How does music affect cognitive functioning?

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Abstract

Music is a widespread form of communication that has been around for over 35,000 years and is prominent in various cultures and identities. Even today, people often listen to music at various times throughout the day. The objective of this paper is to explore whether music affects a person's cognitive functioning, such as enhanced focus, memory retention, and emotion regulation, via a literature review. Understanding the role of music in our brains is important due to its prevalence in our lives, from educational environments to social settings or our psyche. The ability to utilize the potential of music can be valuable to achieving further success.

Section Summaries

Music and attention	People have limited amounts of attention available to be used. Attempting to allocate that attention towards multiple cognitive activities lowers the quality of performance for each activity. Individuals should be mindful of what cognitive activities they are participating in and how much attention each activity requires. For example, songs with lyrics will demand more attention than songs without lyrics. Research suggests that introverts should minimize auditory distractions and extroverts should work in noisy conditions to *improve* learning performance.
Music and memory	**Active recall/encoding specificity principle:** memory recall improves if the contextual conditions of when memory is made and retrieved are the same.
Music and mood	Music can enhance or change an individual's current mood. Music therapy, for instance, can help patients manage symptoms of mood disorders, lower risk of depression, and reduce stress. The two types of music therapy are: ● Active: patients engage directly in musical activities (e.g. singing, dancing, playing instruments) ● Passive: patients don't engage directly in musical activities (e.g. mindfully listening to a piece of music)
Suggested applications	Implementation of whole-brain learning in traditional

	school systems. Matching auditory condition (quiet and noisy) with introversion/extroversion. Pair vocabulary words with a melody to improve memorization
Future directions	How would music listening impact the attention quality and length of those with attention deficit disorders? Further study into introversion and extroversion in relation to music listening and performance. Strengthening the hippocampus Neurologically observing the responses of certain areas of the brain when different genres of music are being played ● Furthering suggested applications based on the final results

Definitions

Music:
A strategic arrangement of sound and rhythm to create melody and harmony.

Mozart Effect:
A temporary increase in performance in individuals after listening to music composed by Mozart.

Spatial-temporal reasoning:
A person's ability to visualize 3D objects and mentally manipulate them.

Context-dependent memory:
A psychological learning phenomenon where memory recall is improved when the environments during memory encoding and recall are repeated.

Mood:
A longer-lasting feeling or state of mind that may be underlying without the individual knowing what prompted the state.

Emotion:
A subjective response resulting from an individual's environment.

Nonsense syllable:
An arbitrarily formed syllable, which doesn't have any prior meaning, that psychologists use to study memory and information retention.

Semantic memory:
The memory of meanings, understandings, and concept-based knowledge that are not attached to specific events.

Introduction

Music is ubiquitous across cultures and time. As a result, understanding what role music may play in cognitive function is certainly warranted. With the cognitive effects of music ranging from providing pleasure to enhancing productivity, there is debate and curiosity surrounding whether these effects of music are fact or myth. There are many possible interpretations and applications from existing literature on this topic, from implementing suggestions within academic settings to influencing emotions inside and outside of therapeutic contexts. Music has the potential to be a valuable tool for enhancing cognitive function, specifically attention and focus, mood regulation, and memory retention. This paper will examine the effects of music in terms of three specific cognitive functions: enhanced focus, memory retention, and emotion regulation. Selecting these three topics narrows the field of study, allowing for a more in-depth understanding. With the power of music, the results have the ability to be applied all around the world at individual and group levels, inside and outside of schools, and within mental health and other medical contexts.

I predict that the literature will support the following hypotheses:

1) The effect of music on an individual's attention depends on the cognitive task the individual is doing and the genre of music being played.
2) Music improves memory when it is being used for context-dependent memory, and there are ways to optimize music to improve memory.
3) The effect of music on mood depends on the genre of music an individual plays, and also why they listen to music.

