

The effects of background music on cognitive functioning

Comprehensive exam paper: First draft

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Background music is present in many aspects of our lives and this music can influence our behaviour. In commercial settings, music can influence the type of wine you buy (Areni & Kim, 1993; North, 1999), the type of food you order (North, 1998), and how much money you spend (Donovan & Rossiter, 1994). 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. Background music has an effect on a person's abilities to perform these tasks, and research shows that, when driving, speed, violations, and steering movements are affected (Brodsky, 2002, 2013; Konz & Mcdougal, 1968). The effects of background music on other cognitive abilities are less clear.

Over the last 60 years, there have been numerous studies investigating whether background music has a positive or negative effect on performance during cognitively demanding tasks. Many of these studies investigated the effects of music on skills important for classroom learning. This includes skills such as reading rate and comprehension (Freeburne & Fleischer, 1952), short-term memory (Salamé & Baddeley, 1989), and spatial manipulation tasks (Patston & Tippet, 2011). One of the most influential papers within this field was a study conducted by Rauscher et al. (1993) which coined the term 'The Mozart Effect'. This study had participants listen to Mozart music for 10 minutes before completing a series of spatial-temporal tasks (the paper cutting and folding task). In this study, they found that participants performed better on the task after listening to Mozart's music. These results opened the floodgates for people trying to use music to bolster cognitive abilities. However, the ecological validity of this study can be questioned as most people listen to music during rather than before completing a task.

This paper will focus on specifically reviewing studies where music was played *during* cognitive task performance. A recent review covered many aspects of the research on music and

cognitive abilities (Schellenberg & Weiss, 2013), however some areas were not discussed and it is those aspects, that have not been previously reviewed at length, that will be focused on here. First, the behavioural literature will be reviewed. Specifically, the effect of music preference, speech presence, age, and the difference between how background music affects musicians compared to non-musicians will be explored. Then, a discussion of how imaging techniques such as electroencephalography (EEG) are being used to understand the relationship between music and cognitive task ability will be presented.

Effect of Preference

When the Mozart Effect was first discovered, many were skeptical of the validity of the results and one of the first approaches to refuting the effect looked at whether a participant's preference for the music modulated the music's effect on cognition. Nantais and Schellenberg (1999) showed that if participants liked the music they were listening to (regardless of composer) then they performed better on a spatial-temporal task than if they didn't like the music. However, in this study the music was played before the task was completed.

More recently, studies have investigated the effect of preference in a more ecologically valid setting where music was played while the task was completed. However, within these studies there are conflicting results. Participants performed better at a spatial rotation task when listening to liked music regardless of the music's tempo (Perham & Withey, 2012), while music preference had no effect on reading comprehension performance (Perham & Currie, 2014). In the reading task, performance was mediated by the presence of lyrics.

When investigating serial recall, there was no difference in performance between liked and disliked music, although both conditions resulted in worse performance compared to silence (Perham & Vizard, 2011). The disliked music was a 'thrash-metal' song chosen by the researcher. Only

participants who disliked thrash metal were recruited and participants provided their own preferred song. In a follow-up study, again both liked and disliked music produced worse performance than the silence condition, but liked music resulted in worse performance than disliked music (Perham & Sykora, 2012). In this case, both the liked and disliked music were provided by the researchers and confirmation of preference was done by questionnaire. The differences in the results of the two studies are counter-intuitive. It could be expected that the biggest difference in preference, and therefore in task performance, would be seen in the first study where participants provided their own preferred song guaranteeing a high preference rating. Instead, the largest effect was seen when researchers provided both categories of songs. In these studies, researchers did not control for characteristics of the music such as tempo or mood.

The inconsistencies in the results indicate that the effect may have less to do with preference, and more to do with characteristics of the music that were not controlled for such as tempo, mood, and arousal. These characteristics have been shown to affect cognitive task performance (Husain, Thompson, & Schellenberg, 2002; W. F. Thompson, Schellenberg, & Husain, 2001). Researchers used music to induce changes in arousal and mood prior to a task being performed and found differences in cognitive abilities as a result. There is also 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), so we could expect that the preferred music's effect on cognitive functioning is really an effect driven by the changes in arousal and mood. However, it seems that the effect that preference, and therefore arousal and mood, have on cognitive task performance depends on the task itself. For example, serial recall is disrupted regardless of music preference (or change in mood), spatial rotation task performance improves with preferred music (with increased mood), and reading comprehension is

affected by the presence of lyrics regardless of preference. These differences will be discussed further below.

