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Examensarbete

The wandering mind on music: A review on mind-wandering and music

Bachelor Degree Project in Cognitive Neuroscience

Basic level 22.5 ECTS

Spring 2023

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Abstract

It is well known that music can influence our emotions. Research on mind-wandering has revealed that our emotional state can influence the valence of thought content and the prevalence of mind-wandering. Recent behavioural studies have suggested that music can modulate mind-wandering. However, the neural mechanisms to support the claims are unknown. This thesis aim was to explore how music can modulate mind-wandering by reviewing functional neuroimaging studies on the topic. The findings suggest that music induces mind-wandering as it engages the default mode network in a similar fashion that resting does. Music-induced activity from the orbitofrontal cortex and the posterior cingulate cortex seems to be a good neural indicator for mind-wandering content that has a negative valence.

Keywords: mind-wandering, music, functional neuroimaging

The wandering mind on music: A review on mind-wandering, emotions, and music

Introduction

Picture this: you have just started to walk home from a friend's place after having a great time. While walking, you start to think about how much fun you had, and plans on what to do next week are already in preparation. Hundreds of thoughts are streaming through your mind. You decide to calm down a bit by putting on some relaxing music while walking. After a few songs, you start to feel quite peaceful. The intensity of your thoughts has toned down. The song “Chamber of reflection” by Mac Demarco starts to play and your mind starts to wander once more. This time, you can´t stop thinking about a sad break-up you had a few months ago. Melancholy has taken over, and now thoughts of loneliness are streaming through your mind.

The notion that music can influence emotions probably does not come as a surprise for anyone who has listened to a really sad or happy song. It has been shown that music can alter activity in core affect structures, one of the structures being the orbitofrontal cortex (Koelsch, 2014). This region has been correlated with mind-wandering, which can be defined as spontaneous self-generated thoughts that are not related to an ongoing task or event (Fox et al., 2018). The majority of the thought content during mind-wandering will be in some way emotional (Killingsworth & Gilbert, 2010).

Two recent studies on mind-wandering and music-evoked emotions suggest that music can be used to alter the valence of thought content during mind-wandering and that listening to music causes mind-wandering (Koelsch et al., 2019; Taruffi, 2021). What remains to be seen are the neural correlates of music and mind-wandering that might support the findings.

Mind-wandering studies that use neuroimaging combined with music-evoked emotions should provide additional data and insight into how music can be used to evoke mind-wandering episodes.

Music and emotion

It is well known that listening to music affects one's emotional state. Emotion is a short and intense affective response to external (seeing something disgusting) or internal stimuli/events (remembering something awkward). What differentiates mood from emotion is the duration of the affective state. Mood lasts much longer; the affective state is more vague and less intense. A feeling is the subjective experience of emotion/mood, commonly measured through self-reports (Juslin & Västfjäll, 2008).

Music has been shown to evoke emotions such as fear, sadness, joy, wonder, peacefulness, and excitement (Vuilleumier, 2015). One factor is the tempo of the music: slow tempo music more often evokes negative feelings (sadness, fear) and high tempo more often evokes positive feelings (happiness, excitement) (Gagnon & Peretz, 2003). Pitch has an influence on emotions as well: Jaquet et al. (2012) suggest that changing octaves (known as modulation) influences the perceived valence of a musical piece. They report that a music excerpt in a lower octave feels less positive compared to the same sample in a higher octave.

Neural correlates of music and emotion

Koelsch (2014) conducted a meta-analysis of functional neuroimaging studies on music-evoked emotions, reporting that music evokes increased activity in brain regions that underlie emotions. Listening to pleasant or unpleasant music activates the amygdala, associated with regulating emotions. Pleasant music causes increased activity in the nucleus accumbens, which is associated with reward processing. Music-elicited activity in a region known as the hippocampal formation (involved in memory and learning), has been associated with both joy and sadness.

The orbitofrontal cortex (OFC) has been correlated with increased activity during music-evoked emotions. It has connections with the amygdala, nucleus accumbens, and hippocampus (part of the hippocampal formation) (Dixon et al., 2017; Koelsch, 2014): all components of a network called the limbic system, which is concerned with emotional and behavioural responses such as fear, rage, appetite, and sexual behaviour (Rajmohan & Mohandas, 2007; Maclean, 1955).