Impacts of music on attention

Most studies that are focused on exploring the connection between music and attention—specifically the distribution of attention—refer to Kahneman's Limited Capacity Theory (Lang, 2000). The theory states that a person has a limited amount (capacity) of attention, or information-processing resources. Attention can be allocated and invested into cognitive tasks, which compete for the same information-processing resources because of the limited supply. The subconscious decision allotting how much attention to invest, and where to invest, is dependent on the two main theories of the Limited Capacity Theory: (1) the amount of attention poured into an activity is dependent on how much arousal level an activity has. More arousal energy means more attention invested into the activity; (2) the difficulty and energy demand of the activity influence the amount of attention a task requires. According to the Limited Capacity Theory, there are two types of interference that can affect performance: **capacity interference** and **structural interference** (Chou, P. T. M., 2010).

Capacity interference occurs when two cognitive activities done simultaneously are competing for the same information-processing resources, but the total amount of attention available is not enough to meet the demands of both activities. If the demand for attention exceeds the capacity, performance quality worsens. This phenomenon is frequently looked into when studying multitasking because performing tasks simultaneously can lead to errors, slower response rates, and reduced efficiency. Specifically, when two simultaneous cognitive tasks require the same amount of information-processing resources, and there are not enough resources available, neither task can be completed unless one task receives more. This distribution of the information-processing resources can be described using structural interference.

Structural interference is a phenomenon that occurs when the attention capacity is exceeded and attention needs to be distributed between the two simultaneous tasks. Mental activities require different levels of attention. When structural interference occurs and the amount of attention required is more than what can be provided, performance for both tasks worsens. In other words, it is important to keep a balance of attention. While attempting a cognitive task that requires more attention, such as learning a brand new topic, having no background music would contribute to effective learning. On the contrary, cognitive tasks with lower attention requirements, such as doing simple, repetitive math problems, can be done with some background music.

A survey (Ballard, 2003) was done in the U.S. with students from two midwestern states who self-reported their media habits. The results showed the participants believed all kinds of media, including cell phones, television, CD players, computers, and iPods, had a negative effect on academic performance, considering it as a “source of major distraction.” As technology evolved, personal laptops have been more commonly implemented into classrooms as assistance, but the study questioned whether they could become a hindrance. Computers amplify the study habits of the students because, according to Ballard (2003), multitasking is more likely to occur if the students have no interest in what they are learning. If the student wants to learn, the computer is an amazing tool to further their learning. On the other hand, if the student wants to stray away from the class, the computer gives them access to the entire internet, which they may use however they’d like. A possible way to prevent this level of distraction in students is by limiting how much of the internet they can have access to. However, this is not a foolproof method; since this method has been so widely used—school and work are good examples—there exists websites designed to be unblockable, such as games encoded into a Google Site. Restrictions are useful in limiting the number of distractions across the internet, but it does not have the ability to completely get rid of them. Another common source of media, used in a similar way as the computer, is television (TV).

TV, often used by students while studying, is considered to be a more potent source of distraction than radio or silence as it stimulates more arousal energy. The presence of background TV pushes the actual task at hand back to be the secondary task, as the student aims to focus more on understanding the TV. However, studies (Armstrong et al., 1991; Cool and Yarbrough, 1994; Pool et al., 2010) show both TV and radio affect the performance of mathematical and reading tasks, as well as the time it takes for the students to complete them. Background TV hindered students’ abilities to recall information from difficult passages. Surprisingly, the results also showed that the time spent wasn’t a sign of lowered performance quality; the difference in the amount of time spent on the task when background TV was on, versus when it wasn't, was exactly equal to the amount of time the participant was looking at the computer (Pool et al., 2010). While performance did decrease, it would have only been due to switching modes from focusing on the TV and on the task. On the contrary, if students are only listening to music—which only consists of an audio component—they will be *less* distracted since their eyes will be focused on the task instead of looking around, trying to understand the visual components of types of media such as TV. Both forms of distraction hindered the individuals' performances, but TV served as a more significant distraction than radio did. Therefore, it is important to be aware of what sort of media to indulge in when carrying out tasks dependent on cognitive ability, especially those needing information processing resources and attention.

