CHAPTER

7

Music, dance, and other art forms: New insights into the links between hedonia (pleasure) and eudaimonia (well-being)

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Abstract

For Aristotle, the goal of human life was to live well, to flourish, and to ultimately have a good life. These goals can be conceptualized as "eudaimonia," a concept distinct from "hedonia" (pleasure). Many people would argue that the arts play a large role in their well-being and eudaimonia. Music in particular is a culturally ubiquitous phenomenon which brings joy and social bonding to listeners. Research has given insights into how the "sweet anticipation" of music and other art forms can lead to pleasure, but a full understanding of eudaimonia from the arts is still missing. What is clear is that anticipation and prediction are important for extracting meaning from our environment. In fleeting moments this may translate into pleasure, but over longer timescales, it can imbue life with meaning and purpose and lead to eudaimonia. Based on the existing evidence from neuroimaging, we hypothesize that a special network in the brain, the default-mode network, may play a central role in orchestrating eudaimonia, and propose future strategies for exploring these questions further.

Keywords

Pleasure, Brain, Eudaimonia, Hedonia, Joy, Dance, Music

Progress in Brain Research, Volume 237, ISSN 0079-6123, https://doi.org/10.1016/bs.pbr.2018.03.019

1 INTRODUCTION

The arts—music, visual art, literature, theater, dance, and film—represent a physical manifestation of the internal creative impulse in humans. Such outlets of expression form an important part of our culture, provide jobs and economic benefits, but importantly give us pleasure and lead to a meaningful life. And although humans ubiquitously seek pleasurable experiences in order to survive, it has been argued that the ultimate goal is a state of eudaimonia: a life well-lived, embedded in meaningful values together with a sense of engagement. The arts, particularly music, provide a prime example of how to bridge the gap between hedonia (pleasure) and eudaimonia (well-being).

Here, following Aristotle, we define hedonia and eudaimonia as separable but highly related constructs (Aristotle, 1976). Focusing on music, we explore how sweet anticipation may lead to pleasure, and how the extraction of meaning from music can promote eudaimonia. We examine how prediction coding likely forms the basis of pleasure wanting derived from anticipation in music, and how the same principles of anticipation are used in other art forms, including dance and poetry. Lastly, we look at how the default-mode network may provide a basis for the eudaimonia associated with music and other art forms and review avenues for future research into well-being.

2 ON HEDONIA AND EUDAIMONIA

The main challenge for the brain is to prioritize survival and procreation, by balancing resource allocation successfully (Kringelbach, 2005). In order to achieve this balance, different rewards compete for resources and they therefore follow a cyclical timescale known as the "pleasure cycle" (see Fig. 1) (Berridge and Kringelbach, 2013). The pleasure cycle first involves "wanting" (otherwise known as "incentive salience"), which can be conscious desires or unconscious processes. "Liking" (hedonic impact) refers to the pleasure component of a reward, although again this may be "core" reactions that need not be conscious, or conscious pleasure borne out of processes of awareness. Lastly, satiety follows consummation of a reward and opens the potential for pursuing other rewards. Throughout the cycle, "learning" takes place constituting the associations, representations, and predictions about future rewards based on past experiences.

These components are interwoven during the pleasure cycle's complex choreography, switching between appetitive, consummatory, and satiety phases. Rewards, such as music, food, or sex, act as motivational magnets to initiate, sustain, and switch between the states. Hedonia refers to either an objecting "liking" response or a subjective liking reaction to the hedonic impact of a stimulus, and usually both occur together (Berridge and Kringelbach, 2008). The pleasure system relies upon a balanced interaction of key brain regions over time, as the change their relative contributions during the pleasure cycle (Berridge and Kringelbach, 2015). Key brain regions in the networks mediating pleasure include subcortical structures (nucleus accumbens, ventral pallidum, periaqueductal gray, ventral tegmental area, and amygdala) and cortical structures (orbitofrontal, cingulate, and insular cortices; see Fig. 2).

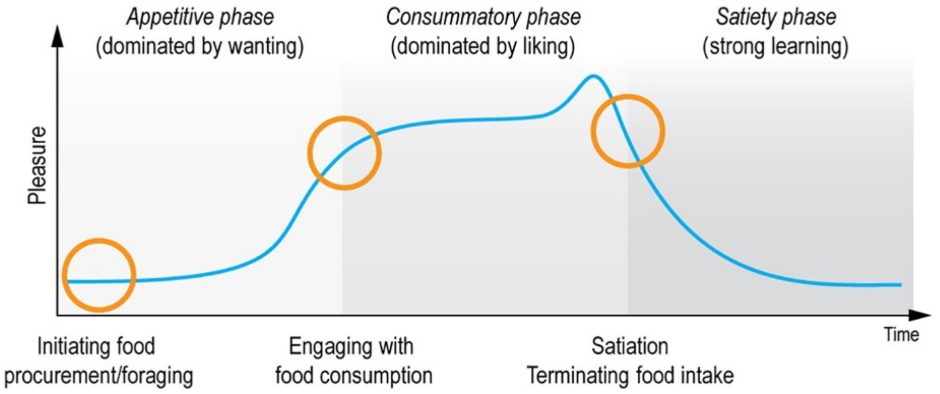

FIG. 1

The pleasure cycle. Both fundamental (i.e., rewards associated with behavior necessary for species survival) and higher order pleasures (such as music or poetry) are associated with a cyclical time course. Normally, rewarding moments begin with a phase of expectation or wanting for a reward. This sometimes leads to a phase of consummation of the desired reward, which may have a peak level of pleasure (e.g., musical "chills" or "shivers down the spine"). The consummation phase can be followed by satiety and learning, where a listener learns and updates his/her predictions for the reward upon future encounters, although learning can take place throughout the cycle.

