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Bara, Ionela; Binney, Richard J; Ward, Robert; Ramsey, Richard

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A generalised semantic cognition account of aesthetic experience

Ionela Bara [a], Richard J. Binney [a], Robert Ward [a], Richard Ramsey [b,*]

[a] Wales Institute for Cognitive Neuroscience, School of Human and Behavioural Sciences, Bangor University, Bangor, Gwynedd, Wales, LL57 2AS, United Kingdom
[b] School of Psychological Sciences, Macquarie University, Sydney, NSW 2109, Australia

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ABSTRACT

Given that aesthetic experiences typically involve extracting meaning from environment, we believe that semantic cognition research has much to offer the field of neuroaesthetics. In the current paper, we propose a generalised framework that is inspired by the semantic cognition literature and that treats aesthetic experience as just one example of how meaning accumulates. According to our framework, aesthetic experiences are underpinned by the same cognitive and brain systems that are involved in deriving meaning from the environment in general, such as modality-specific conceptual representations and controlled processes for retrieving the appropriate type of information. Our generalised semantic cognition view of aesthetic experience has substantial implications for theory development: it leads to novel, falsifiable predictions and it reconfigures foundational assumptions regarding the structure of the cognitive and brain systems that may be involved in aesthetic experiences.

1. Introduction

Art appreciation has a long history, with the first accounts of human-made art dating back to prehistoric times (Davies, 2012). The first instances of empirical investigation of aesthetic experience from a psychological perspective date back to the 19th century (Fechner, 1876). More recently, due to the advent of neuroimaging technologies, the field of neuroaesthetics has begun to reveal how human brain networks are organised during aesthetic experiences (Calvo-Merino et al., 2008; Chatterjee, 2010; Changeux, 1994; Iigaya et al., 2020; Kirsch et al., 2016; Zeki, 1999).

To date, an implicit assumption in many neuroaesthetics frameworks is that the form of cognition and brain function may vary between art and non-art contexts or aesthetic and non-aesthetic contexts (Chatterjee, 2010; Menninghaus et al., 2017; Pearce et al., 2016; Pelowski et al., 2016, 2017). In this paper, and like others recently (Skov and Nadal, 2018, 2020), we outline the value of using a more general framework to understand aesthetic experiences. To do so, we place aesthetic experiences within a semantic framework, which treats aesthetic experiences as just one example of how a sense of meaning can accumulate. We will argue that adopting a generalist framework to guide cognitive and brain-based investigations of aesthetic experiences has substantial implications for theory development, leads to novel predictions and reconfigures expectations regarding the basic cognitive and brain systems that may underpin aesthetic experiences.

Of course, we are not the first to suggest that general-purpose brain systems may play a role in aesthetic judgments. For example, visual (Zeki, 1999), motor (Kirsch et al., 2016; Freedberg and Gallese, 2007) and cognitive systems (Leder et al., 2004; Leder and Nadal, 2014) have previously been implicated in aesthetic judgments (for reviews, see Chatterjee, 2003; Chatterjee and Vartanian, 2014; Pearce et al., 2016). However, these prior accounts have always been framed from the viewpoint of how such systems operate within a specific and specialised context – that is, when making aesthetic judgments. We are proposing something different. We are proposing that it may be more fruitful to consider how meaning is derived from the environment *in general,* rather than how meaning is derived in specific situations that involve aesthetic judgments.

Defining clear and categorical boundaries between what is considered "aesthetic" and "non-aesthetic" is not easy or straightforward. Instead, we prefer to use feature mapping or dimensional approaches, which have been used previously in social cognition and psychopathology (e.g., Brown and Barlow, 2009; Oosterhof and Todorov, 2008; Cross and Ramsey, 2021). Under a dimensional view, different features of a situation (e.g., the task, stimuli, or context) can be more or less aesthetically-oriented. For example, we would consider the evaluation of visual clarity (Whittlesea et al., 1990), implied motion (Bara et al., 2021a, 2021b), or symmetry (Jacobsen and Höfel, 2003; Jacobsen et al.,

* Corresponding author.
E-mail addresses: ionela.bara@bangor.ac.uk (I. Bara), richard.ramsey@mq.edu.au (R. Ramsey).

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2006) to be less aesthetically-oriented than assessing liking, preference, or beauty.

Notably, the dimensional view applies equally to whole objects or scenes, as well as to different features of objects or scenes. For example, a naturally occurring fractal can be assessed as a whole object or by considering the distinct features that a fractal might hold, such as colour or symmetry. That said, irrespective of the target of evaluation (e.g., object-based or feature-based), the dimensional view considers variation along a set of relevant dimensions. One implication that follows from a dimensional approach is that objects, tasks or contexts that have fewer aesthetic qualities are not necessarily devoid of any aesthetic qualities. In the following, therefore, we use the terms "aesthetic" and "non-aesthetic" in a relative sense, one in which the former has more aesthetic qualities than the latter.

A key assumption in the current paper is that aesthetic experiences often involve deriving meaning from the environment. We refer to meaning here in a general sense, which reflects the acquisition of broad and diverse forms of knowledge and understanding of the world around us. On this basis, therefore, we suggest that whether experiences have more and less aesthetic features, they are likely to rely, at least partly, on the same cognitive and brain systems that process meaning and semantic information more generally. Without explicit theoretical or empirical justification to the contrary, we suggest that it will be beneficial to start from completely generalist positions, which make no mention of aesthetics specifically. Only if or when such general accounts are demonstrably false or clearly limited, should more bespoke frameworks be required. Our starting position, therefore, contrasts with the dominant starting position in the neuroaesthetics field, which assumes that something novel needs explaining in neuroaesthetics research that cannot be explained adequately through conventional and well-established lines of cognitive neuroscience research.

