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Neurodynamics of Relational Aesthetic Engagement in Creative Arts Therapies

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Abstract

Aesthetic experiences, emerging saliently in the arts, play a pivotal role in transformative learning and creative processes that elicit physiological, affective, and cognitive responses associated with mental health indices. Interactions between subjects and aesthetic objects (e.g., visual artwork, music, and moving bodies) often entail elements of surprise and uncertainty that drive the inference of the hidden causes in the subject's internal and external environment. These generate dynamics that align with the action-oriented Predictive Processing framework of brain function. Creative Arts Therapies (CATs) harness these dynamics by cultivating relational engagement using the arts modalities, prompting affective and cognitive processing. In this manuscript, we offer a review and conceptual analysis of recent empirical findings and theoretical premises that underpin aesthetic experiences and their relation to the psychotherapeutic use of the arts with a broad spectrum of populations and mental health conditions. We present a neuroscience-based approach to aesthetic intra- and inter-personal experiences, integrating therapeutic change factors of externalization-concretization, embodiment, and symbolization with functional network configurations, and interpersonal brain-to-brain coupling, to support predictive processing, learning, and creativity. Present and future interdisciplinary collaborations are underlined to elucidate the neurodynamic mechanisms driving psychological transformations, bridging neuroaesthetics and CATs.

Keywords

neuroaesthetics, aesthetic experience, creative arts therapies, embodiment, predictive processing, brain-to-brain coupling

Introduction—The Aesthetic Experience in Creative Arts Therapies

With the burgeoning field of neuroaesthetics, the aesthetic experience has reemerged as an essential and valuable evolutionary-based human experience inducing an array of perceptual, cognitive, and affective brain functions that lie at the core of psychological and behavioral change (Chatterjee, 2011; Kenett et al., 2023; Ramachandran & Hirstein, 1999; Sarasso et al., 2023; Schoeller & Perlovsky, 2016; Zeki, 2002). However, little is known about the mechanisms underlying the crosstalk between aesthetic experiences, mental health, and their neural underpinnings.

Broadly defined, aesthetic experiences are a concomitant part of the *Creative Arts Therapies* (CATs), an umbrella term covering health professions in several disciplines, including art therapy, dance/movement therapy, drama therapy, psychodrama, music therapy, and poetry/bibliotherapy. The CATs are characterized by the evidence-informed use of the arts in experiential interventions within a formal therapeutic relationship (Orkibi & Keisari, 2023). Creative arts therapists are experts in using the creative processes and their outcomes to ameliorate health and well-being, while working with patients of all ages, individuals, couples, families, and groups across a variety of mental healthcare, medical, rehabilitation, educational, and community settings (de Witte et al., 2021; Koch et al., 2019; Orkibi & Keisari, 2023). Creative arts-based psychotherapeutic interventions have been shown as

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promising for people with a range of affective conditions, promoting health and well-being across the lifespan (e.g., De Witte et al., 2020; Fancourt & Finn, 2019; Koch et al., 2019; Martin et al., 2018; Shim et al., 2021). Indeed, substantial evidence supports the value of the CATs in both illness reduction and health promotion (Karkou et al., 2022; Orkibi et al., 2023; Shafir et al., 2020). Efforts to examine the neural basis of related aesthetic experiences in clinical health populations are nascent, although progress has been made (Lauring et al., 2019; Richard et al., 2023; Spee et al., 2022; van Leeuwen et al., 2022). We believe the link between the CATs and neuroaesthetics provides a meaningful opportunity to do just that (Oliva et al., 2023). The following section describes the connection of the multidimensional aesthetic experience to therapeutic factors of CATs, which include *externalization-concretization*, *embodiment*, and *symbolization*.

Therapeutic Factors of Multidimensional Aesthetic Processes in CATs

Aesthetic experiences arise dynamically from a complex interplay of factors related to the object viewed (artwork, a piece of music, poetry, body movement, etc.), the individual's subjective response, and the situational context or setting within which the experience emerged (Jacobsen, 2006). In CATs, where aesthetic experiences occur within the therapeutic setting, the key therapeutic change factors are fundamentally grounded in the individual's engagement with the art-making processes and the resulting outcomes (de Witte et al., 2021). These involve the externalization of an intangible inner experience, which is often difficult to articulate or comprehend, into tangible and concrete artistic forms (Kushnir & Orkibi, 2021). In visual art, this *externalization-concretization* occurs through the use of color, shape, or composition. In drama, this is achieved through physical enactment of roles in situations, and in dance through movement, posture, and gesture. Music provides auditory concretization through melody, rhythm, tempo, pitch, etc., and writing concretizes through words (Blatner, 1991; Kushnir & Orkibi, 2021).

