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REVIEW ARTICLE

Effect of Music on Cognitive Performance in Different Contexts

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ABSTRACT: Music is a large part of people's lives, regardless of different sociodemographics or cultural backgrounds. People listen to music in varied contexts, from focusing solely on the music (e.g., concerts) to performing other tasks (e.g., homework or social media) to moments of inaction or while engaged in difficult tasks. Despite the prevalent use of music in our current world, the cognitive effects of listening to music in different contexts are poorly understood and warrant further investigation. This paper examines two theories that provide possible explanations for the varying effects of music (i.e., distraction-conflict theory and mood-arousal hypothesis) and discusses how different elements of music (i.e., monotony and repetition, tempo and valence, and the presence of lyrics), personal characteristics (i.e., introversion, extroversion, sex, age, and musical training), and clinical symptoms (i.e., neurodegenerative and neurodevelopmental disorders) can either provide beneficial or detrimental effects. Findings in this body of research support the distraction-conflict theory and the mood-arousal hypothesis, where the combined impact of fulfilling simple tasks and listening to high arousal and positive valence music result in enhanced performance. This paper endorses the necessity of understanding the relative effects of music in different conditions.

KEYWORDS: Behavioral and Social Sciences, Cognitive Psychology, Music, Cognitive Performance.

Introduction

With today's access to music streaming services, the frequency of listening to music has skyrocketed. The largest streaming service, Spotify, reached over 118 million users worldwide in 2023 alone.[1] Additionally, Spotify has been shown to increase overall music consumption for individuals by 49% on average, lasting even 25 weeks after individuals first adopt the service.[2] This finding is significant because, after 25 weeks, the novelty of using a new application would have worn off, ensuring that increased Spotify usage is due to genuine interest. Much of music listening takes place while working on other tasks: 68% of participants reported in a United States survey that they multitask while also utilizing music.[3] Whether to battle boredom, improve focus, or enhance performance, listening to music during different daily activities has never been more popular.

However, research on the effects of music listening has produced mixed data. Widespread interest in researching music began with the publication of the "Mozart effect." This 1993 study, which sought to demonstrate a relationship between music cognition and spatial reasoning, involved 36 college students. The authors observed higher scores on spatial reasoning tasks after participants listened to pieces of Mozart's music.[4] However, attempts to recreate the Mozart effect have resulted in inconsistent results. Even decades later, research on the effects of listening to music on other tasks — whether before or during — has proven inconclusive. While some researchers claim that music provides a slew of benefits, especially in improving levels of mood and mental stimulation, an excitatory, energizing physiological response by the autonomic nervous system,[5-7] others have found it to take up substantial cognitive capacity, serving as a distraction that impairs performance and memory.[8-10] Given the clear divide between studies pointing to the benefits of music listening and others to its detriments, the question of how music impacts performance has become increasingly imperative to answer.

Research on music listening frequently examines the effects of playing music while engaged in various tasks that capture different aspects of cognitive function. Examining how music impacts cognitive performance in specific scenarios reveals the degree to which music can benefit or hinder cognitive functioning.

This research examines the effects of listening to music while engaging in other tasks by reviewing existing empirical literature on cognitive performance in the presence or absence of music. This review was structured based on available research on the topic of music and cognitive performance. Specifically, this review first focuses on the possible explanations for how music affects performance, such as the distraction-conflict theory and the mood-arousal hypothesis as a basis for organizing later sections. Second, the paper explores how performance on cognitive tasks tends to differ based on certain elements of the music, such as monotony and repetition, tempo and valence, and the presence of lyrics. Third, the review discusses how the impact of music on cognitive performance tends to vary with personal characteristics, like introversion, extroversion, sex, age, and musical training. Lastly, the paper examines the effect of music therapy on two different categories of neurological disorders, specifically, neurodegenerative and neurodevelopmental disorders for clinical relevance.

DOI: 10.36838/v7i2.91

Discussion

Two Hypotheses to Analyze the Impact of Music

The distraction-conflict theory explains how task difficulties affect performance.

Psychology researchers have long grappled with how music affects cognitive performance. The distraction-conflict theory was developed to provide a possible answer to this question. According to this theory, individuals require minimal cognitive processing to perform simple tasks, which leaves the unstimulated mind prone to wandering. A simple task is defined as a task that is generally easy to learn, repetitive, or familiar. Conversely, complex tasks refer to those that are novel, difficult, or have a high degree of variation, which require large amounts of cognitive processing to perform well.[11] Baron claims that distractions like music can cause attentional conflict in two ways: structural and capacity interferences. First, structural interference occurs when two different inputs—the distraction and the task—warrant the same amount of physiological neural mechanisms, such as processing two visual signals simultaneously. Second, capacity interference occurs when a task takes up considerable attentional resources, making it difficult to perform while tolerating the distraction. Additionally, Baron asserts that distractions in both simple and complex tasks evoke a state of increased arousal, which he refers to as "drive".[11]

Distractions enhance performance on simple tasks by narrowing attention or, in other words, presenting elevated arousal that prevents individuals from getting bored or distracted from the otherwise straightforward task. This allows the individual to focus on the task and ignore other irrelevant distractions.[12] On one hand, the small amount of attention that simple tasks require usually leads to mind-wandering. On the other hand, when music takes up that additional attentional processing, it not only doesn't burden the individual but also prevents other types of distractions from drawing attention, enhancing cognitive performance.[13] However, unlike simple tasks, complex tasks are sufficiently stimulating and don't require additional arousal to bolster task performance. Any further attentional conflict takes up mental capacity, mentally overburdening and overstimulating the individual.

The mood-arousal hypothesis posits that arousing and happier music enhances cognitive performance.

Another explanation, the mood-arousal hypothesis, was introduced because of a study by Rauscher and colleagues. The study by Rauscher reported that college students performed better on spatial tasks after listening to music composed by Mozart, compared to lower performances after listening to non-musical relaxation tapes or during silence. Rauscher termed this positive outcome the "Mozart effect."[4] However, several inconsistencies were present. These included the fact that the Mozart effect only lasted 10-15 minutes and that later studies seeking to replicate this effect have been unable to do so.[14-16] Despite the limitations of the original study and the limited capacity to replicate this finding in future studies, the Mozart effect popularized quickly and is one of the main ways people understand the effect of music on cognition.