Fig. 1 illustrates our main argument. Most, but by no means all, neuroaesthetics research to date has used art experience as a model to understand aesthetic experience (Fig. 1i). Moving forward we agree with recent proposals that it may be beneficial for neuroaesthetics research to situate art experience within broader frameworks that are built to understand aesthetic and hedonic experiences more generally (Fig. 1ii; Skov, 2019a, 2019b; Skov and Nadal, 2018, 2021, 2020). In addition, in the current paper, we also go a step further and argue that it will be even more fruitful to consider aesthetic experience within an even broader and more general framework of cognitive and brain systems, such as the semantic cognition framework (Fig. 1iii). A clear prediction that follows from our central thesis, therefore, is that there should be far more similarities than differences in the structure of information processing across what are typically considered aesthetic and non-aesthetic contexts.

The main body of this article is organised into five parts. First, we review prominent brain-based models of aesthetic experience, which are tied to aesthetic contexts and make no mention of semantic cognition. Second, we outline a completely generalised framework for neuroaesthetics; one that treats aesthetic experience as just one example of how a sense of meaning develops. To do so, we adopt an established framework from the semantic cognition literature (Lambon Ralph et al., 2017). The motivation for adopting a semantic framework is the recognition that aesthetic experiences often involve drawing meaning from environmental cues. We therefore relate aesthetic experience to cognitive systems for deriving meaning from the environment, such as conceptual representations and context-dependent retrieval of information. Third, we compare the structure of the proposed model to the existing neurobiological models of aesthetic experiences. Fourth, we consider the implications of such a proposal for the field of neuroaesthetics, which spans updates to current neuroaesthetics models, as well as substantial revision to expectations more generally. Finally, we consider strengths, limitations, and constraints on the generality of the proposal.

2. Neurobiological models of aesthetic appreciation

Aesthetic experience has been modelled with reference to the neurobiological bases of aesthetic appreciation and hedonic value (Chatterjee, 2003; Chatterjee and Vartanian, 2014; Pearce et al., 2016; Skov, 2019a; Skov and Nadal, 2018, 2021, 2020, Fig. 2A and B). In addition, other important neurobiological approaches have highlighted the contribution of the default-mode network (DMN) to aesthetic experience (Cela-Conde et al., 2013; Vessel et al., 2013, 2019). Here, we focus only on two previous neurobiological approaches to aesthetics that are most relevant to our current goals. First, the most dominant neurobiological model proposes an aesthetic triad, which involves inter-relations between sensory-motor, affective-valuation and knowledge-meaning components (Chatterjee and Vartanian, 2014; Pearce et al., 2016, Fig. 2A). Each component of the aesthetic triad is associated with largely distinct neural networks and functional processes. Such neural circuits involve sensory-motor brain areas that are involved in perceptual and motor processes, the reward brain system known to be implicated in processing affective and pleasurable experiences and dorsolateral and medial frontal cortices that are involved in decision-making and so-called 'knowledge-meaning' processing (Chatterjee, 2003; Chatterjee and Vartanian, 2014). The 'knowledge--meaning' component appears to reflect a process of top-down control that biases the operation of other brain systems (Chatterjee and Vartanian, 2014, 2016). For instance, framing effects, changing the environment, the title or artistic status of images has been shown to alter neural activity and aesthetic experiences associated with the evaluation of identical paintings (Huang et al., 2011; Kirk et al., 2009; Lacey et al., 2011; Leder et al., 2006; Wagner et al., 2014, 2016).

A second neurobiological model places greater focus on hedonic value and the operation of brain circuitry associated with processing reward (Skov, 2019a, 2019b; Skov and Nadal, 2018, 2021, 2020);

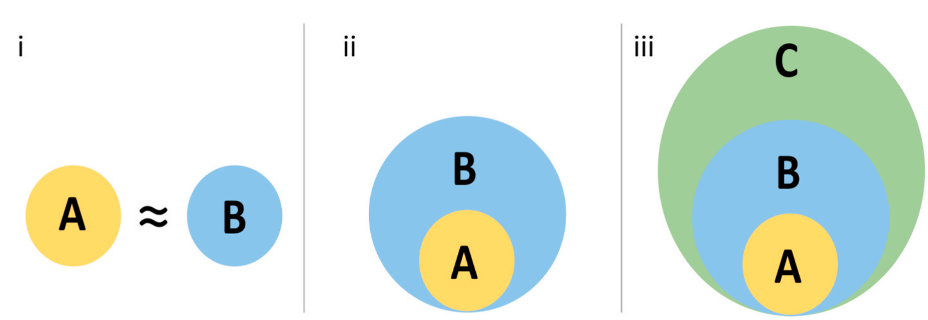

Fig. 1. Three proposed cognitive structures supporting aesthetic experience. A = the psychology of art experiences; B = aesthetic experiences; C = Semantic cognition. I) There is a tendency to use art experience as a proxy for understanding aesthetic experience. ii) Skov and Nadal (2020) propose that art experience overlaps with aesthetic experiences. iii) The semantic framework spans all instances where meaning is derived and therefore includes both art and aesthetic experiences.

