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Emotions, Simulation, and Abstract Art

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Abstract

Some people feel emotions when they look at abstract art. This article presents a 'simulation' theory that predicts which emotions they will experience, including those based on their aesthetic reactions. It also explains the mental processes underlying these emotions. This new theory embodies two precursors: an account of how mental models represent perceptions, descriptions, and self-reflections, and an account of the communicative nature of emotions, which distinguishes between basic emotions that can be experienced without knowledge of their objects or causes, and complex emotions that are founded on basic ones, but that include propositional contents. The resulting simulation theory predicts that abstract paintings can evoke the basic emotions of happiness, sadness, anger, and anxiety, and that they do so in several ways. In mimesis, models simulate the actions and gestures of people in emotional states, elicited from cues in the surface of paintings, and that in turn evoke basic emotions. Other basic emotions depend on synaesthesia, and both association and projection can yield complex emotions. Underlying viewers' awareness of looking at a painting is a mental model of themselves in that relation with the painting. This self-reflective model has access to knowledge, enabling people to evaluate the work, and to experience an aesthetic emotion, such as awe or revulsion. The comments of artists and critics, and experimental results support the theory.

Keywords

Abstract art, aesthetics, beauty, emotions, mental models, simulation

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1. Introduction

People look at works of visual art for various reasons. The three most salient seem to be to evaluate them, to feel emotions, and to gain artistic and intellectual insights. The literature on these topics is too vast to digest here, and so we have chosen to focus on abstract art, and a mystery that it shares with pure music. Even though music and abstract art are not about anything—they express no propositions, they both can evoke emotions and aesthetic experiences. Indeed, recent studies have localized regions of the brain that are active during such aesthetic experiences (e.g., Boccia *et al.*, 2016; Cela-Conde and Ayala, 2018; Ishizu and Zeki, 2011; Pepperell, 2018; Vessel *et al.*, 2013; Zeki, 2004). These studies have initiated the field of neuroaesthetics, and they have shown that art, even its abstract variety, evokes emotions. Other recent studies have led to cognitive theories of what the brain computes in perceiving art. The Vienna Integrated Model of Art Perception (VIMAP) describes seven stages in the perception of visual art, with feedback between them, and it characterizes various essential processes – cognitive appraisals and interpretations of meaning – and their role in the evocation of emotions (Pelowski *et al.*, 2017). The approach has influenced our own theorizing. Three questions, however, remain unanswered:

- First, which particular emotions does abstract art evoke?
- Second, granted that it evokes certain emotions, what mental processes underlie their evocation?
- Third, what underlies aesthetic emotions to abstract art?

Existing theories have answered in part some of these questions. None provides complete answers to them all, e.g., they do not describe the particular emotions that abstract art evokes. We have formulated a new *simulation* theory that aims to answer the three questions in detail.

The simulation theory is based on two precursors, which we have described elsewhere: the theory of mental models (see, e.g., Johnson-Laird, 1983; Johnson-Laird *et al.*, 2021), and the communicative theory of emotions (see, e.g., Oatley and Johnson-Laird, 1987; 2014). Our focus is on those components of them that contribute to the simulation theory. In what follows, this article presents the mental model theory (Section 2) and the communicative theory of emotions (Section 3). It outlines how their combination in the simulation theory applies to representational art (Section 4). It then applies the simulation theory to abstract art (Section 5), spelling out the set of basic emotions that it should evoke, how it evokes them, and summarizing the theory's testable predictions. It shows how a model of one's own self underlies awareness and aesthetic judgements that evoke emotions (Section 6). It reviews

evidence for the simulation theory (Section 7). And it concludes with answers to the three principal questions (Section 8).

2. Mental Models and Simulation

The idea of mental models goes back to Craik (1943), who suggested that humans construct small-scale models of the world in order to make decisions. These models, he suggested, need not have any structural resemblance to what they represent. What matters is only that given an input, they yield the same output as occurs in reality (ibid., p. 51). In contrast, the more recent mental model theory postulates that they are *iconic,* that is, their structure corresponds insofar as possible to the structure of what they represent (Johnson-Laird, 1983, p. 125). So, iconic models underlie visual images, whether perceived (Marr, 1982) or imagined (Johnson-Laird, 1983), and they are also the result of understanding descriptions. Reasoning is based on these models. In contrast, alternative theories postulate that the 'language of thought' is made up from syntactically structured strings of symbols, such as occur in computer programs (Fodor, 1975; Pylyshyn, 2003). For many years, psychologists likewise took for granted that human reasoning was based on logical rules of inference that manipulated such strings (e.g., Rips, 1994). Experiments refuted this hypothesis. The difficulty of inferences did not depend on the number of steps in formal proofs designed to predict it (see Johnson-Laird and Byrne, 1991, for a review). Consider, for instance, this spatial inference:

- The circle is on the left of the rectangle.
- The square is below the circle.
- Therefore, the square is diagonally below and to the left of the rectangle.

If its premises are represented as strings of symbols, such as those from proofs in logic:

- On-left-of (circle rectangle).
- Below (square circle).

they call for complex rules of inference, or axioms, that make possible conclusions such as the one above. Cognitive scientists have tried to formulate such rules, but it is difficult to ensure that they are complete (ibid., p. 95). A much simpler solution is to use the meanings of the premises to construct a mental model of the spatial layout (ibid., p. 96):

This layout is from Malevich's abstract painting of 1915: *Suprematism Self Portrait in Two Dimensions*. However, models can be abstract and contain symbols for concepts that are impossible to visualize, such as possibility, intention, and ownership (Johnson-Laird, 1983, p. 416). Their structure still yields inferences, and the number of distinct models needed for a valid deduction predicts its difficulty (e.g., Johnson-Laird and Byrne, 1991).

Other evidence for mental models occurs in studies of the imaginary rotation of objects, which show that people can rotate models in the picture plane and in depth (Metzler and Shepard, 1982). When individuals envisage a set of pulleys or cogs, their mental models animate the movement of each cog one at a time (e.g., Hegarty and Just, 1993). Kinematic models unfold in time to simulate a temporal sequence of events. They enable individuals to imagine movements of cars in a train on a railway track in order to rearrange them (Khemlani *et al.*, 2013). Analogous simulations are crucial for readers to understand novels and short stories, and to empathize with their characters (e.g., Mar, 2018; Mar and Oatley, 2008; Oatley, 2016). In sum, the mental model theory specifies what is computed and how it is computed in comprehension and reasoning. Computer programs have implemented various applications of the theory (e.g., Khemlani and Johnson-Laird, in press), and fMRI studies have identified regions in the brain for processing mental models (e.g., Knauff *et al.*, 2003; Kroger *et al.*, 2008).