The *externalization* process in CATs has much in common with the *distancing-embracing* model attributed to the emotional effects of aesthetic experiences (Menninghaus et al., 2017). This model highlights the significance of psychological distancing, which refers to the perceived separation between an individual and particular emotions, experiences, or stimuli with a temporary suspension of typical responses. Psychological distancing in aesthetic experience is achieved by cognitively framing the stimuli as art, representation, or fiction that provides personal safety and control over the prolongation or discontinuation of the exposure. In turn, this distancing enables the sensations and emotions to be felt with greater intensity, thus allowing the observer to fully immerse in and embrace the "here-and-now" of the aesthetic experience. This can foster the processing of a broad repertoire of emotional responses including negative emotions (Iigaya et al., 2020; Menninghaus et al., 2017), which is crucial in the context of CATs. These concrete affective bodily experiences involve embodied-enactive-interactive processes that play a crucial role in shaping thoughts and emotions, as well as an understanding of intangible inner experiences and the environment (Vaisvaser, 2021).

The affective bodily experience highlights another core therapeutic change factor in CATs; namely, *embodiment* (de Witte et al., 2021). Aesthetic experience is thought to be embodied in nature (Casale et al., 2023; Crowther, 1993; Gallese, 2005, 2017a). Embodiment is elicited by deep engagement with body movement in dance, role play, music making or listening, writing or reading, and the tactile experience associated with the quality of art materials (de Witte et al., 2021). Accordingly, the concept of *embodied aesthetics* has emerged in the CATs literature (Koch & Fuchs, 2011). It reflects the growing recognition of the plasticity and malleability of an individual's aesthetic experience, in particular as regards the human body (Kirsch et al., 2016), which spans different sensory modalities and encompasses interoceptive, proprioceptive, and exteroceptive signals. Furthermore, the aesthetic object situated in the external world triggers the observers' *embodied simulation* (Azevedo & Tsakiris, 2017; Chatterjee & Vartanian, 2016; Freedberg & Gallese, 2007), a mirroring mechanism provoking emotions, bodily memories, and imaginative associations which influence individuals' aesthetic experience (Gallese, 2017b) and are central to the work of CATs. Within the interpersonal context, a link has been established in brain activity between empathy and sensitivity to information conveyed in an embodied manner (Bekkali et al., 2021; Penagos-Corzo et al., 2022). Embodied actuality, elicited through the lived, bodily experience in CATs, may induce awareness and change perceptions, thoughts and feelings about the self and others (Vaisvaser, 2021). The process of embodiment provides therapeutic opportunities for inciting a brain-body-mind connection, such that sensorimotor and action observation systems brain areas that are activated during artistic engagement (receptive or expressive) are fundamentally integrated with emotional and cognitive processing (Scarinzi, 2015).

Symbolization is also a core therapeutic change factor in CATs (de Witte et al., 2021) in that the arts endow symbolic form to a broad range of human feelings (Langer, 1953). Symbolic and metaphoric expressions deliver succinct implicit messages about the patient's inner experiences and sensations by conveying the maximum meaning of rich inner experiences through a minimum of words or non-verbally and often help bring the subconscious to conscious awareness (Bella & Serlin, 2013; Imus, 2021). Incorporating the creation of metaphors and symbols involves embodied cognitive and emotional processes that support transformative (verbal and non-verbal) expression and narration of experiences that are otherwise difficult to access (Malchiodi, 2020). Thus, the creative process and the resulting artwork can facilitate meaning-making and deepen the understanding of the self and others through symbolic communication expressed and witnessed within the psychotherapeutic encounter (Jones, 2020; King et al., 2019; van Leeuwen et al., 2022).

The interconnected therapeutic factors of *externalization-concretization, embodiment, and symbolization* meaningfully coincide with the aesthetic triad framework that describes aesthetic experiences as emerging from a complex interplay between sensory-motor, emotion-valuation, and knowledge-meaning systems in the brain (Chatterjee & Vartanian, 2014). The CATs enable patients to shift, transform, and integrate embodied engagement in their subjective experience and explicit meaning-making reflections (Vaisvaser, 2021). The dynamic interplay between these self-perspectives triggered via the aesthetic experience may result in a more coherent and adaptive view of reality and the self in the world. It is thus crucial to explore the underlying neurodynamic of these processes. Recent findings in neuroaesthetics and creativity on their neural underpinnings have identified large-scale functional brain networks, as detailed below in the following section.

The Aesthetic Brain Network Dynamics

Aesthetic experiences are integrative in nature, in the sense that they tap perception and imagery across multiple senses as well as memories and associations (Belfi et al., 2019). The aforementioned aesthetic triad framework recognizes distributed neural systems involved in sensory-motor engagement, affective absorption and valuation processes, appraisal and comprehension, that is, meaning (Chatterjee & Vartanian, 2016).