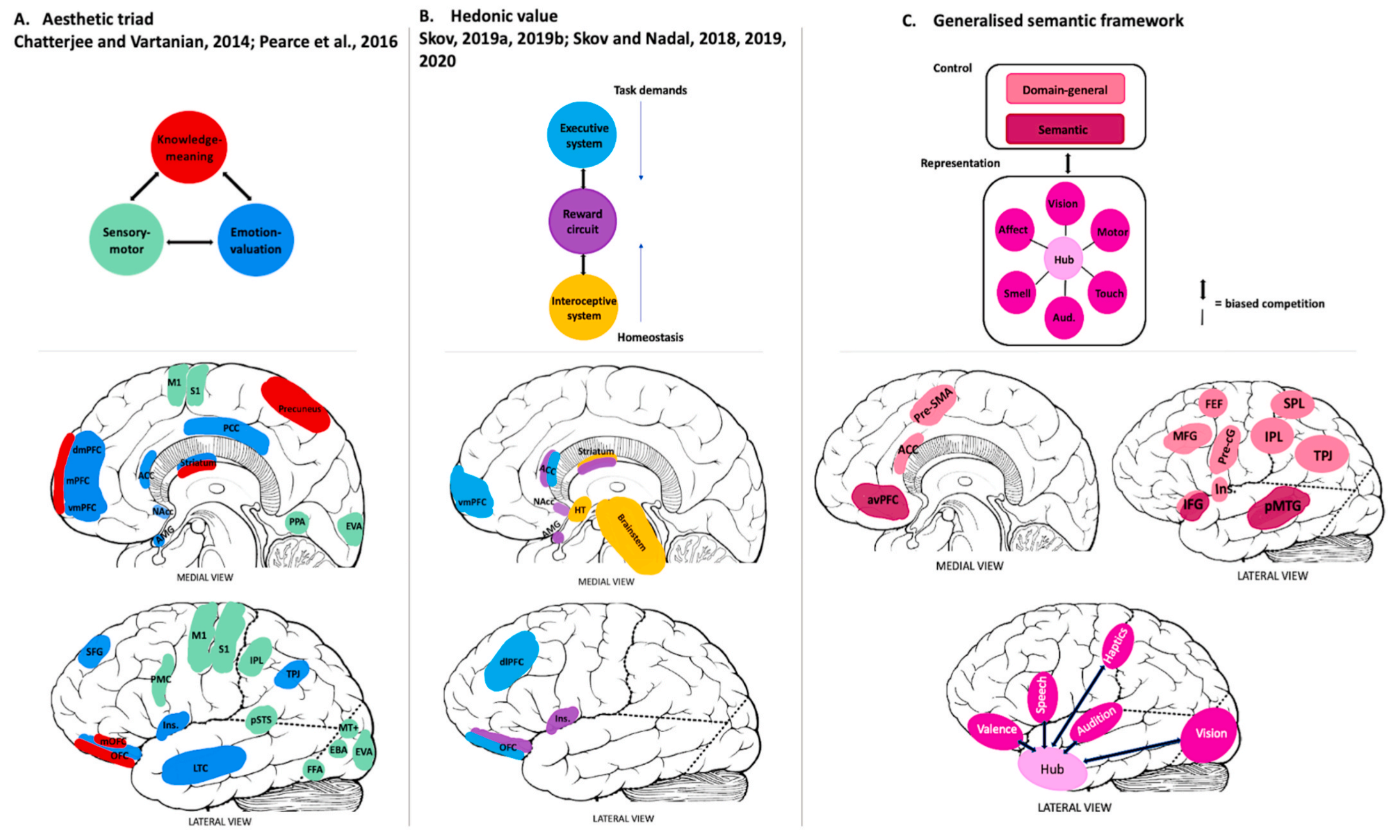

Fig. 2. A schematic representation of three neurobiological models. A) the aesthetic triad model and the neural correlates associated with meaning-knowledge, sensory-motor, emotion-valuation systems; B) the hedonic value model and the brain regions associated with executive system, reward circuit, interoceptive system; C) the generalised semantic framework and the neural correlates associated with representation and control systems. In addition, panel C illustrates the information integration from control and representational system, and from hub and spokes through a process of brain-wide biased competition.

Fig. 2B). Based on previous findings on the neuroscience of pleasure (Kringelbach and Berridge, 2017), Skov's (2019a, 2019b) model acknowledged that aesthetic experience involves the same brain circuitry as other hedonic experiences, thus highlighting the relative lack of specialised or dedicated neural systems in aesthetic processing. More specifically, Skov (2019a, 2019b) describes hedonic aesthetic value signals as integrating the sensory-perceptual input, the projections from top-down decision-making systems and from the bodily interoceptive system (Fig. 2B). An important principle underlying Skov's (2019a, 2019b) model is that aesthetic experience can be treated as a sub-category of more general processing of hedonic value. Consequently, one may understand aesthetic experience by understanding the cognitive and neural systems that support hedonic value more generally.

