S., Stämpfli, P., & Brem, S. (2019). Valence-Dependent Coupling of Prefrontal-Amygdala Effective Connectivity during Facial Affect Processing. *eNeuro*, *6*(4), ENEURO.0079-19.2019. https://doi.org/10.1523/ENEURO.0079-19.2019

Wittfoth, D., Pfeiffer, A., Bohne, M., Lanfermann, H., & Wittfoth, M. (2020). Emotion regulation through bifocal processing of fear inducing and disgust inducing stimuli. *BMC neuroscience*, *21*(1), 47. https://doi.org/10.1186/s12868-020-00597-x

Wrase, J., Klein, S., Gruesser, S. M., Hermann, D., Flor, H., Mann, K., Braus, D. F., & Heinz, A. (2003). Gender differences in the processing of standardized emotional visual stimuli in humans: a functional magnetic resonance imaging study. *Neuroscience letters*, *348*(1), 41–45. https://doi.org/10.1016/s0304-3940(03)00565-2

Yoon, H., Kim, S. A., & Kim, S. H. (2015). Facial expression primes and implicit regulation of negative emotion. *Neuroreport*, *26*(9), 548–553. https://doi.org/10.1097/WNR.0000000000000383

Zhang, W., Li, H., & Pan, X. (2015). Positive and negative affective processing exhibit dissociable functional hubs during the viewing of affective pictures. *Human brain mapping*, *36*(2), 415–426. https://doi.org/10.1002/hbm.22636

Zhang, W., Lai, S., He, X., Zhao, X., & Lai, S. (2016). Neural correlates for aesthetic appraisal of pictograph and its referent: An fMRI study. *Behavioural brain research*, *305*, 229–238. https://doi.org/10.1016/j.bbr.2016.02.029

Zhang, W., He, X., Lai, S., Wan, J., Lai, S., Zhao, X., & Li, D. (2017). Neural substrates of embodied natural beauty and social endowed beauty: An fMRI study. *Scientific reports*, *7*(1), 7125. https://doi.org/10.1038/s41598-017-07608-8

Artwork Sets Compiled from Vienna Art Picture System for ctDCS

PAINTING SET A

Artist Name	*Date*	*Title*
A.R. Penck	1982	Ohne Titel
Anquetin, Louis	1887	Five O'Clock in the Evening
Beckmann, Max	1910	The Prisoners
Beckmann, Max	1918-19	The Night
Boucher, Fran‡ois	1739	The Luncheon
Brugghen ter, Hendrick	1625	Saint Sebastian Tended by Irene
Brugghen ter, Hendrick	1623	David Praised by the Israelite Women
Caillebotte, Gustave	1877	A Paris Street, Rain
Comerre, L,on Fran‡ois	1900-15	The Deluge
Cornelius von, Peter	1816-17	Joseph Interpreting Pharaoh's Dream
Correggio da, Antonio	1530	Holy Night (Adoration of the Shepherds)
Cranach the ELder, Lukas	1510	The Martyrdom of Saint Barbara
Cross, Henri Edmond	N/A	Flight of the Nymphs
Denis, Maurice	1889	Ascent to Calvary
Dix, Otto	1933	The Seven Deadly Sins
Dix, Otto	1920	Skat Players
El Greco	1604-14	Laokoon
Ensor, James	1889	Astonishment of the Mask Wouse
Ensor, James	1883	The Rower
Ernst, Max	1941	The Anti-Pope
Fuchs, Ernst	1978-80	Triumph des Einhorns
F�ssli, Johann Heinrich	1796	The Night-Hag Visiting Lapland Witches
Gauguin, Paul	1886	Do Not Work
Goya de, Francisco Jos,	1814	The Third of May, 1808
Goya de, Francisco Jos,	N/A	Exorcism
Ingres, Jean-Auguste-Dominique	1806	Bathing Woman (Baigneuse de Valpincon)
Ingres, Jean-Auguste-Dominique	1827	Homer's Apotheosis
Ingres, Jean-Auguste-Dominique	1814	The Grand Odalisque
Kandinsky, Wassily	1909	Group in Crinolines
Kirchner, Ernst Ludwig	1915	Artillerymen
Lassnig, Maria	2005	Hospital
Lassnig, Maria	2004	Three Ways of Being
Liebermann, Max	1910	On the Shores of the Alster, Hamburg
Manet, �douard	1870s	The Suicide
Manet, �douard	1874	Argenteuil
Masson, Andr,	1942	There Is No Finished World
Morgner, Wilhelm	1912	Entry of Christ into Jerusalem
Munch, Edvard	1913-14	Weeping Nude
Munch, Edvard	1894	Ashes