3. Emotions: Basic and Complex

The communicative theory of emotions postulates that cognitive appraisals of situations can evoke emotions. Other theories make this claim and so we have reviewed them (Oatley and Johnson-Laird, 2014; see also Scherer, 1999), and we consider several of them later in our analysis of aesthetic emotions. None of these theories, however, addresses the question of which particular emotions abstract art can evoke. A quite different approach to the psychology of emotions makes an instructive contrast: when you feel an emotion on looking at a picture, it is constructed then and there from social and cultural concepts acquired during your lifetime. The underlying neuronal processes for an emotion yield values on two dimensions: its relative pleasantness or unpleasantness and the degree to which it arouses you (e.g., Barrett, 2017; Matravers, 2001). The idea is plausible for the delight and excitement that you get from certain pictures. But, it does not explain which particular emotion the picture evokes in you, or how it can do so if it is abstract. The simulation theory aims to solve these puzzles, and so we turn to the communicative theory of emotions and outline its fundamental principles (see Oatley and Johnson-Laird, 1987, 1996, 2014, for details and corroboratory evidence).

Certain events have happened so often to social mammals – sensing a danger, aiming for a goal, being thwarted, and so on – that the ability to cope with them without prolonged cogitation had an advantage during mammalian evolution (Keltner *et al.*, 2019). Rapid emotional reactions are more appropriate, say, to an immediate threat than doing nothing, or just thinking. Perception and its precursors can trigger specific emotional signals that elicit adaptive behaviours. Humans inherited this system. So, when they see a large entity bearing down on them, its perception evokes an emotion of fear, and it can do so even before they have identified the entity. Psychologists may wonder whether nothing more is at stake than an associative link between large entities and fear. The traditional view of associations is that their links are symmetric. But, that is not so for emotions. When you feel fear, you do not as a consequence have an image of a large shape bearing down on you, or of any other precursor to the feeling. Cognitive appraisals are rapid, but they do call for the recovery of information, which is used to create mental models. Emotions are therefore rooted in preconscious processes that send rapid signals to conscious awareness, to somatic systems, and to pre-arranged suites of actions. The results are a subjective feeling, bodily changes, facial and other expressions of emotion, and an immediate preparedness for an appropriate sort of action. It can, in turn, communicate the emotion to others (Oatley and Johnson-Laird, 1987).

The theory distinguishes between *basic* and *complex* emotions. The difference concerns propositions and consciousness. A proposition is a mental entity that may be true or false about a situation, real or imaginary. Its meaning results from understanding an assertion or from a perceptual judgement. The construction of this meaning is outside awareness, but it can be used to construct a mental model of the situation (Johnson-Laird, 1983). These preconscious processes can evoke the simplest of basic emotions: happiness, sadness, anger, and anxiety. Inherited from social mammals, they are innate (Darwin, 1872). You can experience them without any awareness of their objects, causes, or reasons. You have a subjective feeling without any accompanying propositional content, e.g., you feel happy for no reason that you are aware of. A study of diaries in which participants recorded their daily emotions showed that the four simplest emotions can occur in this way (Oatley and Johnson-Laird, 1996). If they are prolonged, they are moods, which have a distant echo in the four traditional temperaments. They can be communicated in unique and perhaps universal facial expressions (e.g., Ekman, 1992; but cf. Gendron *et al.*, 2014).

Other sorts of basic emotion exist, at least in terms of their innateness and universality, but they can be experienced only with an awareness of at least their objects, e.g., liking, loving, disliking, loathing, and feeling disgust. Representational art can evoke these emotions (see, e.g., Goya's *Disasters of*

War), but they cannot be experienced without knowledge of their objects. They can, however, occur with no knowledge of their causes or reasons, e.g., "I like that painting, but I don't know why". To experience surprise – from a load noise or from unexpected news – is universal, but it can evoke any of the four simplest emotions (Oatley and Johnson-Laird, 1987).

Complex emotions, such as pride, embarrassment, and envy, are rooted in basic emotions, namely, happiness, anxiety, and dislike, but they enter consciousness with accompanying propositional content in mental models of their objects, causes, or reasons. This relation between content and emotion can depend on culture. You learn what to take pride in. And when you feel this emotion, you know its object and its reason. Hence, it would be odd to assert that you feel proud, but you don't know why. To be proud of yourself depends on access to a mental model of yourself that represents the reason for your pride. Models of the self are crucial in making decisions, in metacognition, and, above all, in the experience of self-awareness (Johnson-Laird, 1983, Ch. 16). We argue later that they are also essential for aesthetic judgements.

The communicative theory is borne out in an analysis of nearly two and half thousand different languages (Jackson *et al.*, 2019). These investigators assumed that if a word in one language refers, say, both to grief and to regret, whereas its counterpart in another language refers instead to grief and to fear, then the two languages have different conceptions of emotions. In fact, words referring to different conjunctions of emotions occur from one major language group to another, but geographical closeness predicts semantic similarity. The investigators did not adopt a theory of discrete emotions but reported that pleasant-unpleasant is a common dimension (cf. Barrett, 2017). Likewise, their results showed that the four simplest emotions are universal concepts across all the languages in the study: happiness, sadness, anger, and anxiety.

People who are happy or sad tend to continue to behave in the same predictable ways: their actions tend to be redundant and so have less entropy than the actions of those of who are angry or anxious. Entropy, a notion from physics, refers to a lack of order or predictability, and it has a simple additive measure due to Shannon (1948). And so it can be assessed for cognitive performance (e.g., Ragni *et al.*, 2018) and for pictures (Attneave, 1959). The Gestalt theorist Rudolf Arnheim (1971) used it to try to corroborate his theory of art (see also Van de Cruys and Wagemans, 2011). It correlates with other measures, such as statistical complexity (Sigaki *et al.*, 2018); and low entropy – redundancy – is likely to relate to the fluency of perception, which affects pleasure (e.g., Belke *et al.*, 2010). The four simplest emotions have salient differences in the entropy of their characteristic behaviours: anger, for example, is more likely to lead to unpredictable actions than sadness. Conversely, the degree of entropy in actions is a cue to which emotions a person is experiencing.

3.1. Emotions and Psychological Illnesses

Perhaps surprisingly, psychological illnesses provide clues to how abstract art evokes emotions. An extreme rationalist, such as Plato, would argue that emotional reactions to meaningless shapes in art are pathological: we should not be ruled by our emotions (see *The Republic*, 10-606d). Psychological illnesses are indeed emotional disorders. The emotions are almost always basic ones (Johnson-Laird *et al.*, 2006). Hence, illnesses such as phobias and panic attacks begin when a cognitive evaluation evokes a basic emotion appropriate for the situation but much more intense than normal. If we put to one side eating, drinking, and other biological needs, the ontogeny of human life concerns the following matters, which we state with their basic emotions and corresponding psychological illnesses:

- Maintenance of social relations: happiness and hypomania.
- Loss of social relations: sadness and depression.
- Frustration of social relations: anger and intermittent explosive disorder.
- Avoidance of danger: anxiety and phobias.
- Avoidance of illness: anxiety and hypochondria.
- Avoidance of noxious substances: disgust and obsessive-compulsive disorder.