Correspondingly, the aesthetic experience engages large-scale brain networks, including increased activity and connectivity within the sensory and motor networks, the reward network associated with seeking behavior, and the salience circuitry involved in stimulus-driven attention allocation, interoceptive inference and awareness (Kaimal et al., 2017; Kenett et al., 2023; Koelsch, 2014). The multisensory integration of interoceptive, proprioceptive, and exteroceptive inputs supports body ownership and agency over one's actions (Blanke et al., 2015; Salvato et al., 2019). Aesthetic experiences also engage the Default Mode Network (DMN) (Bolwerk et al., 2014), associated with self-referential processes such as free-ranging thought, spontaneous introspection, autobiographical memory, episodic future thinking, and mentalization (Raichle, 2015; Wen et al., 2020). The DMN functions as a "sense-making" network that integrates incoming extrinsic (including social) information with prior intrinsic information (memories and knowledge) to form rich, context-dependent models of situations as they unfold over time (Yeshurun et al., 2021). Moreover, aesthetic neurodynamics involves crosstalk between networks, supported by evidence of increased connectivity between the DMN and both sensorimotor cortices and the salience and reward networks (Belfi et al., 2019; Bolwerk et al., 2014; Chatterjee & Vartanian, 2016; Vessel et al., 2013). Importantly, higher aesthetic engagement was shown to be characterized by the integration of sensory perception and salience detection with self-referential processing, as reflected in increased resting-state functional connectivity between sensorimotor and salience networks with the DMN, which is posited to be related to stress regulation and positive health outcomes (Williams et al., 2018).

In terms of appraisal and comprehension (i.e., meaning-making) processes, creativity and aesthetic experiences have been associated with dialectical interactions between the DMN and the Executive (or frontoparietal) Control Network (ECN). The former involves internally focused mental ideation processes, whereas the latter involves cognitive control processes such as response inhibition and goal-directed memory retrieval (Beaty et al., 2016, 2019). According to the triple-network framework, the salience network plays a key role in facilitating the shift between internal (DMN) and external (ECN) stimuli, which also occurs during the process of creating art (Lusebrink & Hinz, 2020; Starr, 2023a). Recent research has suggested that the brain networks associated with artistic and social functions may overlap, which thus has significant practical implications for mental health (van Leeuwen et al., 2022). In accordance, aesthetic experiences entrail social understanding, which involves perspective taking, belief attribution, imagination, and other cognitive processes relevant to the theory of mind (ToM) or mentalizing brain network, including the temporoparietal junction, and regions of the DMN (mainly the medial anterior and posterior cortices) (Beudt & Jacobsen, 2015; Liu et al., 2021; Nascimento et al., 2023; Rojiani et al., 2018; van Leeuwen et al., 2022). Relatedly, the flexible configuration of neural networks has been suggested to be sensitive to individuals' desires, expectations, goals, mood, context, and accumulated lifetime experiences with art (Casale et al., 2023; Nadal & Chatterjee, 2019). Neuroaesthetics in its applied form thus suggests that the potential benefits of the arts transcend class, gender, age, race, and culture (Magsamen, 2019).

Efforts have begun to expand the theoretical understanding of the functional networks involved in artistic engagement within the psychotherapeutic context (King & Chatterjee, 2024; Lusebrink & Hinz, 2020). Recent studies have pointed to possible correspondences between neural and psychological outcomes of CATs interventions, which manifest as modifications in functional connectivity between major nodes of these networks in Post-Traumatic Stress Disorder (Payano Sosa et al., 2023) and Parkinson's disease (Cucca et al., 2021). These modifications may be related to facilitated predictive processing, as discussed in the following section.

Aesthetic Experiences as Facilitators of the Predictive Brain

In recent years, the *predictive processing* (PP) framework has become the prominent theory of the fundamental principles of operation of the human brain (Clark, 2013; Friston, 2010). The brain constantly responds to interactions with the environment in an enactive manner (Ramstead et al., 2020) by creating Bayesian probabilistic internal models (predictions) that help interpret and make sense of sensations arising from inside and outside the body, support allostasis (which refers to the proactive maintenance of homeostasis) and anticipate and prepare for future events. This is done through (typically implicit) inferential processes in an effort to decrease internal disorganization, termed "free energy." Prediction errors, or deviations from prior expectations, can be used to guide the updating of predictions ("priors") of the embodied exchange with the world. In addition to minimizing prediction errors by constantly revising internal models of the body and the world, subjects will also act on their surrounding environment to reduce its uncertainty and/or fulfill prior expectations (Parr & Friston, 2019).

The brain networks are hierarchically organized, from lower-level cortical sensory processing toward a functional spectrum of progressively higher-level associative and abstract representations (Wang, 2020). In the context of PP, predictive signals descending (top-down) from higher-level processing areas are integrated with (bottom-up) ascending prediction error signals from sensory areas, refining these predictions and driving action on the surrounding environment to reduce its uncertainty. Signals are transmitted through hierarchical gradients of functional connectivity at all levels of processing, and to different aspects of the incoming sensory signal, with the DMN situated at the highest levels of the predictive hierarchy (Carhart-Harris & Friston, 2010). Accordingly, impaired predictive coding and error processing have been suggested to account for a wide range of mental health conditions and disorders (Smith et al., 2021).