M&#65533;nter, Gabriele	1908	Jawlensky and Werefkin
Picasso, Pablo	1935	Interior with a Girl Drawing
Renoir, Pierre-Auguste	1876	Dance at the Moulin de la Galette
Repin, Ilja Jefimowitsch	1880-91	Reply of the Zaporozhian Cossacks
Ribera de, Jusepe	1637	Apollo and Marsyas
Ribera de, Jusepe	1639	Dream of Jacob
Rivera, Diego	1931	Repression
Rousseau, Henri	1998	War
Rousseau, Henri	1897	The Sleeping Gypsy
Rousseau, Henri	1910	The Dream
Rubens, Peter Paul	1609	Bower
Sarto del, Andrea	1529	Sacrifice of Isaac
Sedlacek, Franz	1938	Evening Song
Slevogt, Max	1914	The Pirates
Slevogt, Max	1904	The Dancer Marietta di Rigardo
Sloan, John	1912	Sunday, Women Drying Their Hair
Tizian	1515	Sacred and Profane Love
Tooker, George	1950	Subway
Vallotton, F‚lix	1899	The Visit
Vel zquez, Diego	1630	Apollo in the Forge of Vulcan
Vermeer, Jan	1665-66	The Painter and his Model as Klio

PAINTING SET B

Artist Name	*Date*	*Title*
A.R. Penck	1981	Ohne Titel (mit Reinhard Stangl)
Altdorfer, Albrecht	1509-16	Saint Sebastian Altar- Christ before Pilate
Bacon, Francis	1976	Figure Writing, Reflected in Mirror
Baldung, Hans Grien	1509-10	The Three Ages of Man and Death
Baselitz, Georg	1962	Acker
Beckmann, Max	1909	Scene from the Destruction of Messina
Boucher, Fran‡ois	1748	The Bird Catchers
Brueghel the Elder, Jan	1600	Aeneas and the Sibyl in Hades
C‚zanne, Paul	1890	Bathers
Caillebotte, Gustave	1876	The Europe Bridge (Le Pont de l'Europe)
Caravaggio, Michelangelo Merisi	1601-02	David and Goliath
Carracci, Ludovico	1582	The Lamentation
Cassatt, Mary Stevenson	1893	The Child`s Bath
Correggio da, Antonio	1532	Leda and the Swan
Degas, Edgar	1872	Ballet Studio at the Opera in Rue Le Peletier
Denis, Maurice	1893	The Muses
Denis, Maurice	1892	Ladder in the foliage
Dix, Otto	1943	Die Operation

Ensor, James	1890	The Intrigue
Fischl, Eric	06.júl	Scenes from Late Paradise: The Parade
Freud, Lucian	1997	Sunny Morning Eight Legs
Fuchs, Ernst	1983	Der Tanz mit dem Tod
Gauguin, Paul	1896	Nave Nave Nahana (Delicious Day)
Gericault, Th,odore	1819	The Raft of the Medusa
Goncharova, Natalia	1927	Death of Jean-Paul Marat
Goya de, Francisco Jos,	1797-98	Witches' Sabbath
Honthorst van, Gerrit	1655	Susanna and the Elders
Hopper, Edward	1930	Tables for Ladies
Janmot, Louis	1854	Nightmare
Kahlo, Frida	1939	The Suicide of Dorothy Hale
Lothe, Andr,	1917	Rugby (Les Jouers de Rugby)
Luce, Maximilien Jules	03.jún	A Street in Paris in May 1871
Luks, George Benjamin	1905	The Wrestlers
Macke, August	1912	Zoological Garden I
Magritte, Ren,	1927	The Menaced Assassin
Manet, &#65533;douard	1879	At PŠre Lathuille's
Manet, &#65533;douard	1863	Luncheon on the Grass
Manguin, Henri	1905	The Prints
Masson, Andr,	1937	Tauromachie
Matisse, Henri	05.jún	Interior with a Young Girl (Girl Reading)
Millet, Jean-Fran‡ois	1858-59	Death and the Woodcutter
Moreau, Gustav	1874	The Apparition
Pissarro, Camille	1888	Apple Picking at Eragny-sur-Epte
Renoir, Pierre-Auguste	1880-81	Luncheon of the Boating Party
Repin, Ilja Jefimowitsch	1870-73	Volga Boatman
Ribera de, Jusepe	1639	Martyrdom of Saint Philip
Rivera, Diego	1914	Two Women
Rothko, Mark	1933-34	Bathers of Beach Scenes
Rubens, Peter Paul	1615-21	Wolf and Fox Hunt
Schiele, Egon	1915	Death and the Maiden
Schwind von, Moritz Ludwig	1844	Sabina von Steinbach
Seurat, Georges-Pierre	1884	Bathers at AsniŠres
Seurat, Georges-Pierre	1890	Chorus in a Night Club
Severini, Gino	1912-13	Dancer at Pigalle's
Sloan, John	1915	Sun and Wind on the Roof
Tizian	1538	Venus of Urbino
Vermeer, Jan	1661-62	The Glass of Wine
Watteau, Jean-Antoine	1717	The Embarkment to Cythera
Wright of Derby, Joseph	1770	Academy by Lamplight
Wright of Derby, Joseph	1765	At the light of a candle, three men study a small replica of the Borghese gladiator