In a small epidemiological study, patients in Italy tended to report the four simplest emotions at the onset and recurrences of their illnesses and only one complex emotion, guilt (ibid., p. 832). And commonplace situations, such as leaving your home or a mild pain in your abdomen, can for patients with mental illnesses evoke almost overwhelming emotions.

3.2. Emotions and Pure Music

Pure music has no propositional content, and yet it too can evoke powerful emotions. Some philosophers argue that emotions must be about something, music is not about anything, and so it cannot evoke emotions (Nussbaum, 2001). But, as we pointed out earlier, the simplest emotions can be experienced without any knowledge of what they are about. Likewise, listeners report feeling emotions in response to music, and fMRI studies confirm that the brain regions that mediate emotions are active when they make such reports (for a review of the evidence, see Johnson-Laird and Oatley, 2016). The emotional impact of music, as Aristotle observed (1984, *Politics*, 1340a11) and Helmholtz (1912, p. 370) re-iterated, depends on mimesis. We define mimesis as the evocation of an emotion from the perception of something that mimics features of the emotion's characteristic expressions or behaviours. In music, sounds mimic tone of voice, and speed of thinking or moving, characteristic of an emotion,

such as slow walking or rapid dancing, and thereby evoke these emotions in others. Listeners with no technical knowledge of music have a perceptual system that can maintain a kinematic mental model of a musical phrase, where a kinematic model is one that unfolds in time in order to represent a temporal sequence of events. Thus, such listeners can sing aloud a simple melodic phrase that they have just heard. Their model for a phrase of Western music represents its rhythmic sequence of pitches, its metre, tempo, and volume, and the degree of consonance or dissonance of its accompanying chords.

To corroborate this hypothesis of simple models of these variables, we examined the consonance or dissonance of chords (Johnson-Laird *et al.*, 2012). What causes dissonance in music is the oldest problem in cognitive science – Pythagoras was the first to address it in the 6th century BCE. Helmholtz (1912) tried to reduce it to the roughness, even painfulness, of the buzzing sound produced when auditory vibrations stimulate adjacent regions of the cochlear in the inner ear. But, as he realized, culture matters too. We showed that dissonance depends on the scale of notes in tonal music out of which chords are constructed: chords with notes from the major scale (e.g., C E G) are more consonant than those with notes found only in the minor scale (e.g., C E Ab). Likewise, the context of a chord affects its dissonance: chords are more consonant in a context of tonal chords – those built from a scale – than in an atonal context (Johnson-Laird *et al.*, 2012). The participants' sensitivity to the context of a chord – those chords occurring before and after it – bears out the representation of music in a kinematic model. Scales depend on culture, not the innate foundations of music. People who are not musicians concur in their ratings of consonance and dissonance. So, their kinematic models of music represent, not just innate sensations, but also tacit cultural knowledge acquired from listening to music.

Mimesis in music relies on an inner simulation in a kinematic model to evoke emotions (Johnson-Laird and Oatley, 2016). The four simplest emotions have the following mimetic cues:

- Happiness: people move at a medium pace, they speak with moderate loudness, their intonation contour has a wide range of pitches, and their voice quality is smooth. So, the mimetic settings for happy music are medium tempo, moderate loudness, large range of pitches, consonant harmony, and moderate entropy.
- Sadness: the mimetic settings are slow tempo, quiet volume, low pitches, small range of pitches, mild dissonance, and low entropy.
- Anger: the mimetic settings are rapid tempo, loud volume, high pitches, wide range of pitches, great dissonance, and high entropy.

– Anxiety: the mimetic settings rapid tempo, moderate volume, low pitches, small range of pitches, dissonance, and high entropy.

To test this theory, we wrote a computer program that creates new melodies from given chord sequences, and uses the settings above as cues to constrain the nature of both the accompanying chords and the program's melodic outputs. In an experiment, which Olivia Kang carried out, the participants tended to feel the predicted emotions for the pieces of music. And for those pieces with mixtures of settings for two different emotions, they tended to feel the corresponding mixed emotions (Johnson-Laird and Oatley, 2016). Musical mimesis works, and like psychological illnesses, it demonstrates how little is needed for simulations to evoke the four simplest emotions. These emotions are pertinent to abstract art, because like pure music it too has no propositional content.

Two other sources of an emotion to a piece of music are extra-musical associations and projections. Music played at ceremonies, such as weddings, funerals, and birthdays, or as accompaniments to familiar movies or advertisements, often evokes emotions, and individuals soon acquire a conditioned association so that the music alone elicits the emotion, e.g., Ligeti's compositions *Atmosphères* and *Lux Aeterna* evoke feelings of mysterious awe from their use in Stanley Kubric's movie, *2001*. Analogous associations of a personal kind can be potent. The projection of propositional content onto music is a common enterprise of critics, listeners, and sometimes composers themselves in programme music. These projections can elicit emotions of their own, which the music alone might not, and they can evoke complex emotions, e.g., the moment the eponymous hero is hung for blasphemy in Richard Strauss's tone poem in *Till Eulenspiegel*.

4. Emotions and Representational Art

Most paintings in the history of art are akin to windows onto scenes. You look through the window and you see what is going on. The surface of the window, however, can be clear or it can obscure your view. This contrast between painting as depiction and as surface has a long history in Europe (e.g., Vasari, 1568/1965). Our concern is abstract art, which is largely surface though it can have cues to depth. But, the simulation theory, which we present in the next section, does apply to representational art. Its scenes are not given to viewers by magic. Perceptual processes construct iconic models – in the sense we defined in Section 2 – from various cues in the picture's surface: the arrangements of lines, shapes, textures, and so on. The conventional cues vary from one culture to another. And for three-dimensional depth they may include occlusion, relative size, lighting, shadows, aerial perspective in the lower saturation of hues for distant vistas, true perspective with one or more

vanishing points (Kubovy, 1986), and even interactions between ordinary and fluorescent colours (De Winter *et al.*, 2017). They can all contribute to the construction of a three-dimensional mental model of a scene from its two-dimensional depiction. This model can elicit just about any emotion, basic or complex, that occurs in everyday life. But, just as fiction can depart from reality, pictures can depart from the conventions for representing the shapes of entities, their colours, and their spatial relations. These distortions in turn affect the emotions that viewers experience.