The PP framework provides a basis for a unifying explanation of aesthetic phenomena (Sarasso et al., 2023), which involves generating inferences about current sensations based on past experience. Because they are highly salient, aesthetic experiences are laden with tension and fluctuations in uncertainty, generate prediction errors (surprises) that create a yearning for resolution, and trigger predictive processes directed at future events of emotional significance (Koelsch, 2014; Lehne & Koelsch, 2015; Shany et al., 2019). Beyond homeostatic maintenance, humans are also curious and seek surprise and novelty in non-threatening settings (Clark, 2018). These prediction errors have epistemic value or affordance, in that relative short-term certainty (the possibility of a short-term uncertainty) is traded off for the possibility of more long-term certainty (or gain) from which new options (or updated predictions) can arise (Friston et al., 2015; Gallagher & Allen, 2018; Schwartenbeck et al., 2013). Aesthetic objects and experiences stimulate the reward system, leading to heightened curiosity, pleasure, and motivation, which is a process elicited by dopaminergic-driven information-seeking (Van de Cruys et al., 2017). This aesthetic learning helps to optimize behavior by balancing internal expectations and external signals and is considered to shape personal, social, and cultural interactions (Friston et al., 2017; Kesner, 2014).

Indeed, uncertainty and ambiguity play a central role in the impact of aesthetic experiences, as well as in the concept of the "beholder's share" (Gombrich, 1961), where the viewer's perceptual expectations and memories (predictions) are projected onto (and into) an aesthetic object (Seth, 2019). In other words, those engaged with the work of art (receptively or expressively) contribute their own personal interpretation and experience (thoughts, emotions, memories, and cultural background) to the overall aesthetic experience. "Bottom-up" sensations are then matched with these "top-down" predictions, creating an interplay between the forward and backward flow of information. The interaction between external input from the world (aesthetic object) and internal models (i.e., predictions) can provide an opportunity for a mismatch (a prediction error), that can then update current predictions to accommodate unexpected signals. These processes can induce remodeling, adjustment, and modification of the internal models of the embodied exchange with the world, and serve to scaffold subjective perceptual, emotional, and cognitive meaning.

Minimizing prediction errors through active and enactive inference involves the embodied capacity to generate experience through action, thereby fostering creativity (Schiavio & Benedek, 2020). As living beings, embedded in social environmental contexts, functionality and novelty are essential to survive and thrive in the uncertain and changing world (Orkibi, 2023; Orkibi et al., 2021). The arts, rich in aesthetic experiences, enable genuine moments of discovery that encompass tensions and uncertainties (*change*) as well as self-validating certainty (*order*) that often serves as an impetus for further forays into change; they are transformative as they shape (freedom of) action (Van de Cruys et al., 2024). In this sense, CATs may tap into the intrinsic motivation to seek predictive progress and provide patients with opportunities to venture out of predictable zones (Gottlieb et al., 2013), exploring new ways of being, acting, and relating. Because the therapeutic encounter involves interpersonal dynamics, the following section delves into the relational aspect of aesthetic experiences.

Interactive Relational Aesthetic Experiences at the Core of Mental Health

The interpersonal context in which aesthetic experiences emerge within the CATs, which are inherently relational, may also engender an intersubjective synchronization pattern.

Interactive real-world aesthetic experiences have repeatedly been shown to induce interpersonal brain-to-brain coupling or Interpersonal Neural Synchrony (INS). These are addressed using the conceptual and methodological frameworks of two-person neuroscience (Hari et al., 2015) and second-person neuroscience (Redcay & Schilbach, 2019) that use simultaneous recordings from two or more interacting individuals (i.e., hyperscanning). These studies illuminate the potential of exploring how interactive real-world aesthetic experiences induce interpersonal brain-to-brain coupling. Coordinated or synchronized brain activation between people (i.e., intersubject correlation) was suggested as a mechanism of transmission of shared meaning and interpretation that goes beyond cultural and linguistic boundaries (Honey et al., 2012). Moments of neural synchrony may be driven by shared attention to external stimuli in the environment (i.e., artwork, sound cues or a musical instrument, a prop, and bodily interaction) or directly mediated by the person-to-person communicative signals through which interaction is conveyed (e.g., eye contact, facial expression, bodily gestures, and vocal prosody).

INS is viewed as an entrainment phenomenon, shown to be promoted and enhanced by real-time interactive behavior (Koul et al., 2023). Neural synchrony has consistently been reported during joint artistic engagement, such as while creating, performing or listening to music (Abrams et al., 2013; Babiloni et al., 2012; Liu et al., 2021; Müller et al., 2013; Nascimento et al., 2023; Osaka et al., 2015; Ramírez-Moreno et al., 2023; Rojiani et al., 2018; Sachs et al., 2020; Sänger et al., 2012; Zamm et al., 2018), after musical interaction (Khalil et al., 2022), while performing dramatic scenes (Greaves et al., 2022), in collaborative drawing (da Cruz Monteiro et al., 2022), while viewing a dance performance (Herbec et al., 2015; Jola et al., 2013), and in shared movement (Reddish et al., 2013; Varlet et al., 2020).

