The effects of background music on cognitive functioning

Comprehensive exam paper

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Listening closely in almost any public space reveals how background music, unobtrusive music in the environment, is especially present in day-to-day life. While the human ear is regularly stimulated by auditory stimuli that are inevitable products of the environment (background noise), background music is added to the environment with a goal in mind, like setting a mood or impacting human behaviour. In commercial settings, background music is used to influence the things you buy (Areni & Kim, 1993; North, 1999), the type of food you order (North, 1998)⁠, and how much money you spend (Donovan & Rossiter, 1994)⁠. People also choose to listen to music on a regular basis. Americans over the age of 13, spend an average of four hours per day listening to music from a variety of sources (*Share of Ear*, 2014)⁠. Many will choose to listen to that music while performing cognitively demanding tasks such as driving a car, working, or studying. However, background music affects a person’s abilities to perform these tasks. For example, listening to music while driving can affect speed, traffic violations, and steering movements (Brodsky, 2002, 2013; Konz & Mcdougal, 1968)⁠. Previous research has shown that tasks involving complex cognitive processes such as working memory, spatial manipulation, and recall are susceptible to music’s influence, but how background music specifically affects these processes remains unclear.

Over the last 60 years, numerous studies have investigated whether background music enhances or impairs performance during cognitively demanding tasks. Many of these studies investigated how music affects skills important for classroom learning, such as reading rate and comprehension (Freeburne & Fleischer, 1952)⁠, short-term memory (Salamé & Baddeley, 1989)⁠, and spatial manipulation tasks (Patston & Tippett, 2011)⁠. One of the most influential findings within this field was the discovery of ‘The Mozart Effect’ (Rauscher et al. 1993)⁠. Participants listened to Mozart music for 10 minutes before completing a series of spatial-temporal tasks. Participants performed better after listening to Mozart’s music compared to when the task was completed following a period of relaxation or silence. These results inspired research into the use of music to bolster cognitive abilities. However, like the Rauscher et al. (1993) study, in many of these studies participants listened to music before completing a task. In a real-world setting, people tend to listen to music while driving, working, or studying. This paper reviews studies in which music was played *during* cognitive task performance in an effort to understand music’s effect in real-world situations.

A recent review by Schellenberg and Weiss (2013)⁠ covered many aspects of the research on the effects of music on cognitive abilities including: emotional responses and cognitive capacity; the effect of background music on mathematics, memory, and reading comprehension; and the role of individual differences in personality. However, important areas of research on the effects of background music were not discussed and this paper will tackle those areas. I will review research manipulating musical characteristics, such as preference and the presence or absence of lyrics, to gain a clearer understanding of the effects these characteristics have on cognitive task performance. Listener age and musical training have been shown to affect cognitive task performance, and I will review these individual differences to examine the effects of background music across listeners. Fully understanding the mechanism of music’s effects requires exploring why musicians and non-musicians perform differently on cognitive tasks in the presence of music. I will review studies regarding how these two groups interpret musical information and how this might affect their task performance. Importantly, all of the studies discussed above use behavioural tasks to measure cognitive performance, but recently researchers have begun to use electroencephalography (EEG) to examine the neural basis for the relationship between music and cognitive task ability. To paint a more complete picture than previously offered in the literature, I will review this important new area of EEG-based research.

**Effect of Preference**

One of the first approaches to further exploring the Mozart Effect was an investigation into whether a participant’s preference for the music modulated the music’s effect on cognition.There is evidence to show that people choose to listen to music because of the way it makes them feel (Juslin & Västfjäll, 2008; Lonsdale & North, 2011; Sloboda, 1992)⁠ and studies have shown that changes in mood and arousal may also affect cognitive task performance (Husain, Thompson, & Schellenberg, 2002; Thompson, Schellenberg, & Husain, 2001)⁠. For example, Husain et al. (2002)⁠ found that increased levels of arousal account for 60% of the variance in scores on a spatial manipulation task. This change in arousal, driven by preference, may be related to how music affects cognition.