Both of these prior neurobiological models have made considerable progress towards building an understanding of neuroaesthetics. At the same time and given that aesthetic experiences often involve inferring meaning, we feel that there is a great opportunity for the field of neuroaesthetics to benefit from embracing established models from semantic cognition. Notably, the semantic cognition literature has studied the cognitive, neurobiological and computational principles of how meaning is arrived at in general and therefore this work seems particularly relevant to consider in more depth (e.g., Lambon Ralph et al., 2017; Jefferies, 2013). More specifically, we feel that interfacing with the semantic cognitive literature will provide a framework to extend and develop the 'meaning-knowledge' component of the aesthetic triad model (Chatterjee and Vartanian, 2014) and also add a semantic component to model proposed by Skov (2019a, 2019b), as we outline in the next sections.

3. Rethinking neuroaesthetics: a generalised semantic cognition view of aesthetic experience

In this section, we outline our approach to modelling aesthetic experiences from a cognitive and neurobiological perspective. Our starting point is different to prior accounts, as we embed aesthetics into an account of people's ability to interpret meaning in the environment. Under such a view, aesthetic experiences have similar features to many other complex and multimodal experiences, and therefore they may rely on a similar set of cognitive and brain mechanisms. We share a similar motivation and set of principles to some prior work, which also favoured a general set of systems (Skov and Nadal, 2018, 2020). However, we go further and frame aesthetic experiences within a well-established semantic framework, one that includes affective processing, but is not centred on affective processing.

3.1. Basic features of the semantic framework

In this section, we outline the basic tenets of the controlled semantic cognition (CSC) framework (Lambon Ralph et al., 2017). We first outline key computational principles before detailing the neurobiology of the framework.

3.1.1. Computational principles

The CSC framework is divided into two principal sub-systems: representation and control (Lambon Ralph et al., 2017). The representational sub-system contributes to both gathering and storing conceptual knowledge and it is characterised by a hub-and-spoke organisation. The hub-and-spoke structure refers to the idea that modality-specific systems distributed across the brain (the 'spokes') play an essential role in supplying the information required to establish concepts, namely our multimodal sensorimotor, linguistic, and affective experiences of concept exemplars. The supramodal hub is distinct from the spokes and serves two functions: 1) it mediates transmodal interactions between different modes of input from the 'spokes' and 2) it encodes a deeper level of representation that abstracts beyond a linear combination of such inputs from the 'spokes'. This deeper and more abstract level of representation is argued to be critical for the production of generalisable concepts. For example, the concept "dog" has modality-specific semantic representations in the 'spokes' relating to sounds, smells, appearance, and actions. The representation of dog at the level of the hub associates these modality-specific representations together, to provide an integrated and fuller semantic representation of the concept "dog".

The second sub-system of the CSC framework is responsible for controlled processes required for retrieving the appropriate type of knowledge. Control processes are a necessary feature of the framework because our extensive and varied experiences of words, people and objects result in deep and complex representations, and in many circumstances, we need only to retrieve a few details. Indeed, automatically retrieving all aspects of our knowledge would be computationally expensive and might be inappropriate and/or interfere with our ability to achieve our goals. For example, the pianist need not retrieve all their expert knowledge of how to use their instrument to play a concerto, if their only task be to move it across the stage (Saffran, 2000). The CSC framework distinguishes between two types of control: domain-general control and semantic control. Domain-general control operates in all contexts (e.g., orienting attention to salient locations in space), whereas semantic control is particularly linked to control processes that operate in semantic contexts (e.g., prioritising and directing attention to which aspects of meaning are most relevant to a given context). For example, the word "bark" has multiple meanings and control processes are required to guide whether in a particular context, the bark on a tree is more relevant than the bark of a dog. Importantly, the two key tenets of the CSC framework - representation and control - do not operate in a manner that is completely detached from each other. Instead, they dynamically interact and integrate semantic information.

3.1.2. Neural substrates of the CSC framework

The representational spokes are distributed throughout the brain and span the full range of sensory-motor and affective signals, such as brain circuits associated with vision, touch, olfaction, motor control and reward (Fig. 2C). The supramodal hub, by contrast, is located within the anterior temporal lobes (ATL). Converging evidence from neuropsychological examinations of semantic dementia patients has demonstrated that the ATL plays a critical role in sustaining conceptual knowledge (Coccia et al., 2004; Piwnica-Worms et al., 2010; Lambon Ralph et al., 2001).

Semantic control is associated with a range of brain regions, including the ventrolateral prefrontal cortex and temporoparietal cortex (Noonan et al., 2009; Whitney et al., 2011), and extended to middle frontal gyrus and posterior inferior frontal sulcus (Fedorenko et al., 2012). As such, control processes partially overlap with extensive evidence for domain-general cognitive control and executive functions, which have been associated with frontoparietal cortex (Botvinick et al., 2004; Corbetta et al., 2008; Duncan, 2010; Petersen and Posner, 2012).

3.2. A generalised semantic cognition view of aesthetic experience

The CSC framework has recently been used to model another domain of cognitive neuroscience, which involves social information processing (Binney and Ramsey, 2020). In this section, we use a similar strategy to apply the CSC framework to aesthetic experience.. Before we outline the specifics of the model in relation to aesthetic experiences, however, we want to make two general points. First, it should be noted that the CSC framework has a parallel distributed processing (PDP) structure which assumes interactionist principles between different processors (McClelland and Rumelhart, 1981). Second, the main focus in semantics has been on acquiring and storing of conceptual knowledge. Here, in contrast, we use the semantic framework as a model to understand how one may understand mental processes that may occur during ongoing, live aesthetic experiences, which emphasises the retrieval or access of semantic knowledge. In the following sub-sections, we use an example piece of visual art - Sorolla's painting in Fig. 3 - as a running example to illustrate how the 'spokes', the 'hub' and the control systems would operate together during aesthetic experiences.

