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The Pleasure of Music: Psychological and Neurobiological Mechanisms

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Abstract. Music is a powerful source of pleasure in our lives although it provides no direct biological benefit as food does. This review asks how musical sounds come to be experienced as rewarding and how this pleasurable experience may influence emotion and cognition. Researches on musical perception show that the brain first represents basic features, such as pitch, maintains successive sounds in working memory, and uses learned musical regularities to form expectations about upcoming events. These perception and prediction processes can interact with general reward mechanisms, allowing abstract musical stimuli to generate rewards. Studies of biological rewards demonstrate the involvement of mesolimbic and dopaminergic systems. Music studies link pleasurable listening to reward-related brain activity, physiological arousal, and dopamine release in the striatum. Functional connectivity between the nucleus accumbens and auditory and frontal regions further suggests that musical pleasure emerges from interactions between perceptual, predictive, and reward systems. The nucleus accumbens thus serves as an important interface between cortical representations of musical structure and the assignment of reward value. Beyond immediate enjoyment, music may influence emotion regulation, stress reduction, attention, and cognitive performance. These effects vary across tasks, musical characteristics and listeners. Future applications can therefore benefit from context-sensitive and personalized approaches in learning, care settings, and music recommendation.

Keywords: musical pleasure, reward system, dopamine, music perception, cognitive performance

1. Introduction

In contrast to food and water, music has no obvious physiological utility for survival; it does not provide calories and other material benefits, and yet people spend considerable time listening to music and enjoy doing so. People repeatedly listen to their favorite music, go to live concerts and experience intense pleasure from simple structured sounds. Why does music induce pleasure?

Musical pleasure cannot be accounted for by a single psychological or neurophysiological mechanism. Sound stimulus should be processed and represented perceptually to enable appreciation of a musical piece. Pitches have to be encoded, successive sounds have to be maintained in working memory and integrated, and regularities in melody, harmony and rhythm

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have to be learned and memorized to create expectations. Perceptual processing and prediction can thus be coupled with reward and valuation circuits [1].

The following sections will address the issues of music representation and formation of expectations by the brain based on the acoustic patterns. Then the involvement of the general reward mechanisms such as the mesolimbic and dopaminergic systems in musical pleasure will be addressed. Finally, the interaction of auditory system with the general reward mechanisms and the generation of musical pleasure will be discussed. The role of musical pleasure in modulating emotions, stress, attention and cognition will be considered. The potential uses of music-induced pleasure will be addressed at the end of the paper.

2. Psychological and neurobiological mechanisms

2.1. Neural mechanisms of musical perception

Pitch is an essential component of music and one of the key elements of the perception and organization of auditory stimuli by listeners. Pitch-selective neurons were found in one specific region of the marmoset monkey's auditory cortex, indicating that auditory cortical processing plays a role in the formation of a relatively stable representation of pitch [2].

However, music comprises more than just pitches. In a study of the pitch-memory task using functional magnetic resonance imaging (fMRI), activation was observed throughout temporal and frontal regions. The activity in the supramarginal gyrus (SMG) and dorsolateral cerebellum was associated with better task performance [3]. The SMG and dorsolateral cerebellum thus appear to play a critical role in the short-term storage of pitch information and the continuous pitch discrimination necessary for pitch memory.

Listening repeatedly allows listeners to learn regularities that occur in musical sequences [4]. These learned regularities can act as perceptual templates that give rise to expectations of likely continuations of musical material [1]. Furthermore, the brain is sensitive to violations of regularities. Unexpected changes in melodic contours, intervals, or harmonies produced characteristic electrophysiological responses [5, 6]. Maess et al. found that harmonically inappropriate chords activated Broca's area and its right-hemisphere homologue, demonstrating that these structures are involved in the processing of musical syntactic structure [7]. Together, these findings illustrate the broad perspective that musical perception involves context-dependent expectations based on the learned regularities of structure. The brain applies the learned rules of music to anticipate future events and respond to violations of these expectations.

In general, it can be stated that auditory cortical processes underlie stable pitch representations, working-memory systems maintain and integrate successive sounds, and learned musical regularities allow the listener to predict future events.

2.2. The reward system and musical pleasure

In order to understand why listening to music can become pleasurable, it is important to first consider how reward is processed more generally. One of the classic demonstrations of a neural reinforcement system came from the work of Olds and Milner at McGill University. They found that electrical stimulation of particular brain regions in rats could act as a powerful positive reinforcer, causing animals to repeatedly seek conditions associated with the stimulation [8]. Later human studies linked food reward to dopaminergic activity in the striatum. Small et al. examined dopamine release during eating in healthy volunteers using raclopride positron emission tomography (PET)

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[9]. Participants were scanned after fasting and after consuming a favorite meal. Eating was associated with dopamine release in the dorsal striatum, and the amount of dopamine release correlated with participants' ratings of meal pleasantness.

Human reward, however, is not limited to stimuli with direct biological value. An event-related fMRI study investigating anticipation of monetary incentives showed that increasing monetary reward selectively recruited the nucleus accumbens (NAcc) [10]. Money does not have an intrinsic physiological value comparable to food, yet learning and social experience allow it to become highly motivating. The evidence points to the idea that abstract, learned rewards can engage the human reward system.

Blood and Zatorre provided early evidence that intensely pleasurable music recruits neural systems involved in reward, emotion, and arousal. Using positron emission tomography (PET), they measured cerebral blood flow while participants listened to self-selected music that elicited pleasurable chills, finding changes in regions including ventral striatum, midbrain, amygdala, orbitofrontal cortex, and ventral medial prefrontal cortex [11]. Salimpoor et al. further examined the physiological component of this response by having participants listen to self-selected highly pleasurable music while continuously reporting their level of pleasure [12]. At the same time, heart rate, respiration, electrodermal activity, body temperature, and blood volume pulse were recorded. Greater subjective pleasure was associated with stronger physiological arousal. Neural and physiological measures therefore converge on the conclusion that musical pleasure involves both reward-related neural activity and measurable changes in physiological arousal.