Another approach to observing the effects of music on attention is in relation to the level of extroversion or introversion of the individual(s). To explore this, Furnham and Strbac (2010) and Belojevic et al. (2001) conducted studies to observe the differences in impact that background-music listening has on introverts versus extroverts, with introversion measured using the Eysenck Personality Questionnaire (EPQ). Both studies show that compared to introverts, extroverts tend to produce *better* results when in a noisier environment and are able to work significantly faster under noisy conditions. Specifically, the introverted participants in the study by Belojevic et al. (2001) reported their levels of fatigue and concentration problems were more prominent when in a noisy environment compared to when in a quiet environment. For both personality types, the accuracy of mental processes was not impacted by noise. Furnham and Strbac (2010) provided results similar to those of Belojevic. The methodology tested reading comprehension, prose recall, and mental arithmetic. Their data showed a trend favoring extroverts' performance in noisy conditions, but performance of both personality types were similar under quiet conditions. However, more studies should be done to corroborate these findings. Additionally, there is a flaw that lies within the categorization of introversion and extroversion. Personality tests—such as the Myers-Briggs Type Indicator (MBTI) and the EPQ—are not 100% accurate (Randall et al., 2017; Caruso and Edwards, 2001). Therefore, there is no guarantee that an introvert is being tested as an introvert, or an extrovert as an extrovert. Overall, this study provides conclusions on music's impact on attention from a different approach than the previously discussed studies. As opposed to focusing on different types of auditory distraction, this experiment groups individuals based on their own personality types. This pattern provides further insight into how music can be utilized for further improvement in cognitive function, as well as opening the door to future study into introversion vs extroversion, potentially spreading it to other fields of cognitive psychology.

Impacts of music on memory

A study (Smith, 1985) was conducted with the goal of testing active recall. The experiment explored whether the presence of background music would affect the ability of participants to recall a given set of words. The results of the study supported the notion of context-dependent memory, which is a theory stating recall of memory is improved when the environment during memory encoding and recall are the same. The experiment's methodology went as follows: 54 volunteer participants took part in two experimental sessions. During the first session, the participants saw a list of words. The words were each printed on an index card, which the experimenter switched out every five seconds. Immediately after seeing the cards, the participants participated in a five-minute active recall "test." After two days, the participants returned to the same space for a final five-minute active recall test. What differentiated the first session and the final test was the acoustics in the background. During the first session, one-third of the participants heard a Mozart piano concerto (M) in the background, another third heard jazz (J), and the last third had no background acoustics (Q). In the second session, the three groups (M, J, Q) were again split into thirds, each of the subgroups listening to one of the options (M, J, Q) for the final test. The combinations were categorized as SC groups (MM, JJ, QQ) if the same acoustics were playing in the background for both sessions or DC groups (MJ, MQ, JM, JQ, QM, QJ) if different acoustics were playing for the two sessions. The results showed recall was improved when music was added during session one and was not replaced or taken away during session two. However, the recall abilities were not enhanced when quiet conditions were kept across both sessions. Adding or removing music did not prove to have a negative effect on recall. The findings of this study showed an applicable way of optimizing active recall. Should the environments in which an individual is taking in information and attempting to actively recall that information be the same—specifically acoustically speaking in relation to this study—the ability to recall the information drastically improves. Active recall is also commonly named the encoding specificity principle, which can be viewed as an intersection between context-dependent memory and active recall. The encoding specificity principle states that memory recall is enhanced when the contextual factors of when memory is encoded and when it is being recalled are the same (Tulving and Thomson, 1973). This principle is seen clearly in Smith's experiment. When there is an auditory stimulus that is repeated when information is being encoded and when it is being recalled, the memory recall ability improves.