Default mode network

The OFC is a component of the resting-state network known as the default mode network, which is relatively deactivated during any cognitively demanding task and active when the brain is at rest (Raichle et al., 2001). The default mode network comprises the dorsal medial prefrontal cortex (responsible for a sense of self and inferring mental states), ventral medial prefrontal cortex (including the OFC; responsible for emotional processing and decision-making), posterior cingulate cortex (responsible for internally directed thought and key node in the default mode network), precuneus (responsible for first-person perspective taking, episodic memory retrieval and integrating perceptual information of the environment) and temporoparietal junction (responsible for social cognition and language processing) (Raichle, 2015). Mind-wandering has been strongly associated with increased activity in the default mode network (Christoff et al., 2009).

Mind-wandering and emotion

A study measuring self-reported mind-wandering and emotions with 2,250 participants found that thought contents during mind-wandering were emotional more often than not; 69% of the mind-wandering episodes were emotional to some degree (Killingsworth & Gilbert, 2010). Thought content during mind-wandering is mainly limited by the mind-wanderer's imagination, while biases towards thoughts about the past have been correlated with unhappiness (Smallwood & Schooler, 2015). Rumination (a type of mind-wandering dominated by negative thought content) has been suggested to be linked to activity in the default mode network; clinically depressed people seem to have greater activity in the orbitofrontal cortex during rest compared to healthy people (Zhou et al., 2020; Zhou et al., 2017). Thoughts that are interesting (intriguing, pleasant, or exciting) have been correlated with enhanced mood (Franklin et al., 2013)

Fox et al. (2018) conducted a systematic review on spontaneous thought (which includes but is not limited to mind-wandering) and emotions in which the majority of studies measured task-unrelated thought (i.e., mind-wandering) using experience sampling. Experience sampling is a self-report method used to capture participants’ experiences in daily life by collecting information about what they were thinking and feeling during a certain moment, using for example, questionnaires or recordings. Participants do not know in advance when their thoughts will be requested. Fox and his colleagues report that the content of spontaneous thought is usually emotionally valenced and reliably recruits brain regions associated with emotional processing (orbitofrontal cortex, pregenual anterior cingulate cortex, amygdala, and hippocampal formation). The researchers conclude that the valence of self-generated thought can be influenced through such factors as nightmares, mindfulness practice, and lucid dreaming.

Music and mind-wandering

Since music influences emotions and mind-wandering is influenced by emotional states, it sounds reasonable that music should be able to influence mind-wandering. Taruffi (2021) conducted a study on mind-wandering during music listening using experience sampling. Results suggest that music has an overall positive influence on the valence of thought during mind-wandering. Music-evoked emotions successfully predicted thought valence during mind-wandering.

A similar study (Koelsch et al., 2019) investigated the effects of heroic (empowering and motivating) and sad orchestral music on mind-wandering using experience sampling. Both the heroic and sad music evoked mind-wandering to a similar degree, but the valence of thought content was significantly different. Participants reported having more positive and motivating thoughts during heroic music compared with sad music, in which the thought content was often demotivating or sad. Koelsch et al. (2019) and Taruffi (2021) provide a foundation for the idea that music can induce and even modulate mind-wandering. However, no information regarding neural mechanisms can be extracted from the studies, which only rely on self-reports.

We know that there are brain regions that are active in both emotional states and mind-wandering, such as the orbitofrontal cortex. It should be possible to measure changes in the activity of brain areas that are connected with mind-wandering (the default mode network) and emotions (the limbic system) through functional neuroimaging while participants are listening to music. Researching the neural connections between music and mind-wandering could help to explain how emotions more generally affect the contents of mind-wandering. This could be useful to combat symptoms of disorders associated with mind-wandering, such as major depressive disorder (MDD; a disorder in which the person generally shows symptoms of depressed mood or loss of interest). One common symptom for MDD is rumination, and if listening to sad music can lead to more rumination, then doctors could recommend that the patient listen to happy music instead as it may alter the valence of the thoughts in a more positive way.

Aim

It has been established that mind-wandering is affected by emotional states, and music can invoke different emotions depending on what type of music is played. Mind-wandering recruits brain regions associated with emotional processing such as the orbitofrontal cortex, which is also active during music listening. Self-report literature on mind-wandering and music supports the notion that music can be used to evoke mind-wandering. Combining self-reports with functional neuroimaging could show which brain regions are active during music-induced vs. non-music-induced mind-wandering, as a way to see if there is a distinct neural signature for music-induced mind-wandering. The research question is, does the literature support such a neural signature that is distinct from mind-wandering in general? The aim of this review is to see if the existing literature supports the existence of a distinct neural signature for music-induced mind-wandering.