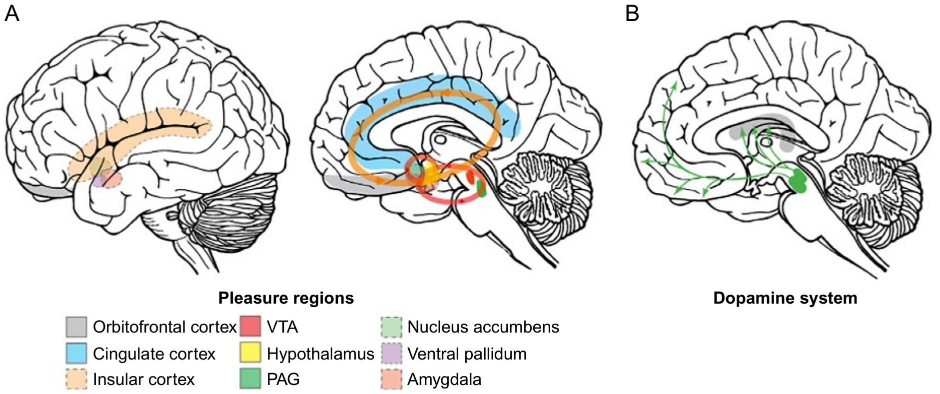

FIG. 2

Brain areas involved in pleasure and in music. (A) Pleasure networks in the human brain, including the orbitofrontal cortex, cingulate cortex, ventral tegmental area in the brainstem, hypothalamus, periventricular gray/periaqueductal gray, nucleus accumbens, ventral pallidum, amygdala, and the insular cortices. (B) The dopaminergic system in the human brain.

Pleasure has a strong impact on subjective well-being and happiness, often referred to as eudaimonia. Eudaimonia refers to the evocation of a life well-lived, embedded in meaningful values together with a sense of engagement (Kraut, 2017). To define a "good life" has sparked debate across millennia. What Aristotle referred to as *eudaimonia* might be commensurable to what in the Buddhist tradition is called *nirvana*, or the existentialist philosopher Satre called *authenticity*. The Greek term "eudaimon" is composed of two parts: "eu" means "well," while "daimon" means "spirit" or "divinity." Aristotle proposed that the state of eudaimonia is the highest end, and that all subordinate goals, such as health, wealth, and similar resources, are sought because they promote eudaimonia or well-being (Kraut, 2017). He conceptualized living well as an activity, a physical manifestation of virtuous activity, rather than a state or a condition.

Although hedonia and eudaimonia are separable constructs, they have many similarities. Hedonic and eudaimonic aspects empirically cohere together in happy people. For example, in happiness surveys, over 80% of people rate their overall eudaimonic life satisfaction as "pretty to very happy," and comparably, 80% of people also rate their current hedonic mood as positive (Kesebir and Diener, 2008).

3 ON MUSIC

Music is a universal feature of human societies. In the Western world, individuals on average choose to listen to around 18 h of music per week (Schafer, 2016). Music is consistently rated to be among the top 10 things that people find pleasurable in life (Dube and Lebel, 2003). The ability to derive pleasure from music appears to be a unique trait among humans (Vuust and Kringelbach, 2010), as studies in other animals such as nonhuman primates have failed to find any reactions denoting pleasure or displeasure related to music perception or activity (Bates and Horvath, 1971; Hauser and McDermott, 2003).

3.1 BRAIN SYSTEMS UNDERLYING MUSICAL PLEASURE

Processing of music in the human brain has been well studied. Perceptual features of music typically elicit activity in primary auditory cortex and associated areas, while the pleasure of music is associated with the aforementioned pleasure network (for review see Koelsch, 2010; Zald and Zatorre, 2011). Of note, the musical pleasure cycle has been shown to involve brain regions that comprise the reward system, in particular parts of the orbitofrontal cortex, the ventral tegmental area, and the nucleus accumbens (Blood and Zatorre, 2001; Brown et al., 2004; Koelsch et al., 2006; Menon and Levitin, 2005; Mitterschiffthaler et al., 2007; Osuch et al., 2009; Suzuki et al., 2009). The pattern of activity for musical pleasure is remarkably similar to the brain networks involved in the pleasure cycles of food (Kringelbach et al., 2012) and sex (Georgiadis and Kringelbach, 2012).

3.2 HOW DOES MUSIC LEAD TO PLEASURE? THE ROLE OF ANTICIPATION

Music induces emotions, and most conspicuously pleasure. Scientists have long tried to understand and explain how music translates to hedonic experience, and explanations typically fall into one of three categories. First, hardwired responses in the brain may be triggered by survival-related responses in the auditory system, such as brainstem responses to hearing a loud sound and a subsequent fear response. Second, extramusical associations can be formed to link music to a particular affective response. These may include emotional contagion, visual imagery, episodic memory, or evaluative conditioning (Juslin and Vastfjall, 2008). Third, music establishes, fulfills, or disappoints our anticipatory neural structures and mechanisms, on several different levels of abstraction. This process hinges on the brain's intrinsic capacity for predictive coding and can cause pleasure in a multitude of ways.

It has been proposed that anticipation must be viewed as the most fundamental mechanism underlying musical pleasure (Vuust and Frith, 2008) and we therefore concern ourselves with this element. One strength of anticipation is that it directly links musical and psychological mechanisms. This is in contrast to the array of extramusical associations such as episodic memory or visual imagery, within which pleasure is derived through the association of music with an external stimulus. Furthermore, many of the six mechanisms proposed by Juslin and Vastfjall may or may not be involved in the pleasure response to a specific piece of music. For example, one track may be strongly linked to a childhood memory or vivid visual imagery, while another may not be. However, anticipation is always inherent in the experiential component of music, and other factors may therefore act "on top" of musical anticipation (Vuust and Frith, 2008).

3.3 EVIDENCE FOR STATISTICAL LEARNING IN MUSIC

The structure of music is governed by statistical regularities and is highly repetitive (Loui et al., 2010; Pearce and Wiggins, 2006; Pearce et al., 2010; Saffran et al., 1996, 1999). Within the first few seconds of listening to a piece of music, we carve out musical expectations based on factors such as meter and tonality. This occurs without conscious cognitive effort (Eerola, 2003; Koelsch et al., 2000; Krumhansl et al., 1982; Tillmann, 2005) and may rely on a general learning mechanism that is sensitive to statistical contingencies in incoming sensory stimuli, including musical structure (Loui et al., 2010; Pearce and Wiggins, 2006).