Another study (Zhang, 2020) was conducted to test the influence of music listening on academic performance in terms of time taken and errors made. The eight selected students from a Chinese international high school were divided into four categories in terms of academic performance in school: Good, Fair, Limited, and Weak. There were two rounds of color memorization tests: one before listening to music and one after. Results show that after listening to music, the students in the Good category had a significant decrease in errors made. A positive correlation was found between academic performance and response time, indicating that students with higher academic performance tended to have shorter response times. Similarly, the same was also true with the number of errors made: the better the academic performance, the fewer errors made. However, the results failed to provide any convincing evidence that listening to music could improve memory retention and decrease the number of errors made as the data patterns did not hold true for each category of students. This study's methodology found excelling students can perform better after listening to music, but there is no overarching conclusion to be made.

Looking at applications of optimizing music to enhance learning, Bulgarian scientist and neurologist Georgi Lozanov, the "father of accelerated learning," was a leading figure in the study of the effects of music on memory and learning. He found that music has the ability to induce a state of relaxed alertness, or "psycho relaxation." During this state of "psycho relaxation," the brain shows a large increase in alpha brain waves. Alpha brain waves (frequencies of 8-13 Hz) are one of the five electrical waves produced by the brain. When they dominate brain activity, it is usually a signal of relaxed alertness. The benefits of increasing the amount of alpha brain waves include: improved levels and maintenance of focus, heightened memory, reduction of stress and anxiety, and elevated creativity levels; this significant increase due to psycho relaxation, according to Ushi Felix (1993) should result in higher achievement. To achieve this state of psycho relaxation, the individual should take part in “whole-brain learning.” To introduce this method into classrooms, Lozanov later created a certain teaching system: “Suggestopedia.” Whole brain learning is using both the left and right hemispheres of the brain simultaneously to carry out an action. The left hemisphere is responsible for language processing, logic and reasoning, communication, and memory. On the other hand, the right hemisphere oversees music processing, creativity, and artistic skills. As such, reformatting education to create activities merging music processing with reasoning and memory will likely result in heightened performance. Overall, this holistic approach has been shown to optimize an individual’s learning. Suggestopedia can be a very useful tool to be implemented, and future research and testing in this method is likely to provide more insight into its abilities and limitations.

Additionally, the German evolutionary biologist Richard Semon first introduced the “engram theory,” describing memory storage from a neurological lens. He stated that memory leaves physical changes in the brain. When a memory is being recalled, these neurons storing the memory are reactivated. Semon's theory has since inspired future scientists and modern information on memory. Susumu Tonegawa’s lab at MIT was the first to prove the credibility of the engram theory. To cure his seizures, 27-year-old Henry Molaison’s hippocampi were removed. As a result, he was unable to make new memories; because of this, the key purpose of the hippocampus was uncovered (Zhang, 2020). Without the hippocampus, new episodic memories cannot be formed. As such, strengthening the hippocampus has the potential to enhance an individual’s memory capacity. Due to the hippocampus’s role in memory, it is a region of interest in memory studies involving music (for review., see Toader et al., (2023)). From a neuroscientific point of view, Hotz (1998) and Molnar-Szakacs and Overy (2006) reviewed evidence that music stimulates specific regions of the brain responsible for memory, such as the amygdala and medial prefrontal cortex, which work with the hippocampus, lateral prefrontal cortex, and parietal cortex (Buchanan, 2007). The activation of these centers leads to the retrieval of emotions corresponding to pieces of memory. Similarly, the amygdala, one sector noted above to be stimulated by music, is responsible for encoding the emotional associations of information as it is transferred from short-term storage to long-term memory. The amygdala, along with the hippocampus, prefrontal cortex, and parietal cortex, is located in the cerebrum, which makes up 80% of the brain (Ackerman, 1992) and is responsible for memory, emotional response, and learning. The hippocampus, situated deep within the brain's central region, is crucial for learning and memory formation (Eichenbaum, 1999). Its primary job is storing short-term memories and transferring them to long-term storage. The emotional connection to certain pieces of memory has the ability to enhance memory storage through the release of hormones that stimulate regions of the brain (Fogarty, 1997). Listening to music, along with other forms of music and auditory stimulation, has been shown to strengthen brain synapses and neural pathways, specifically by inducing LTP (Long-Term Synaptic Potentiation/Long-Term Potentiation) in the brain (Chatterjee et al., 2021). LTP, when prompted, increases signal transmission between the neurons. When this is triggered in the hippocampus, which is responsible for forming and retrieving memory, its ability to carry out its memory-related duties is heightened. De Deus et al. (2017) conducted a study on how short-term loud sounds impact on synapse plasticity and function in the hippocampus of rats. The experiment found that daily exposure to sound stimulation of 60 db led to enhanced learning performance and the increase of BDNF (neurotransmitter modulator important for memory and learning and plays a key role in LTP). This study provides a habit that is easily incorporated. Adding daily exposure to certain sounds to benefit cognitive function can be a less attention-demanding replacement for background music.