Nantais and Schellenberg (1999)⁠ showed that if participants liked the music they were listening to (regardless of composer) then they performed better on the same spatial-temporal task used in the Rauscher et al., (1993)⁠ study than if they didn’t like the music. This could be caused by an increased level of arousal as a result of listening to preferred music. This musical preference result was replicated by Perham and Withey (2012)⁠ when participants performed better on a similar spatial-temporal task when listening to liked music than when listening to disliked music. Studies exploring the preference effect on other cognitive tasks, however, have found conflicting results. In a reading task, music preference had no effect on reading comprehension performance (Perham & Currie, 2014)⁠. Instead, performance was mediated by the presence of lyrics as participants performed worse when lyrics were present in the music. The effects of lyric presence will be discussed further in the following section. When investigating the effect of music preference on serial recall, the ability to store and recall a list of items, one study showed that both liked and disliked music resulted in worse performance on the task than when it was performed in silence but the two music conditions did not differ from each other (Perham & Vizard, 2011). Another study replicated the first result (both liked and disliked music produced worse performance than silence), but in this study liked music resulted in worse performance than disliked music (Perham & Sykora, 2012)⁠. The conflicting results from these studies could be due to how the music used in each study was chosen. In the 2011 study, participants provided their own liked music, but in the 2012 study both liked and disliked songs were provided by the researcher. The differences could be a result of different moods or arousal levels induced by the songs that were chosen by the individual and the songs chosen by the researcher. By choosing both of the songs, the researchers were able to ensure the largest difference between the liked and disliked music conditions.

Music preference does have an effect on cognitive task performance, but it seems that the effect is largely dependent on the type of task. For example, serial recall is disrupted regardless of music preference (Perham & Sykora, 2012; Perham & Vizard, 2011)⁠, spatial rotation task performance improves with preferred music (Perham & Withey, 2012)⁠, and reading comprehension is disrupted by the presence of lyrics regardless of preference (Perham & Currie, 2014)⁠. Although the results are inconsistent across tasks, different characteristics of music may affect different types of cognitive processes. For example, people who prefer to perform spatial tasks while listening to music may benefit from an optimal arousal level induced by preferred music while students who listen to music while studying may find that music with lyrics worsens their ability to understand written materials. Applying these results to background music played in real-world situations, like factories where workers perform spatial tasks in assembly lines or student study spaces where written materials are prevalent, may assist (or at least interfere less) with task performance.

**Effect of the Presence of Speech**

Many of the early studies assessing the effects of music on cognition used classical instrumental pieces that did not include lyrics (Freeburne & Fleischer, 1952; Rauscher & Shaw, 1998; Rauscher et al., 1993; Sogin, 1988)⁠. In recent studies, participants listen to popular music where lyrics are present while completing cognitive tasks. The difference in lyric presence may be contributing to the disparate results within the literature. Understanding how irrelevant sounds affect short-term memory – the irrelevant sound effect (ISE) – may provide insight into how the presence of lyrics in background music affects cognitive function.

A review by Banbury, Macken, Tremblay, & Jones (2001)⁠ proposes that the key factor in the amount of distraction by sound is the degree to which both the task and the sound involve seriation (maintenance of a serial order in memory). The hypothesis is that attention to a task is interfered with because of the similarities in the way the brain perceptually organizes the serial task and the serial auditory input. When listening to music while performing a reading task, the reading is the first source of serial information. Changes in the tonal or rhythmic pattern of the music requires organization of the order of the auditory input making the music the second source of serial information. When the brain tries to organize information from both inputs at once, there is a breakdown in attention and the participant performs poorly on the task. To understand how music affects cognitive task performance, the serial nature of the music must be taken into account. Listening to a song with lyrics requires a person to hold previous words in memory in order to understand the meaning of a phrase. This adds to the serial nature of the music and, based on the interpretation by Banbury et al. (2001)⁠, increases the detrimental effects on a task requiring serial processing.