In summary, scenes in representational art elicit models simulating what paintings depict, which can evoke emotions—much as perceptions of real scenes or their descriptions can (see Oatley, 2011, 2016). Insofar as the appeal of any art rests on its power to move people, it follows that representational art should be more popular than abstract art, because the contents of scenes – even those difficult to identify (Muth *et al.*, 2013) – are more likely than surfaces to evoke emotions. Representational art yields considerable evidence to corroborate the simulation theory. Viewers can construct kinematic models of the scenes implicit in narrative art, and experience emotions, both basic and complex. Artists themselves, such as Leonardo (Richter, 1980, p. 176), Van Gogh (Ghiselin, 1952, pp. 54–55), and Picasso (Behrens, 1986, p. 57), have commented on the emotions they aim to convey in their paintings and to prompt in viewers. A significant change occurred in Western art from the static tableaux in medieval art, culminating in the false perspective of Giotto, to Renaissance paintings in true perspective, such as those of Masaccio that depict real people experiencing real emotions. A further transformation occurred in the early twentieth century in the deliberate flouting of representational conventions (Cooper, 1970), and in the invention of abstract art.

5. The Simulation Theory of Abstract Art

5.1. What Emotions can Abstract Art Evoke?

Theorists have argued that abstract art cannot evoke emotions. Indeed, Konečni's (2015) view is that not even representational paintings can do so; they are static two-dimensional images that have only limited narrative resources. And so they are unable to engage viewers' associative memories of a sort to invoke empathy, and thereby to induce fundamental 'psychobiological emotions' (ibid., p. 305). Still less should abstract paintings evoke emotions. We mentioned earlier that some philosophers, such as Nussbaum (2001), argue that emotions are about something, and so – as they assert about music – abstract art cannot evoke emotions. Yet, people do experience emotions that are not about anything, and, as we also mentioned earlier, experimental and brain-imaging studies corroborate the occurrence of genuine emotions in response to pure music.

The new simulation theory combines mental models and communicative emotions. Its central assumption is that viewers' perceptions create iconic models of what they perceive, and that when a model or its process of construction simulates aspects of human emotions, viewers can experience these emotions too. We refer to this process using its traditional term: mimesis, which we defined in Subsection 3.2. Because abstract art contains no propositional content, mimesis can evoke only the four simplest emotions: happiness, sadness, anger, and anxiety. Synaesthesia can also elicit emotions, and we return to it in the next section.

Abstract art can evoke other emotions, even complex ones, but only by association or projection – mechanisms that apply to all arts and even to domain outside them. The swastika was once an abstract shape, but its associations with Nazis can evoke powerful emotions of hatred and disgust. Projection is the creation of a propositional interpretation of a work of art, which lacks one (see Subsection 3.2). It, in turn, can evoke emotions. The abstract painter Piet Mondrian first heard Boogie Woogie in New York City during World War II, and it inspired him to paint a picture entitled *Broadway Boogie Woogie* (see Fig. 1). This title is liable to lead viewers – those familiar with both entities to which its title refers – to project both the city-block geometry of Manhattan and the cross-cutting rhythms of Boogie Woogie onto the picture. These

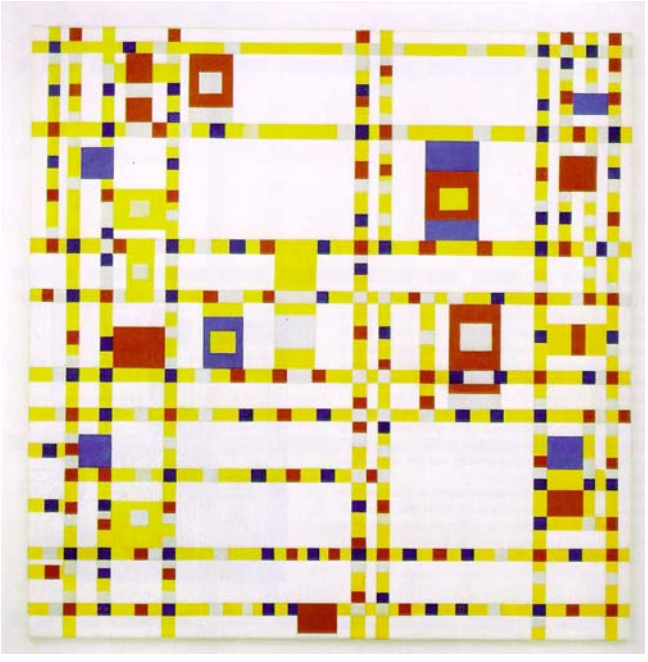

Figure 1. Piet Mondrian: *Broadway Boogie Woogie* (1943). From Wikipedia: https://en.wikipedia.org/wiki/Broadway_Boogie_Woogie#/media/File:Piet_Mondrian,_1942_-_Broadway_Boogie_Woogie.jpg

projections and its bright colours – it lacks the black lines typical of Mondrian – can evoke feelings of joy. Granted the almost universal occurrence of associations and projections, we say little further about their role in abstract art.

Not all art, whether representational or abstract, is intended to evoke emotions. It aims instead for an intellectual evaluation and an aesthetic judgement. Paintings such as Vermeer's portraits and his two surviving landscapes seem designed to elicit such reactions, and many abstract works seem to aim only for aesthetic effects, e.g., Kandinsky's paintings, such as: *A Transverse Line* (1923). As we show later, the simulation theory predicts that aesthetic judgements can evoke complex emotions. So, we now describe its account of the origins of basic emotions in the surface cues of abstract art.

5.2. How Simulation Evokes the Simplest Basic Emotions from Colours, Shapes, and Lines

Minimal cues from mental models can evoke feelings of the four simplest basic emotions. These cues in abstract art include colours, shapes, lines, and spatial arrangements. Happiness and sadness tend to yield more predictable behaviours than those from anger or anxiety, and so the entropy in an abstract painting can also help in the evocation of a simple emotion.

The palette of hues evokes different emotions, and it has a large literature, often reflecting idiosyncratic beliefs. Kandinsky (1911/2001), one of the pioneers of abstract art and a likely synaesthete, had strong views about the relations between colours, music, emotions, and spirituality. For instance, he argued that yellow represents warmth, appears to move towards you, but can be terrestrial and aggressive. When he writes that certain colours are 'without hope', 'silent', and 'immobile', he is projecting onto them a propositional content from his beliefs. (Music critics make analogous and more extreme projections.) Yet, like Kandinsky, individuals do make associations between colours and shapes (see Jacobsen and Wolsdorff, 2007). One of Kandinsky's colleagues at the Bauhaus school, the abstract painter Josef Albers, wrote a manual of colours that does not mention emotions, though it allows that certain combinations of colour are consonant whereas others are dissonant (Albers, 1963, p. 68). Extreme clashes of bright, highly saturated, hues from opposite sides of the colour wheel yield unpleasant 'vibrations'.