Linear Mixed Model Selection across Dependent Variables and Stimulation Montages

Cathodal ctDCS Model Selection:

Change in Feeling Moved:

Model fit comparisons indicated that Model 1 was the most parsimonious and best fitting model outside and across individual differences, encompassing Perspective Taking, Empathic Concern, Cognitive Empathy, and Art Experience (Table XX). Model 1 showed lower AIC values (AIC = 589 - 599) compared to Model 2 (AIC= 599 - 605), while the BIC, a more conservative fit criterion, showed similar or slightly higher values for Model 1 (BIC= 610 - 630) compared to Model 2 (BIC= 610 - 630). The likelihood ratio test (LRT) demonstrated that including tDCS stimulation as a random slope significantly improved the fit of the data ($\chi 2$ (1)= 7.742 - 9.456, p= 0.009 - 0.021). In addition to the variance explained by the random effects (please see tables XX and XX), the Intra-class Correlation Coefficient (ICC) showed that a substantial proportion of the total variance was attributed to differences between participants (ICC=.519 - .534), indicating that nesting the data within participants promotes the appropriate comparison between participants. Therefore, Model 1 was selected as the best fitting model oustide and across individual differences.

Table s3. Model comparisons and model-fits of Cathodal ctDCS in Change in Feeling Moved.

Model	**R^2**	**LRT χ^2**			**AIC**	**BIC**	**loglik**
Individual Difference		Value	df	*p*			
N/A							
Model 1	0.616	26.566	6	<.001	589	610	-287
Marginal	0.022	5.188	3	0.159			
Model 2	0.376	16.908	4	0.002	595	610	-291
Marginal	0.022	3.364	3	0.339			
Δ Model 1 > Model 2	0.240	9.256	2	0.010	-5.256	-1.27	4.628

Perspective Taking							
Model 1	0.634	31.854	10	<.001	595	626	-285
Marginal	0.059	10.477	7	0.163			
Model 2	0.427	23.409	8	0.003	599	624	-289
Marginal	0.059	9.865	7	0.196			
Δ Model 1 > Model 2	0.207	7.742	2	0.021	-3.742	1.387	3.871
Empathic Concern							
Model 1	0.638	30.881	10	<.001	597	628	-287
Marginal	0.052	9.503	7	0.219			
Model 2	0.399	20.565	8	0.008	603	628	-291
Marginal	0.052	7.021	7	0.427			
Δ Model 1 > Model 2	0.239	9.456	2	0.009	-5.456	-0.327	4.728
General Empathy							
Model 1	0.637	31.784	10	<.001	594	625	-285
Marginal	0.059	10.406	7	0.167			
Model 2	0.417	22.504	8	0.004	599	625	-289
Marginal	0.059	8.960	7	0.256			
Δ Model 1 > Model 2	0.220	8.507	2	0.014	-4.507	0.622	4.253
Art Experience							
Model 1	0.638	30.398	10	<.001	599	630	-288
Marginal	0.043	9.021	7	0.251			
Model 2	0.399	20.084	8	0.010	605	630	-292
Marginal	0.043	6.539	7	0.478			
Δ Model 1 > Model 2	0.238	9.455	2	0.009	-5.455	-0.326	4.728