The findings from various studies have disproved the phenomenon deemed the Mozart effect. In Chabris' 16-study meta-analysis on the effect of Mozart's music on the performance of cognitive tasks, a small intermittent beneficial effect that would typically support Mozart's effect was found. This finding was determined to be caused by the specific piece of Mozart's music. However, Chabris concluded that the effect was caused by a shared right hemisphere locus that produces "enjoyment arousal."[17] In other words, since sitting in silence or using relaxation tapes produces less arousal, their results had fewer positive effects. Thus, it could be that enhanced performance found in successful recreations of Mozart's effect could result from increased arousal levels and not because of the specific Mozart piece of music. A 1999 study by Nantais and Schellenberg tested this possibility by having participants listen to either Mozart's music or a narrated story by Stephen King. The study also had the participants record which audio they preferred. With both conditions of this study offering pleasant and engaging stimuli, the authors were able to disprove the Mozart effect. Therefore, the enhanced performance brought by the Mozart effect is not a result of a specific piece of music but because the Mozart piece provided pleasant and engaging stimuli. Additionally, those who preferred Mozart's music had improved performance if they listened to the music beforehand, and those who preferred Stephen King's narration also had higher scores if they listened to the narration beforehand.[18]

The mood-arousal hypothesis replaces Rauscher's original hypothesis that the enhanced performance resulted from a specific type of music—Mozart's—with the explanation that music influences cognitive performance by changing states of arousal and mood. In these two emotional reactions, arousal is the intensity of the emotion, while mood differentiates between positive and negative emotions.[19] Specifically, pleasant music enhances performance by increasing mood and arousal, while unpleasant music decreases mood and arousal. Highly arousing music, even if pleasant, overstimulates the listener and impairs performance.[20] Optimal music to listen to during a task would have a moderate arousal level and positive valence.

The distraction-conflict theory offers an explanation for why simple tasks benefit from music, but complex tasks don't. Due to variances in available attentional processing, cognitive performance is dependent on the task difficulty. In contrast, the mood arousal hypothesis is dependent on the music. More arousing music would be beneficial, to a point, and positive valence would lead to better cognitive performance. It should be noted that the distraction-conflict theory is only relevant if music is played during the task, but the mood arousal hypothesis is valid whether music is played before or during the task.

The Influence of Various Elements of Music

Monotony and repetition foster boredom.

Music with monotonous or repetitive elements can be perceived as boring. Boredom, "the experience of being disengaged from the world and stuck in a seemingly endless and dissatisfying present…while wanting, but being unable, to engage in stimulating and satisfying activity" (p. 68), often re-

DOI: 10.36838/v7i2.91

sults in low arousal and decreased focus on tasks.[21] A study by Fahlman and colleagues, which worked to develop a new measure of boredom, found that the intensity of boredom could be affected by how many options are available to escape the situation and the under- or over-stimulation of the participant.[21] The impact of boredom proneness on attention was studied by Hamilton and colleagues. It examined data from men over a 2-year period, which found better-sustained attention in participants who coped better with boredom.[22]

Elements of boredom in music include repeating melodies or rhythms within a piece and repetition between different pieces. In other words, repeatedly listening to too many musical works by the same composer or piece can lead to perceived boredom.[23] Likewise, a lack of variety, where the listener can predict upcoming parts of the musical piece, yields boredom.[23]

Match tempo and valence to optimize performance.

Researchers are divided on the effects of the tempo of the music that individuals listen to while performing other tasks. Musical tempo refers to the speed or pace of a particular piece of music. Some researchers say that background or instrumental music tends to inhibit performance when it is fast. In one study by Thompson and colleagues, where 25 participants read a passage and answered comprehension questions while listening to music with varying tempo and volume, loud and fast music disrupted reading comprehension. Thompson and colleagues posited that it was harder to ignore the music due to the greater intensity and, therefore, greater amounts of auditory events per time provided by fast-paced music.[24] Conversely, another study by Baldwin and Lewis testing the impact of varying music tempo on the participants' restoration of attentional resources, found that slow tempo music allows for more time to recover from its distractions. Task performance is enhanced by preserving mental processing efficiency and providing a restorative environment. However, slow music only improved task performance by increasing reaction time and preserving processing efficiency, not accuracy. Baldwin and Lewis concluded that there may have been a high ceiling effect for accuracy since most participants achieved near the highest scores.[25] In addition, Quan and colleagues, in a study that analyzed the impact of different tempo music on executive attention in children, found that reaction time is generally more sensitive to tempo changes as compared to accuracy.[26]

Others hold that fast-tempo music bolsters performance. In Schellenberg *et al.*'s experiment, 5-year-old Japanese participants drew more creative and energetic art for more extended periods when listening to faster music than a slower piece.[7] Additionally, Chie and Karthigeyan reported that faster music leans towards improving memory,[27] and Day *et al.* found that it also caused participants to make more accurate decisions in their study with 40 college students who listened to varying tempo music.[28] Slow music, by contrast, may hinder performance. When participants finished three cognitive processing tests while listening to fast, slow, and no-music conditions, slow music led to worse performance, while the fast and no-music conditions were almost the same. Slow-tempo music increased necessary processing time and thus inhibited performance.[29]

Is there an explanation for these contradictory results? Tempo usually correlates with arousal levels, where fast-tempo music increases arousal and slow-tempo music decreases arousal. Valence, the mood of the music, is also a factor. Listening to music with high valence, usually in a major key, positively boosts the listener's mood. Similarly, low valence music, generally in a minor key, causes negative shifts in mood. Husain *et al.*, in a study where 36 undergraduates performed a spatial task while listening to music with varying tempo and valence, found that the enjoyment ratings depended on specific combinations of tempo and mood. Specifically, performance was optimized if positive valence music was played at a fast tempo. Negative valence music was matched with slow tempo music.[19]

The effects of tempo on arousal and valence on mood are entirely separate, according to a meta-analysis of 22 studies. An increase in tempo does not imply a boost in mood.[30] The previously discussed optimal combinations of tempo and valence need to be separately fulfilled. High-valence, fast-tempo music requires a musical piece in the major key played at high speeds, while low-valence, slow-tempo matches a piece in the minor key played at slow speeds. The effect on performance is consistent with the arousal-mood theory discussed in a previous section. The optimal piece of music would have positive valence and moderate arousal, as high arousal could lead to overstimulation. A fast tempo and, therefore, high arousal enhance performance to a higher degree compared to a slow tempo with low arousal. However, the latter combination is still optimal if both conditions are present.

Lyrics always result in hindered performance.