Even infants in utero and newborn infants appear to be sensitive to very basic auditory contingencies based upon qualities such as pitch, timbre, or temporal sequencing. They appear to form expectations, as they show a neural mismatch negativity (MMN) when expectations are violated (Nätänen et al., 2007; Winkler et al., 2009).

To illustrate what happens when we listen to music, Loui et al. (2010) composed an artificial musical grammar. This was played to individuals for 25–30 min, who listened passively, and afterward they demonstrated extensive learning characterized by recognition, generalization, and sensitivity to the event frequencies in their given grammar. They also had an increased preference for melodies in the new musical system they had been exposed to, which together provides evidence that acoustical and statistical properties of musical sounds in the environment are processed and learnt by the brain. This perhaps occurs through a domain general statistical learning mechanism, as results are very similar to language acquisition studies using passive listening to an artificial grammar.

Not all musical expectations are universal. While the MMN appears to occur to deviant sounds in most situations, other musical expectations may be shaped by the musical culture that surrounds us. For instance, Western individuals appear to be less sensitive to deviations in North Indian classical music, compared to Western folk music, and find the melodies less congruous overall (Demorest and Osterhout, 2012). Further, French adults were less able at tapping in time to music of Tunisian origin, compared to French music, demonstrating lower synchronicity (Drake and Ben El Heni, 2003). Acculturation evidently drives our expectations as well as statistical learning mechanisms. Lastly, musical training also has an impact upon musical expectations. Musically trained children have larger amplitudes of the early right anterior negativity, elicited by music-syntactic irregularities (Jentschke and Koelsch, 2009), and this effect also transfers to musically trained adults (Tervaniemi et al., 2012).

3.4 HOW DOES MUSICAL ANTICIPATION LEAD TO PLEASURE?

It makes intuitive sense that the brain rewards correct predictions, given their vital importance for our survival and navigation of the unpredictable external world. While music is not directly related to survival, when musical expectations are fulfilled, they are experienced as rewarding and pleasurable (Vuust et al., 2018). Importantly, however, we can also feel pleasure when we experience the unexpected—a violation of our predictions. Musical anticipation refers to the process during which an emotion is induced in a listener because a specific feature of the music violates, delays, or confirms the listener's anticipation of the continuation of the music (Vuust and Frith, 2008). Both failed anticipation and chills neatly describe how musical anticipation leads to pleasure.

3.5 FAILED ANTICIPATION

At first it may seem counterintuitive that a failed prediction could lead to pleasure in music. Correct predictions are of crucial importance to our survival and are duly rewarded. However, many features of music that produce pleasure and associated strong feelings explicitly violate our expectations: for instance, when you move up an octave, or the music begins softly and then sharply becomes loud, or when a new instrument or voice is abruptly introduced. The transition to the chorus usually involves a period of dissonance or a sharp change in the melody, and ornamental notes such as an appoggiatura suspend the resolution of the melodic line for a brief moment, creating a sense of dissonance before it resolves.

Huron (2006) stratified the response of an individual in the advent of an event into two separate reactions. One type of response is fast, coupled with an immediate somatic response, and named the "reaction response." The second response is a conscious assessment of the event and is termed the "appraisal response." When an individual is surprised, that is, their expectation or prediction is incorrect, the reaction response is perpetually negative. However, Huron argues that whenever we experience a negatively valenced emotion such as pain or fear, analgesic opiates are released by the body to counteract the pain and allow you to continue to function. Experiencing a brief, negative emotion may therefore lead to ensuing pleasant feelings. We then appraise the unexpected event as pleasant and derive a sense of satisfaction from its occurrence.

Huron further proposes that the delight from failed anticipation or surprise stems from a contrast between the fast track response, mediated by subcortical brain regions, and the slower appraisal response which is mediated by cortical structures (LeDoux, 1989). While the rapid response to the surprise has a negative valence, the slower appraisal processes follow quickly and often have a neutral or a positive valence.

3.6 CHILLS

The study of pleasurable responses to music can be difficult as interindividual differences in favored tracks are rife, and even during a track the individual may not exhibit stable emotional responses. Studies which use neuroimaging methods such as fMRI and PET may be troubled by their poor temporal resolution, aggregating the brain response over seconds or minutes rather than tracking moment-by-moment emotional response. One study tried to circumvent this problem by contrasting pleasant and unpleasant music (Koelsch et al., 2006), but it may be preferable to use temporally sensitive neuroimaging modalities such as MEG in order to fully untangle the hedonic valence associated with music.

One means to addressing these problems is to focus in on relatively stable affective reactions while listening to music, often known as "chills" or "shivers down the spine," which are particularly salient (Blood and Zatorre, 2001; Goldstein, 1980; Panksepp, 1995; Sloboda, 1991). Laeng et al. (2016) amassed various descriptions of chills to define them as comprising three elements: (1) a cognitive state of intense absorption and full focus or concentration on the relevant musical events, (2) an intense peak of pleasure and rapture, a personal "merging" into the musical moment, and (3) a bodily component that has been referred to as feeling "chills" or "thrills" at specific moments during the musical stream.

From an evolutionary perspective, chills are related to the survival mechanisms of what has been termed the four Fs of life ("feeding," "fighting," "fleeing," and "reproduction"), and specifically to the fulfillment or violation of expectancy such as surprise. Such survival mechanisms are present in most species and usually involve automaticity, speed, and subcortical and cortical involvement. A physiological response relating to changes in general arousal prepares the body for "fight or flight." In the case of music, postchill appraisal processes always determine that the surprising event does not imply real danger and this may lead to the delightful qualia of shivers down the spine. Surprise is inherently linked to musical anticipation, as it indicates a biological failure to predict a future event. As described earlier, it denotes a failure to predict an event, and the brain's fast and slow processes result in an overall feeling of pleasure.