Effect of Speech

Many of the early studies assessing the affects of music on cognition used classical instrumental pieces that did not include lyrics (Freeburne & Fleischer, 1952; F. H. Rauscher & Shaw, 1998; Frances H. Rauscher et al., 1993; Sogin, 1988). In more recent studies, participants listen to popular music where lyrics are present while completing cognitive tasks. The difference in lyric presence may be a contributing factor to the disparate results within the literature. These conflicting results may be explained by understanding the body of work on how irrelevant sounds affect short-term memory – the irrelevant sound effect (ISE). Banbury, Macken, Tremblay, & Jones (2001) propose that the key factor in the amount of distraction by environmental sound is the degree to which both the task and the sound involve seriation (maintenance of an order in memory). The hypothesis behind the disruption is that the serial nature of the task and the serial nature of the auditory input are being analyzed by similar brain processes, causing competition for processing power, and ultimately fewer resources devoted to the task. Specifically, the acoustic changes in pitch, timbre, or tempo of the sound are the main cause of the disruption. When listening to music while performing a reading task, the reading is the first source of serial information. When there is a change in the tone or rhythmic pattern of a sound, this requires processing of the order of the incoming sounds and this becomes the second source of serial information.

To understand the effects of music on cognitive tasks, the composition and serial nature of the music must be taken into account. If a piece of music includes lyrics, this will increase its serial nature. 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 load required to process the music and, based on

the interpretation by Banbury et al. (2001), increase the detrimental effects on a task requiring serial processing.

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 performed worse than in the other conditions (Salamé & Baddeley, 1989). This may be because the vocal music and the foreign language speech are the most serial in nature of the five conditions. This result has been replicated a number of times since then (Beaman & Jones, 1997; Jones & Macken, 1993; Kantner, 2009; Macken, Tremblay, Houghton, Nicholls, & Jones, 2003). In 1990, Jones, Miles, & Page also replicated this finding, but in their study they made a distinction between the effects that irrelevant speech has on serial recall 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. This may indicate that meaningful speech requires more processing power because words are not only being processed serially, but are also being held in memory in order to extract meaning. Irrelevant speech has also been shown to have an effect on reading comprehension (Martin, Wogalter, & Forlano, 1988), logical reasoning, and long-term memory tasks (Crawford & Strapp, 1994). The differences in the effects of irrelevant sound on these tasks may have to do with the degree to which the serial nature of the sound interacts with the serial nature of the task.

The effects of background music on cognition were initially explored with an interest to discovering whether cognitive performance could be enhanced by music. As discussed in the previous section, music preference has an effect on cognitive performance, but the results proved inconsistent.

Some studies showed a positive effect on task performance while others reported the opposite. Perham and Vizard (2011) performed an experiment to better understand the role of preference in the context of the ISE. They found that preference did not mediate the ISE and that regardless of whether a participant liked or disliked the music with lyrics they listened to, their performance on the serial recall task was impaired. This indicates that there are limits to the degree to which music can assist cognitive functions, and music with lyrics combined with a serial task may be beyond these limits.

Musicians vs Non-Musicians

When discussing how background music affects cognitive functioning, it is important to take individual differences into consideration. 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 is relatively consistent with the results in this area. 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 Tippet (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 the training type and the music type interacted to affect cognitive performance. They found that the musician's performance was most affected on a variety of cognitive tasks when they listened to music featuring the instrument on which they were trained. Although this line of research is relatively new, there are no studies that look into why this difference between music and non-musicians occurs. There may be some indication as to why these differences occur by looking conceptually at how musicians process 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 serial processing power being 'occupied' by the sound and therefore not able to devote resources to the task. 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. This allows them to not only detect features of the music an untrained listener would not hear, but also to attribute meaning to each feature. 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 the 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 small parts of a musical piece, process the music more holistically and are therefore not as affected by its detrimental effects.

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 way 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 more efficient our schemas become at processing that stimulus. Schemas are automatically invoked to process and understand incoming stimuli (Anderson, 1984).