Overall, a systematic review seeking to clarify the impact of background music on cognitive task performance concluded that the presence of lyrics significantly hindered performance when performing other tasks. Specifically, lyrics impede memory-related tasks and reading comprehension.[31] Instrumental music, which doesn't have lyrics, is less likely to impact cognitive performance. This also applies to lyrics of a foreign language, where the lyrics are perceived as unintelligible and, therefore, not distracting. When the same song was transformed into a native dialect, the negative effects reappeared. Furthermore, the only positive effects discovered when listening to music happened during instrumental pieces.[32] Additionally, Souza and Leal Barbosa found that in a study of 123 participants, the presence of lyrics in music resulted in perceived impairment, while instrumental music was seen as beneficial. However, it should be noted that the instrumental music was not actually beneficial.[33]

This general negative effect may be due to semantic (the language or meaning in music) or phonological interference with the current task.[34] The presence of lyrics in music is always detrimental, whether non-lyrical music leads to better or worse performance than silence.

In summary, if the listener perceives a piece of music to be boring, it will lead to decreased arousal, focus, and attention. Monotony and repetition are two elements that can cause the music to be boring. Matching high (or better, moderate) arousal with a fast tempo in music would optimize perfor-

DOI: 10.36838/v7i2.91

mance. Having low arousal and slow music could achieve a similar effect. Cognitive performance is always worse during lyrical music than instrumental music.

Personal Characteristics Vary the Effect of Music Even Further

Introversion vs. extroversion in Eysenck's theory of personality.

Introverts and extroverts require different amounts of arousal to reach optimal performance. This is explained in Eysenck's theory of personality, who conducted a study to confirm his theory. Introverts, who tend to be shy during socialization and are generally more closed off, were found to experience higher levels of arousal when faced with lower-intensity situations than extroverts. Eysenck additionally concluded that introverts typically have greater arousal at rest. Thus, the presence of music would quickly surpass their optimal levels of stimulation, leading to over-stimulation. In contrast, extroverts possess less arousal at rest and would benefit from the additional stimulation provided by instrumental music. To this extent, introverts generally avoid situations with external stimulation. In complete opposition, extroverts willingly partake in these same situations. Instrumental music would, therefore, inhibit introverts to a greater degree than extroverts, at least according to the theory.[35]

According to Eysenck's personality theory, introverts should be negatively affected, and extroverts should be positively affected.[24] Many studies have found that instrumental music negatively impacts introverts during different tasks.[8,9,36] A study by Furnham and Strbac examining the effect of music and background noise on 38 introverts and 38 extroverts found that introverts performed significantly worse in the reading comprehension tasks in the presence of music and noise, but performed equally well in silence.[37] Another study by Dobbs *et al*., with 118 female secondary school students completing a perceptual reasoning task, general cognitive ability test, and verbal reasoning test in the presence of music, office simulated noise, or silence. They reported a positive relationship to extroversion during music for perceptual reasoning and general cognitive ability tasks. No relationship was found between extroversion and performance in the verbal reasoning test for music, but extroverts performed better under noisy conditions.[38]

Impact of music on different biological sexes.

Inherent biological differences in men and women lead to different ways of processing music and impact the resulting performance on tasks. Evidence shows that men's arousal levels increase faster and easier when significant stimuli are present. In addition, some studies have found that men need more time to return to their original arousal levels than women.[39-41] Schirmer *et al*. posited that women are initially affected more by prosodic (rhythm and intonation of language) and emotional signals from words. Schirmer and colleagues also found that men start by processing word valence instead.[42] Additionally, a study by Jing and colleagues, which tested gender differences in completing simple and complex tasks, found that the collective processing of prosody and words may be more efficient in women than men. Men tend to be impacted by external stimuli more than women.[43] Thus, women may be advantaged when listening to music and completing tasks involving word processing. It remains to be tested if music helps women's performance in other tasks. However, in scenarios where higher arousal levels are beneficial (e.g., to counteract boredom), men may be advantaged.

Old age decreases the beneficial effects of music.

There is some evidence to show that aging inhibits cognitive performance while listening to music.[10,44] Exempting the non-musical related impairments that come with old age, such as declines in frontal-based executive control processes,[45] the processing in older adults may be less effective in suppressing task-irrelevant stimuli. In their literature review of age's effect on memory, Hasher and Zacks proposed that these memory-related impairments result from failures when encoding and retrieving information. When information is encoded, individuals can focus on task-relevant stimuli instead of task-irrelevant stimuli. They can narrow their attention to relevant memory searches when data is retrieved.[46] Music likely inhibits both of these mechanisms, leading to worse performance.

While exposed to music, musicians perform worse on cognitive tasks.

Positive effects of music have been found to significantly enhance the performance of professionally trained musicians compared to non-musicians.[47] A study by Strait *et al*. examined the relationship between 31 musically-trained children and their speech processing, auditory memory, and auditory attention. They concluded that if children engage in musical training, their attention levels rise above those without music training. In other words, their ability to focus on distracting environments increases.[48] Although music training provides cognitive advantages such as mathematical and visuospatial abilities and literacy,[49] a study by Patston and Tippett found that musicians performed worse on the language comprehension task when listening to music, but non-musicians were not affected. However, both groups were not affected by the visuospatial task.[47] Additionally, Yang *et al*. found that musicians performed the worst on cognitively demanding tasks when listening to music that featured their respective instruments.[49]

In summary, extroverts perform better than introverts in the presence of music due to having less arousal at rest. Men's arousal levels increase faster than women's in the presence of music and thus can be advantaged or disadvantaged in different scenarios. Old age, in addition to already hindering natural cognition, also inhibits the beneficial effects of music on performance. Lastly, musicians perform worse on tasks compared to non-musicians when listening to music.

Therapeutic use of music to alleviate symptoms of neurological disorders

Beyond using music during tasks in everyday life, the potential beneficial effects of music on cognitive performance make it viable to use to help with neurological disorders. Music is commonly used as an adjunct treatment for patients with neurological disorders. Its ability to elicit a wide range of emotions, induce and focus attention, enhance memory, bolster speech and language communication, and improve motor skills helps preserve cognitive function and memory and boost mood. The rehabilitative effects of musical interventions (including music therapy) have been proven through empirical research, especially for diseases that cause deficits in emotions, attention and sensory functions, memory, communication, and motor functions.[50] Music therapy can be active or passive. Active music therapy includes the direct participation of individuals and can consist of elements of exercise, dance, and music creation.

Conversely, passive music therapy only consists of more idle activities, such as listening to music. Both types of music therapy have been found to diminish the symptoms of certain diseases. The following sections explore the specific effects of music therapy on two different types of disorders: neurodegenerative and neurodevelopmental.

Music decreases the symptoms of Alzheimer's disease and dementia.