Scientific studies of colour and emotion are numerous, and they have burgeoned in recent years, because they are amenable to automation, i.e., programs for computer vision can analyze colour, texture, and their interaction, and enable investigators to test predictions in studies of viewers' eye movements and judgements (e.g., Yanulevskaya *et al.*, 2012). Likewise, machine learning can acquire those features that evoke emotions (e.g., Lu, 2016).

Experiments have established various mechanisms linking colours to emotions. Synaesthesia is a neuronal link from one feature of an event or entity to a perception of an unrelated feature perhaps in a different modality. Some individuals, for example, on hearing a musical note have an image of a particular colour. Others have a synaesthetic link from colours to emotions. These links cross cultures to some degree (D'Andrade and Egan, 1974), but individuals differ in the nature and strength of these links (van Leeuwen, 2013). Mimesis is another mechanism linking colours to emotions, e.g., angry people tend to get red in the face, and so red, which tends to be bright and saturated, relates to anger, whereas green does not (Palmer *et al.*, 2013). Likewise, anxious people tend to get paler in the face, and so paler hues relate to anxiety (Prochazkova and Kret, 2017). Associations link colours to emotions. As Palmer and Schloss (2010, p. 8877) wrote: "People like colors strongly associated with objects they like (e.g., blues with clear skies and clean water) and dislike colors strongly associated with objects they dislike (e.g., browns with feces and rotten food)".

The links from colour to emotion appear to be quite stable. For example, a cross-linguistic study of 22 languages showed that the participants linked similar emotions to 12 colour names, though there were some cultural differences (Jonauskaite *et al.*, 2020), and a subsequent study showed comparable emotions in response to patches of colour and to the names of colours (Jonauskaite *et al.*, 2021). Both studies included the four simplest emotions, which tended to be linked to the following colours:

- Happiness: any hue except black, grey, or brown.
- Sadness: black, and to a lesser degree grey or blue.
- Anger: red and to a lesser degree black.
- Anxiety: black, and to a lesser degree grey and red.

Shapes have mimetic links to emotions. People who are sad move slowly, large objects tend to move slowly, and so large shapes are mimetic cues to sadness. In contrast, small shapes move faster, and cue other basic emotions. Smooth lines and regular shapes, such as ovals, are more predictable – they have less entropy, and more associations with happy or sad events, and so they are cues to these emotions. Rough or jagged lines are less predictable and have more associations with unpleasant events, and so they cue anger and anxiety (cf. Arnheim, 1954, 1969). These cues cross cultures to a greater degree than the meanings of emotion words do (Oyama *et al.*, 2008). Straight lines and linear arrangements also cue the artist's use of calculation. Lines that are curved suggest a more spontaneous means of production. Studies of the global organizations of pictures vary in entropy. Minimalism works have the lowest

entropy and pointillistic paintings have the highest (Sigaki *et al.*, 2018). The overall organization of an abstract picture can also be characterized in terms of entropy: an organized arrangement is predictable – it has less entropy, whereas a wholly random arrangement has maximum entropy. So, this variable should also be a mimetic cue to corresponding emotions. It correlates with human judgements of abstract art (Burns, 2015), and variability in the entropy of the distribution of intensities in images is greater in abstract than in the art that preceded it (Mather, 2018; Redies and Brachmann, 2017).

5.3. How Gestures and Manner of Painting Evoke Emotions

Nineteenth century connoisseurs emphasized the importance of brushstrokes in the attribution of paintings, but also in communication (e.g., Berenson, 1909). In an analogous way, Gombrich (1960, p. 243) wrote of a hypothetical abstract artist:

> "He must try to prevent us from interpreting his marks on the canvas as representations of any kind by compelling us to switch over to that alternative which we have observed in the interpretation of drawings: he must make us read his brushmarks as traces of his gestures and actions."

As an example, Gombrich cites Jackson Pollock's abstract-expressionist painting: *Number 12* (from 1952).

Like this picture, the surface of a painting can yield cues to how it was painted. Their representation in the simulation model of the picture results from an 'analysis by synthesis' in which perception depends on a simulation of the process of creation. The resulting model can lead viewers to empathize with the artist and to experience emotions lying behind a painting's creation. It can prompt a simulation of the artist's state of mind in creating it, whether veridical or not, and as a result viewers empathize and feel these emotions themselves. They may, for instance, find themselves mentally simulating brushstrokes, perhaps in calmness or in agitation. Of course, the artist may have had no such emotion – any more than a composer of a requiem feels sad, or an actor in a comedy feels happy. Nonetheless, the manner in which pigment is applied – brushstrokes, thick impasto, sgraffito, pointillism, dripping, and so on, can have emotional effects.

The theoretical role of gestures embodied in the surfaces of pictures owes much to Gallese and Freedman (e.g., Freedberg and Gallese, 2007). Their account rests on the discovery of mirror neurons in the frontal cortex of macaques and humans (see Rizzolatti *et al.*, 2014). These neurons are active when individuals see a goal-driven action and also when they initiate a similar action. As Rizzolatti (2015) wrote: "The mirror mechanism is the only one that allows understanding others from the inside providing the observer with a 'first-person' grasp of others' motor goals, intentions and emotions." Its

activity underlies empathy (Gallese, 2001), and it is a major component in observing and experiencing such emotions as happiness, fear, and disgust (Rizzolatti and Caruana, 2017). So, a neural mechanism exists that underlies the perception and performance of actions, and that can evoke the simplest emotions from them (Freedberg and Gallese, 2007, p. 197; though cf. Casati and Pignocchi, 2007).

To evoke the simplest emotions, the surface of a painting needs to embody gestures and movements characteristic of them. Darwin (1872) was the first to make systematic observations of actual behaviours characteristic of emotions, from which we have selected those pertinent to the four simplest emotions:

- Happiness: purposeless movements, dancing, stamping, clapping hands.
- Sadness: motionless, passive.
- Anger: trembling, frantic and violent gestures.
- Fear: motionless, crouching.

Our concern is those aspects of an artist's bodily movements that are liable both to be evident in the surface of a picture and to evoke a particular emotion. No such study appears to be in the literature. Indeed, twenty years ago, whether bodily movements alone indicated particular emotions was controversial. Wallbott's (1998) analysis of video clips of actors portraying a dozen or so emotions appeared to yield identifiable cues that evoked emotions better than chance. People can identify happiness, sadness, and anger, from their characteristic movements (e.g., Montepare *et al.*, 1999). And, as Darwin anticipated, other studies show that movements in sadness are slow, in joy sprightly, in anger rapid and violent, and in fear defensive. Viewers can identify these emotions from point-light displays in the dark, which show only the movement of joints, and they can even do so when these displays are upside down (e.g., Dittrich *et al.*, 1996; Pollick *et al.*, 2001).