The effects of background music and irrelevant sounds on serial recall tasks have previously been investigated. An early study compared participants’ performance on an immediate serial recall of a sequence of visually presented digits while they listened to instrumental music, vocal music, pink noise, foreign language speech, or a silent control. In the presence of lyrics (in both vocal music and foreign language speech) participants recalled fewer digits than in the other conditions (Salamé & Baddeley, 1989)⁠. According to the hypothesis presented by Banbury et al. (2001)⁠, this is because the vocal music and the foreign language speech are the most serial in nature of the five conditions. The vocal music requires the order of the words to be kept in memory to understand what is being sung. In the case of the foreign language speech, while the words may not be held in memory in order to be understood, the rhythmic and tonal changes created by the sounds of the words are of a more serial nature than the other conditions. This result has been replicated (Beaman & Jones, 1997; Jones & Macken, 1993; Kantner, 2009; Macken, Tremblay, Houghton, Nicholls, & Jones, 2003)⁠. In 1990, Jones, Miles, & Page⁠ also replicated this finding, but they made a distinction between the effects irrelevant speech has on a serial recall task and on proofreading, a task that involves reading comprehension. Like Salame and Baddeley (1989), they showed that serial recall is impaired by any speech-like sound, regardless of that speech being understood by the participant. Proofreading, however, was impaired only when the heard speech was meaningful (i.e. was understood by the participant). In a proofreading task, a participant must read, hold in memory, and manipulate the order and meaning of a series of words. Meaningful speech requires that the auditory input be processed serially and the words held in memory to extract meaning. When occurring simultaneously, there may be competition between the words held in memory from the two sources causing impairment in performance on the proofreading task. Words from irrelevant speech are not held in memory and therefore do not compete with or impair performance. These results indicate that music with lyrics should be avoided when performing cognitive tasks of a serial nature, such as serial recall or reading tasks.

**Effect of Music Training**

Individual differences also affect how background music affects cognitive functioning. One of the most obvious differences is how music may differentially affect people who have music training (musicians) and those who are not musically trained (non-musicians). The literature shows that if music is going to have an impact on a particular cognitive task, musicians will be more negatively affected than non-musicians. Aheadi, et al (2010)⁠ found that Mozart music helped non-musicians perform a mental rotation task when the same music had no effect on musicians, while Patston and Tippett (2011)⁠ found that classically trained musicians did worse than non-musicians on a language comprehension task when listening to classical music. Yang, et al (2016)⁠ explored this topic further and investigated whether training type and music type interacted to affect cognitive performance. They found that a musician’s performance was most affected on three cognitive tasks (arithmetic, verbal fluency, problem solving) when they listened to music featuring the instrument on which they were trained than when they listened to music involving other instruments. Despite the research comparing task performance of musicians and non-musicians, there are no studies that investigate what it is about musical training that causes these task performance differences to occur. Exploring how musicians and non-musicians process music as they listen may help understand why musicians and non-musicians perform differently on cognitive tasks in the presence of music.

As discussed previously, the hypothesis for why the serial nature of language interferes with tasks that require serial processing has to do with the brain’s ability to organize incoming serial information from multiple sources. Something similar may be occurring in the case of musicians and background music. Musicians spend years learning to recognize the intricate details of a piece of music. In music, different notes have different roles similar to how, in language, words play specific roles in a sentence (verbs, adjectives, etc.). With training, a musician can not only detect features of the music an untrained listener would not hear, but also understand how the structure of a series of notes are assembled to produce a piece of music. To a musician, the music may be a type of language requiring serial processing where previous musical information must be kept in memory to make sense of incoming information. This interpretation fits with the hypothesis that it is the serial nature of the irrelevant sound that is important for producing negative effects on cognitive tasks (Banbury et al., 2001)⁠. Non-musicians, who are not trained to listen and understand the structure the music, process the music holistically (Bever & Chiarello, 2016)⁠ and are therefore not as affected by the serial nature of music when concurrently performing a task.