Inter-brain synchrony has been associated with improved social functioning (Gvirts & Perlmutter, 2020; Hu et al., 2017). Notably, there seems to be a consensus that brain-to-brain networks become increasingly efficient and integrated as the level of interaction between subjects intensifies (Falk & Bassett, 2017). Increased INS has also been linked to feelings of shared intentionality, positive beliefs in cooperativity, perceived social closeness (Dikker et al., 2017) and social behavior, that is, joint action and eye contact (Dikker et al., 2021). Since many forms of psychopathology are associated with a reduced ability to achieve INS in various contexts, it was suggested as a neurobiological mechanism underlying plastic change in psychotherapy (Sened et al., 2022b). Indeed, INS between patient and therapist, shaped by the embodied and relational aspects, has been associated with work alliance in psychological counseling (Zhang et al., 2018), and has been proposed as a neurobiological mechanism to infer the other's inner states and facilitate mutual understanding and emotional exchange (Koole & Tschacher, 2016).

Engagement in aesthetic experiences in the relational therapeutic environment of CATs holds significant potential in the context of synchronization. Indeed, recent studies have begun investigating brain-to-brain coupling in the context of CATs, examining moment-to-moment inter-brain synchrony during music therapy sessions involving various pairs, including a child with disabilities (cerebral palsy or autism spectrum disorder) and the parent/therapist (Kang et al., 2023; Samadani et al., 2021), a stroke rehabilitation patient and therapist (Tucek et al., 2022), and a person with dementia and a therapist (Maidhof et al., 2023).

Inter-brain synchrony, shown in meaningful "moments of interest," suggests clinically relevant shared emotional processing (Fachner et al., 2019; Maidhof et al., 2023). Through the lens of the PP framework, this intersubjective synchronization is thought to induce the phenomenon termed "a duet for one" during which the ontology of the brain becomes interpersonal through communication based on a shared meaning between subjects exchanging sensory signals (Friston & Frith, 2015). The sensory input of the communicating person (verbal and non-verbal) can be taken and subjected to top-down predictions as though it arose in the other person. By using cooperative communication, shared active inference induces action-perception cycles that operate to minimize uncertainty and optimize the individual's internal model of the world, establishing a shared narrative and mutual predictability (Vasil et al., 2020). The resulting interpersonal synchrony, which emerges from the coupling of active inference systems, underscores the importance of embodiment and dynamical interaction (Gallagher & Allen, 2018). It was proposed to reflect the dynamics of therapeutic conversations in psychotherapy and is thought to help bind potentially disruptive "free energy" in creative ways, thus fostering psychological resilience (Holmes & Nolte, 2019). These ideas are further developed in the next section by exploring the clinical application of using the arts and aesthetic experience in psychotherapy.

The Psychotherapeutic Use of Arts and Aesthetic Experiences

Within the context of a therapeutic relationship, the CATs promote a sense of self-ownership and self-agency by utilizing aesthetic experiences and the interdependent processes of *externalization-concretization*, *embodiment*, and *symbolization* to access a wide range of learning and memory processes (de Witte et al., 2021; Malchiodi, 2020; Vaisvaser, 2021). In individual and group settings, The CATs provide a safe environment for sensory exploration by promoting the development of interoceptive self-awareness, emotional embodiment, and cognitive understanding through the processing of (working through) the aesthetic experience (Samaritter, 2018; Vaisvaser, 2021). The exploratory experiential nature of CATs, interlaced with emotional and cognitive aesthetic learning processes, expands the spectrum oscillating between uncertainty (surprise) and predictability. This holds great promise for working with different kinds of neuropsychiatric disorders, such as those characterized by stereotyped rigid conditions, that is, autism spectrum disorder, obsessive-compulsive disorder, and Parkinson's disease (Spee et al., 2022).

The strong hedonic response to aesthetic stimuli, engaging the reward system, was suggested to have beneficial effects in reward-related dopaminergic disorders, such as depression (Jain et al., 2023a). Indeed, major depressive disorder patients showed improved brain function following music therapy in prefrontal regions of the DMN, reward network, and frontoparietal executive networks, that is, ventromedial prefrontal cortex (vmPFC), orbitofrontal cortex (OFC), and dorsolateral prefrontal cortex (dlPFC), respectively (Feng et al., 2019). Moreover, the widespread engagement of brain networks in aesthetic experiences used in CATs, may induce experience-dependent plasticity to support brain function in rehabilitation, improving affective as well as cognitive functioning (Chatterjee et al., 2021; Cucca et al., 2021; Martínez-Molina et al., 2022).

