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 the mechanisms through which 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 in the 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 and many commercial products such as the *Baby Einstein – Baby Mozart* video series aimed at stimulating infant development (Birch, 2015). 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 the effect of background music on cognitive task performance 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 in that review, and this paper will tackle those gaps. I will review research manipulating the musical characteristics of background music during task performance, 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 musicians and non-musicians interpret musical information and how this difference in musical training might affect their task performance. Understanding how these different factors interact may be useful for creating cognitively supportive personalized environments by optimally combining listener, music, and task characteristics.

In this paper, I will present two hypotheses regarding why differences in task performance may occur in the presence of background music. First, the brain's ability to process competing inputs may depend on the degree of similarity between the two inputs. If the background music and the task depend on similar brain mechanisms to be understood, then their simultaneous processing will result in competition between the inputs resulting in poor task performance. Second, the listener's amount of exposure to the music or the task may affect how each is processed. According to the schema theory of learning (Rumelhart, 1978), all inputs are grouped into meaningful patterns, called schemas, that allow for efficient processing of new, incoming information. The more one is exposed to a stimulus, the stronger and more efficient the schema for processing that stimulus becomes. An overlap in the schemas for processing music and a task would create competition resulting in poorer performance on the task.

Lastly, 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. Using EEG allows us to probe the relationship between neural oscillations induced by music and by cognitive task performance and to observe how they interact. Understanding the neural basis for the effect of background music on task performance will bring clarity to the mechanisms behind the effect that background music has on cognitive task performance.

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 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.

Some research into the effect of musical preference on cognitive task performance has shown that, in some cases, musical preference aids cognitive task performance. 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. The preferred music could have caused an increased level of arousal that bolstered the cognitive performance through an increase in attention and vigilance to the task. 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 have found results that conflict with those from studies using spatial-temporal tasks (Nantais & Schellenberg, 1999; Perham & Withey, 2012). 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 and therefore the largest difference in arousal levels.

The studies reviewed above indicate that 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). Harnessing the different effects that music has on different cognitive processes may be useful for creating environments that assist performance on particular cognitive tasks. For example, people who prefer to perform spatial tasks while listening to music may benefit from an optimal arousal level induced by preferred music (Perham & Withey, 2012) while students who listen to music while studying may find that music with lyrics worsens their ability to understand written materials (Perham & Currie, 2014). 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

The presence of lyrics is an important part of how background music affects cognitive tasks. For example, as noted in the previous section, the presence of lyrics disrupted performance on a reading comprehension task regardless of music preference (Perham & Currie, 2014). 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 more recent studies, participants listened to popular music where lyrics were present while completing cognitive tasks (Perham & Currie, 2014; Perham & Sykora, 2012; Perham & Vizard, 2011). The difference in lyric presence may be contributing to the disparate results within the literature.

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. Seriation refers to the maintenance of a serial order in memory. Their hypothesis proposes that the ways the brain perceptually organizes both the serial task and the serial auditory input are very similar and therefore interfere with each other. When listening to music while performing a reading task, the reading is the first source of serial information because word meanings need to be kept in order to make sense of a sentence and sentence meanings need to be kept in order to make sense of a story. In the music, changes in the tonal or rhythmic pattern 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. The lyrics add to the serial nature of the music and, based on the interpretation by Banbury et al. (2001), increase the detrimental effects on a task requiring serial processing.

Previous studies have investigated the effects of background music on serial recall tasks. An early study compared participants' performance on an immediate serial recall of a visually presented sequence of 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 of Banbury et al. (2001), the recall of fewer digits in the presence of lyrics is because vocal music and foreign language speech require the most seriation 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. The disruption of digit recall using the presence of speech has been replicated (Beaman & Jones, 1997; Jones & Macken, 1993; Kantner, 2009; Macken, Tremblay, Houghton, Nicholls, & Jones, 2003).

In 1990, Jones, Miles, & Page also managed to disrupt digit recall in the presence of speech, but they made a distinction between the effect of irrelevant speech on a serial recall task and on proofreading, a task that involves reading comprehension. Like Salamé 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 proofreading and listening to music with lyrics simultaneously, there may be competition between the words from the two sources causing impairment in performance on the proofreading task.