Given that music arouses our emotions, and emotions are characterized by autonomic changes, it is fitting to expect robust effects of chills upon psychophysical parameters. Indeed, psychophysical and behavioral measures are apt for measuring what happens in the body when an individual experiences musical chills. According to a study by Rickard (2004), the skin conductance response (SCR) co-occurring with chills may be the best indicator of strong emotional responses to music, compared to other peripheral measurements such as heart rate and cortisol levels. Chills are related to changes in loudness (Nagel et al., 2007), depending upon familiarity with a musical style (Kringelbach and Berridge, 2010) and on personality factors such as reward dependence or sensation seeking (Kringelbach and Berridge, 2010). A distinct acoustical pattern that reliably induces chills has remained elusive, but it seems that important musical factors include harmonic sequences, the entrance of a new voice or instrument, and the beginning of a new part. Notably, these relate to violations of expectation.

Blood and Zatorre (2001) provided a pivotal study linking the pleasurable chill response to its neural foundations. They measured heart rate, skin conductance, respiration, and brain activity using PET, in 10 music students while they listened to a chosen classical piece of music that they believed to elicit chills and strong emotional experiences. Participants reported chills, which correlated with changes in psychophysical measures, during listening to their chosen pieces compared to control pieces (each control piece was a musical track chosen by another participant). Regression analyses assessed the relationship between increasing intensity ratings related to chills and PET measurements of regional changes in blood flow and identified changes in brain structures related to reward, motivation, emotion, arousal, and pleasure. Of note, these included the ventral striatum (nucleus accumbens), midbrain, amygdala, and the orbitofrontal cortex. This finding suggests that listening to music can, in certain circumstances, induce intense pleasure in the brain's reward systems and tap directly into these survival-related brain mechanisms. The authors suggest that although music is evidently not necessary for human survival, it may have notable psychological benefits.

3.7 HOW IS MUSICAL ANTICIPATION GENERATED IN THE BRAIN? PREDICTION CODING

Bayes' theorem proposes that the probability of an event is based upon prior knowledge of conditions related to the event. Following from this, Bayesian inference is a method of statistical inference in which incoming evidence is used to update the probability of a hypothesis being true. These principles form the corner stone of the predictive coding theory (Friston, 2010; Friston and Kiebel, 2009) in which the brain is seen as a "hypothesis tester" that has the purpose of generating predictions and minimizing prediction errors (incorrect predictions).

The predictive coding theory was first applied to understanding sensory perception (Friston, 2005). Here, the task of the brain is to infer the cause of sensory input using Bayesian inference, that is, using the sensory input cross-referenced with previous "knowledge." This is a tough enterprise as previous knowledge may not encompass all possible scenarios, and incoming sensory information changes rapidly.

Effective prediction requires an internal model of the world, and this is argued to be provided by internal generative predictive models, which continuously predict what the sensory input will be if it is caused by a certain (predicted) environmental event. In light of ever-accumulating evidence, the models are continuously updated to maximize the veracity of the predictions and minimize prediction errors (Fig. 3).

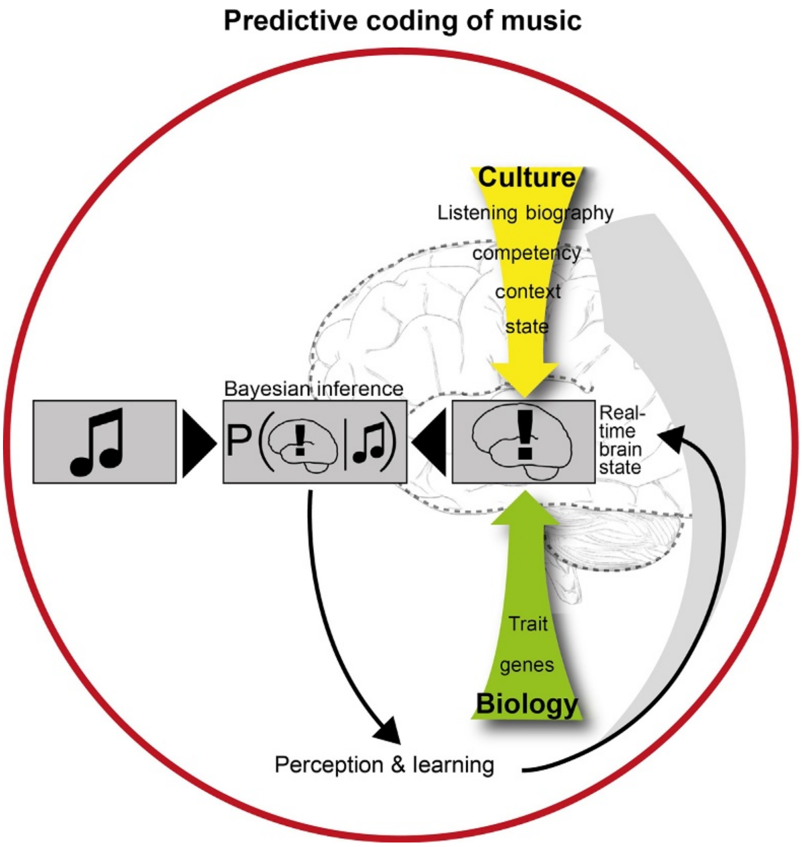

FIG. 3

Prediction coding. The experience and learning of music occurs in a dynamic interplay between anticipatory structures in music, such as the buildup and relief of tension in rhythm, melody, harmony, form, and other intramusical features on one side, and the predictive brain on the other. The real-time brain model is dependent on cultural background, personal listening history, musical competence, context, brain state (including attentional state and mood), and innate biological factors. The brain is constantly trying to minimize the discrepancy between its interpretation model and the musical input by iteratively updating the real-time brain model (or prior) by weighting the model with the likelihood (musical input) through Bayes' theorem. This leads to a constantly changing musical experience and long-term learning.