Another way to explain the differences between musicians and non-musicians is through the schema theory of learning. The term schema was first introduced by Piaget (1953)⁠ and refers to a method of organizing knowledge about the world around us. Schemas make processing of incoming information more efficient by indexing the relationships between elements and creating connections between the processes required to understand those relationships. The more we are exposed to a stimulus, the stronger the connections and the more efficient the schemas become. Schemas are automatically invoked to process and understand incoming stimuli (Anderson, 1984a)⁠. Schema theory, when applied to reading words, involves simultaneous analysis at many different levels: from a phoneme, to syntax, to overall interpretation of a phrase, to following the overarching story (Anderson, 1984b). Music, like a story, contains many different levels of information: rhythm, timbre, tone semantics, dynamics, etc (Leman, 2012)⁠. Musicians are trained to listen and process music in a way that allows them to understand this information. Their schemas for processing music are efficient and well-formed, especially the schemas for the music of their primary instrument.

Due to the similarity between the structure of written language and a music piece, the cognitive processes used to understand the music (working memory, short term memory, contextual comprehension etc.) may be similar in nature to those used during reading (Baddeley, Logie, Nimmo-Smith, & Brereton, 1985; Stanovich, 1982a, 1982b)⁠. The similarity between the cognitive processes involved in music listening and a task like reading may be the reason that musicians are more affected by background music during cognitively demanding tasks. A musician’s schemas for music listening and for task completion are in conflict and this interference may affect performance. Non-musicians, who do not have such strong schemas for processing music, do not have as much overlap between their schemas and perform better on the task. When the background music features the musician’s primary instrument, the schema for the music is stronger because of the length of time spent training on the instrument resulting in further task performance decreases (Yang et al., 2016)⁠. The theory of competing schemas likely explains why musicians are more affected by background music than non-musicians.

**Effect of Age**

Much of the research on music’s effects on cognitive abilities have been done in young adults and whether these effects transfer to other age groups is not clear. Studies have begun to explore these effects in both younger and older populations. In school-aged children, research shows that calming music leads to better performance on arithmetic and memory tasks in 10 and 11 year olds (Hallam, Price, & Katsarou, 2002)⁠ and children who listened to familiar and enjoyable music have better spatial abilities (Schellenberg & Hallam, 2005)⁠ and are more creative (Schellenberg, Nakata, Hunter, & Tamoto, 2007)⁠ than after listening to unfamiliar music. In this case, creativity was measured by having adults rate the creativity of the child’s drawing created during the experiment.

In older adults, a meta-analysis indicated that background music has a negative effect on reading abilities and memory in adults, but a positive effect on emotions (Kämpfe, Sedlmeier, & Renkewitz, 2011)⁠. Category fluency, the ability to generate a list of items within a category, in older adults has also been shown to be enhanced by background music (Thompson, Moulin, Hayre, & Jones, 2005)⁠. Since the 2011 meta-analysis, studies have continued to explore the effects of background music in older adults. Background classical music (without lyrics) was shown to have a positive effect on the working memory (Mammarella, Fairfield, & Cornoldi, 2013)⁠, processing speed, and episodic and semantic memories abilities in older adults (Bottiroli, Rosi, Russo, Vecchi, & Cavallini, 2014)⁠. Music listening has also been shown to alter perceptions about quality of life in older adults (Coffman, 2002)⁠, so further understanding the effect of music on the cognitive abilities of older adults may have potential therapeutic implications.

**Using Electroencephalography**

All of the research studies discussed up to this point have used behavioural measures to investigate the effects of music on cognition. Recently, some researchers have begun to use electroencephalography (EEG) to understand the neural basis of the effects of background music on cognitive functions. When exploring this topic using EEG, it is important to keep in mind the results of EEG studies that have explored cognitive performance without the presence of music. In 1999, Klimesch⁠ wrote a review paper summarizing how EEG signal frequencies are related to different cognitive processes. His main findings showed that good working memory performance relates to changes in EEG alpha (7.5-12.5 Hz) and theta (4-7.5 Hz) frequencies on two scales: tonic (long-term or over the life-time) and phasic (short-term or event-related). Alpha power is generally thought of as an index of attention with large alpha power being an indicator of cortical “idling”. When external task load increases, alpha power decreases (Ward, 2003)⁠. At the tonic level, Klimesch describes good working memory performance as being related to an increase in alpha power and a decrease in theta power. For example, alpha power increases and theta power decreases with age into adulthood as working memory abilities increase. The reverse is true as a person ages into the late lifespan and working memory abilities decrease. In contrast, at the phasic level a large decrease in alpha, but increase in theta power, is related to good cognitive performance. Others have found similar relationships between the alpha and theta bands of the EEG signal and abilities to focus and sustain attention (Gevins & Smith, 2000)⁠.