3.2.1. Sensorimotor 'spokes'

The first set of spokes considered are sensorimotor representations. Prior neuroaesthetics research has highlighted that aesthetic experience is partly associated with sensory systems, such as those underpinning visual, auditory or somatosensory processes (Chatterjee et al., 2009; Chatterjee and Vartanian, 2014; Iigaya et al., 2020, 2021; Kawabata and Zeki, 2004; Vartanian and Goel, 2004; Yue et al., 2007; Zeki, 1999). In the case of Sorolla's painting, therefore, the observer's visual system can recognise stimulus features, which serve as the target of aesthetic evaluation (e.g., blue sea, rocky landscape, the two people). In this case, category-selective responses in the ventral visual pathway are likely to be important in the detection of visual features such as motion cues, faces, bodies and natural landscapes (Kanwisher, 2010, 2017; Spiridon and Kanwisher, 2002; Zeki, 1999). Indeed, responses in the visual system have been shown to be modulated by aesthetic preferences (Calvo-Merino et al., 2010; Chatterjee et al., 2009; Iigaya et al., 2020; Kawabata and Zeki, 2004; Orgs et al., 2013; Vartanian and Goel, 2004; Yue et al., 2007).

Similarly, due to the implied action of the two characters, we would expect that the action observation network in inferior frontal and parietal cortices would be engaged, thus reflecting the motor information that is implied in visual images (Calvo-Merino et al., 2008; Caspers et al., 2010; Cross et al., 2009, 2011; Di Dio and Gallese, 2009; Orgs et al., 2008; Urgesi et al., 2006). The action observation network, therefore, would be another domain-specific representational "spoke", which also has been shown to contribute to aesthetic experiences (Kirsch et al., 2016). Finally, given the social interaction between two agents, we would also expect posterior superior temporal sulcus to be engaged (Isik et al., 2017; Walbrin et al., 2018).

3.2.2. Affective 'spokes'

The second relevant 'spoke' in the representational system concerns affective responses that are associated with rewarding and pleasurable experiences, as well as experiences one would wish to avoid. In regard to assessing hedonic value, it has been demonstrated that art and non-art stimuli are assessed in terms of positive and negative hedonic value. The assessment of hedonic value has been associated with a distributed neural circuit that spans prefrontal cortex, orbitofrontal cortex (OFC), the ventral striatum, anterior cingulate cortex, insula, and amygdala (Berridge et al., 2009; Brown et al., 2011; Skov, 2019a). As such, whichever aspects of Sorolla's painting an individual may find rewarding or not, we would expect an affective representation to be signalled in these brain regions. In principle, valence or affective signals can be associated with basic image properties (colour, form, symmetry, visual complexity), the human form, the representation of a mother and child, as well as waves crashing into rocks. There could also be a mixture of differently valenced signals in one piece of artwork. For example, the viewer might positively evaluate the two characters as mother and daughter, but negatively signal that the rocky path is difficult to climb. Such valence signals are of course central to any notion of preference whether in an art or non-art context.

3.2.3. The supramodal 'hub'

In contrast to processes within the 'spokes', the supramodal 'hub' would integrate conceptual information from multiple modalities. Therefore, diverse signals from all the 'spokes' would combine in the

Fig. 3. Clotilde and Elena on the Rocks at Javea by Joaquin Sorolla, 1905. Joaquin Sorrolla y Bastida (1863–1923) is one of the great Spanish painters, famously known as the 'Master of Light' (Allen, 2019) for his iridescent representations of seascapes, portraits and typical Spanish life scenes. The main two characters illustrated in this painting are his wife Clotide and his youngest daughter, Elena having a walk on the rocky shore of Javea.

ATL to produce an integrated conceptual representation. In the case of Fig. 3, the joint semantic representation in the ATL would combine affective signals with sensory motor representations that were derived from observing the image, as well as the affective signals from the reward system. Indeed, previous neuroimaging studies have demonstrated that operations in the ATL are based on continuous interaction with modality-specific systems and lower-order heteromodal association cortices (Kuhnke et al., 2021; Patterson et al., 2007; Pobric et al., 2010).

Current evidence for ATL involvement in aesthetic processing is complicated and hard to interpret for several reasons. Some research has implicated in the ATL in semantic processing, which spans meta-analyses (Vartanian and Skov, 2014), as well as studies of art (Jacobsen et al., 2006; Kirk et al., 2009) and music (Koelsch, 2014). In contrast, other studies have not implicated the ATL. One obvious limitation with current evidence stands out. Signal loss and image distortion is well documented in the ATL due to the use of standard or conventional imaging protocols in fMRI (Devlin et al., 2000). As such, it is hard to interpret a lack of ATL engagement under these scanning conditions. In the future, researchers should adopt newer imaging protocols, as well as post-acquisition distortion correction techniques that have been successfully employed to assure signal throughout the ATL (Jackson et al., 2016; Rice et al., 2018).

A further consideration for future research studying ATL involvement in aesthetics is the anatomical mapping of ATL and its graded semantic function. Previous research has defined ATL broadly as the anterior half of the temporal pole including BA 38, the anterior superior, middle and inferior temporal gyri and sulci plus the fusiform gyrus (Binney et al., 2010). Previous research has also highlighted the ATL's graded function in meaning extraction, such that certain aspects of the ATL are more involved with certain modalities (Binney et al., 2016; Olson et al., 2013; Rice and Lambon Ralph, 2015). To more systematically and comprehensively probe the role of the ATL in aesthetics, a detailed understanding of the anatomical mapping and graded semantic function would be required to formulate more specific hypotheses.