Methods

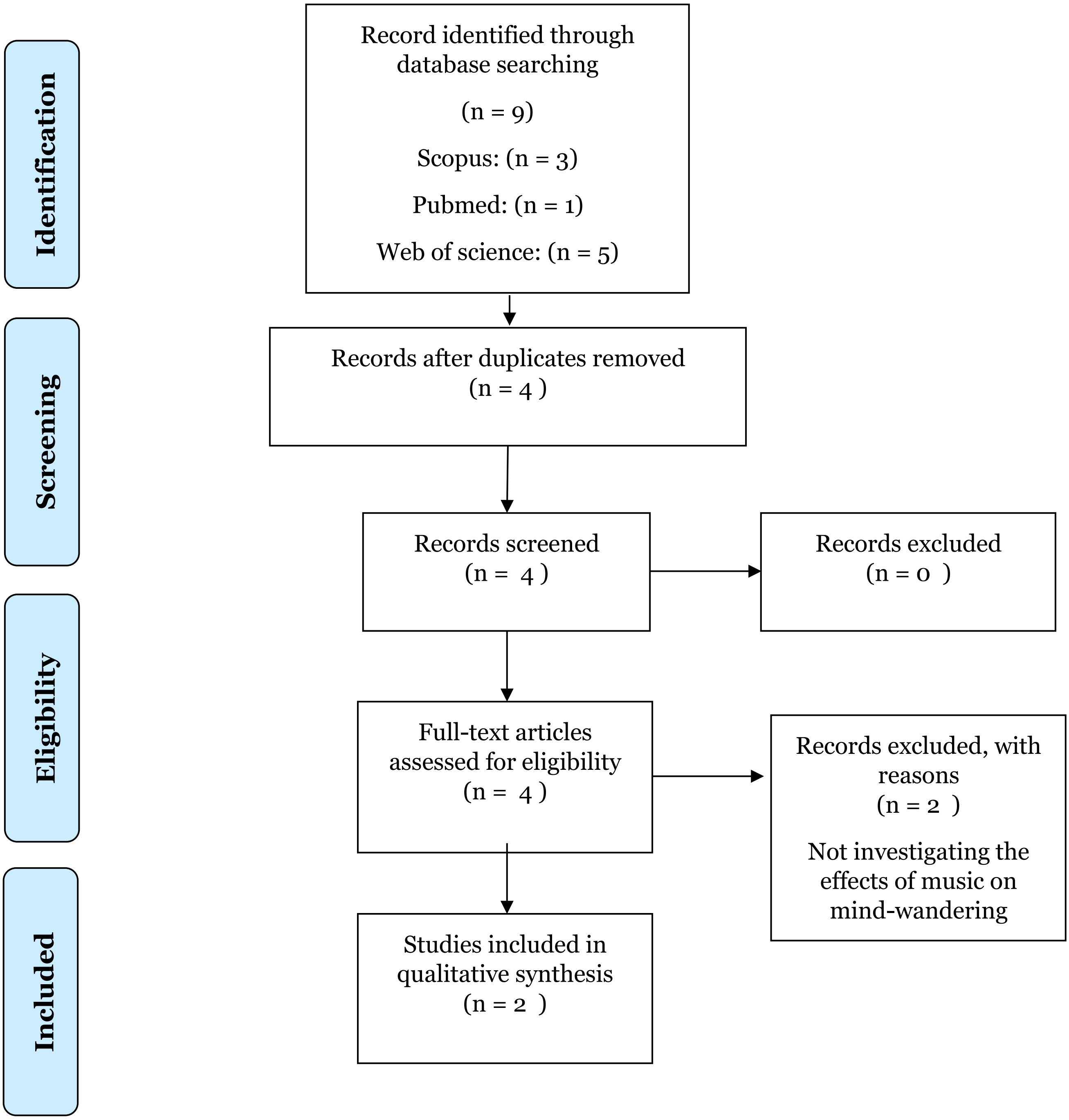
Search strategy

Studies were selected through database search (PubMed, Scopus, and Web of Science) on May 9, 2022, using the search string “mind wandering” AND music AND emotion AND (“functional neuroimaging” OR fMRI OR EEG OR PET OR MEG).

There were nine hits. Four articles were left after duplicate removal, all written in English and published in peer-reviewed journals. All four articles remained after the abstract examination. Two articles were excluded after full-text examination, due to not investigating the effects of music on mind-wandering and music as a discussion point. A flowchart describing the literature search process can be found below (Figure 1).