The relation between movements and emotions is under active investigation in artificial intelligence, because it is amenable to machine-learning techniques and can help to make sociable robots (e.g., Piana *et al.*, 2016; Wu *et al.*, 2020). Some experimental studies have examined these relations in pairs of cultures (e.g., Sogon and Masutani, 1989). But, as far as we can tell, no large cross-cultural study has tested whether characteristic movements can convey basic emotions, and that the participants both identify these emotions and feel them.

5.4. A Summary of the Simulation Theory's Predictions about Basic Emotions

The perception of an abstract painting yields a simulation model that can predict the four simplest emotions. Table 1 summarizes these cues, mainly

Table 1.
The predicted cues in abstract art for evoking the four simplest basic emotions.

Basic emotions	Cues from surface in the simulation						
	Hues	Shapes			Lines	Gestures	Entropy
		Number	Size	Sort			
Happy	Bright, saturated, not black	Many	Medium	Simple	Smooth	Smooth	Moderate
Sad	Black	Few	Large	Simple	Smooth	Passive	Low
Angry	Red, black	Many	Medium	Irregular	Angular	Violent	Very high
Anxious	Black, red	Many	Small	Irregular	Angular	Repetitive	High

mimetic but sometimes synaesthetic, and entropy refers to the unpredictability of features and of a work's spatial organization. One corollary of Table 1 is that of the six possible pairs of emotions, the two most likely to be confused are anger and anxiety. Association and projection are secondary in that they can introduce propositional content into abstract art and many other domains.

6. Self-Awareness and Aesthetics

Many theorists have considered aesthetic emotions. Frijda (1988, 2007) distinguished between two sorts: emotions that 'complement' those of everyday life and are consequences of the contents of representational pictures, such as sympathy for the suffering of a depicted character, and 'responding' emotions arising from the structure of a work of art, such as a delight in its perfect composition. Cupchik (1994) drew a similar disjunction, but harked back to William James's (1890) views about emotions in response to aesthetic objects. Reactive processes focus on the content of a work of art, and concern pleasure and arousal; whereas reflective processes concern the multiple layers of meaning in works of arts. Scherer (2005) makes a similar contrast between what he refers to as utilitarian emotions, which approximate to the basic emotions of daily life, and aesthetic emotions, which follow from the appreciation of beauty in nature or in art, and which include awe, wonder, ecstasy, and solemnity (ibid., p. 705). Only Marković (2012), however, considers abstract art, which depends on expertise for its appreciation (p. 10). He distinguishes three characteristics of aesthetic experience: motivation, cognition, and affect (ibid., p. 3). The motivational component concerns a fascination with an aesthetic object, which elicits high level of arousal in which one loses self-consciousness and awareness of anything else, as in a 'flow' experience (Csikszentmihalyi and Robinson, 1990). The cognitive component concerns the appraisal of aesthetic objects, which transcends their everyday uses. And the affective component concerns a viewer's emotional feeling of unity with the aesthetic object.

The simulation theory takes into account these precursors, but it also seeks to incorporate the roles of self-awareness and beauty in aesthetic emotions.

6.1. Self-Reflective Models and Aesthetics

Art can indeed be so absorbing that you enter a state of 'flow' in which you forget all about yourself, and may feel an one with a painting (Csikszentmihalyi and Robinson, 1990; Wanzer *et al.*, 2018). A contrasting state is one in which you make an aesthetic judgement of a work of art. You are aware that you are evaluating such a work, and so your brain must represent this relation, and a crucial part of it is a model of yourself – a 'self-reflective' model

(Johnson-Laird, 1983, p. 474) – and a model of the particular work of art. Self-reflective models are schematic, incomplete, and often wrong, but they can access your memories, your preferences, and much else, and they are the basis of your intentions (ibid, p. 473). You and the object of your awareness is what you are experiencing, and so a complete recursive grasp would include your awareness of your awareness, and so on, ad infinitum (ibid., p, 473). That this recursion does not occur shows that your simulation cannot be embedded within itself more than once or twice (see Johnson-Laird *et al.*, 2021). Self-reflection underlies many complex emotions, such as embarrassment, regret, and sympathy. It is also a channel to your explicit knowledge both of yourself and of the world. If you judge that a picture is similar to one of Klee's abstracts, you are aware of this judgement. So, your self-reflection has accessed your critical knowledge that enables you to evaluate works of art – their beauty, their skill in execution, their veracity, they novelty, or, alas, their lack of these desirable qualities. And this model, in turn, as Legrenzi (2017) has argued, yields your awareness of your emotional reaction to a picture: you like this painting, hate that one, and are annoyed by another. So, your self-reflective evaluation of a work of art can evoke an aesthetic emotion. It can also fail to do so. These aesthetic emotions seem mainly to depend on judgements of beauty or of its absence.

6.2. Darwin and the Nature of Beauty

The first experimental investigation of aesthetics was Fechner's corroboration of the pleasantness of the golden ratio (1876; see also Ortlieb *et al.*, 2020). But, there has been a recent resurgence of studies (e.g., Schellekens and Goldie, 2011; Shimamura, 2015; Starr, 2015). Darwin's (1859) theory of evolution lies behind many studies (e.g., Chatterjee, 2014; Dutton, 2009; Høgh-Olesen, 2019; Menninghaus, 2020; and Prum, 2017). These theories identify potential evolutionary sources of beauty. Early humans were nomadic, and so they saw certain environments and routes through them as likely places where water would be found, where plants would grow so that food would be plentiful, and where they would feel safe and comfortable. And, when they judged whether someone would be a likely mate, they saw some individuals as more attractive than others. So, the evolutionary sources of beauty are woodlands, florescent landscapes, and potential mates. The claim is plausible, hard to test, and silent about other sources of beauty.

Beauty is a mysterious perceptual quality. Compare it with, say, triangularity. People agree about what is triangular, it is constant, and it has necessary and sufficient conditions that define an operational test – three lines meet at three corners at the ends of each pair of them. Beauty has no such characteristics. People disagree about it (Vessel *et al.*, 2013). It isn't constant: people

change their minds about what is beautiful. And no operational test exists for it. Yet, critics tend to think that something must be common to everything that they find beautiful. Bell (1914) asked himself what it was about the windows of Chartres, a Persian bowl, Giotto's frescoes at Padua, and the works of Cézanne, that led him to judge them all as beautiful. Only one answer seemed feasible: *significant form* (ibid., p. 11). It depended on "lines and colors combined in a particular way, certain forms, and relations of forms, that stir our aesthetic emotions." But, he conceded that it was dependent on unknown and mysterious laws. Evolutionary theories likewise posit that beautiful configurations tend to include symmetry, certain shapes and their juxtapositions, certain colours and their combinations, round edges rather than straight ones, smooth textures rather than rough ones. In abstract art, comparable arrangements and properties can occur on surfaces. Yet, if someone makes a genuine aesthetic judgment, and as a result tells you: *X is beautiful*, you are likely to infer that the speaker experienced an aesthetic emotion on looking at X. Beyond that, you know nothing. What matters is the identity of X and the speaker's reasons for its beauty. It may be that X is neither a scene in nature nor a potential mate, and not even a work of art. They have no monopoly on beauty.