Adapted from Gebauer, L., Kringelbach, M.L., Vuust, P., 2012. Ever-changing cycles of musical pleasure: the role of dopamine and anticipation. Psychomusicol. Music Mind Brain 22 (2), 152–167.

In this way, the causes of our sensory input are not deduced in a bottom-up fashion from the incoming sensory information alone, but are inferred and anticipated based on contextual cues and previous sensory inputs. The predictive coding theory is closely aligned with the statistical learning approach proposed by Pearce and Wiggins (2006) to account for melodic perception. Initially, the predictive coding theory was proposed to account solely for perception. However, many other areas of cognitive neuroscience have found its main tenets and Bayesian framework to be helpful. This has led to the suggestion that the predictive coding theory may even be a core principle of brain functioning (Friston, 2010).

The predictive coding theory describes neural signals passing between different levels of cortical hierarchies, and this view of hierarchical functional organization is in agreement with known brain anatomy (Friston, 2002a). The predictive coding theory works upon two key principles: (1) functional segregation, which means that cells with common functional properties are grouped in the same area, and (2) functional integration, which means that information from a range of different specialized neuronal populations is integrated at higher cortical levels (Friston, 2002b, 2005).

Prior experience is vital for modeling expectations for the future, giving a prior probability which describes how probable an internal hypothesis is to be true. There are always a range of alternative hypotheses, and some are more likely to be true than others. These prior probabilities are therefore hierarchical and context sensitive. Therefore, the hypotheses that the brain generates in a particular situation are constrained by hypotheses at the same level or at higher levels (Friston, 2002a). More contextual knowledge will offer more contextual constraints, making hypotheses more specific, and the predictions will be thus improved. Consequently, our predictions are a mixture of the available sensory information and prior learning and knowledge, to form the internal hypothesis or the model.

Each hierarchical level in the brain provides a predictive model, or several models under uncertainty or ambiguity, of the expected input to the specific layer. Forward and backward connections permit the hierarchical layers to "communicate" (Friston, 2005). Backward connections allow high-level structures to communicate to low-level structures, with a strong modulatory effect on functionally specialized brain areas. In this way, high-level structures can exert contextual constraints on the models in low-level structures.

Sensory information progresses through forward connections from lower layers to higher layers and is processed as it passes through the system, acting as driving signals. At each level, the sensory information is matched to the internal predictive model. If there is a mismatch between the predictions made by the model and the sensory input at any level of the hierarchy, it creates a prediction error and a neuronal error message is fed forward to higher, more integrative levels. This is an important step, as here the prediction error is evaluated and the brain has two options: (1) to change the internal model, or (2) to change the way it samples information from the environment. This may depend upon the degree to which the actual sensory data violate the internal prediction. Accordingly, prediction errors are central for adaptive learning. When predictions are altered, the connectivity between neurons is believed to also change, so that neuron A will predict neuron B's response to a stimulus in a given context (Friston, 2005). The brain is constantly attempting to optimize its internal model by minimizing prediction errors (Friston, 2010; Friston and Kiebel, 2009).

Predictive coding and Bayesian principles have formerly been suggested to provide a helpful framework for understanding music perception (Gebauer et al., 2012; Temperley, 2007; Vuust and Witek, 2014; Vuust et al., 2009, 2018; Wacongne et al., 2011). Vuust et al. (2009) demonstrated an MMN to rhythmic incongruence in expert jazz musicians and nonmusicians and suggest that neuronal markers of rhythmic incongruity are concordant with a predictive coding framework, and that musical competence may affect the networks involved in the processing of statistical regularities in rhythm. Wacongne and colleagues refine this account with a paradigm demonstrating how hierarchical predictions at different levels work in parallel (Wacongne et al., 2011). This is also demonstrated by the work of Pearce et al. (2010). Vuust and Witek (2014) developed a predictive coding model of musical rhythm, in which rhythm perception is conceptualized as an interaction between what is heard ("rhythm") and the brain's anticipatory structuring of music ("meter"). Gebauer et al. (2012) extended the predictive coding approach to pleasure processing, arguing that because predictions are both fundamental to music perception and pleasure, they must be interrelated.

3.8 THE ROLE OF DOPAMINE NEURONS IN ANTICIPATION

The fact that pleasurable music listening elicits activity in the dopaminergic reward system has prompted researchers to propose a direct link between the pleasurable feeling and the release of dopamine. Wise and colleagues were among the first to suggest that dopamine is involved in pleasure (Wise et al., 1978). Their suggestion was based on the observation that rats that were administered neuroleptic drugs, which block dopamine, became ignorant to previously rewarding stimuli such as food. As a consequence, the rats ended up starving, apparently because they found no pleasure in eating (Wise, 1982; Wise et al., 1978).

However, there is evidence to the contrary to suggest that dopamine may not be the prime agent in hedonic sensations. Dopamine depletion of the striatum and the nucleus accumbens does not affect hedonic pleasure (Berridge et al., 1989). In clinical cases, Parkinson's disease is caused by degeneration of dopamine neurons in the midbrain; however, individuals with this disease do not show signs of decreased pleasure to sweet tastes, when compared with healthy controls (Sienkiewicz-Jarosz et al., 2005). Such findings have generated renewed assumptions about the role of dopamine in reward. Berridge and Kringelbach (2008) have therefore proposed that dopamine is associated with the anticipation of reward (the "wanting" phase, see Fig. 1), as well as coding of prediction errors (the "learning" phase), instead of the "liking" phase and feelings of pleasure. Different populations of dopaminergic neurons are now believed to be involved in reward anticipation and registration of prediction errors (Schultz, 2010).