When the lyrics are not meaningful they are not held in memory and therefore do not compete with or impair performance.

The research into how the presence of speech in music affects cognitive task performance indicates that the key component is the degree of seriation present in the music and required by the task. Whether in a serial recall task like digit recall or a reading comprehension task, the presence of irrelevant speech interferes with task performance. Future research should investigate methods of quantifying the degree of seriation in music and cognitive tasks and determining at what levels of seriation the two compete to cause performance disruption.

Effect of Music Training

Individual differences affect how background music affects cognitive functioning. One of the most obvious differences is how music may affect people who have music training (musicians) and those who are not musically trained (non-musicians). Exploring how musicians and non-musicians process music as they listen may help understand why they perform differently on cognitive tasks in the presence of music.

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. Non-musicians did better on a spatial-rotation task after listening to Mozart music while musicians were not affected by the music (Aheadi, Dixon, & Glover, 2010). Non-musicians also did better than musicians on a language comprehension task when listening to classical music Patston and Tippett (2011). Yang, et al (2016) explored the differences in how musicians and non-musicians are affected 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 compared to 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.

As discussed previously, the hypothesis for why the serial nature of language interferes with tasks that require serial processing is a result of how the brain organizes incoming 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 a trained musician also understands 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.

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. 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). 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.

The difference in how musicians and non-musicians process music may be responsible for why they are affected differently by background music when performing a task. Musicians spend years learning to understand the inherent structures in music. It is possible that musicians process music like a language increasing the amount of seriation involved in music listening. When presented with a task requiring serial processing, the competition between the two serial inputs (music and task) result in poorer task performance. Another reason why musicians may be affected differently than non-musicians by background music has to do with the strength of their schemas for music listening. Schema theory states that the strength of a person's schema for a stimulus increases with exposure. As a result of their training, musicians have stronger schemas to music than non-musicians. When there is overlap between the schema for music listening and for task performance, musicians are more affected than non-musicians resulting in poorer task performance.

Effect of Age

Much of the research on music's effects on cognitive abilities has been done in young adults and whether these effects transfer to other age groups is not clear. A few 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 drawings created immediately after music listening. As of yet, there are no studies that have investigated children's creativity during music listening.

Background music can also affect the cognitive abilities of older adults. A recent meta-analysis indicated that background music has a negative effect on reading abilities and memory, but a positive effect on emotions (Kämpfe, Sedlmeier, & Renkewitz, 2011). It is not clear what aspects of the music was responsible for the emotional effects as the studies included in the meta-analysis did not control for musical characteristics that could be triggering the emotional reaction (e.g. tempo or dynamics). The positive emotional effect has implications for improving the quality of life in older adults therefore future studies should aim to understand what aspects of music can be manipulated for the best outcomes in these individuals. Another cognitive aspect that is important to quality of life is the ability to maintain attention on a task. Category fluency, the ability to generate a list of items within a category, is a task that relies on attentional mechanisms and has been shown to be enhanced by background music in older adults (Thompson, Moulin, Hayre, & Jones, 2005). Increasing attention has therapeutic benefits for older adults who may be losing some of their cognitive capacities as they age. 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 working memory (Mammarella, Fairfield, & Cornoldi, 2013), processing speed, and episodic and semantic memories abilities in this population (Bottiroli, Rosi, Russo, Vecchi, & Cavallini, 2014). Music listening has also been shown to alter perceptions about quality of life (Coffman, 2002), so further understanding the effect of music on the cognitive abilities of older adults may have potential therapeutic implications.

Research on the effects of background music on cognitive abilities has been investigated largely in young adults. The effects are less studied in other age groups but are equally as important to understand and may assist in creating cognitively supportive environments. In a classroom setting, the effects of calming music may help reduce anxieties that children have regarding subjects like mathematics (Ramirez, Gunderson, & Levine, 2012) and help them succeed academically. In older adults, classical music may increase quality of life and help support some cognitive functions such as attention, and working memory. Further research into the effects of different types of music on cognitive abilities in children and older adults is required.