Music is notably effective in alleviating symptoms associated with major neurocognitive disorders, the most being dementia. Initially, dementia is determined through the deterioration of emotional control, social behavior, and several cognitive functions over time.[51] As the symptoms of dementia progress, the loss of motor function grows more apparent.[52] The escalating decline in cognitive functions, such as memory and language abilities, is, however, the primary symptom of dementia.[53]

Music can affect people with dementia even until the end stages of neurocognitive disorders, even as cognition worsens over time. Indeed, brain regions that control musical memory are near the last areas that display atrophy.[54] Music also provides a way to improve the emotional health of people with dementia. Music makes non-verbal influence possible in these situations where verbal language declines.[55] In terms of cognitive performance for people with dementia, music's effect has not been researched as thoroughly. Nevertheless, Gallego and García, after playing music that aligned with the participants' music preferences, found that listening to music diminished most symptoms of Alzheimer's disease, which is the most common type of dementia and, therefore, contains most of the same symptoms. Gallego and Garcia also reported that no matter the severity of dementia, memory, and orientation in time and place improved as tested by the Mini-Mental State Examination. Music's enhancing effect may have been a result of its impact on neuroplasticity mechanisms (the neural networks in the brain that allow for change) or its effects on increasing arousal levels, improving motor performance and learning.[56] Lastly, language and speech processing have also been found to improve because of music. A study that repeatedly tested individuals with Alzheimer's while in music therapy reported that music positively impacted their speech content and fluency.[55]

Compared to other diseases, Alzheimer's disease may be especially well-suited for enhancement by music. A study inspected the brain using a 7 T functional magnetic resonance imaging technique, which uses a powerful magnet and radio waves to track blood flow in the brain to figure out how the brain's musical memory regions were impacted by Alzheimer's. It was found when these areas were examined for biomarkers of Alzheimer's that despite the consistent levels of amyloid disposition when compared to the control group, there had been a significant decline in cortical atrophy. This is evidence that musical memory areas are primarily unaffected by Alzheimer's and demonstrates how music therapy recovers memories in people with the disease so well.[57]

Active music therapy can attenuate the symptoms of Parkinson's disease.

Parkinson's disease, one of the two most common neurodegenerative disorders (second to only Alzheimer's disease), is a disabling age-related disorder recognized through the loss of dopaminergic neurons. It is caused by decreased dopamine production, a neurotransmitter in the brain.[58] Postural instability, resting tremor, bradykinesia, muscular rigidity, freezing, and gait impairment are some of the most prominent signs of Parkinson's disease.[59] However, damage to cognitive functioning is also present.[60]

Since Parkinson's main symptom includes impaired motor function, most music therapy is active and involves mild exercise, dance, or rhythmic aspects. While testing participants' cognition, Pohl *et al*. used the Ronnie Gardiner Rhythm and Music Method, which combined rhythm, music, and movement to improve cognitive and motor skills. After undergoing the method, Pohl *et al*. reported higher verbal memory test recall scores. Specifically, for cognitive performance, the technique is intended to raise mental flexibility, general alertness, and thus the ability to concentrate.[61] Spina *et al*. also found a beneficial effect on cognition after participants with Parkinson's disease underwent a music therapy program consisting of music creation, singing, and dancing sessions. At the end of the program, frontal lobe function was observed to have been enhanced. This included working memory, attention, cognitive flexibility, and processing speed, showing how music benefits those with mild cognitive impairments.[62]

Music therapy can help the social, emotional, and cognitive deficiencies in autism spectrum disorder.

Autism spectrum disorder (ASD) is an umbrella term for a range of disorders. These include developmental brain disorders that cause problems in communication, like autism, Asperger's, pervasive developmental disorder, and disintegrative disorder.[63] ASD is primarily distinguished by problems with interpersonal communication and repetitive behaviors but also includes alternations in many different brain networks.[53] Most studies involving music therapy are aimed towards improving the general social-emotional difficulties that come with ASD. However, social communication blocks could come not only from changes in the brain socially but also from deficits in sensorimotor and cognitive functions.[64] In Sharda *et al*.'s study, 8-12 weeks of music intervention were found to improve social communication and functional brain connectivity.[65]

DOI: 10.36838/v7i2.91

Researchers have found that some people with ASD have been found to have deficiencies in reading comprehension and language acquisition. To find out if music has an enhancing effect, Schwartzberg *et al*. had 29 children with ASD perform five comprehension checks while listening to live music-based short stories. Ultimately, both short- and long-term increases in cognitive function were observed. Schwartzberg *et al*. concluded that the effect may have been due to increased cognitive arousal and attention span.[66]

Lessening symptoms of attention deficit hyperactivity disorder by listening to music.

Attention deficit hyperactivity disorder (ADHD) is the most prevalent neurodevelopmental disorder, occurring in an estimated 5-10% of the world.[67] The most prominent and dangerous effects of ADHD occur during developmental stages, resulting in substance use, a higher risk of dropout, and increased chances of unemployment in young adulthood.[68] Similarly, ADHD in adults can cause a variety of problems. Dalsgaard *et al*. associated adult ADHD with high rates of mortality because of its association with several factors, such as higher chances of traffic accidents and an increased risk of sustaining injuries,[69] where ADHD lingers in around 65% of adult cases.[70]

Music therapy, both active and passive, has been used to lessen symptoms of many disorders, such as ADHD. People with ADHD experience problems with timing-related rhythms,[71] struggle with perceptual timing tasks that require participants to distinguish the difference between milliseconds and seconds, and exhibit poorer performance for temporal foresight and motor timing.[72] Researchers have found that music can speed up the growth of timing skills and, therefore, the long-term development of the auditory cortex.[73] Therefore, music therapy is a viable way to help those with ADHD. Additionally, Madjar *et al*., while finding out if calm music helped the reading comprehension of preadolescents with ADHD, concluded that calm music assisted their control over their autonomous responses and bolstered their performance. Although ADHD should result in an easier time getting distracted, the music becomes the primary distraction and masks other, more irrelevant distractions.[74]

Music can alleviate negative symptoms of Alzheimer's disease, especially in relation to memory. Active music therapy (music with direct participation of individuals, such as with dance, singing, or music creation) can also help the cognitive symptoms of Parkinson's disease. Music therapy was found to increase cognitive function (both short- and long-term) in patients with ASD, and also bolsters the performance of individuals with ADHD.

■ Conclusion

The first section of this paper focused on theories to explain the impacts of different factors. Specifically, the distraction-conflict theory explains why music can affect simple and complex tasks differently. Unlike complex tasks, simple tasks do not require large amounts of attentional resources. This behavior is reduced when the music takes up the leftover cognitive resources that would otherwise get channeled into mind-wandering. However, the same scenario has led to overstimulation for complex tasks.[13] Additionally, the mood-arousal hypothesis states that pleasant music enhances performance and arousal somewhat, while unpleasant music does the opposite.[20] Taken together, the distraction-conflict theory and the mood-arousal theory help explain the differential effects of music listening on cognitive performance, as the former accounts for different outcomes relating to the level of task complexity, and the latter justifies varied outcomes relating to the arousal and valence of music.