First, dopaminergic neurons have been linked to reward anticipation. In macaque monkeys, during a conditioned stimulus paradigm, dopaminergic neurons have been shown to fire even before the reward is delivered (Schultz et al., 1992). When rewards are paired with a reinforcer, dopaminergic neurons respond to events predicting reward, but not to the actual rewarding stimuli (Schultz, 1998). There is a clear link between the anticipation of a reward and dopaminergic firing (Schultz, 2000, 2002). Dopaminergic neurons can also represent the expected reward value of a reward (Tobler et al., 2005), the likelihood of the reward occurring, or its probability (Hollerman and Schultz, 1998), and they also register the ambiguity or reward variance (Burke and Tobler, 2011). Specific neuronal populations in the striatum and orbitofrontal cortex thereby appear to encode specific aspects of anticipation. Reward anticipation and monitoring of rewards are a continually adapting process, as new evidence flows through the system (Nomoto et al., 2010). Dopaminergic pathways from the striatum to the orbitofrontal cortex and the posterior cingulate cortex show sustained dopamine firing in response to increased uncertainty, leading to improved learning.

Second, dopaminergic neurons have also been linked to prediction error. Prediction errors are reflected in dopaminergic neurons in a bidirectional manner (Schultz, 2002, 2010), with positive events resulting in increased firing, and negative events resulting in decreased firing. The registration of prediction errors and adjustment of predictions seem to be modulated by the mesocortical dopaminergic pathway, and dopamine may also contribute to the updating of predictions and internal models by its involvement in learning-dependent synaptic plasticity (Lisman and Grace, 2005). The orbitofrontal cortex codes outcome expectations and updates these during learning (Schoenbaum et al., 2009; Walton et al., 2010), while the amygdala of rats and monkeys is involved in updating reward estimations in lieu of changing conditions (Murray and Izquierdo, 2007). The dopamine signal has been argued to be the most well-characterized of neuronal activations in brain structures associated with goal-directed behaviors (Schultz, 2010).

3.9 THE POTENTIAL ROLE OF DOPAMINE IN MUSICAL ANTICIPATION AND LEARNING

In Gebauer et al. (2012) the authors outline how dopamine may play a role in musical anticipation and learning, in eight hypotheses:

(1) The three phases of the pleasure cycle (wanting, liking, and learning) can be identified in behavior and neural activity, as well as in music theoretical and computational models of music perception.

(2) Music is a collection of sound features to which the brain subscribes perceptual salience and responds with *alert signals*. Alert or salience signals are widespread in reward-coding dopaminergic neurons, encoding motivational salience and supporting brain networks involved in orienting, cognition, and general motivation (Bromberg-Martin et al., 2010).

(3) Music “liking” responses are not directly associated with dopaminergic neurons. Instead, these neurons represent musical wanting/anticipation and musical learning. More work is needed to determine which neurotransmitters mediate the subjective liking response.

(4) Musical anticipations are hierarchically organized.

(5) There is an association between the dopamine signal and physiological arousal.
(6) Failed anticipations are linked to dopaminergic anticipatory firing followed by a prediction error. It is likely that there is an optimum level of surprise, where an unanticipated musical sequence is experienced as pleasurable, resulting in increased dopamine firing and release than when a musical sequence is fully predicted. A sequence judged to be too novel may result in a prediction error manifested as a depression in dopaminergic firing.
(7) Music with high uncertainty, such as jazz, might result in sustained dopamine firing and increased higher order neural integration as a result of learning.
(8) Following dopaminergic prediction errors (both positive and negative), the internal predictive model is updated through learning, which may be integrated across multiple regions of the brain. Musical anticipation would therefore be represented in functionally segregated brain areas as well as higher level integrated areas.

Importantly, the coding of reward predictions is not functionally located in the dopaminergic neurons of the striatum, but is distributed across the brain (Burke and Tobler, 2011). The most significant areas for this include the striatum, orbitofrontal cortex, amygdala, hippocampus, lateral intraparietal, and anterior cingulate cortices. Interestingly, these are the very regions that are consistently found to be active in studies of musical emotions (Koelsch, 2010).

If expectations on all hierarchical levels are violated, this will probably be experienced as very unpleasant, whereas subtle violations to one stream of expectations, be it key, meter, rhythm, melody, harmony, or phase structure, may just create the kind of tension that gives rise to pleasure (Gebauer et al., 2012). Likewise, different hierarchical levels of sequences may be violated separately, with the degree of violation determining the valence of the response.

4 ON DANCE

From an anthropological perspective, cross-cultural research has shown that in many societies, there are no general terms for music and dance, rather people use words for specific performances involving dance and music (Lewis, 2013). In yet other societies, the same word is used for music-making, singing, and dancing.

Dancing is one of the most overtly expressed forms of affective engagements with music. Regular rhythmic body movement to repetitive beats characterizes many musical practices across the world, and rhythmic synchronization is often listed as a possible candidate for explaining the adaptive value of music, based on its prosocial effects (Bispham, 2006; Merker et al., 2009; Ravignani et al., 2014; Tarr et al., 2014). While embodied theories of cognition (Semin and Smith, 2008; Wilson, 2002) have received a significant empirical support from studies showing connections between affective and motor systems (Barrett and Lindquist, 2008; Niedenthal, 2007; Niedenthal et al., 2005; Winkielman et al., 2008), we have yet to determine how and why music compels us to move.

It is clear however that similar to music, dance is a ubiquitous feature of all cultures and has been historically important in ritual, courtship, and human expression. Dance is a pleasurable activity, involving moving to rhythmic sound, often in groups. The word emotion is closely linked to the concept of movement, as implied by its Latin root ("movere," to move).

Synchrony is the central feature of dance, whether one is in synchrony with the music, with other people, or with both (Neveu-Kringelbach, 2013). Synchrony develops from a very early age in the context of infant–caregiver interactions, and such behavior is often referred to as a "dance." It utilizes familiarity with a social partner's behavioral repertoire and interaction rhythms, to initially produce synchronous behavior including gestures, vocalizations, gaze, facial expressions, and postures. It is more complex than simple mirroring because it involves the use of memory, predictions, and theory of mind to anticipate the most likely next step, and this is where predictive coding may once again play a role with anticipatory structures and violation or fulfillment of expectation.