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. Using imaging techniques to explore this topic offers a unique view on the mechanisms through which cognitive processes are affected by background music.

When exploring how background music affects cognitive performance 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). Observing changes in the EEG frequency bands offers a glimpse into the brain’s mechanisms for cognitive task performance.

Different types of changes in the EEG frequency bands can be measured. Some studies quantify overall power, a measure of the amount of activity within a certain frequency band in the EEG signal, while others use 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 increase 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 increase in performance 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. The frequency enhancement may make it easier to perform the task 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. For music to have a positive effect on cognitive task performance, it may be necessary for the music to produce neural oscillations at the same frequencies as those that occur during performance of the task. Future studies may want to investigate, and quantify, the frequencies of neural oscillations that occur during different cognitive tasks.

Synthesizing the results of EEG studies on cognitive tasks with and without the presence of music may provide some clues as to the mechanisms through which background music affects cognitive 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 difference 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 an 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. Future research may uncover how specific music characteristics and different cognitive tasks affect neural oscillations. Understanding how music and tasks affect the EEG signal will allow for fine-tuning of optimal environments that support cognitive functioning with music.

A new way of looking at the effects of background music on cognitive processes is with the use of EEG. Studies have shown that cognitive tasks and music affect EEG signals in different ways. The overall power within a frequency band or the frequency of the oscillations may change as a result of either a task or the music listened to. If the changes induced by the task and the music are in competition (for example, increases in power or synchrony in different frequencies) then task performance may be negatively affected. If the task and the music induce the same changes (for example, both cause increased alpha power), then task performance may be positively affected. EEG frequencies can also be affected by other factors such as age, attention required, and music type. All of these interacting factors may by the reason that 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 three 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. Third, the music and the task may be differently affecting neural frequency oscillations. When the effects on the neural oscillations are the same, cognitive task performance may be supported. When the effects on the neural oscillations are different, cognitive task performance may be negatively affected.

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 finely-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

Aheadi, A., Dixon, P., & Glover, S. (2010). A limiting feature of the Mozart effect: Listening enhances mental rotation abilities in non-musicians but not musicians. *Psychology of Music*, *38*(1), 107–117. https://doi.org/10.1177/0305735609336057

Anderson, R. C. (1984a). Role of the reader's schema in comprehension, learning, and memory. *Learning to Read in American Schools: Basal Readers and Content Texts*, *29*, 243–257.

Anderson, R. C. (1984b). Role of the reader's schema in comprehension, learning, and memory. *Learning to Read in American Schools: Basal Readers and Content Texts*, *29*, 243–257.

Areni, C. S., & Kim, D. (1993). The influence of background music on shopping behavior: Classical versus top-forty music in a wine store. In L. McAlister & M. L. Rothschild (Eds.), *Advances in Consumer Research* (pp. 336–340). Provo, UT : Association for Consumer Research.

Baddeley, A., Logie, R., Nimmo-Smith, I., & Brereton, N. (1985). Components of fluent reading. *Journal of Memory and Language*, *24*(1), 119–131. https://doi.org/10.1016/0749-596X(85)90019-1

Banbury, S. P., Macken, W. J., Tremblay, S., & Jones, D. M. (2001). Auditory distraction and short-term memory: Phenomena and Practical Implications. *Human Factors: The Journal of the Human Factors and Ergonomics Society*, *43*(1), 12–29. https://doi.org/10.1518/001872001775992462

Beaman, C. P., & Jones, D. M. (1997). Role of serial order in the irrelevant speech effect: Tests of the changing-state hypothesis. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *23*(2), 459–471. https://doi.org/10.1037/0278-7393.23.2.459

Bever, T. G., & Chiarello, R. J. (2016). Cerebral Dominance in Musicians and Nonmusicians. *American Association for the Advancement of Science*, *185*(4150), 537–539. Retrieved from http://www.jstor.org/stable/1738305

Birch, J. (2015, October). How to Raise a Cultured Baby. *New Parent*. Retrieved from www.babyeinstein.com