Being aesthetically moved creates a drift in emotional arousal and the induction of strong affective valence (Jain et al., 2023b), which have repeatedly been shown to impact memory (Kensinger, 2004). Traumatic autobiographical memories have a profound influence on individuals' well-being and have been suggested to be a transdiagnostic feature of multiple mental health difficulties, including Post-Traumatic Stress Disorder (Dalgleish & Hitchcock, 2023). Aesthetic fluctuations in uncertainty induce prediction error signals that may drive representations at higher levels of the cortical hierarchy to provide better predictions, while also driving associative plasticity to update internally generated predictions that draw on memory traces (Barron et al., 2020). Prediction error renders current actions salient again, and attracts attention, making the prediction that was generated by the past episode in need of revision or reconsolidation (Solms, 2015). Thus, aesthetic experiences may modulate traumatic memories. Error in memory prediction was shown to affect different stages of learning and memory (Dudai, 2012) and can also drive the updating of consolidated memories in the process of reconsolidation, when memory is labile and susceptible, during its reactivation (Exton-McGuinness et al., 2015; Fernández et al., 2016; Gershman et al., 2017; Lee et al., 2017; Sevenster et al., 2014). These processes may lead to affective change and reduced emotional consequences deriving from memories of traumatic events, thus highlighting the potential for clinical interventions (Monfils & Holmes, 2018).

Activation of brain regions associated with autobiographical memory, as well as self-referential processing, including the mPFC, precuneus and temporal gyrus, was presented following music therapy (Raglio et al., 2016). A study with military service members showed increased resting-state functional connectivity between regions associated with memory, attention, and salience processing in patients who depicted a theme of closure and/or healing of traumatic memories within the context of art therapy (Payano Sosa et al., 2023). These findings coincide with the increased resting-state functional connectivity within the DMN that was associated with psychological stress resilience, following visual art production group sessions encouraging self-expression (Bolwerk et al., 2014).

Through therapeutic engagement in autobiographical content, CATs facilitate the processing of maladaptive hyper-precise "priors" (predictions), enabling the assimilation of novel salient emotional information into these internal prediction models. Within these interactions, patients can test their habitual prior beliefs about themselves and the world (and their related emotions and behaviors) and create alternative, more flexible opportunities for experience and action. CATs promote the articulation of otherwise disarticulated aspects or fragmented felt parts of experiences. CATs' characteristic of dual receptive and expressive artistic engagement facilitates the integration and articulation of experience in a subjective process of meaning-making (Samaritter, 2018). In the context of CATs, an attuned therapist with empathic openness (who is in a reverie-like or mind-wandering state, using their own reflective and imaginative thinking to understand and interpret the experiences and emotions of their patients) may venture into the unknown through artistic engagement and thereby facilitate possibilities for working through the patient's psychological problems.

Spontaneous INS may emerge from behavioral synchrony during social interaction (Koul et al., 2023), modulated by oxytocin (Josef et al., 2019), and fostered by the relational aesthetic engagement in CATs. This interpersonal phenomenon is clinically highly relevant for inducing psychotherapeutic change, which has been shown, for example, in conditions associated with social impairments, such as autism spectrum disorder (Kang et al., 2023; Samadani et al., 2021). Through inter-brain synchrony in shared moments of connection, the attuned therapist's brain activity might influence the patient's brain activity (Kang et al., 2023; Maidhof et al., 2023; Samadani et al., 2021; Tucek et al., 2022). In such interaction, the therapist's "loaning" of brain functions may serve as a means to enter the predictive moment, mobilizing the active inference in the context of intimate relationships (Holmes & Nolte, 2019; Vaisvaser, 2021).

The therapy process in the CATs consists of treatment plans and goals, but at the same time has chaotic (or stochastic) ingredients. For example, an intentional treatment goal can be the enhancement of interoceptive self-awareness through emotional and memory processing, while a stochastic change would indicate more exploratory states that patients can be in, creating a wider range of experience or actions possible. Both may play a potential role in the patient's development. Within the therapeutic, safe, predictable setting, the tolerance for surprising experiences might increase. The CATs include construction-deconstruction and reconstruction processes, where therapists accompany their patients and dwell with them in uncertainties while exploring individual meaning. They simultaneously co-construct memories and are attentive to the multisensory aesthetic dimensions that they encounter.

Creative arts therapists help patients process and transform their pain, stress, and losses by attending to their first-person phenomenological experience using the art forms and interpreting the personal and symbolic meaning of the artistic process and/or the resulting artwork (Malchiodi, 2020). Through artistic intersubjective experiences, one could reconfigure self-narratives, as an interactive agent of transformation (Azoulay & Orkibi, 2015). Within the context of the therapeutic relationship, coping with traumatic content and reducing "free energy" could be accomplished by updating predictions and optimizing the flow of sensory input via action, creation, and expression.