Impacts of music on mood

While the two terms are often interchangeable, many believe there is a root difference between “mood” and “emotion.” While emotions arise from a scenario-specific cause, moods are the underlying feelings an individual experiences and have longer durations (APA). Moods are considered to be tools that “provide information about internal states,” while emotions provide hints to the “states of the environment” (Saarikallio, 2007). When discussing emotional reaction, most emotion theorists believe it is composed of three types of experiences: subjective, behavioral, and physiological (Saarikallio, 2007). The subjective experience refers to the emotional and mental experience—the feelings that arise. The behavioral component describes how the individual chooses to express their emotions. Lastly, the physiological element represents the reaction of the rest of the physical body (Saarikallio, 2007). Music has shown the capability to affect all three of these components. Due to its extensive reach, music can be optimized as a tool for individuals to regulate their moods and emotions. However, ‘mood regulation’ is more often used when discussing music-related regulation. Mood regulation refers to a process that aims to change or maintain the current mood that an individual is in (Saarikallio, 2007). Music-related regulation is more targeted to the subjective experience as opposed to the behavioral and physiological responses. Multiple studies have observed results proving its impact. Thayer et al. (1994) found that in a self-assessment, listening to music was a tool ranked second in effectiveness to change bad moods. The Wells group noted that in their study group, 85% of women and 74% of men use music to change their mood (1990). In addition to being used to change their moods, some participants have also reported using music to express their current state. The Benhe group (1997) found that adolescents chose happy music when happy, aggressive music to vent when angry, and emotional music for comfort. In conclusion, it is possible to use music to enhance certain moods as desired.

Music therapy is a widely practiced form of therapy. It is a treatment method that focuses on optimizing music activities to improve the mental and physical health of individuals. Physiologically, music therapy makes use of external factors to stimulate the sections of the brain responsible for mood and emotions. When used in conjunction with drug therapy, the effects prove to be significant, particularly on patients with senile depression, schizophrenia, and preoperative anxiety (Zhang, 2020). There are two types of music therapy: active and passive. In active music therapy, patients are actively participating in musical activities; this includes singing, dancing, and playing musical instruments. On the other hand, passive music therapy activities can include listening to music with extra care, really feeling the piece internally. With these methods, music therapy has been used to manage depression, specifically post-stroke depression in parts of China (Zhang, 2020). When paired with exercise/physical therapy, music therapy can improve paralysis, with benefits extending even to patients with early stages of a stroke.