Bottiroli, S., Rosi, A., Russo, R., Vecchi, T., & Cavallini, E. (2014). The cognitive effects of listening to background music on older adults: Processing speed improves with upbeat music, while memory seems to benefit from both upbeat and downbeat music. *Frontiers in Aging Neuroscience*, *6*(Oct), 1–7. https://doi.org/10.3389/fnagi.2014.00284

Brodsky, W. (2002). The effects of music tempo on simulated driving performance and vehicular control. *Transportation Research. Part F, Traffic Psychology and Behaviour*, *4*(4), 219–241. https://doi.org/10.1016/S1369-8478(01)00025-0

Brodsky, W. (2013). Background music as a risk factor for distraction among young-novice drivers. *Accident Analysis and Prevention*, *59*, 382–393. https://doi.org/10.1016/j.aap.2013.06.022

Coffman, D. D. (2002). Music and quality of life in older adults. *Psychomusicology*, *18*(1–2), 76–88. https://doi.org/http://dx.doi.org/10.1037/h0094050

Donovan, R. J., & Rossiter, J. R. (1994). Store Atmosphere and Purchasing Behavior. *Journal of Retailing*, *70*(3), 283–294. https://doi.org/10.1016/0022-4359(94)90037-X

Freeburne, C. M., & Fleischer, M. S. (1952). The effect of music distraction upon reading rate and comprehension. *Journal of Educational Psychology*, *43*(2), 101–109. https://doi.org/10.1037/h0054219

Gevins, A., & Smith, M. E. (2000). Neurophysiological Measures of Working Memory and Individual Differences in Cognitive Ability and Cognitive Style. *Cerebral Cortex*, *10*(9), 829–839. https://doi.org/10.1093/cercor/10.9.829

Hallam, S., Price, J., & Katsarou, G. (2002). The Effects of Background Music on Primary School Pupils' Task Performance. *Educational Studies*, *28*(2), 111–122. https://doi.org/10.1080/03055690220124551

Husain, G., Thompson, W. F., & Schellenberg, E. G. (2002). Effects of Musical Tempo and Mode on Arousal, Mood, and Spatial Abilities. *Music Perception: An Interdisciplinary Journal*, *20*(2), 151–171.

Iwaki, T., Hayashi, M., & Hori, T. (1997). Changes in Alpha Band Eeg Activity in the Frontal Area after Stimulation with Music of Different Affective Content. *Perceptual and Motor Skills*, *84*(2).

Jaušovec, N., & Habe, K. (2003). The "Mozart Effect": An Electroencephalographic Analysis Employing the Methods of Induced Event-Related Desynchronization/ Synchronization and Event-Related Coherence. *Brain Topography*, *16*(2), 73–84. https://doi.org/10.1023/B:BRAT.0000006331.10425.4b

Jaušovec, N., & Habe, K. (2005). The influence of Mozart's sonata K. 448 on brain activity during the performance of spatial rotation and numerical tasks. *Brain Topography*, *17*(4), 207–218. https://doi.org/10.1007/s10548-005-6030-4

Jones, D. M., & Macken, W. J. (1993). Irrelevant tones produce an irrelevant speech effect: Implications for phonological coding in working memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *19*(2), 369–381. https://doi.org/10.1037/0278-7393.19.2.369

Jones, D. M., Miles, C., & Page, J. (1990). Disruption of proofreading by irrelevant speech: Effects of attention, arousal or memory? *Applied Cognitive Psychology*, *4*(2), 89–108. https://doi.org/10.1002/acp.2350040203

Juslin, P. N., & Västfjäll, D. (2008). Emotional responses to music: The need to consider underlying mechanisms. *The Behavioral and Brain Sciences*, *31*(5), 559. https://doi.org/10.1017/S0140525X08005293

Kämpfe, J., Sedlmeier, P., & Renkewitz, F. (2011). The impact of background music on adult listeners: A meta-analysis. *Psychology of Music*, *39*(4), 424–448. https://doi.org/10.1177/0305735610376261

Kantner, J. (2009). Studying with music: Is the irrelevant speech effect relevant? *Applied Memory*, (May), 19–40.