A similar approach can be taken when looking at EEG signals produced while listening to music and performing a task. Some studies have looked at overall power, a measure of the amount of activity within a certain frequency band in the EEG signal, while others have used techniques called event related desynchronization (ERD) or event related synchronization (ERS). ERD/ERS are a measure of changes in the amount of power in a frequency band over time and are an indication of how synchronous neural activity is as a result of an external stimulus compared to a baseline (Pfurtscheller & Lopes da Silva, 1999)⁠. An increase in ERS indicates that neurons have responded to an external stimulus and become more synchronized in their firing compared to a baseline period.

The changes seen in the EEG frequency bands can be related both to a participant’s performance on a cognitive task and to changes that occur while listening to music. Researchers have used this ability to explore neural activity responsible for the ‘Mozart effect’. These studies have shown that there is an increase in alpha power in the participants’ EEG signal after listening to a Mozart piece (Petsche, Linder, Rappelsberger, & Gruber, 1988; Verrusio et al., 2015)⁠. Alpha ERS also increases after listening to Mozart music (Jaušovec & Habe, 2003)⁠, and this has been shown to coincide with an increase in performance on spatial rotation tasks but a decrease in performance on numerical tasks (Jaušovec & Habe, 2005)⁠. This may indicate that the changes in alpha power induced by the music are interacting with the rate of neural oscillations that naturally occur when performing cognitively demanding tasks. In the case of spatial rotation tasks, the music may be enhancing the same frequencies causing an increase in performance. However, the cognitive processes involved during numerical tasks may create oscillatory frequencies at a different rate and the alpha increase induced by the music may be interfering with these oscillations and decreasing performance.

If cognition studies have found that good cognitive performance is associated with a decrease in alpha power, but music causes an increase in alpha power, then this may be a potential mechanism for music’s detrimental effects on certain cognitive tasks. For a task to be completed, alpha power may need to be at a particular optimal level. The amount of alpha power available may depend on a number of factors like the age of the participant (Klimesch, 1999)⁠, the amount of attention required to complete the task (Gevins & Smith, 2000; Klimesch, Doppelmayr, Russegger, Pachinger, & Schwaiger, 1998)⁠, and the type of music being listened to (Iwaki, Hayashi, & Hori, 1997)⁠. All of these factors affect alpha levels in different ways and music may positively or negatively interact with the alpha power levels. This may explain the differing results discussed in previous sections and why music has such a wide range of effects on different people during different cognitive tasks. Experiments designed to take all of these factors into account may be able to specifically identify the relationship between alpha activity, background music, and cognitive tasks.

**Conclusion**

This paper complements the review by Schellenberg and Weiss (2013)⁠, filling in some of the relevant and new areas of research not discussed in 2013. There is little dispute that background music has an effect on performing cognitive tasks. However, these effects are mediated by the musical background and age of the listener, the type of task, and the composition of the music. In this review, I have presented two hypotheses regarding why these differences in task performance may occur. First, the serial nature of both the task and the sound may compete for serial processing power. Second, the listener’s schemas that are invoked for processing the task and the music may be similar. This overlap creates competition that results in poorer performance on the cognitive task.

The initial goal of this field of research was to determine how music could help support cognitive functioning, but this is a simplistic view. Both ‘music’ and ‘cognitive functioning’ are all-encompassing terms that describe complex and multi-faceted concepts. Many characteristics of music can be manipulated and, as discussed here, they exert different effects on different components of cognition. The results reviewed in this paper make it clear that future research towards uncovering the fine-grained effects of music on cognition will need to take mood and arousal, individual differences of age and musical background, the composition of the music, and the mental processes required to complete a task into account. Optimally combining these factors may create personalized environments in which background music could support cognitive task performance.

Bibliography