Note. Model 1 = MeanMoveChange ~ 1 + Stimulation + Valence + Individual Difference + Stimulation:Valence + Stimulation:Indivudal Difference + Stimulation:Valence:Individual Difference (1+ Stimulation | Participant; Model 2 = MeanMoveChange ~ 1 + Stimulation + Valence + Individual Difference + Stimulation:Valence + Stimulation:Indivudal Difference + Stimulation:Valence:Individual Difference (Intercept | Participant); Marginal = respective models without variance explained by random effects; AIC, BIC and loglik differences are the model of each Individual Difference; AIC for Akaike information criterium; BIC for Baysian information criterium; LRT = Likelihood ratio test statistic; loglik = loglikelihood estimate; R^2 = percent of variance explained; * indicates $p < .05$; ** indicates $p < 0.01$; *** indicates $p < .001$.

Table s4: Random Components and Intraclass Correlation Coefficients Across Individual Differences for Cathodal ctDCS in Change of Feeling Moved.

Individual Differences	Random Component	Variance	SD	ICC
N/A	Participant (Intercept)	14.2	3.76	0.519
	Stimulation	24.6	4.96	
	Residual	13.1	3.62	
Perspective Taking	Participant (Intercept)	14.8	3.85	0.535
	Stimulation	25.5	5.05	
	Residual	12.9	3.59	
Empathic Concern	Participant (Intercept)	14.5	3.81	0.530
	Stimulation	25.5	5.05	
	Residual	12.9	3.59	
General Empathy	Participant (Intercept)	14.7	3.83	0.532
	Stimulation	23.5	4.85	
	Residual	12.9	3.59	
Art Experience	Participant (Intercept)	14.8	3.85	0.535
	Stimulation	25.5	5.05	
	Residual	12.9	3.59	

Note: Random components and intraclass correlation coefficients (ICC) for individual differences of interest. Variance and standard deviation (SD) values are shown for the participant as a random intercept, stimulation as a random slope, and residuals. ICC represents the proportion of total variance explained by the participant-level random effects.

Change in Response Time of Feeling Moved:

Model fit comparisons indicated that Model 1 was the most parsimonious and best fitting model outside and across individual differences, encompassing Perspective Taking, Empathic Concern, Cognitive Empathy, and Art Experience (Table XX). Model 1 showed lower AIC values (AIC = 1491 - 1529) compared to Model 2 (AIC= 1526 - 1573), while the BIC, a more conservative fit criterion, showed lower values for Model 1 (BIC= 1522 - 1549) compared to Model 2 (BIC= 1551 - 1589). The likelihood ratio test (LRT) demonstrated that including

tDCS stimulation as a random slope significantly improved the fit of the data ($\chi 2$ (1)= 38.806 - 50.543, $p < .001$). In addition to the variance explained by the random effects (please see tables XX and XX), the Intra-class Correlation Coefficient (ICC) showed that a substantial proportion of the total variance was attributed to differences between participants (ICC=.600 - .611), indicating that nesting the data within participants promotes the appropriate comparison between participants. Therefore, Model 1 was selected as the best fitting model outside and across individual differences.

Table s5. Model comparisons and model-fits of Cathodal ctDCS in Change of Response Time in Feeling Moved.

Model	R^2	LRT χ^2			AIC	BIC	loglik
Individual Difference		Value	df	*p*			
N/A							
Model 1	0.788	54.353	6	<.001	1529	1549	-756
Marginal	0.004	2.071	3	0.558			
Model 2	0.174	3.999	4	0.406	1573	1589	-781
Marginal	0.004	0.554	3	0.907			
Δ Model 1 > Model 2	0.613	48.256	2	<.001	-44.456	-39.127	24.128
Perspective Taking							
Model 1	0.796	62.456	10	<.001	1491	1522	-733
Marginal	0.132	10.175	7	0.179			
Model 2	0.319	20.122	8	0.010	1526	1551	-753
Marginal	0.132	16.678	7	0.020			
Δ Model 1 > Model 2	0.477	38.806	2	<.001	-34.806	-29.677	19.403
Empathic Concern							
Model 1	0.810	62.503	10	<.001	1492	1523	-734
Marginal	0.043	10.221	7	0.176			
Model 2	0.187	7.3647.	8	0.498	1539	1565	-759
Marginal	0.043	3.920	7	0.789			
Δ Model 1 > Model 2	0.623	50.543	2	<.001	-46.543	-41.415	25.272
General Empathy							