Using [^{11}C]raclopride positron emission tomography (PET), together with psychophysiological measures of autonomic nervous system activity, researchers found endogenous dopamine release in the striatum during peak emotional arousal to music [13]. Using functional magnetic resonance imaging (fMRI) with the same listeners and stimuli, they further found that the caudate was more involved during anticipation, whereas the nucleus accumbens (NAcc) was more involved during peak emotional responses [13].

Beyond dopamine release itself, later research examined how auditory processing interacts with the reward system to determine musical reward value. Salimpoor et al. provided an especially important connection between musical perception and reward in 2013 [14]. Participants listened to excerpts of unfamiliar music during fMRI scanning. They then indicated how much they liked each excerpt and how much they were willing to pay for it in an auction paradigm. The amount bid was used as a behavioral measure of reward value. Activity in the nucleus accumbens was strongly associated with the amount bid. Critically, higher reward value was associated with stronger functional connectivity between the nucleus accumbens and the auditory cortices, as well as the right inferior frontal gyrus. The latter region has been implicated in higher-level musical processing.

These results support a model in which musical reward emerges from interactions between cortical systems involved in perceptual analysis and prediction and subcortical reward circuitry. Auditory regions process musical structure and, through previous experience, contribute to expectations about how a sequence may continue. Prediction-related processes may then interact with reward-related regions such as the nucleus accumbens, contributing to the reward value of music [1, 14].

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3. From musical pleasure to behavioral and cognitive effects

3.1. Emotion regulation and stress

The effects of music do not end with the immediate experience of pleasure. Because pleasurable listening can alter emotional arousal and recruit systems involved in motivation and reward, music can also become a tool for changing or maintaining emotional states. Music might be used to increase an emotional state, reduce an undesirable state, or even maintain one that is considered desirable. A recent scoping review of 47 studies showed that music has been extensively studied as a tool for emotion regulation [15].

The effects of music on arousal may also extend to stress responses. De Witte et al. conducted two multilevel meta-analyses of 104 randomized controlled trials, including 9,617 participants and 327 effect sizes [16]. Music interventions produced significant reductions in both physiological stress-related outcomes, such as heart rate, blood pressure, and hormone levels, and psychological outcomes, such as anxiety, restlessness, and nervousness.

3.2. From attention to cognitive performance

Pleasant music has an effect on increasing arousal, mitigating boredom, improving mood, and the enjoyment of a task. This can have implications on concentration, memory, reading, and problem solving. In a meta-analysis of 66 studies and 4501 adult participants by Kämpfe et al. background music has an effect on emotional states as well as the performance of the task [17]. As compared to no music background music was associated with more positive emotional response and better performance in some activities such as sports but poorer reading and a small negative effect on memory. The authors found that musical tempo can affect the speed of ongoing activities. These results imply that music can affect the emotional and attentional conditions under which cognitive tasks are performed.

Characteristics of music such as lyrics, complexity, familiarity, tempo, and intensity also change the degree of attention captured by the background stimulus. Individual differences add a layer of variation. For instance, musical preference is partially associated with characteristics of the listener. It is found that there are connections between personality traits and preferences for musical attributes such as arousal, valence, and depth [18]. Preference could determine if music is experienced as rewarding, distracting, or emotionally useful although personality should not be considered as a complete explanation of preference. In the meantime, stress level, habitual listening behavior, and current goals may also change the effect.

4. Applications and future directions

In real-life contexts, the effects of music vary across situations, leaving considerable potential for future research and application. In learning, music may help concentration and engagement; a study of adolescents found that students who listened to music while studying or working reported higher perceived facilitation in focus, persistence, and efficiency [19]. The effects of music may also vary across age groups and stages of life. Music-based interventions may benefit people with dementia by supporting cognitive function, and quality of life [20]. During pregnancy, music interventions have been associated with reduced maternal anxiety [21].

Beyond external contexts, personality may influence musical preference, making individual differences relevant to personalized applications. The mechanisms reviewed in Section 2 indicate

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that reward value depends partly on learned musical templates and previous listening experience. Recommendation systems could combine listening history, preference, current emotional state, task demands, and contextual information. Physiological measures and repeated behavioral feedback can also be used to estimate whether a particular type of music is calming, stimulating, rewarding, or distracting for a particular listener.

Future research will need to move toward larger and more comprehensive models of musical effects in real-world settings. Instead of considering only isolated factors, future models will integrate listener characteristics, musical features, task demands, emotional state, and environmental context to capture the complexity of everyday listening. With larger and more diverse datasets, these systems could learn increasingly fine-grained patterns and generate more personalized predictions. This approach will be able to finally support adaptive recommendation systems that continuously refine music selection for different individuals.

5. Conclusion

Music can produce strong pleasure despite lacking the direct biological value of primary rewards such as food. This effect appears to stem from the interaction between auditory perception, working memory, expectations based on learning, and reward mechanisms. Cognitive and auditory processes arrange sounds into meaningful patterns and predictions, which then interact with the nucleus accumbens and dopaminergic striatal circuitry to evaluate music in terms of its reward value. Such processes could affect other psychological outcomes like emotion states, arousal, attention, and cognitive functioning. However, each person is affected differently by such processes according to the tasks that they carry out and the type of music that they listen to. Future research should therefore determine which forms of music are most effective for particular people in specific contexts.

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