Klimesch, W. (1999). EEG alpha and theta oscillations reflect cognitive and memory performance: A review and analysis. *Brain Research Reviews*, *29*(2–3), 169–195. https://doi.org/10.1016/S0165-0173(98)00056-3

Klimesch, W., Doppelmayr, M., Russegger, H., Pachinger, T., & Schwaiger, J. (1998). Induced alpha band power changes in the human EEG and attention. *Neuroscience Letters*, *244*(2), 73–76. https://doi.org/10.1016/S0304-3940(98)00122-0

Konz, S., & Mcdougal, D. (1968). The Effect of Background Music on the Control Activity of an Automobile Driver. *Human Factors*, *10*(3), 233–243. https://doi.org/10.1177/001872086801000305

Leman, M. (2012). *Music and schema theory: Cognitive foundations of systematic musicology* (Vol. 31). Springer Science & Business Media.

Lonsdale, A. J., & North, A. C. (2011). Why do we listen to music? A uses and gratifications analysis. *The British Journal of Psychology*, *102*(1), 108–134. https://doi.org/10.1348/000712610X506831

Macken, W. J., Tremblay, S., Houghton, R. J., Nicholls, A. P., & Jones, D. M. (2003). Does auditory streaming require attention? Evidence from attentional selectivity in short-term memory. *Journal of Experimental Psychology: Human Perception and Performance*, *29*(1), 43–51. https://doi.org/10.1037/0096-1523.29.1.43

Mammarella, N., Fairfield, B., & Cornoldi, C. (2013). Does music enhance cognitive performance in healthy older adults? The Vivaldi effect. *Aging Clinical and Experimental Research*, *19*(5), 394–399. https://doi.org/10.1007/BF03324720

Nantais, K. M., & Schellenberg, E. G. (1999). The Mozart Effect: An Artifact of Preference. *Psychological Science*, *10*(4), 370–373. https://doi.org/10.1111/1467-9280.00170

North, A. C. (1998). The Effect of Music on Atmosphere and Purchase Intentions in a Cafeteria1. *Journal of Applied Social Psychology*, *28*(24), 2254–2273. https://doi.org/10.1111/j.1559-1816.1998.tb01370.x

North, A. C. (1999). The influence of in-store music on wine selections. *Journal of Applied Psychology*, *84*(2), 271–276. https://doi.org/10.1037/0021-9010.84.2.271

Patston, L. L. M., & Tippett, L. J. (2011). The Effect of Background Music on Cognitive Performance in Musicians and Nonmusicians. *Music Perception: An Interdisciplinary Journal*, *29*(2), 173–183. https://doi.org/10.1525/mp.2011.29.2.173

Perham, N., & Currie, H. (2014). Does listening to preferred music improve reading comprehension performance? *Applied Cognitive Psychology*, *28*(2), 279–284. https://doi.org/10.1002/acp.2994

Perham, N., & Sykora, M. (2012). Disliked Music can be Better for Performance than Liked Music. *Applied Cognitive Psychology*, *26*(4), 550–555. https://doi.org/10.1002/acp.2826

Perham, N., & Vizard, J. (2011). Can preference for background music mediate the irrelevant sound effect? *Applied Cognitive Psychology*, *25*(4), 625–631. https://doi.org/10.1002/acp.1731

Perham, N., & Withey, T. (2012). Liked Music Increases Spatial Rotation Performance Regardless of Tempo. *Current Psychology*, *31*(2), 168–181. https://doi.org/10.1007/s12144-012-9141-6

Petsche, H., Linder, K., Rappelsberger, P., & Gruber, G. (1988). The EEG: An Adequate Method to Concretize Brain Processes Elicited by Music. *Music Perception: An Interdisciplinary Journal*, *6*(2), 133–159. https://doi.org/10.2307/40285422

Pfurtscheller, G., & Lopes da Silva, F. H. (1999). Event-related EEG / MEG synchronization and desynchronization : basic principles. *Clinical Neurophysiology*, *110*, 1842–1857. https://doi.org/10.1016/S1388-2457(99)00141-8