Model 1	0.807	62.020	10	<.001	1491	1522	-733
Marginal	0.076	9.739	7	0.204			
Model 2	0.225	11.377	8	0.181	1533	1559	-757
Marginal	0.076	7.932	7	0.339			
Δ Model 1 > Model 2	0.582	46.423	2	0.001	-42.423	-37.294	23.212
Art Experience							
Model 1	0.788	55.247	10	<.001	1501	1531	-738
Marginal	0.184	2.966	7	0.888			
Model 2	0.184	4.950	8	0.763	1543	1568	-761
Marginal	0.012	1.506	7	0.982			
Δ Model 1 > Model 2	0.604	46.106	2	<.001	-42.106	-36.977	23.053

Note: Model 1 = MeanMoveRTChange ~ 1 + Stimulation + Valence + Individual Difference + Stimulation:Valence + Stimulation:Indivudal Difference + Stimulation:Valence:Individual Difference (1+ Stimulation | Participant; Model 2 = MeanMoveChange ~ 1 + Stimulation + Valence + Individual Difference + Stimulation:Valence + Stimulation:Indivudal Difference + Stimulation:Valence:Individual Difference (Intercept | Participant); Marginal = respective models without variance explained by random effects; AIC, BIC and loglik differences are the model of each Individual Difference; AIC for Akaike information criterium; BIC for Baysian information criterium; LRT = Likelihood ratio test statistic; loglik = loglikelihood estimate; R^2 = percent of variance explained.

Table s6: Random Components and Intraclass Correlation Coefficients Across Individual Differences for Cathodal ctDCS in Change of Response Time in Feeling Moved.

Individual Differences	Random Component	Variance	SD	ICC
N/A	Participant (Intercept)	401452	634	0.603
	Stimulation	2.29e+6	1513	
	Residual	264432	514	
Perspective Taking	Participant (Intercept)	394520	628	0.600
	Stimulation	1.84e+6	1357	
	Residual	263078	513	
Empathic Concern	Participant (Intercept)	388381	623	0.611
	Stimulation	2.42e+6	1557	
	Residual	246879	497	

Individual Differences	Random Component	Variance	SD	ICC
General Empathy	Participant (Intercept)	381060	617	0.605
	Stimulation	2.26e+6	1504	
	Residual	249199	499	
Art Experience	Participant (Intercept)	420367	648	0.604
	Stimulation	2.36e+6	1536	
	Residual	275121	525	

Note. Random components and intraclass correlation coefficients (ICC) for individual differences of interest. Variance and standard deviation (SD) values are shown for the participant as a random intercept, stimulation as a random slope, and residuals. ICC represents the proportion of total variance explained by the participant-level random effects.

Anodal ctDCS:

Change in Feeling Moved:

Model fit comparisons indicated that Model 1 was the generally the most parsimonious and best fitting model outside and across individual differences. Outside individual differences and across Perspective Taking, Empathic Concern, and Cognitive Empathy (Table XX), Model 1 showed lower AIC values (AIC = 617 - 621) compared to Model 2 (AIC= 614 - 622), while the BIC, a more conservative fit criterion, showed similar or slightly higher values for Model 1 (BIC= 637 - 652) compared to Model 2 (BIC= 634 - 648). For Empathic Concern and Cognitive Empathy, the likelihood ratio test (LRT) demonstrated that including Stimulation as a random slope significantly improved the fit of the data ($\chi 2$ (1)= 6.394 – 7.562, p= 0.023 - 0.041), while this trended near significance outside individual differences ($\chi 2$ (1)= 5.409, p= 0.067) and for Perspective Taking ($\chi 2$ (1)= 5.433, p= 0.066). For Art Experience, Model 1 revealed a slightly higher AIC (AIC = 619) and moderately higher BIC (BIC 650) value than Model 2 (AIC = 618; BIC = 644), and the LRT indicated a non-significant improvement of fit by including Stimulation as a random slope ($\chi 2$ (1)= 3.226, p= 0.199). Considerable variance was explained by the random effects across all models (please

see tables XX and XX), and the Intra-class Correlation Coefficient (ICC) showed that a substantial proportion of the total variance was attributed to differences between participants (ICC=.292-.334), indicating that nesting the data within participants promotes the appropriate comparison between participants. Therefore, Model 1 was selected as the best fitting model across individual differences of trait empathy while Model 2 was determined to best fit the data for Art Experience.