3.2.4. *Cognitive control*

In the case of Sorolla's painting in Fig. 3, we would expect processes associated with semantic control to regulate responses in other brain regions depending on a range of factors, such as whether you see the stimuli in an art gallery, whether you have prior knowledge of the artist, piece of art or style of art. For example, we would expect semantic control to be relevant to guide and prioritise which features are most important if you are asked to classify the type of art (expressionist, abstract etc.) versus asked to evaluate the meaning of the artwork. Evaluating the type of art may be addressed by focussing on superficial assessment of the basic features and judging whether it is expressionist or abstract, for example. In contrast, if you were asked to evaluate the meaning of the artwork, it may require one to go beyond the surface-level features and consider more abstract concepts, such as the importance of mother-daughter relationship or any hidden meanings that might be expressed symbolically rather than literally. In a similar vein, previous studies have proposed a meaning-driven mechanism that requires top-down processing to explain the semantic incongruities or the aesthetic preference for challenging and ambiguous art (Belke et al., 2015; Markey et al., 2019; Muth et al., 2015). Moreover, research investigating the top-down effects on implicit face preference judgments (Chatterjee et al., 2009; Kim et al., 2007) have provided support for the always-on hypothesis (Wassiliwizky and Menninghaus, 2021), suggesting that some elements of aesthetic preference might operate without explicit aesthetic awareness.

To date, only a small amount of prior work in neuroaesthetics has focussed on the role of cognitive control. For example, Cupchik et al. (2009) found that brain areas associated with reward processing were involved in aesthetic liking and evaluation processes, whereas the activation of the lateral prefrontal cortex was interpreted as the top-down attentional effort required in regulating high task demands. Such findings mark the interplay between representational and control processes, but do not address whether such control processes are semantic or general in nature.

4. Biased competition

Although our model is largely based upon the CSC framework, we also make one important addition, which is not specified in the CSC framework. The CSC framework does not provide a mechanism by which information in different processors becomes integrated. In the current model we suggest that integration between processors occurs through biased competition (Fig. 2C). Biased competition frameworks have been used in cognitive neuroscience to provide a means for communication between different brain systems through the combination of signals from multiple processors (Beck and Kastner, 2009; Desimone and Duncan, 1995; Duncan et al., 1997). The basic idea is that different information processors across the brain process visual, motor and affective information, and signals from these processors settle on the "winning" target of attention, which guides a behavioural response (see Ramsey and Ward, 2020a, 2020b) for more detail about biased competition in social contexts).

In much the same way, we suggest that neuroaesthetics could apply the principles of biased competition as a roadmap for how signals from multiple processors may be combined. From this perspective, aesthetic judgments are arrived at through a process of biased competition whereby there is mutual influence within and between systems of representation and control. As such, competition would occur between control and representational systems, and also between the hub and spokes. In the case of Fig. 3, signals from the spokes would bias processing in the hub and the control circuits would bias the representational units. Under this view, aesthetic experiences would represent a dynamic and evolving flux of signals across a widespread neural architecture, which at any one time would provide a sense of aesthetic evaluation.

Importantly, this basic principle of biased competition would operate the same across all contexts whether or not there was a strong affective component. Indeed, signals from diverse sub-systems across the brain would compete and settle on a target of attention or judgement, whether one was choosing their favourite t-shirt to wear, having lunch with a friend, climbing a mountain, doing sums or evaluating architectural elegance.

For example, Sorolla's painting (Fig. 3) illustrates an outdoor scene containing multiple objects that would compete with each other via activation of neural representations (e.g., sensorimotor, affective) to become the "winning" target of attention. Indeed, there would be competition between the neural representation of the rocky shore in the background and the human bodies in the centre of the painting. The winner would gain an advantage in processing weight due to its greater relevance in that context. The type of relevance that can influence the processing weight can include, but is not limited to, current contextual, affective, and attentional states, as well as object features such as colour, shape, and luminance. All else being equal, if we assume that the human bodies hold higher relevance and bias than the rocky shore in this context, it would mean that the human body would become the primary target of attention and the processing of meaning.

5. Model comparison

5.1. Compared to prominent neurobiological models of aesthetics

There are at least two key differences between our model and all prior neurobiological models of aesthetics. First, we include a role for a supramodal 'hub', which no other account of aesthetics has included. The supramodal hub is important in integrating functionally relevant information from distributed modality-specific regions, thus it is critical in providing an extra computational capability to the model in order to draw coherent and generalisable concepts together. Second, we also propose an account of how system-wide neural integration occurs via biased competition. By doing so, we provide a solution to the computational problem of multiple processors acting in parallel by providing an adaptive mechanism to accommodate both the maintenance of modality-specific representations with controlled selection and prioritisation processes.

5.2. Compared to the aesthetic triad model (Chatterjee and Vartanian, 2014; Pearce et al., 2016)

Although there are many similarities, the major difference between our model and the aesthetic triad model concerns the 'knowledge-meaning' component. In the aesthetic triad model, 'knowledge-meaning' is a separable component that is dissociable from 'sensory-motor' and 'affective-valuation' components, and which largely resembles functions associated with top-down cognitive control (Fig. 2A). In our model, meaning is a product of the interaction between representation and control systems (Fig. 2C). Therefore, meaning in our model is not restricted to specific neural circuits or dissociable from sensorimotor and affective representations or cognitive control resources. Instead, representation and control circuits are both part of the signal that gives rise to meaning.