In the second section of the paper, empirical studies that examined the various impacts of different elements of music were discussed. Some studies found that monotony and repetition in the music subjects listened to resulted in boredom and worsened performance.[23] Husain and colleagues found that faster tempo and high arousal should be paired together to produce optimal performance, and slower tempo with low arousal to a lesser extent.[19] Moreover, studies have consistently found that the presence of lyrics hinders cognitive performance.[33-34] More specifically, Chew and colleagues conducted a study that found that cognitively demanding tasks will be completed more poorly if words can be distinguished (i.e., not in a foreign language or an instrumental piece).[32]

The mood-arousal theory and the distraction-conflict theory contribute to our understanding of the research findings above on the effect of music on cognitive performance; however, these two theories are only somewhat supported by the data. Empirical support is lent to the mood-arousal hypothesis, given that matched tempo and valence were found to optimize performance. However, results were inconsistent with the aspect of the mood-arousal hypothesis that predicted enhanced performance when a slower tempo and lower valence were present. According to the mood-arousal hypothesis, a slower tempo and lower valence should result in inhibited instead of enhanced performance. Other inconsistencies were also found in the distraction-conflict theory. While repetition and monotony in a piece could lead to boredom and, therefore, inferior performance, it could also minimize the distraction the music causes. Gonzalez and Aiello found that higher music salience, which has greater complexity and louder volume, enhances simple task performance.[13] Thus, decreased repetition and increased music complexity should lead to increased concentration until it reaches overstimulation.

The paper's third section examined the impact of personal characteristics on cognitive performance based on various studies. Studies found that introverts, men, older people, and the absence of training in singing, playing an instrument, or other musical endeavors led to worsened cognitive performance. According to Eysenck's study, introverts always perform worse than extroverts when listening to music and completing a task, as introverts exhibit a higher level of resting arousal and are more easily overstimulated.[35] Haviland and Malatesa found that men are more easily impacted by external stimuli, and concluded that because their arousal levels increase more quickly, their performance is hindered more.[40] A study by Hasher and

Zacks found that aging eventually weakens the encoding and retrieval mechanisms in the brain, making it harder to ignore task-irrelevant stimuli.[46] Lastly, experience with musical training leads to worsened performance in language comprehension and cognitively demanding tasks while listening to music.[47,49]

Concerning the implications of this body of literature, it is important to consider the populations that engage in music and could be negatively or positively impacted by music-listening multi-tasking practices. Studies have found that individuals have somewhat accurate perceptions of the effects of listening to music on cognitive performance. Goltz and Sadakata's experiment involved 140 participants completing an online questionnaire and self-reporting their music habits while engaging in other tasks. For every single type of task, participants (even those who believed in music's beneficial effects) reported using music less as tasks became harder. Participants also favored non-vocal, classical, and calm music while completing difficult tasks but were less considerate when completing easy tasks, matching the distraction-conflict theory. These choices match the two theories discussed, where the more cognitively demanding difficult tasks would be overburdened by lyrical music. It must be noted that while calm music can be beneficial, energetic music can also boost arousal to a degree, enhancing cognitive performance. Most of the participant's musical beliefs still align with existing research; however, some effects are still unknown.[20]

Being aware of the effects of listening to music while completing other tasks is especially important in current times. Because of rapidly improving technology and the COVID-19 pandemic, desk jobs and remote work have become more frequent. According to an April 2020 census for the United Kingdom, 46.6% of people working in jobs also have worked at home, and 86% of those did so because of the COVID-19 pandemic.[75] Since music is frequently used in these types of jobs, knowledge of the exact effects of the music is important for job productivity. According to a study by Sanseverino et al. in 2022, 57.7% of participants reported listening to music while working.[76]

The fourth section of the paper recognized that listening to music has real clinical applications. Music therapy includes all the previously discussed effects of music and more active variants. For the four neurological disorders covered (i.e., Alzheimer's disease, Parkinson's disease, autism spectrum disorder, and ADHD), the presence of music lessens their symptoms and overall improves performance. Compared to pharmaceutical options that only temporarily subdue symptoms and lead to side effects, music is a safer alternative option. Clinicians should consider incorporating music therapy for Alzheimer's (improves memory, language, and speech), Parkinson's (improves memory and attention), ASD (improves social communication and attention), and ADHD (calm music improves attention and reading comprehension).

Future Direction

Most studies in this review played music during cognitive tasks. However, in the 1993 study by Rauscher *et al*. about the "Mozart Effect," participants performed tasks after listening to music. This might have contributed to inconsistent findings and posed challenges to the generalization of results. Future studies need to compare performance both during and after music is played. There were also some studies that did not play music during the entire task. They would split the tasks into the recognition phase (where participants would try to remember the information) and the encoding phase (where participants would try to recall the information), so music was played for only part of the task. Therefore, future studies should compare the performance of music during the recognition phase only, the encoding phase only, or both.

There is a great heterogeneity of tasks used across the studies which could have interfered with the findings. For example, reading comprehension could refer to comprehension of passages of different lengths accessed by different numbers of multiple-choice questions using different time limits. It could also mean completing the last word of sentences or correcting incorrect grammar in sentences. Thus, future studies could benefit from better characterization of the tasks used.

Furthermore, studies should consider more standard methodologies. For example, almost all of the studies used different pieces of music. Even though the music could be under the same genre or mood category, this could still affect their findings. As evident in this review, different elements of music, such as repetition, tempo, and presence of lyrics, can affect cognitive performance. Therefore, inconsistencies in research findings could result if different pieces of music were used to study the same research question, even under the same genre or mood category.

Lastly, since personal characteristics can affect cognitive performance in music, future studies need to take into account relevant personal characteristics (e.g., level of extroversion, age, and musical training) to achieve more accurate results.

Limitations

Concerning the limitations of the studies reviewed in this paper, a pattern of considerably more women in each study was found. This is especially notable, given that women tend to be affected by the presence of music less than men, thus skewing the effects of the studies into having less of an effect. Also, exempting the studies that examine the impacts of music therapy, which are focused on older people, and the studies that specifically look at younger children, most experiments are near an average age of 21. There needs to be more research on the effects of music on middle-aged people, as focusing on the extremes of the age scale only limits the available findings. Lastly, the section on aging is supported with only limited evidence. It lacks sufficient studies to truly cover the broad category of cognitive performance.