Table s7. Model comparisons and model-fits of Anodal ctDCS in Change of Feeling Moved.

Model	R^2	LRT χ^2			AIC	BIC	loglik
Individual Difference		Value	df	*p*			
N/A							
Model 1	0.439	14.445	6	0.025	617	637	-300
Marginal	0.056	8.941	3	0.030			
Model 2	0.205	8.801	4	0.066	618	634	-303
Marginal	0.056	6.704	3	0.082			
Δ Model 1 > Model 2	0.234	5.409	2	0.067	-1.409	3.720	2.705
Perspective Taking							
Model 1	0.478	19.777	10	0.031	621	652	-298
Marginal	0.093	14.272	7	0.047			
Model 2	0.252	13.850	8	0.086	622	648	-301
Marginal	0.093	11.753	7	0.109			
Δ Model 1 > Model 2	0.226	5.433	2	0.066	-1.433	3.696	2.717
Empathic Concern							
Model 1	0.559	30.592	10	<.001	612	643	-294
Marginal	0.159	25.087	7	<.001			
Model 2	0.322	22.342	8	0.004	616	641	-298
Marginal	0159	20.245	7	0.005			
Δ Model 1 > Model 2	0.237	7.562	2	0.023	-3.562	-1.566	3.781
General Empathy							
Model 1	0.533	26.467	10	0.003	614	645	-295
Marginal	0.132	20.962	7	0.004			
Model 2	0.307	19.492	8	0.012	617	642	-298

Marginal	0.132	17.395	7	0015			
Δ Model 1 > Model 2	0.225	6.394	2	0.041	-2.394	2.735	3.197
Art Experience							
Model 1	0.466	23.666	10	0.009	619	650	-297
Marginal	0.138	18.161	7	0.011			
Model 2	0.312	20.147	8	0.010	618	644	-299
Marginal	0.138	18.050	7	0.012			
Δ Model 1 > Model 2	0.238	3.226	2	0.199	0.774	5.903	1.613

Note: Model 1 = MeanMoveChange ~ 1 + Stimulation + Valence + Individual Difference + Stimulation:Valence + Stimulation:Indivudal Difference + Stimulation:Valence:Individual Difference (1+ Stimulation | Participant; Model 2 = MeanMoveChange ~ 1 + Stimulation + Valence + Individual Difference + Stimulation:Valence + Stimulation:Indivudal Difference + Stimulation:Valence:Individual Difference (Intercept | Participant); Marginal = respective models without variance explained by random effects; AIC, BIC and loglik differences are the model of each Individual Difference; AIC for Akaike information criterium; BIC for Baysian information criterium; LRT = Likelihood ratio test statistic; loglik = loglikelihood estimate; R^2 = percent of variance explained.

Table s8: Random Components and Intraclass Correlation Coefficients Across Individual Differences for Anodal ctDCS in Change of Feeling Moved.

Individual Differences	Random Component	Variance	SD	ICC
N/A	Participant (Intercept)	8.42	2.90	0.270
	Stimulation	28.41	5.33	
	Residual	2.74	4.77	
Perspective Taking	Participant (Intercept)	9.08	3.01	0.292
	Stimulation	28.56	5.34	
	Residual	21.99	4.69	
Empathic Concern	Participant (Intercept)	9.29	3.05	0.334
	Stimulation	29.80	5.46	
	Residual	18.50	4.30	
General Empathy	Participant (Intercept)	9.71	3.12	0.331
	Stimulation	28.41	5.33	
	Residual	19.64	4.43	
Art Experience	Participant (Intercept)	8.94	2.99	0.285
	Stimulation	19.36	4.40	
	Residual	22.43	4.74	

Note: Random components and intraclass correlation coefficients (ICC) for individual differences of interest. Variance and standard deviation (SD) values are shown for the participant as a random intercept, stimulation as a random slope, and residuals. ICC represents the proportion of total variance explained by the participant-level random effects.