CATs are both personalized and process-oriented, as are the therapeutic relationship and transference/countertransference dynamics, thus considering subjective individual differences in aesthetic experiences, which differ significantly between individuals and within an individual over time (Brielmann et al., 2024). Intertwined individual factors related to personality, age, gender, physiological features, personal and sociocultural background, experience, preferences, and motivation, as well as contextual and situational factors tune the predictive apparatus toward salient objects and experiences (Kesner, 2014; Spee et al., 2022). Additionally, individual emotional constructs, such as emotional awareness, emotional differentiation/granularity, and emotional creativity, that is, the ability to produce emotional responses that are novel, authentic, and effective, as well as one's preparedness to use them (Averill, 1999), have clinical applications for diagnosis and treatment (Hoemann et al., 2021). These were suggested to underly mental representations of emotional experiences, which depend on the interconnected processing of information from the body and from the world (Hoemann et al., 2021). Individual differences may also relate to cognitive and behavioral flexibility, that is, the mental ability of a person to switch and adjust thoughts and actions according to context, whereas rigidity (inflexibility) appears to be a core feature of diverse neurodevelopmental and psychiatric conditions (Uddin, 2021). Indeed, creative ideas and performance benefits from a balance between flexibility and stability (Orkibi, 2023), associated with large-scale functional brain networks encompassing frontoparietal, DMN, reward, and salience regions (Uddin, 2021). These individual differences are taken into account and explored in CATs, presenting initial empirical research and methods of assessment related to the aesthetic experiences in different expressive artistic modalities (e.g., Rose et al., 2022; Schwenke et al., 2021; Vaartio-Rajalin et al., 2021). The following section elaborates on developing ecologically valid technologies to further explore the natural, aesthetically driven therapeutic relational environment.

Present and Future Research on the Neuroscience of CATs

Thus far, we have defined creative arts therapists as mental health professionals who seek to effect change in patients through receptive and expressive aesthetic practices within a therapeutic relationship. We have suggested a shared definition of aesthetic experience that hypothesizes the underlying neural mechanisms of key therapeutic change factors within the categorization of the aesthetic triad (Chatterjee & Vartanian, 2014; Vartanian & Chatterjee, 2021). We posited that the Bayesian brain may be a logical framework to explore aesthetic, arts-based interventions that engage predictive processing neurodynamics to enhance the learning of updated embodied internal models of the self in the world, within the context of the therapeutic relationship. We further interconnected these relational processes with modulations in brain-to-brain coupling dynamics and described intra- and inter-personal neural processes associated with psychotherapeutic change mechanisms.

The partnership of neuroaesthetics and CATs provides opportunities to study the underlying mechanisms of change that are integral to therapeutic practices. However, broad gaps exist when linking the dimensions of applied clinical practices to the cognitive and emotional mechanisms identified in neuroaesthetics research. Incorporating receptive and expressive aesthetic experiences into the inquiry makes the challenge of isolating and operationalizing variables much more complex. The rigorous quantitative methods of neuroaesthetics do not easily align with the methodologies of applied science. These translational barriers may be addressed through advances in modern neuroscience that view theory, ecological behavior, and the search for mechanisms as central to the process (King & Parada, 2021).

The restrictions of brain imaging technologies traditionally used in neuroaesthetics research (e.g., fMRI) can be overcome with mobile neuroimaging. Some of these devices have been used in CATs studies, such as functional near-infrared spectroscopy (fNIRS) (e.g., Feng et al., 2019; Yan et al., 2021) and electroencephalography (EEG) (e.g., Fachner et al., 2019; Kang et al., 2023; Maidhof et al., 2023; Samadani et al., 2021; Tang et al., 2022; Tucek et al., 2022; Ventouras et al., 2015). Yet, the embodied nature of aesthetic experiences emphasizes the role of the body in emotional and mental processes and, therefore, calls for the use of mobile technology such as Mobile Brain-Body Imaging (MoBI). MoBI closely relates to the theoretical understanding of cognition as an Embodied, Embedded, Extended, and Enactive (4E) process, thus making it suitable for studying therapeutic interactions (Costa-Cordella et al., 2023; King & Parada, 2021). MoBI makes it possible to study cognition in natural settings and provides an approach to investigating the connections between the brain, body, and behavior (Gramann et al., 2011; Makeig, 2009). MoBI embraces a variety of hardware and software solutions to record and analyze brain dynamics in actively behaving participants and combines different types of neuroimaging including fNIRS and EEG, as well as other physiological measures such heart rate variability (HRV) and eye tracking to investigate brain dynamics in real-world environments. This integrative technology has the potential to explore the intersection of CATs and neuroaesthetics by measuring neurophysiological dynamics outside the confines of laboratory settings (Barnstaple et al., 2021; King & Parada, 2021; Parada, 2018). Here, the experimental design must aim for rigorous neuropsychophysiological measures, while including the first-person phenomenological experience (Oliva et al., 2023; Parada & Rossi, 2018; Petitmengin & Lachaux, 2013). Ecological validity should represent the natural aesthetically driven therapeutic environment that allows for the capture of functional patterns of patients' creative expression and reception, along with the observation of the therapist as a witness to the artistic process and product.