■ Acknowledgments

Thank you, Aliza Spruch-Feiner, for your continued mentorship throughout the process of writing this paper.

DOI: 10.36838/v7i2.91

References

1. Götting, M. C.. *Statista.* https://www.statista.com/statistics/367739/spotify-global-mau/
2. Datta, H.; Knox, G.; Bronnenberg, B. J. Changing their tune: How consumers' adoption of online streaming affects music consumption and discovery. *Mark. Sci*. **2017**, *37* (1), 5-21. DOI: 10.1287/mksc.2017.1051
3. Guttmann, A.. *Statista.* https://www.statista.com/statistics/1347916/share-respondents-multitasking-media-us/
4. Rauscher, F. H.; Shaw, G. L.; Ky, C. N. Music and spatial task performance. *Nature* **1993**, *365* (6447), 611. DOI: 10.1038/365611a0
5. Lesiuk, T. The effect of music listening on work performance. *Psychol. Music.* **2005**, *33* (2), 173-191. DOI: 10.1177/0305735605050650
6. Schellenberg, E. G.; Hallam, S. Music listening and cognitive abilities in 10- and 11-year-olds: The blur effect. *Ann. N. Y. Acad. Sci*. **2005**, *1060* (1), 202-209. DOI: 10.1196/annals.1360.013
7. Schellenberg, E. G.; Nakata, T.; Hunter, P. G.; Tamoto, S. Exposure to music and cognitive performance: Tests of children and adults. *Psychol. Music.* **2007**, *35* (1), 5-19. DOI: 10.1177/0305735607068885
8. Cassidy, G.; MacDonald, R. A. The effect of background music and background noise on the task performance of introverts and extroverts. *Psychol. Music.* **2007**, *35* (3), 517-537. DOI: 10.1177/0305735607076444
9. Furnham, A.; Bradley, A. Music while you work: The differential distraction of background music on the cognitive test performance of introverts and extroverts. *Appl. Cogn. Psychol.* **1997**, *11* (5), 445-455.
10. Reaves, S.; Graham, B.; Grahn, J.; Rabannifard, P.; Duarte, A. Turn off the music! Music impairs visual associative memory performance in older adults. *Gerontol.* **2015**, *56* (3), 569-577. DOI: 10.1093/geront/gnu113
11. Baron, R. S. Distraction-Conflict theory: Progress and problems. *Adv. Exp. Soc. Psychol.* **1986**, 1-40. DOI: 10.1016/s0065-2601(08)60211-7
12. O'Malley, J. J.; Poplawsky, A. Noise-induced arousal and breadth of attention. *Percept. Mot. Skills*. **1971**, *33* (3), 887-890. DOI: 10.2466/pms.1971.33.3.887
13. Gonzalez, M. F.; Aiello, J. R. More than meets the ear: Investigating how music affects cognitive task performance. *J. Exp. Psychol. Appl.* **2019**, *25* (3), 431-444. DOI: 10.1037/xap0000202
14. McCutcheon, L. E. Another failure to generalize the Mozart effect. *Psychol. Rep*. **2000**, *87* (1), 325-330. DOI: 10.2466/pr0.2000.87.1.325
15. Newman, J.; Rosenbach, J. H.; Burns, K. L.; Latimer, B. C.; Matocha, H. R.; Vogt, E. R. An experimental test of "The Mozart effect": Does listening to his music improve spatial ability? *Percept. Mot. Skills.* **1995**, *81* (3_suppl), 1379-1387. DOI: 10.2466/pms.1995.81.3f.1379
16. Steele, K. M.; Bass, K. E.; Crook, M. D. The mystery of the Mozart effect: Failure to replicate. *Psychol. Sci.* **1999**, *10* (4), 366-369. DOI: 10.1111/1467-9280.00169
17. Chabris, C. F. Prelude or requiem for the 'Mozart effect'? *Nature* **1999**, *400* (6747), 826-827. DOI: 10.1038/23608
18. Nantais, K. M.; Schellenberg, E. G. The Mozart effect: An artifact of preference. *Psychol. Sci.* **1999**, *10* (4), 370-373. DOI: 10.1111/1467-9280.00170
19. Husain, G.; Thompson, W. F.; Schellenberg, E. G. Effects of musical tempo and mode on arousal, mood, and spatial abilities. *Music Percept.* **2002**, *20* (2), 151-171. DOI: 10.1525/mp.2002.20.2.151
20. Goltz, F.; Sadakata, M. Do you listen to music while studying? A portrait of how people use music to optimize their cognitive performance. *Acta Psychol*. **2021**, *220*, 103417. DOI: 10.1016/j.actpsy.2021.103417
21. Fahlman, S. A.; Mercer-Lynn, K. B.; Flora, D. B.; Eastwood, J. D. Development and validation of the multidimensional state boredom scale. *Assessment* **2013**, *20* (1), 68-85. DOI: 10.1177/1073191111421303
22. Hamilton, J. A.; Haier, R. J.; Buchsbaum, M. S. Intrinsic enjoyment and boredom coping scales: Validation with personality, evoked potential and attention measures. *Pers. Individ. Differ.* **1984**, *5* (2), 183-193. DOI: 10.1016/0191-8869(84)90050-3
23. Margulis, E. H. *On repeat: How music plays the mind*; Oxford University Press, 2014.
24. Thompson, W. F.; Schellenberg, E. G.; Letnic, A. K. Fast and loud background music disrupts reading comprehension. *Psychol. Music.* **2011**, *40* (6), 700-708. DOI: 10.1177/0305735611400173
25. Baldwin, C. L.; Lewis, B. A. Positive valence music restores executive control over sustained attention. *PLOS ONE* **2017**, *12* (11), e0186231. DOI: 10.1371/journal.pone.0186231
26. Quan, Y.; Ma, W.; Li, H.; Thompson, W. F. Slow tempo music preserves attentional efficiency in young children. *Atten. Percept. Psychophys*. **2022**, *85* (4), 978-984. DOI: 10.3758/s13414-022-02602-3
27. Chie, Q. T.; Kartpagam, K. K. The effects of music tempo on memory performance using maintenance rehearsal and imagery. *Sunway Academic Journal* **2009**, *6*, 114-132. http://sunway.edu.my/media/academic-journal
28. Day, R.-F.; Lin, C.-H.; Huang, W.-H.; Chuang, S.-H. Effects of music tempo and task difficulty on multi-attribute decision-making: An eye-tracking approach. *Comput. Human Behav*. **2009**, *25* (1), 130-143. DOI: 10.1016/j.chb.2008.08.001
29. Lin, H.-M.; Kuo, S.-H.; Mai, T. P. Slower tempo makes worse performance? The effect of musical tempo on cognitive processing speed. *Front. Psychol.* **2023**, *14*. DOI: 10.3389/fpsyg.2023.998460
30. Pelletier, C. L. The effect of music on decreasing arousal due to stress: A meta-analysis. *J. Music. Ther*. **2004**, *41* (3), 192-214. DOI: 10.1093/jmt/41.3.192
31. Cheah, Y.; Wong, H. K.; Spitzer, M.; Coutinho, E. Background music and cognitive task performance: A systematic review of task, music, and population impact. *Music Sci.* **2022**, *5*, 205920432211343. DOI: 10.1177/20592043221134392
32. Chew, A. S.-Q.; Yu, Y.-T.; Chua, S.-W.; Gan, S. K.-E. The effects of familiarity and language of background music on working memory and language tasks in Singapore. *Psychol. Music*. **2016**, *44* (6), 1431-1438. DOI: 10.1177/0305735616636209
33. Souza, A. S.; Leal Barbosa, L. C. Should we turn off the music? Music with lyrics interferes with cognitive tasks. *J. Cogn*. **2023**, *6* (1). DOI: 10.5334/joc.273
34. Vasilev, M. R.; Hitching, L.; Tyrrell, S. What makes background music distracting? Investigating the role of song lyrics using self-paced reading. *J. Cogn. Psychol*. **2023**, 1-27. DOI: 10.1080/20445911.2023.2209346
35. Eysenck, H.J. *The biological basis of personality*; Thomas: Springfield, Ill, 1967.
36. Daoussis, L.; Mc Kelvie, S. J. Musical preferences and effects of music on a reading comprehension test for extraverts and introverts. *Percept. Mot. Skills*. **1986**, *62* (1), 283-289. DOI: 10.2466/pms.1986.62.1.283
37. Furnham, A.; Strbac, L. Music Is as Distracting as Noise: The Differential Distraction of Background Music and Noise on the Cognitive Test Performance of Introverts and Extraverts. *Ergonomics*. **2002**, *45* (3), 203-17. DOI: 10.1080/00140130210121932
38. Dobbs, S.; Furnham, A.; McClelland, A. The Effect of Background Music and Noise on the Cognitive Test Performance of Introverts and Extraverts. *Appl. Cogn. Psychol*. **2011**, *25* (2), 307-13. DOI: 10.1002/acp.1692