Change in Response Time of Feeling Moved:

Model fit comparisons indicated that Model 1 was the most parsimonious and best fitting model outside and across individual differences, encompassing Perspective Taking, Empathic Concern, Cognitive Empathy, and Art Experience (Table XX). Model 1 showed lower AIC values (AIC = 1433 - 1466) compared to Model 2 (AIC= 1469 - 1505), while the BIC, a more conservative fit criterion, showed lower values for Model 1 (BIC= 1463 - 1486) compared to Model 2 (BIC= 1494 - 1520). The likelihood ratio test (LRT) demonstrated that including tDCS stimulation as a random slope significantly improved the fit of the data ($\chi 2$ (1)= 39.997 – 43.095, $p < .001$). In addition to the variance explained by the random effects (please see tables XX and XX), the Intra-class Correlation Coefficient (ICC) showed that a substantial proportion of the total variance was attributed to differences between participants (ICC=.900 - .905), indicating that nesting the data within participants promotes the appropriate comparison between participants. Therefore, Model 1 was selected as the best fitting model outside and across individual differences.

Table s9: Model comparisons and model-fits for Anodal ctDCS in Change of Response Time in Feeling Moved.

Model	**R^2**	**LRT χ^2**			**AIC**	**BIC**	**loglik**
Individual Differences		Value	df	*p*			
N/A							
Model 1	0.920	98.473	6	< .001	1466	1486	-746
Marginal	0.008	2.972	3	0.396			
Model 2	0.681	53.419	4	< .001	1505	1520	-725

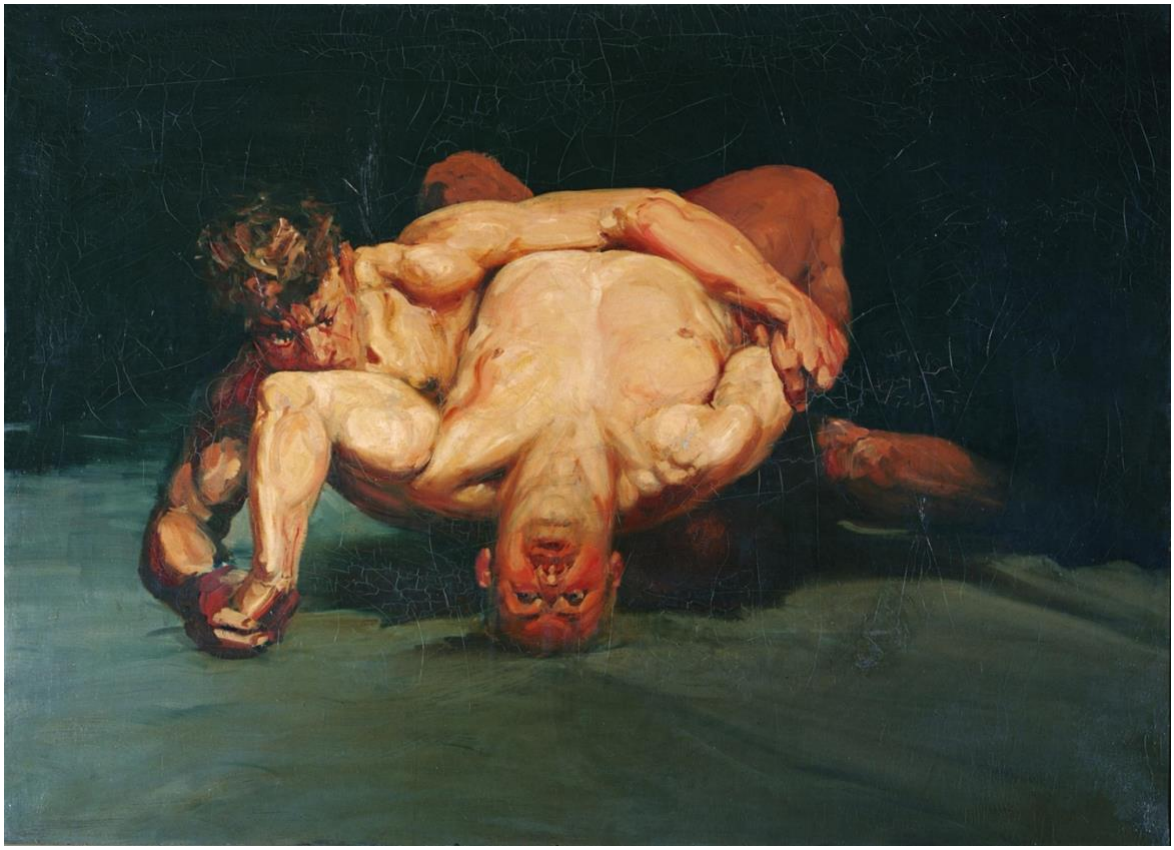
Marginal	0.008	2.237	3	0.525			
Δ Model 1 > Model 2	0.240	43.095	1	< .001	-39.095	-34.052	21.548
Perspective Taking							
Model 1	0.921	98.592	10	< .001	1435	1465	-705
Marginal	0.008	3.090	7	0.877			
Model 2	0.681	53.455	8	< .001	1472	1497	-726
Marginal	0.008	2.273	7	0.943			
Δ Model 1 > Model 2	0.240	41.211	2	< .001	-37.211	-32.168	20.606
Empathic Concern							
Model 1	0.923	101.991	10	<.001	1433	1463	-704
Marginal	0.022	6.490	7	0.484			
Model 2	0.701	58.185	8	<.001	1469	1494	-724
Marginal	0.022	7.003	7	0.429<.			
Δ Model 1 > Model 2	0.222	39.997	2	001	-35.997	-30.953	19.998
General Empathy							
Model 1	0.922	99.945	10	< .001	1433	1463	-704
Marginal	0.013	4.444	7	0.727			
Model 2	0.688	55.173	8	< .001	1470	1495	-725
Marginal	0.013	3.990	7	0.781			
Δ Model 1 > Model 2	0.233	40.880	2	< .001	-36.880	-31.836	20.440
Art Experience							
Model 1	0.921	99.989	10	< .001	1434	1464	-705
Marginal	0.030	4.488	7	0.722			
Model 2	0.683	54.754	8	<.001	1472	1497	-726
Marginal	0.030	3.572	7	0.828			
Δ Model 1 > Model 2	0.238	41.302	2	0.001	-37.302	-32.258	20.651