Mathematics and science can elicit judgements of beauty (Farmelo, 2002), and so the concept cannot have a set of necessary and sufficient properties that apply to all its instances. It is tempting to adopt a prototype theory: people judge a work to be beautiful if it shares sufficient elements in common with a paragon for the domain. Alas, that passes the explanatory task back to what led to the paragon. Moreover, both familiarity and its apparent opposite, novelty, influence the assessment of beauty, and they are sensitive to an individual's "cognitive and affective coping potential" (Menninghaus *et al.*, 2019)

Beauty is neither just in the eye of the beholder, nor just in the essence of the object. Not in the beholder's eye, because its lack in certain objects yield a universal agreement. Not inherent in the object, because people disagree about what's beautiful. We can conclude only that beauty depends on an interaction between aspects of the perceiver and the perceived. Likewise, its 'mysterious laws' depend on interactions between innate factors and personal experiences (see Darwin, 1871, pp. 54, 55), and so they differ from one individual to another. Hence, certain configurations in the surface of abstract works of art can be beautiful to some viewers, but not to others, and so too is whether or not they evoke aesthetic emotions.

6.3. The Aesthetic Emotions

Individuals can make judgements of the beauty of works of art, and as a result they can experience aesthetic emotions, which range from awe to disgust. Differences in personality and experience yield different emotions to abstract

art. On one side is the critic Clement Greenberg, who admired modern art, and was in awe of abstract expressionism. On the other side is Alfred Munnings, a painter of horses, who detested Picasso and modern art (Chew, 2006). A picture can be shocking because it violates expectations about works of art. Or, in contrast, it can evoke an aesthetic pleasure, admiration, and a sense that the artist has done something so extraordinary that no-one else could have done it, not even badly.

In reaction to beauty, the principal aesthetic emotion is awe (Armstrong and Detweiler-Bedell, 2008). Its telltale somatic signs in many people are chills or goose flesh (e.g., Silvia, 2009; Silvia and Nusbaum, 2011): they seem to be signals from an intense mix of happiness and anxiety (Konečni, 2005). In reaction to ugliness the principle aesthetic emotion is revulsion – an intellectual disgust obvious in Munning's reaction to modern art. When you have a sense of beauty unlike any previous experience, it adds to your knowledge of the sort of art that moves you. And this thoughtful self-reflection, to which an abstract painting can lead you, may presage an aesthetic emotion.

7. Evidence for the Simulation Theory of Abstract Art

Many works of abstract art seem intended to convey only an aesthetic response. Yet, they can evoke basic emotions in the way that music does (e.g., Schama, 2006). Music is more intense because it exists in time. Heider and Simmel (1944) showed a movie that animated abstract shapes, and asked their participants to describe it: only one of them described the movement of geometric shapes, and the rest projected an anthropomorphic interpretation onto it. Eliminate the animation, and the result is a piece of abstract art unlikely to evoke emotions. The real thing however, does. Abstract artists themselves confirm this point. For example, Mark Rothko (2006) wrote: "I'm interested only in expressing basic human emotions – tragedy, ecstasy, doom and so on – and the fact that a lot of people break down and cry when confronted with my pictures show that I communicate those basic human emotions." People know the difference between identifying an emotion that a work of art communicates and feeling that emotion themselves. Yet, studies of whether abstract art evokes real feelings are over once experimenters have selected the relevant paintings: the selection shows that at least some individuals, the experimenters themselves, feel real emotions on looking at them (see Johnson-Laird and Oatley, 2016, for the same point about music). So, at least some abstract art evokes emotions in at least some viewers, and we can examine evidence pertinent to the simulation theory's predictions.

7.1. Abstract Art: Colour, Shape, Gestures, and Basic Emotions

Participants in a study due to Melcher and Bacci (2013) agreed that certain abstract pictures evoked positive emotions and others evoked negative emotions, and a computer program made reasonable predictions about the consensus, using only two variables: colour and shape. These results bore out the simulation theory's predictions in Table 1 in that paintings of geometric shapes with primary colours evoked 'positive' emotions, whereas others in black evoked 'negative' emotions. Another study yielded a similar result for abstract paintings (Van Paasschen *et al.*, 2014). Likewise, individuals agreed in their judgements of happy/sad for artworks but lacked a consensus for contrasts that did not concern basic emotions (Specker *et al.*, 2020). We need to be cautious about generalizing from these results until a systematic study examines the surface cues to the four simplest emotions. As an example, we invite readers to judge whether four reproductions of paintings tend to evoke the emotions that the simulation theory predicts. According to the cues in Table 1, the bright saturated colours and simple medium-sized shapes in Fig. 1 should tend to evoke joy. The large black shape in Fig. 2 should tend to evoke sadness.

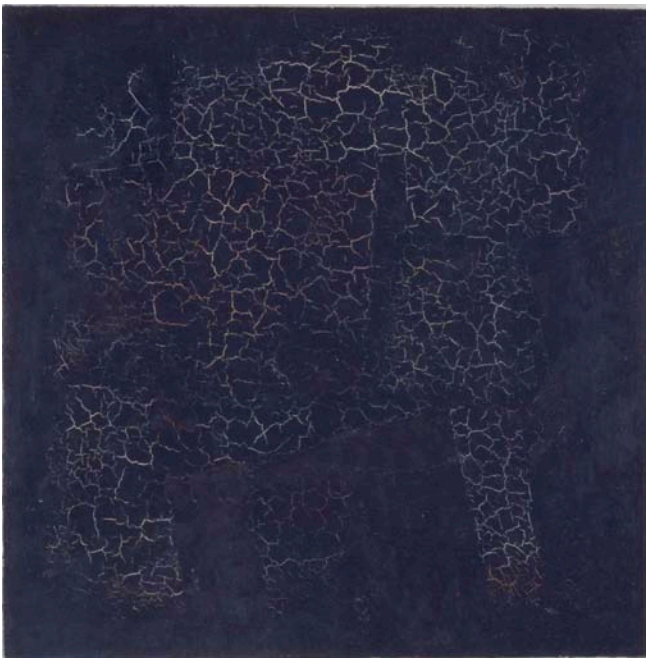

Figure 2. Kazimir Malevich: *Black square* (1913). From Wikipedia: https://en.wikipedia.org/wiki/Black_Square_(painting)#/media/File:Kazimir_Malevich,_1915,_Black_Suprematic_Square,_oil_on_linen_canvas,_79.5_x_79.5_cm,_Tretyakov_Gallery,_Moscow.jpg

Figure 3. Kazuo Shiraga: *Hatsu* (2007). From Christies: https://www.christies.com/en/lot/lot-5972455

Iconoclastic works of art convey anger, such as Lucio Fontana's knife cuts in canvasses. So, too, the red, black, and violent brush strokes in Fig. 3 should tend to convey anger. And the insistent repetitions of small shapes in Fig. 4 should tend to evoke anxiety. Such a study needs to distinguish between judgements of which emotions a picture is intended to convey and the evocation of real feelings.