39. Fabes, R. A. Physiological, emotional, and behavioral correlates of gender **segregation**. *New. Dir. Child. Adoles*. **1994**, *1994* (65), 19-34. DOI: 10.1002/cd.23219946504
40. Haviland, J. J.; Malatesta, C. Z. The development of sex differences in nonverbal signals: Fallacies, facts, and fantasies. *Gend. Nonverbal Behav*. **1981**, 183-208. DOI: 10.1007/978-1-4612-5953-4_10
41. Moss, H. A. Early sex differences and mother-infant interaction. In R. C. Friedman,; R. M. Richart,; R. L. Vande Wiele,; L. O. Stern (Eds.), *Sex. Diff. Behav*. **1974**. John Wiley & Sons.
42. Schirmer, A.; Kotz, S. A.; Friederici, A. D. Sex differentiates the role of emotional prosody during word processing. *Cogn. Brain Res*. **2002**, *14* (2), 228-233. DOI: 10.1016/s0926-6410(02)00108-8
43. Jing, Y.; Jing, S.; Huajian, C.; Chuangang, S.; Yan, L. The gender difference in distraction of background music and noise on the cognitive task performance. In *8th International Conference on Natural Computation*, Chongqing, China, May 29-31, 2012; pp 584-587 DOI: 10.1109/ICNC.2012.6234719
44. El Haj, M.; Omigie, D.; Clément, S. Music causes deterioration of source memory: Evidence from normal aging. *Q J. Exp Psychol*. **2014**, *67* (12), 2381-2391. DOI: 10.1080/17470218.2014.929719
45. Campbell, K. L.; Grady, C. L.; Ng, C.; Hasher, L. Age differences in the frontoparietal cognitive control network: Implications for distractibility. *Neuropsychologia* **2012**, *50* (9), 2212-2223. DOI: 10.1016/j.neuropsychologia.2012.05.025
46. Hasher, L.; Zacks, R. T. Working memory, comprehension, and aging: A review and a new view. *Psychol. Learn. Motiv.* **1988**, 193-225. DOI: 10.1016/s0079-7421(08)60041-9
47. Patston, L. L. M.; Tippett, L. J. The effect of background music on cognitive performance in musicians and nonmusicians. *Music. Percept*. **2011**, *29* (2), 173-183. DOI: 10.1525/mp.2011.29.2.173
48. Strait, D. L.; Parbery-Clark, A.; Hittner, E.; Kraus, N. Musical training during early childhood enhances the neural encoding of speech in noise. *Brain. Lang*. **2012**, *123* (3), 191-201. DOI: 10.1016/j.bandl.2012.09.001
49. Yang, J.; McClelland, A.; Furnham, A. The Effect of Background Music on the Cognitive Performance of Musicians: A Pilot Study. *Psyc. of Music* **2016**, *44* (5), 1202-08. DOI: 10.1177/0305735615592265
50. Särkämö, T.; Tervaniemi, M.; Huotilainen, M. Music perception and cognition: Development, neural basis, and rehabilitative use of music. *Wiley Interdiscip. Rev. Cogn.* **2013**, *4* (4), 441-451. DOI: 10.1002/wcs.1237
51. Knopman, D. S.; DeKosky, S. T.; Cummings, J. L.; Chui, H.; Corey–Bloom, J.; Relkin, N.; Small, G. W.; Miller, B.; Stevens, J. C. Practice parameter: Diagnosis of dementia (an evidence-based review). *Neurology* **2001**, *56* (9), 1143-1153. DOI: 10.1212/wnl.56.9.1143
52. Brinton R. D. A women's health issue: Alzheimer's disease and strategies for maintaining cognitive health. *Int. J. Fertil. Womens Med.* **1999**, *44* (4), 174–185.
53. American Psychiatric Association. *Diagnostic and statistical manual of mental disorders*; American Psychiatric Association, 2013. DOI: 10.1176/appi.books.9780890425596
54. Aldridge, D. *Music therapy research and practice in medicine: From out of the silence*; Jessica Kingsley, 2004.
55. Brotons, M.; Koger, S. M. The impact of music therapy on language functioning in dementia. *J. Music Ther.* **2000**, *37* (3), 183-195. DOI: 10.1093/jmt/37.3.183
56. Gómez Gallego, M.; Gómez García, J. Music therapy, and Alzheimer's disease: Cognitive, psychological, and behavioral effects. *Neurología (English Edition)* **2017**, *32* (5), 300-308. DOI: 10.1016/j.nrleng.2015.12.001
57. Jacobsen, J.-E.; Stelzer, J.; Fritz, T. H.; Chételat, G.; La Joie, R.; Turner, R. Why musical memory can be preserved in advanced Alzheimer's disease. *Brain* **2015**, *138* (8), 2438-2450. DOI: 10.1093/brain/awv135
58. Walsh, D. M.; Selkoe, D. J. A critical appraisal of the pathogenic protein spread hypothesis of neurodegeneration. *Nat. Rev. Neurosci*. **2016**, *17* (4), 251-260. DOI: 10.1038/nrn.2016.13
59. Bloem, B. R.; de Vries, N. M.; Ebersbach, G. Nonpharmacological treatments for patients with Parkinson's disease. *Mov. Disord*. **2015**, *30* (11), 1504-1520. DOI: 10.1002/mds.26363
60. Wirdefeldt, K.; Adami, H.-O.; Cole, P.; Trichopoulos, D.; Mandel, J. Epidemiology and etiology of Parkinson's disease: A review of the evidence. *Eur. J. Epidemiol*. **2011**, *26* (S1), 1-58. DOI: 10.1007/s10654-011-9581-6
61. Pohl, P.; Dizdar, N.; Hallert, E. The Ronnie Gardiner rhythm and music method – a feasibility study in Parkinson's disease. *Disabil. Rehabil.* **2013**, *35* (26), 2197-2204. DOI: 10.3109/09638288.2013.774060
62. Spina, E.; Barone, P.; Mosca, L. L.; Forges Davanzati, R.; Lombardi, A.; Longo, K.; Iavarone, A.; Amboni, M. Music therapy for motor and nonmotor symptoms of Parkinson's disease: A prospective, randomized, controlled, single-blinded study. *J. Am. Geriatr. Soc*. **2016**, *64* (9). DOI: 10.1111/jgs.14295
63. Belousova, E. D.; Zavadenko, N. N. Epilepsy and autism spectrum disorders in children. *Zhurnal Nevrologii I Psikhiatrii Im. S.S. Korsakova* **2018**, *118* (5), 80. DOI: 10.17116/jnevro20181185280
64. Ronconi, L.; Molteni, M.; Casartelli, L. Building blocks of others' understanding: A perspective shift in investigating social-communicative deficit in autism. *Front. Hum. Neurosci.* **2016**, *10*. DOI: 10.3389/fnhum.2016.00144
65. Sharda, M.; Tuerk, C.; Chowdhury, R.; Jamey, K.; Foster, N.; Custo-Blanch, M.; Tan, M.; Nadig, A.; Hyde, K. Music improves social communication and auditory–motor connectivity in children with autism. *Transl. Psychiatry* **2018**, *8* (1). DOI: 10.1038/s41398-018-0287-3
66. Schwartzberg, E. T.; Silverman, M. J.. Effects of a Music-based Short Story on Short- and Long-term Reading Comprehension of Individuals with Autism Spectrum Disorder: A Cluster Randomized Study. *The Arts in Psychotherapy*. **2016**, *48*, 54-61. DOI: 10.1016/j.aip.2016.01.001
67. Erskine, H. E.; Norman, R. E.; Ferrari, A. J.; Chan, G. C.; Copeland, W. E.; Whiteford, H. A.; Scott, J. G. Long-Term outcomes of attention-deficit/hyperactivity disorder and conduct disorder: A Systematic review and meta-analysis. *J. Am. Acad. Child Adolesc. Psychiatry* **2016b**, *55* (10), 841-850. DOI: 10.1016/j.jaac.2016.06.016
68. Erskine, H. E.; Baxter, A. J.; Patton, G.; Moffitt, T. E.; Patel, V.; Whiteford, H. A.; Scott, J. G. The global coverage of prevalence data for mental disorders in children and adolescents. *Epidemiol. Psychiatr. Sci.* **2016a**, *26* (4), 395-402. DOI: 10.1017/s2045796015001158
69. Dalsgaard, S.; Østergaard, S. D.; Leckman, J. F.; Mortensen, P. B.; Pedersen, M. G. Mortality in children, adolescents, and adults with attention deficit hyperactivity disorder: A nationwide cohort study. *Lancet* **2015**, *385* (9983), 2190-2196. DOI: 10.1016/s0140-6736(14)61684-6
70. Faraone, S. V.; Biederman, J.; Mick, E. The age-dependent decline of attention deficit hyperactivity disorder: A meta-analysis of follow-up studies. *Psychol. Med.* **2005**, *36* (2), 159-165. DOI: 10.1017/s003329170500471x
71. Puyjarinet, F.; Bégel, V.; Bella, S. D. *Entretiens de Psychomotricité*; Toulouse: Europa Digital & Publishing. 2017.
72. Noreika, V.; Falter, C. M.; Rubia, K. Timing deficits in attention-deficit/hyperactivity disorder (ADHD): Evidence from