Note: Model 1 = MeanMoveRTChange ~ 1 + Stimulation + Valence + Individual Difference + Stimulation:Valence + Stimulation:Indivudal Difference + Stimulation:Valence:Individual Difference (1+ Stimulation | Participant; Model 2 = MeanMoveChange ~ 1 + Stimulation + Valence + Individual Difference + Stimulation:Valence + Stimulation:Indivudal Difference + Stimulation:Valence:Individual Difference (Intercept | Participant); Marginal = respective models without variance explained by random effects; AIC, BIC and loglik differences are the model of each Individual Difference; AIC for Akaike information criterium; BIC for Baysian information criterium; LRT = Likelihood ratio test statistic; loglik = loglikelihood estimate; R^2 = percent of variance explained.

Table s10: Random Components and Intraclass Correlation Coefficients Across Individual Differences for Anodal ctDCS in Change of Response Time in Feeling Moved.

Individual Differences	Random Component	Variance	SD	ICC
N/A	Participant (Intercept)	1.55e+6	1244	0.902
	Stimulation	1.52e+6	1232	
	Residual	167955	410	
Perspective Taking	Participant (Intercept)	1.62e+6	1273	0.902
	Stimulation	1.59e+6	1261	
	Residual	175541	419	
Empathic Concern	Participant (Intercept)	1.62e+6	1273	0.905
	Stimulation	1.47e+6	1212	
	Residual	169615	412	
General Empathy	Participant (Intercept)	1.62e+6	1273	0.904
	Stimulation	1.55e+6	1243	
	Residual	172944	416	
Art Experience	Participant (Intercept)	1.57e+6	1254	0.900
	Stimulation	1.57e+6	1254	
	Residual	175153	419	

Note: Random components and intraclass correlation coefficients (ICC) for individual differences of interest. Variance and standard deviation (SD) values are shown for the participant as a random intercept, stimulation as a random slope, and residuals. ICC represents the proportion of total variance explained by the participant-level random effects.



George Benjamin Luks. *The Wrestlers.* 1905.