Schema theory, when applied to reading words, states that reading involves simultaneous analysis at many different levels: from a phoneme, to syntax, to overall interpretation of a phrase, to following the overarching story (Anderson, 1984). Music, like a book, contains many different levels of information: rhythm, timbre, tone semantics, etc (Leman, 2012). Musicians are trained to listen and

process music in a way that allows them to understand the information at all levels at the same time. A musician's extensive training results in schemas for processing music that are efficient and well-formed, especially the schemas for the music of their primary instrument. Because of the complexity of the information involved in processing the different levels of the music, these schemas may call on the participation of cognitively demanding processes. Due to the similarity between the structure of reading materials and a music piece, the cognitive processes used to understand the music may be similar in nature to those used during reading and include the use of short term and working memory, reading comprehension, contextual interpretation, and access to a pre-existing lexicon (Baddeley, Logie, Nimmo-Smith, & Brereton, 1985; Stanovich, 1982a, 1982b).

This 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. The schema for processing music, which is automatically invoked, is in competition with the schema invoked for the cognitive task that the musician is trying to complete. Non-musicians, who do not have such strong schemas for processing music, do not have this competition for resources and therefore perform better on the task. A musician's schemas are in conflict in the demand for resources, and this interferes with task performance. The stronger the schema for the music, the more attentional resources are diverted from the task. This interpretation explains why musicians perform worse on a task when the background music features their primary instrument (Yang et al., 2016).

Age Groups

The first studies that investigated the effects of background music on cognitive functions were done with university aged participants. When researchers realized that music could have a positive effect on learning, the research shifted to look at the effects in school-aged children. These experiments showed that calming music led to better performance on arithmetic and memory tasks in 10 and 11 year

olds (Hallam, Price, & Katsarou, 2002) and students who listened to music they were familiar with and enjoyed had better spatial abilities (Schellenberg & Hallam, 2005) and were more creative (Schellenberg, Nakata, Hunter, & Tamoto, 2007).

Being able to help bolster learning in children has its obvious benefits, but whether these effects are transferrable to other age groups is not clear. Recently, the effects of music on the cognitive abilities of older adults have been explored. 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 in older adults has also been shown to be enhanced by background music (R. G. Thompson, Moulin, Hayre, & Jones, 2005). Since the meta-analysis, studies have continued to explore the effects of background music in older adults. Background classical music 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 (Coffman, 2002) in older adults, so further understanding the effect of music on the cognitive abilities of older adults has potential therapeutic implications.

Using Electroencephalography

All of the papers 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 for the effects. 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 cognitive performance relates to changes in EEG frequencies on two scales: tonic (long-term or over the life-

time) and phasic (short-term or event-related). At the tonic level, Klimesch describes good cognitive 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, but the reverse is true as a person ages into the late lifespan. 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). Alpha power is generally thought of as an index of attention with large alpha power being an indicator of cortical “idling” and when external task load increases, alpha power decreases (Ward, 2003).

A similar approach can be taken when looking at EEG signals during background music and cognitive tasks. In most of these studies, the focus has been on the changes seen in the alpha frequency band. There are different types of changes that can be measured. Some studies have looked at overall alpha power, a measure of the amount of alpha activity in the EEG signal, while others have used techniques called event related desynchronization (ERD) or event related synchronization (ERS). These techniques are a measure of the synchronicity of neural firing, for example an increase in ERS indicates that neurons have become more synchronized in their firing as a result of an external stimulus.

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 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).

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. The changes seen in the alpha band during cognitive tasks and music listening may be an index of the conflicting processes that are active when both music and cognitive tasks are being processed at once. 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, the amount of attention required to complete the task, and the type of music being listened to. All of these factors affect alpha levels in different ways and music may positively or negatively add to the alpha power levels explaining 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 review 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 schemas that are invoked for processing the task and the music are separate but may overlap in their

cognitive processing needs. Regardless of its origin, 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. Now that there is a clearer understanding of how music negatively affects cognitive performance, it may be possible to guide future research towards uncovering how to create a reliable positive effect on cognitive performance using music. This will require taking the effects of mood and arousal, individual differences of age and musical background, the composition of the music, and the processes required to complete a task into account. There may be an optimal combination of all factors that will allow background music to support cognitive functioning.

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