The mimetic nature of gestures was corroborated in a study of sculptures of humans in various postures: viewers spontaneously tended to imitate these postures (Kreitler and Kreitler, 1972). Likewise, experiments have corroborated Freedberg and Gallese's (2007) conjecture that viewers of abstract paintings such as a Jackson Pollock drip painting have a sense of bodily movements reflecting a mental simulation of the artists' gestures (see Leder *et al.*, 2012; Sbriscia-Fioretti *et al.*, 2013; Taylor *et al.*, 2012; Umiltà *et al.*, 2012). In this way, abstract pictures can evoke empathetic emotions at least in certain viewers.

Figure 4. Umberto Boccioni: *States of mind: those who go* (1911). From Italian Art Society: https://www.italianartsociety.org/2016/10/3-3-umberto-boccionis-stati-danimo-in-1911-umberto-boccioni-made-two-versions-of-the-same-work-stati-danimo-gli-addii-quelli-che-vanno-and-quelli-che-restano/

7.2. Abstract Art, Self-Awareness, and Aesthetic Emotions

The simulation theory predicts that a viewer looking at an abstract painting can experience an aesthetic emotion – from awe to revulsion. One corroboration comes from a study in which participants rated how much each of a large set of unfamiliar pictures moved them (Vessel *et al.*, 2013). Some of the pictures did move them, and fMRI results showed that those that participants found most moving activated the Default Mode Network in the brain. This network becomes active when people think about themselves. This finding supports the hypothesis that a self-reflective model underlies more intense aesthetic reactions to art. As the authors of the study concluded, your experience of art is at its greatest when it 'reaches within you'.

Many works of art appear to aim at evoking an aesthetic reaction. So, representational scenes can even lack cues to evoke emotions. Consider, for example, Vermeer's (c. 1658) portrait of a milkmaid. It depicts a mundane scene – an ordinary woman in plain garb pours milk from a jug. The surface of the picture is transparent with no evident brush strokes or cues to its creation. Yet, this domestic scene and others that Vermeer painted did not depict spontaneous events. He s*et up* the scene with care, with a careful choice of elements and their arrangement, and even rehearsed it as in a theatrical

performance (Oatley, 2011). His aim seems to have been to elicit a judgement of beauty. And he succeeded: a self-reflective evaluation of these pictures is of their extraordinary veracity and harmony in their spatial organization.

On first viewing a picture, some individuals are confused, later they have an emotional reaction, and still later they may experience an aesthetic emotion (Pelowski, 2015). One of the corollaries of later self-reflections of works of art is illustrated in another empirical study (Medved *et al.*, 2004). As visitors left an art gallery, an interviewer them asked to identify which painting they had found most interesting. They then had to imagine this picture and to talk about it as they would to a friend, to say whether any personal memories had come to mind in looking at it, and to name any emotions that it had evoked. Some five months later, as they had agreed, they were telephoned and asked the same questions. About three-quarters of the initial participants completed this interview. When they had left the art gallery, most of them reported that their chosen picture had evoked an emotion, and in their later telephone interview they experienced it again, albeit at a reduced level. However, the main difference between the two interviews probably occurred because the interval between them allowed the participants to reflect on their experiences. Their initial impressions on leaving the gallery had been piecemeal, whereas their later accounts were coherent reports of their own feelings in looking at the picture, and so they referred to themselves more often than in the first interview (see also Specker *et al.*, 2017).

People differ, and visual art does not move everyone. And these differences are likely to result from interactions between innate factors and experience. One pertinent difference is in personality, and evidence bears out its effects on viewing pictures (Djikic *et al.*, 2012). Individuals with 'openness to experience' are more likely to prefer abstract art than those without this trait (e.g., Feist and Brady, 2004). Another difference is in acquired critical skill: experts rated artworks as more beautiful than novices did (van Paasschen *et al.*, 2014). Likewise, in a study of early twentieth century paintings, from 1900 to 1935, experts rated abstract paintings as more interesting, beautiful, informative, and similar to representational art than novices did (Bimler *et al.*, 2019). Self-reflection allows access to expertise.

8. Conclusions

Anecdotal reports from artists, critics, and viewers, suggest that people feel emotions on looking at abstract art. Brain-imaging studies support this claim, because regions that mediate emotions are active during such experiences. This article therefore began with three questions, and the new simulation theory combines mental models and emotions to answer them.

Which particular emotions does abstract art evoke? According to the simulation theory, it can evoke the simplest basic emotions that individuals can experience without knowing their objects, causes, or reasons. In English these

emotions are referred to as happiness, sadness, anger, and anxiety. They occur in listening to pure music (Miu *et al.*, 2016), and also at the onset and recurrence of psychological illnesses. Abstract art evokes them, but it can also evoke complex emotions. They can occur from a viewer's association between a feature of a picture, such as a particular shape, and an entity or event that evokes a complex emotion in daily life. They can also occur when a viewer projects a creative propositional interpretation onto a work of abstract art, but that itself evokes a complex emotion. Projections of this sort are ubiquitous, and can occur with representational paintings, music, and other sorts of art.

What mental processes underlie the evocation of basic emotions to abstract art? It does not take much to provoke basic emotions in humans or other species (Darwin, 1871, p. 56 *et seq.*). An abstract painting yields a simulation that encodes several cues, including colours, lines, spatial organization, and manner of painting. These cues can evoke particular basic emotions, e.g., bright unsaturated colours of regular shapes with a moderate degree of entropy can evoke happiness (see Table 1). Such evocations depend on mimesis in which characteristics of emotional behaviours and expressions occur in simulations, which in turn evoke these emotions, on associations with other objects that elicit emotions, and for some individuals on synaesthesia. Corroboratory evidence supports the simulation theory, but whether different kinds of abstract art evoke different negative emotions – sadness, anger, and anxiety – is not yet known (cf. Elliott and Maier, 2014).

What underlies aesthetic emotions to abstract art? The simulation theory predicts that your model of yourself, with access to explicit knowledge, can yield an evaluation of the work, and evoke an aesthetic emotion, ranging from awe to revulsion. The main corroboration of this hypothesis is that aesthetic judgements activate the Default Mode Network in the brain – an activation that occurs when individuals think about themselves.

A major goal for future research on emotions and art is to develop a computer program that takes as input an electronic image of an abstract painting, and constructs its mental simulation that in turn predicts the likely emotions that it will evoke in humans.

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