DOI: 10.36838/v7i2.91

neurocognitive and neuroimaging studies. *Neuropsychologia* **2013**, *51* (2), 235-266. DOI: 10.1016/j.neuropsychologia.2012.09.036
73. Serrallach, B.; Groß, C.; Bernhofs, V.; Engelmann, D.; Benner, J.; Gündert, N.; Blatow, M.; Wengenroth, M.; Seitz, A.; Brunner, M.; Seither, S.; Parncutt, R.; Schneider, P.; Seither-Preisler, A. Neural biomarkers for dyslexia, ADHD, and ADD in the auditory cortex of children. *Front. Neurosci.* **2016**, *10*. DOI: 10.3389/fnins.2016.00324
74. Madjar, N.; Gazoli, R.; Manor, I.; Shoval, G. Contrasting effects of music on reading comprehension in preadolescents with and without ADHD. *Psychiatry Res*. **2020**, *291*, 113207. DOI: 10.1016/j.psychres.2020.113207
75. Office for National Statistics. *Coronavirus and homeworking in the UK: April 2020*, last revised February 2024. https://www.ons.gov.uk/employmentandlabourmarket/peopleinwork/employmentandemployeetypes/bulletins/coronavirusandhomeworkingintheuk/april2020
76. Sanseverino, D.; Caputo, A.; Cortese, C. G.; Ghislieri, C. "Don't Stop the Music," Please: The Relationship between Music Use at Work, Satisfaction, and Performance. *Behavioral Sciences*. **2022**, *13* (1), 15. DOI:10.3390/bs13010015

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