5.3. Compared to the hedonic model of aesthetics (Skov, 2019a, 2019b; Skov and Nadal, 2018, 2021, 2020)

The major difference between our proposal and the hedonic value model is one of scale and emphasis. Our model is similar to Skov (2019a, 2019b) in terms of the proposed role for domain-general affective and reward processing. The difference in our model is that we provide much more scaffolding around the reward system, in terms of other cognitive and brain processes. In some ways, therefore, the Skov (2019a, 2019b) model is subsumed entirely within our model. We provide a more elaborate account of the non-reward processes that we feel are also likely to play key roles in aesthetic process in combination with reward processing. As such, we do not see any disagreement between our model and Skov's (2019a, 2019b) model; instead, we just see our model as a substantial extension of the Skov (2019a, 2019b) model.

6. Implications

In this section, we outline three implications for neuroaesthetics research that follow from our generalised semantic account of aesthetic experience.

6.1. There may be, counterintuitively, less to explain

A theoretical re-positioning towards similarities over differences when comparing aesthetic and non-aesthetic cognition has one very general implication. The field of neuroaesthetics may have considerably *less* to explain than it initially appeared. It may seem an odd or counterintuitive argument, but some of the intrigue and mysticism that surrounds aesthetic experiences may dissolve and thereby need no additional explanation in terms of cognitive and brain systems. Or, at the very least, such experiences may need the same sort of explanations as routine experiences such as why someone has a favourite coffee mug or why they find someone's face more attractive than another face. For example, general preferences for features and experiences that appear on average across individuals may be combined with personal preference and engage reward circuits accordingly. Indeed, many life experiences, if not every experience to some degree, have hedonic value and these play a critical part in human motivated behaviour (Dickinson and Balleine, 2010; Symmonds and Dolan, 2012).

6.2. Cognitive and brain models of aesthetics require updating and revision

A second implication of the current proposal is that neuroaesthetics models should be updated to embrace and include contemporary research on semantic cognition. For example, by re-conceptualising the cognitive and brain systems that underpin how meaning is extracted from the environment, we have demonstrated how semantic cognition research can extend current models of neuroaesthetics. Moreover, it is worth noting that these changes are not trivial, but instead reflect a major reworking of how meaning is determined in terms of cognitive and brain systems. As such, our proposal transforms the way basic building blocks of cognition may be expected to integrate information in aesthetic contexts. Such a reworking in expectations is important to acknowledge because it leads to novel and falsifiable predictions, as we outline in section 7.

6.3. *Generalist approaches are an important way to determine if aspects of aesthetic experience rely on distinct processing mechanisms*

Informally, a criticism that our approach has received is that aesthetic experience is *a priori* a unique and even sublime form of human experience, which may be underpinned by a partially distinct set of cognitive and brain mechanisms. Our response is: prove it. We argue that the only way to prove that aesthetic experience relies on partially distinct processing mechanisms is to start as we are, by assuming that aesthetic experience is a generalised form of meaning extraction and then falsify that position. This means the field must consider the power inherent in a general semantic framework, which makes no mention of aesthetics specifically. From there, predictions that the model makes can be tested and potentially falsified.

7. Predictions, strengths, limitations, and constraints on generality

7.1. *Predictions*

The model provides clear and falsifiable predictions. By definition, generalist positions inherently predict that differences will be minimal compared to similarities when comparing information processing mechanisms across a variety of contexts. In other words, it is expected that largely similar mechanisms will be at play across aesthetic and non-aesthetic contexts and such predictions can be tested empirically. More specifically, we would expect the same interactions between the supramodal hub, the modality-specific spokes and the executive systems, which have been demonstrated previously in semantic contexts (e.g., Lambon-Ralph et al., 2017), to operate the same in aesthetic and non-aesthetic contexts. As one concrete example, a series of experiments in our lab tested the hypothesis that executive control processes operate in a largely similar manner across aesthetic and non-aesthetic contexts (Bara et al., 2021b.). The results suggest that across different experimental contexts, as well as distinct aspects of working memory (visual and verbal), executive resources are deployed in a largely similar manner in aesthetic contexts compared to non-aesthetic contexts. As such, the results provide support for our proposed model, in that common cognitive resources are deployed across aesthetic and non-aesthetic judgments.

7.2. *Strengths*

Here, we outline two major strengths of the proposal. First, the proposed model follows relatively well-established principles of brain organisation, which are based on decades of cognitive neuroscience evidence, spanning distinct research domains and methodologies: neuropsychology, neurostimulation and neuroimaging methods (Duncan, 2010; Petersen and Posner, 2012; Lambon-Ralph et al., 2017). This provides firm empirical ground, robustness and credibility in supporting the theoretical framework. In addition, the proposed framework fully embraces domain-general features of cognition such as prioritisation and selection, which, by definition, are engaged to some extent across all processes and contexts, including aesthetic experiences. Therefore, it makes more effective use of existing knowledge and frameworks rather than remaining more encapsulated from such work.