Efforts are underway to understand the biological mechanisms of body-world coupling (Rojas-Líbano & Parada, 2020). MoBI has been used to investigate the multimodal nature of dance using real-time changes in brain dynamics and behavior. It has provided important insights into the range of symptoms experienced in neurodegenerative diseases (Barnstaple et al., 2021). The use of MoBI enables an evaluation of the cortical physiology of patients with Parkinson's disease, a direction that has been propelled by Cucca et al. (2018, 2021) who explored the neural connections between visual-spatial processing and the artistic experiences in patients who received (visual) art therapy for purposes of neurorehabilitation. MoBI allows for the acquisition of brain/body physiological signals in the *wild*, and also paves the way for the investigation of interoceptive accuracy. For example, quantifying visceral signals linked to anxiety in a less structured naturalistic/therapeutic environment becomes feasible by coupling a felt sensation of subjective anxiety with a heartbeat-tracking task and a behavioral measure (King & Parada, 2021; Quadt et al., 2018). Doing so would provide insights into how individuals perceive their bodily signals, and how these may be influenced by creative expression and reception. Predicting therapeutic outcome measures with neural biomarkers from MoBI recordings could be associated with patients' subjective experiences, thus providing an accessible approach for the necessary mixed-method research when working with clinical health populations. The utility of a mixed-methods approach in examining the interplay between neuronal dynamics and phenomenological descriptions, by combining neuroimaging and qualitative interviews, has been recently demonstrated in CATs research (Fachner et al., 2023; Poikonen et al., 2023; Tucek et al., 2022).

Here, we also highlight the consideration of neuroimaging studies of longitudinal changes within the psychotherapeutic relational context. The longitudinal approach corresponds with the temporal dynamics of aesthetic experiences that change over time (Aleem & Grzywacz, 2023; Brielmann et al., 2024; Starr, 2023b). Indeed, hyperscanning research on parent-child, youth-elderly, therapist-patient social interactions, which weave in behavioral/psychological observations can address the need and potential for longitudinal designs (Moffat et al., 2024; Russo & Senese, 2023; Sened et al., 2022, 2022b; Turk et al., 2022). The use of MoBI in a hyperscanning setting is at the forefront of advancing our understanding of the complex interaction between the brain, body, the environment, and social behavior (Crasso-Cladera et al., 2024).

Hyperscanning over multiple sessions could address several methodological aspirations, that is, ecological validity, two-brain design, and longitudinal assessment (Moffat et al., 2024). Incorporating MoBI recordings and associated subjective reports is of great significance for untangling the mechanisms underlying the link between neurophysiological and psychological effects of continuous therapy.

Summary and Conclusion

The abundance of theoretical and empirical literature interlinking neuroaesthetics and CATs offers novel integrative avenues to address the psychotherapeutic use of art forms for diverse clinical conditions. The untangling of an interwoven theoretical and applicable base for such interventions is crucial to the pursuit of human mental health and well-being.

The act of creating in an individually tailored therapeutic intervention entails aesthetic experiences that resonate with an individual's sense of self (Vessel et al., 2013) and engages multiple brain networks that interact to compose an aesthetic triad of sensory-motor, emotion-valuation, and knowledge-meaning processes (Chatterjee & Vartanian, 2016). This aesthetic triad meaningfully coincides with CATs therapeutic factors as interdependent processes of *externalization-concretization*, *embodiment*, and *symbolization*. The epistemic uncertainty inherent to creative processes and aesthetic experiences prompted by art-based therapeutic interventions hold great promise in triggering active inference and predictive mechanisms directed at future events (Lehne & Koelsch, 2015; Vaisvaser, 2021). Sensory systems pass on the surprising error that differs from expectation, which further serves to update the model (i.e., learning) of the self in the world. Within a relational constellation, these aesthetic "moments of meeting" may induce enhanced brain-to-brain synchronization, such that the predictive processing mechanism can be shared between interacting individuals.

There are many future directions and strategies to further strengthen evidence-based research on arts-based interventions in conjunction with brain circuitry and brain-body-mind interactions. There is growing recognition of the role of the arts in promoting human well-being (Bone & Fancourt, 2022). CATs stand to benefit from its integration and collaboration with psychology and neuroscience, but further systematic research is needed to establish its effectiveness and advocate for its integration into mainstream healthcare.

Understanding the mechanisms underlying psychotherapy, particularly when the creative expressive and receptive elements of aesthetic experiences are involved, is a complex task. Collaborative partnerships and technological progress hold promise for advancing interdisciplinary research at the intersection of neuroscience, the arts, and mental health (King, 2018; King & Parada, 2021).

Through engagement in relational aesthetic experiences, subjects become meaning-makers who dynamically co-evolve with the world they inhabit and predict. We believe valuable opportunities arise from the interdisciplinary approach presented in this work that acknowledges and intertwines the neurobiological and psychological processes involved in aesthetic creation. The relational context in which these processes occur in CATs further expands the value and promise of the psychotherapeutic use of the arts.

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