In Durkheim's concept of "collective effervescence," synchrony leads to positive emotional states and joint arousal (Páez et al., 2015). Evidence suggests that the social context of dancing is linked with the release of endorphins, the body's "feel good" chemicals. One elegant study measured pain thresholds before and after individuals danced, as an indirect measure of endorphin levels (Tarr et al., 2015). Individuals danced in groups, either synchronized with each other or unsynchronized, and at either high or low exertion levels. The groups who danced in synchrony experienced higher perceptions of closeness to their fellow dancers, and also higher pain thresholds. So did the individuals who danced at higher levels of exertion, suggesting that exertion and synchronization both have positive effects on social bonding and endorphin release.

In a second study, the authors replicated their findings in a "silent disco," finding that synchronized dancing leads to increases in pain thresholds (inferred as higher endorphin levels) and also social bonding (Tarr et al., 2016). However, they did not find that individuals were more cooperative or altruistic in a subsequent economic game, contrary to previous findings (Wiltermuth and Heath, 2009).

Building on synchrony but closely linked to the musical syncopation enabling synchrony, the concept of "groove" is psychologically defined as a musical quality associated with a pleasurable wanting to move (Janata et al., 2012; Madison, 2006), frequently found in response to musical genres such as funk, soul, hip-hop, and electronic dance music. Structurally, this music manifests the prominent use of syncopation, a form of rhythmic complexity in music (Butler, 2006; Danielsen, 2006; Gioia, 2011; Greenwald, 2002).

Syncopations are associated with positive emotions (Keller and Schubert, 2011), supporting the theory that stimulated expectations and predictions are the sources of emotion and pleasure in music (Huron, 2006; Meyer, 1956). In a recent study, it was found that syncopation is an important predictor in groove and that there is an inverted U-shaped relationship between syncopation and ratings of experienced pleasure and wanting to move (Witek et al., 2014). Via a web-based survey, listeners rated medium degrees of syncopation in funk drum breaks as eliciting the most pleasure and wanting to move, compared to low and high degrees of syncopation, suggesting that in groove, listeners prefer a balance between rhythmic predictability and complexity. Ongoing neuroimaging studies are currently investigating the eudaimonia of groove.

The question of whether dance and/or music, via the mechanism of social bonding, has a measurable impact on behavior is interesting to our understanding of eudaimonia. One facet of eudaimonia is feeling connected, and in this respect, social bonding might be an end in itself. Social contexts also appear to increase musical competencies, showing bidirectional relations between social interaction and music. Children as young as two and a half years old are better able to drum in synchrony with a human agent, compared to an impersonal drum beat (Kirschner and Tomasello, 2009).

Christensen et al. (2017) proposed at least six neural and biobehavioral functions of dance, to explain why it remains such a ubiquitous and central element of human life: attentional focus, basic emotional experiences, imagery, communication, self-intimation, and social cohesion. They further suggest that well-being or eudaimonia may be a secondary effect of the above functions of dance. Although we do not know precisely what is happening in the brain when we dance, due to logistical difficulties of measuring brain activity during dancing, we might hypothesize that the brain recruits reward-related regions and may even reach a eudaimonic state of bliss, similar to the "runner's high" that is experienced following vigorous exercise, yet distinct in the sense that dance is in its essence a social activity.

5 POETRY

Aristotle famously stated that "poetic language must appear strange and wonderful," highlighting how poetry makes use of anticipation and violation of anticipation in order to lead to pleasure and meaning. This was formally recognized by Shklovsky (1998) as the process of *defamiliarization* in poetry, that is, the artistic technique of presenting common things in an unfamiliar or bizarre way in order to enhance perceptions of the familiar. To illustrate this, consider this excerpt from the poem *A Martian Sends a Postcard Home* by Craig Raine:

> *Caxtons are mechanical birds with many wings*
> *and some are treasured for their markings –*
>
> *they cause the eyes to melt*
> *or the body to shriek without pain.*
>
> *I have never seen one fly, but*
> *sometimes they perch on the hand.*
>
> **Raine (1979)**

Here, the poet refers to books as "Caxtons" (the name of the man who invented the printing press in 1476 was William Caxton), crying as the eyes melting, and laughter as shrieking without pain. The "strangeness" of the everyday objects and occurrences being explained in this "martian" manner gives pleasure to readers as they resolve the initial mystery of what the poem is referring to. This has many parallels with the use of anticipation and prediction in music and dance. On initial reading, the predictions made about the meaning of the phrases are upturned. Eyes cannot melt, and what cannot fly but can perch like a bird? As Huron noted, our fast reaction may be surprise, but that can be superseded by appraisals. On appraisal of the poem, the reader is able to work out that the author is referring to everyday objects, and pleasure is produced from the resolution of the text's meaning.

The above example highlights semantic predictions, but poetry also confirms or violates predictions in other domains. Meter, for example, is the basic rhythmic structure of a verse or lines within a verse. Prosodic use varies between poetic styles and languages. English verse is a succession of syllables, each of which has a different emphasis, either heavily stressed or lightly stressed. Shakespeare played with meter in his plays, in order to give emotive emphasis and color to his character's speeches. He tended to stick to iambic pentameter, which is a rhythm with alternative unstressed and stressed syllables, much favored in Tudor times, for example:

> *If* ***mu-*** / *-sic* ***be*** / *the* ***food*** / *of* ***love,*** / *play* ***on***
>
> **Twelfth Night, Act 1, Scene 1, line 1**

As is evident, the use of a predictable meter like iambic pentameter makes predicting the rhythm of the poetry easy and also pleasurable. But Shakespeare's work gradually moved away from the strict Tudor pentameter, and by the end of his career his tireless experimentation had led the English dramatic blank verse line to be hospitable to virtually any phrase the poet wished to use (Wright, 1991). Shakespeare played with different patterns of stresses, for example, raising the stress level of an unstressed syllable to make the iambic pattern more deliberate and grave (forming a "spondee"), or making the pattern proceed rapidly by withholding the expected stress on a stressed syllable (forming a "pyrrhic"). Take this for example:

> *The* ***or-*** / *-ange* ***sky*** / *of* ***eve-*** / ***-ning died*** / ***away***
>
> **Line 446 of Wordsworth's The Prelude, book 1**

Here, Wordsworth's words may be mistaken for iambic pentameter, but for the penultimate two syllables (-ning died), which are stressed to emphasize the abrupt disappearance of the sun. Expectation and anticipation in poetry may follow very similar patterns to the same qualities in music and, as is evident, may occur on different hierarchical levels (semantic and meter are but two examples). Whether the poetry meets expectations, or defies them, reading poetry can be pleasurable and insightful. Those moments where meaning is revealed often lead to deep satisfaction, not dissimilar to a eudaimonic state.