Discussion

Overall, the findings of the studies provide important information on the relationship between music and cognitive function. With multiple methods of use, music listening has the ability to enhance and maintain positive moods, and improve active recall. Its effects on quality and duration of attention—as well as memory retention—has shown to be slim to none, given the level of distraction caused by the music does not exceed the individual's capacity of attention. This information can be used by anyone who relies tremendously on the three aspects of cognitive function mentioned in this paper. This includes students as they choose between listening to background music while studying, educators as they debate whether to allow students to listen to music while working, and parents when they see their child working with headphones on.

Some suggested applications include implementing Suggestopedia or other forms of whole-brain learning in school systems and other academic settings (Waluyo, 2018). For example, playing soft background music during lectures or learning vocabulary by repeating words with a melody (the Alphabet song and the Periodic Table of Elements song are good examples of this), stimulating both hemispheres of the brain and making it easier for students to encode a series of words into long-term memory (Anderson, 2000). A possible application best used by those in studying conditions is optimizing learning by matching the amount of auditory distractions to the individual's personality type in terms of introversion and extroversion: more auditory distractions for extroverts and less for introverts. However, there is room left for further study into music and cognitive function. In addition to being a relatively new science, psychology studies complex, and often unpredictable, creatures. What environment works for an individual's learning one day will likely not be the same the next, as human cognition is affected by many other factors, to begin with.

There exists limitations with the research done in this paper. There is no inclusion of studies with results that can generalize individuals with different attention capacities than the average population, for example, those with attention disorders. This would be a valuable field of study as individuals with attention disorders will likely react to surrounding auditory stimuli differently than those without, making this a useful direction for future study. Another interesting addition would be the study of introversion/extroversion and susceptibility to auditory distractions from a neurological perspective: analyzing if the brains of introverts and extroverts have different responses to auditory distractions, and *why* this correlation or causation exists. It's possible that this deeper look into the reason behind this phenomenon can provide better insight and applications. Another direction for neurological research is observing which different parts of the brain are stimulated when an individual listens to different genres of music or silence. This study could be worthwhile, especially if there are differences in behavior that hint at causation. Another path would be further exploration of how music therapy impacts the brain; which parts of the brain does it appeal to in order for the effects to combat depression? Additionally, another beneficial research focus would be studying ways to strengthen the hippocampus. A limitation of this paper is the lack of suggestions for improving attention capacity. A way to apply the findings of this paper would be analyzing the difference in one's memory capacity before and after strengthening the hippocampus through exercise, obtaining more knowledge, and any other form of mental stimulation.

Conclusions

In this study, I reviewed the literature on attention, memory, and mood as they relate to music. Overall, I found support for the hypothesis of

1. The effect of music on attention is dependent on the cognitive task the individual is doing and the genre of music that is being played.
2. Music will improve memory when it is being used for context-dependent memory, and there are ways to optimize music to improve memory.
3. The effect of music on mood will depend on the genre of music an individual plays, and also what their goal for listening to music is.

In conclusion, music has a large impact on cognitive function. The majority of existing studies analyzing the connection/causation between music and cognitive function are focused on how music affects *attention*, relating well to other areas of studies on multitasking. Participating in multiple cognitive tasks simultaneously—specifically music listening and another cognitive task—can be done, as long as the amount of attention is balanced. An individual can listen to music in the background if they are not actively attempting to listen and if the other cognitive task does not demand more attention than they have available. Introverts study better in quiet conditions, and the opposite holds true for extroverts. Repeated musical or auditory conditions during memory encoding and recall can improve (context-dependent) memory recall. Suggestopedia can be implemented by individuals and in academic environments alike to improve memory retention. Daily exposure to sounds of 60db can improve LTP and, in turn, enhance memory and learning. Music can also be used as a tool to enhance, release, or change an individual's mood. It is also widely-used for music therapy to treat patients with mood disorders. These findings are applicable to anybody, with applications extending from studying to improving memory to being used as a coping method.

Future studies in this field can focus on neuroscientific approaches to understand why the brain reacts the way it does to music, as well as expanding the ranges of experiment subjects, such as researching people with different attention and memory capacities and different mental health conditions.

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