Second, generalist frameworks are computationally efficient, in the sense that they explain the same set of information processing steps with fewer processing components or add-on assumptions. By doing so, generalist theoretical positions also provide a natural framework to generalise to a broader class of object, which includes everyday items, such as photos, tools, landscapes, faces and bodies. Indeed, no new computational add-ons are required to incorporate a new object type or setting, such as attractiveness judgments and mate preferences in everyday life.

7.3. *Limitations*

A possible criticism of the proposed model is that it seems reasonable to expect that any generalised framework has the potential to suffer a loss in specificity. That is, there may be some instances of aesthetic experience that are not well accounted for by the proposed semantic framework. We accept that this is a valid criticism and that we should expect a loss in specificity in some instances. We suggest that part of the empirical challenge is to identify, quantify and qualify the nature of any lack of specificity. In other words, we should identify what, if anything, is missing, which requires further, more bespoke computational processes to be added. Another possible critique of the current framework might be that we have not reviewed research on the neuropsychology of art (Bäzner and Hennerici, 2007; Chatterjee, 2004, 2006; Sacks, 1995; Zaidel, 2015). Although acknowledging that a detailed discussion about the role of ATL in neuropsychological deficits and aesthetic experience would be a valuable extension of our framework, we do not have the space to cover it adequately here.

Finally, we recognise that the current framework does not address how variations in exposure to cultural artefacts shape the understanding of aesthetic experience. However, we acknowledge previous contributions on that topic (Germine et al., 2015; Vessel et al., 2018) and also emphasise that how experience shapes aesthetic processing more generally is a valuable and relatively under-studied line of research (Kirsch et al., 2016).

7.4. *Constraints on generality*

As previously suggested, it can be helpful to be explicit regarding the generality of our proposal (Simons et al., 2017). We are not claiming that the aesthetic experience is not “special” in an everyday sense or on a phenomenological level. That is, we are not suggesting that aesthetic or art experiences are not rich and fulfilling experiences. People make and engage with works of art in museums, galleries, and performances around the world, and art creation and appreciation has been shaped through education, cultural development and transmission of knowledge, practices, and values (Bell, 1914; Carroll, 2000; Dutton, 2009; Krumbein et al., 1994; O'Neill et al., 2017; Scott, 2013). That is special. What we are claiming is that the cognitive and brain systems that underpin aesthetic experience are not special purpose, and may share much greater similarity with cognitive processes that are typically not considered to reflect or underpin the experience of art and aesthetics more generally (Skov and Nadal, 2018).

Second, we are not claiming that our proposed semantic framework explains all of aesthetics. That is simply impossible. There are many aspects of aesthetics, which are beyond the scope of our model, and potentially all neurobiological models of aesthetics. For example, at present, our semantic account does not distinguish between different types of meaning that could be relevant in aesthetic contexts. However, our starting point would be that different types of meaning may be supported by largely similar cognitive and brain structures that have been outlined in our framework. Nevertheless, investigating how different types of meaning are processed in terms of cognitive and brain systems would be a valuable direction for future neuroaesthetics research.

Furthermore, a focal aspect of aesthetic experiences is likely to concern how value is assigned to different aspects of the world or how emotions are expressed. Such processes may, of course, be inherently meaningful. We are just not suggesting that aesthetics is only concerned with deriving meaning from the environment without reference to any other processes. We are, however, making two more restricted claims. First, we are claiming that meaning has to be a central and large part of any understanding of aesthetics, which makes existing semantic frameworks particularly relevant. Second, we are claiming that in terms of the same type of cognitive and brain mechanisms that prior aesthetics-specific models have focussed upon such as visual, motor and cognitive processes (Chatterjee, 2003; Chatterjee and Vartanian, 2014; Pearce et al., 2016), our proposed model gives a computationally efficient answer to the same questions without requiring any special focus on aesthetic contexts.

Finally, we are not suggesting that the proposed semantic framework is the only generalist framework that may be useful to consider. We provide it as a worked example to illustrate the broader point that generalist frameworks can provide considerable value. Examples of useful alternative generalist frameworks may include attention and memory. Indeed, the role played by cognitive control processes in aesthetic experience has been previously considered by most of the cognitive information processing frameworks (Graf and Landwehr, 2015; Leder et al., 2004; Leder and Nadal, 2014; Pelowski et al., 2017). However, the extent to which aesthetic and non-aesthetic judgments involve similar modular stages of cognitive processing - from early automatic to intermediate and late controlled cognitive processing levels - has been modestly investigated. Therefore, connecting neuroaesthetics to broader domains of cognitive neuroscience, such as the executive control research would provide useful paths to examine aesthetic specificity (Duncan, 2010; Petersen and Posner, 2012).

8. Conclusion

For neuroaesthetics research to develop further, we argue that one fruitful future direction would be to adopt more generalist theoretical frameworks. In order to demonstrate the benefits of embracing generalist perspectives, we propose a novel generalised framework inspired by semantic cognition research, which treats aesthetic experiences as one example of a meaningful experience. Our proposal outlines that meaning derived in an aesthetic context should rely on largely overlapping and similar cognitive and brain systems than those that are typically considered non-aesthetic contexts. The benefits for theory development are fourfold: (1) it is a more efficient use of resources and has firmer empirical foundations by leveraging already well-established research programmes; (2) it provides novel and falsifiable predictions; (3) it naturally generalises to a wider class of objects and contexts; and (4) it encourages researchers to address boundary conditions between art and aesthetics and a wider array of objects and settings.

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