6 ORCHESTRATION IN THE DEFAULT-MODE NETWORK

Many of the key regions of the pleasure system are part of the brain's default-mode network, a key resting state network that is most active when we are not directly engaged in tasks (Gusnard et al., 2001). There is also an emerging literature, suggesting that the default-mode network supports representations of the self (Lou et al., 1999), internal modes of cognition (Buckner et al., 2008), and perhaps even states of consciousness (Laureys et al., 2004). It has also been linked to self-awareness, remembering the past and prospecting the future (Addis et al., 2007). These are all qualities which may support a eudaimonic state, as a sense of well-being necessitates security of the self in future endeavors.

We have previously suggested that the default-mode network may play a role in connecting eudaimonic and hedonic happiness to the self (Kringelbach and Berridge, 2009), particularly given the activity changes in the frontal regions such as the orbitofrontal and ventromedial prefrontal cortices correlating with pathological changes in subjective hedonic experiences, such as in depressed patients (Drevets et al., 1997).

In one relevant study, individuals picked their favorite song and then underwent an fMRI scan (Wilkins et al., 2014). Despite differences in acoustic qualities such as the presence or absence of lyrics, this allowed the scientists to explore how the brain responds to the similar experience of hearing a favored piece of music. They found that when participants listened to their favorite song, a network of brain regions was active that corresponded to the default-mode network. The particular state of bliss encountered when listening to a favorite track may have parallels with a eudaimonic brain state.

Overall it would seem a judicious assumption that eudaimonia relies in part on the brain mechanisms of the pleasure system. This is especially relevant given the direct link between the lack of pleasure, *anhedonia*, and affective disorders (Rømer Thomsen et al., 2015). Intriguing evidence suggests that the default-mode network may help orchestrate both pleasant and eudaimonic brain states.

7 CONCLUSIONS

Ryan and Deci (2001) conceptualize two different perspectives on well-being, delineating either the “hedonic” approach that focuses upon happiness and pleasure attainment, or the “eudaimonic” approach that emphasized meaning and self-realization. However, as we have shown through the arts, these two perspectives are not mutually exclusive and may even be mutually enhancing. Both happiness and eudaimonia are brain states, and both are fleeting and transitory. While science has characterized pleasurable states in some detail to date, corresponding findings about the eudaimonia are currently lacking. However, as we suggest, the default mode and the pleasure system may provide some of the necessary brain mechanisms supporting eudaimonic brain states, and this remains an area to be explored.

Music in particular can provide a strong pathway to well-being. Music therapy is a growing phenomenon, particularly in dementia, where it has been shown to reduce aggressive behavior and agitation (Johnson and Taylor, 2011), and increase mood and social skills (Wall and Duffy, 2010). Music has also been used as a “reward” in an intervention to alter attentional bias in socially anxious individuals (Lazarov et al., 2017). In this RCT, individuals were trained to not dwell on socially threatening faces as their chosen favorite music was played when their eye gaze settled on neutral faces, but stopped when their eye gaze moved to fixate on the socially threatening faces. Three months following the intervention, individuals maintained reductions in social anxiety, rated both by themselves and by clinicians. This suggests that the rewarding value of music has a significant effect on our ability to learn.

Huron defines the term *sweet anticipation* as “the positive feelings that arise from conscious thought about some future event” (Huron, 2006). This is remarkably similar to eudaimonia, where one consciously reflects on their overall happiness and well-being. As we demonstrate, the arts, and music in particular, operate by a process of anticipation and are comprised of anticipatory structures on multiple levels of abstraction. While hedonia may be generated on a rapid timescale, with moment-by-moment predictions being fulfilled or violated, eudaimonia may operate on a slower timescale, with conscious processing of one’s situation and life satisfaction.

One resounding theme that emerges from exploring the links between art and hedonia is that as humans we are optimized to search for meaning in everything we encounter. Something has meaning when it stands for or signifies something outside itself. We interact with the world through our senses, interpreting neural signals from the hundred billion neurons that constitute our brain, to make meaning from the world around us. As demonstrated, the brain is a prediction machine, constantly extracting meaning from the events we encounter, and appraising them with further meaning. The arts typify this process, through anticipatory structures and hedonic reactions, and we imbue meaning and depth into the music, dance, visual art, and poetry that we confront. One of the defining features of eudaimonia is a “meaningful” life. Many people say that they are unable to survive without music or the arts, that it means something to them and gives them more than just pleasure. Perhaps art is perfunctory, but perhaps it also survives because it exploits the very nature of what makes us human.

ACKNOWLEDGMENTS

Our research is supported by an MRC studentship to E.A.S. As well as an ERC Consolidator Grant: CAREGIVING (no. 615539) to M.L.K. and the Center for Music in the Brain, funded by the Danish National Research Foundation (DNRF117) to M.L.K. and P.V. This chapter benefitted from a fellowship at the Paris Institute for Advanced Studies (France), with the financial support of the French State, programme “Investissements d’avenir” managed by the Agence Nationale de la Recherche (ANR-11-LABX-0027-01 Labex RFIEA+). This chapter is in part based on the material from previously published articles including Gebauer et al. (2012).

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