Piaget, J. (1952). The origins of intelligence in children. *Journal of Consulting Psychology*, *17*(6), 467–467. https://doi.org/10.1037/h0051916

Ramirez, G., Gunderson, E., & Levine, S. (2012). Math Anxiety, Working Memory and Math Achievement in Early Elementary School. *Journal of Cognition and Development*, *8372*(May), 1–34. https://doi.org/10.1080/15248372.2012.664593

Rauscher, F. H., & Shaw, G. L. (1998). Key components of the Mozart effect. *Perceptual and Motor Skills*, *86*(3), 835–841. https://doi.org/10.2466/pms.1998.86.3.835

Rauscher, F. H., Shaw, G. L., & Ky, K. N. (1993). Music and spatial task performance. *Nature*, *365*(6447), 611. https://doi.org/10.1038/365611a0

Rumelhart, D. E. (1978). *Schemata: The building blocks of cognition*. Center for Human Information Processing, University of California, San Diego San Diego, CA.

Salamé, P., & Baddeley, A. (1989). Effects of background music on phonological short-term memory. *The Quarterly Journal of Experimental Psychology Section A*, *41*(1), 107–122. https://doi.org/10.1080/14640748908402355

Schellenberg, E. G., & Hallam, S. (2005). Music listening and cognitive abilities in 10 and 11 year-olds: The Blur effect. *Neurosciences and Music Ii From Perception to Performance*, *1060*(The Neurosciences and Music II: From Perception to Performance), 202–209. https://doi.org/10.1196/annals.1360.013

Schellenberg, E. G., Nakata, T., Hunter, P. G., & Tamoto, S. (2007). Exposure to music and cognitive performance: tests of children and adults. *Psychology of Music*, *35*(1), 5–19. https://doi.org/10.1177/0305735607068885

Schellenberg, E. G., & Weiss, M. W. (2013). *Music and Cognitive Abilities*. *The Psychology of Music (Third Edition)*. https://doi.org/10.1016/B978-0-12-381460-9.00012-2

Share of Ear. (2014). Edison Research.

Sloboda, J. A. (1992). Empirical studies of emotional response to music.

Sogin, D. W. (1988). Effects of three different musical styles of background music on coding by college-age students. *Perceptual and Motor Skills*, *67*(1), 275–280. https://doi.org/10.2466/pms.1988.67.1.275

Stanovich, K. E. (1982a). Individual Differences in the Cognitive Processes of Reading: I. Word Decoding. *Journal of Learning Disabilities*, *15*(8), 485–493. https://doi.org/10.1177/002221948201500809

Stanovich, K. E. (1982b). Individual differences in the cognitive processes of reading: II. Text-level processes. *Journal of Learning Disabilities*, *15*(9), 549–554. https://doi.org/10.1177/002221948201500908

Thompson, R., Moulin, C. J. A., Hayre, S., & Jones, R. W. (2005). Music Enhances Category Fluency In Healthy Older Adults And Alzheimer's Disease Patients. *Experimental Aging Research*, *31*(1), 91–99. https://doi.org/10.1080/03610730590882819

Thompson, W. F., Schellenberg, E. G., & Husain, G. (2001). Arousal, Mood, and The Mozart Effect. *Psychological Science*, *12*(3), 248–251. https://doi.org/10.1111/1467-9280.00345

Verrusio, W., Ettorre, E., Vicenzini, E., Vanacore, N., Cacciafesta, M., & Mecarelli, O. (2015). The Mozart Effect: A quantitative EEG study. *Consciousness and Cognition*, *35*, 150–155. https://doi.org/10.1016/j.concog.2015.05.005

Ward, L. M. (2003). Synchronous neural oscillations and cognitive processes. *Trends in Cognitive Sciences*, *7*(12), 553–559. https://doi.org/10.1016/j.tics.2003.10.012

Yang, J., McClelland, A., & Furnham, A. (2016). The effect of background music on the cognitive performance of musicians: A pilot study. *Psychology of Music*, *44*(5), 1202–1208. https://doi.org/10.1177/0305735615592265