Figure 1.

The process of finding articles for the review.



Note. From Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group (2009). Preferred reporting items for systematic reviews and meta-Analyses: The PRISMA Statement. *PLoS Med* 6(7): e1000097. https://doi.org/10.1371/journal.pmed.1000097

Inclusion/exclusion criteria

Studies needed to investigate the effects of music on mind-wandering. Studies had to use functional neuroimaging or electrophysiological brain measurements to measure neural activity associated with mind-wandering. Studies using participants with a clinical diagnosis were to be excluded.

Data extraction

The PICO model was used to guide the choice of categories for data extraction from the studies. Age, sex, and expertise in playing music were extracted. The relevant intervention was the musical stimulus used. Data from comparisons of different groups were extracted. Functional neuroimaging results were extracted.

Results

The two studies used for the systematic review both reported an increase in activity from the default mode network during music listening. Activity from the default network during music listening from the second study was comparable to a resting state. Sad/negative music showed significant activity from the orbitofrontal cortex and posterior cingulate cortex when compared to both happy/positive music and being at rest. Table 1 gives a short summary of both articles.

Taruffi et al. (2017) investigated if music could be used to modulate mind-wandering. The authors conducted two experiments. The first was to see if sad music induces more mind-wandering compared to happy music. The second was to measure if sad music increases activity in the default mode network compared to happy music. The first experiment did not use functional neuroimaging and so is not relevant for the systematic review. Twenty-four participants (12 female) ages 21-34 years participated and were not part of the first experiment. Of the participants, 58.3% were non-musicians, 29.2% were amateur musicians, and 12.5% were semi-professional musicians; this mix was an incidental byproduct of the sampling process and was not used for analysis. Music stimuli consisted of four sad and four happy instrumental songs from movie soundtracks and classical music. Sad and happy songs that had similar beats per minute were matched together.

Table 1.

A short summary of the included articles.

Study	Participants	Experimental condition	Neuroimaging technique	Hypothesis	Findings
Taruffi et al. (2017)	24 participants (12 females, age 21-34) 41.7% musicians	sad versus happy music	fMRI	Sad music elicits greater default mode network activity compared to happy music.	Sad music elicits greater activity in the default mode network and the left- and right bilateral posterior inferior parietal lobule compared to happy music.
Koelsch et al. (2021)	33 participants (18 females, age 20-31) 54.4% musicians.	positive music versus negative music	fMRI	Stronger default mode network activity for negative music compared to positive, especially in the orbitofrontal cortex and posterior cingulate cortex.	Similar activity from the default mode network was found between resting state and music listening. Increased activity was found in the regions of interest.

Participants were placed in an fMRI scanner and instructed to relax with closed eyes and listen with headphones on to the music, which consisted of short (35-37 seconds) and long (71-90 seconds) samples. The music stimuli were divided into four-minute blocks; each block played music of the same emotion category. The order of the music blocks was pseudo-randomized (the order of the music blocks appears to be random, but they are played in a determined order that the researchers have made) across participants. After listening to a music excerpt, participants were asked to rate how they felt using four six-point Likert scales for sadness, happiness, valence, and arousal. The fMRI data was computed to show functional connectivity images from the sad and happy conditions. Both conditions were then compared to see if there were any significant differences.

They found that the sad condition elicited significantly more activity compared to the happy condition in the ventral medial prefrontal, dorsomedial prefrontal cortex (responsible for a sense of identity and inferring mental states in others), posterior cingulate cortex, and precuneus which are all part of the default mode network, as well as the bilateral posterior inferior parietal lobule (responsible for interpreting sensory information).

Koelsch et al. (2021) investigated if music could be used to evoke mind-wandering, if the valence of music could affect the valence of thought content during mind-wandering, and if the default mode network was more active during negative compared to positive music. The authors conducted an fMRI study using two types of positive music stimuli (joyful and peaceful) and two of negative stimuli (sad and nervous). Thirty-three participants (18 women) ages 20-31 years participated. Eleven participants had no experience playing music, nine had played an instrument but taken no music lessons, and nine had taken music lessons (for an average of 3.5 years); this mix was an incidental byproduct of the sampling process and was not used for analysis. Twenty instrumental songs were preselected from pilot-study data where each piece (five per emotion) was known to induce the target emotion: joyful, sad, peaceful, or nervous. The average tempo of the joyful (positive) music matched that of the nervous (negative) music, being faster than that of the peaceful (positive) and sad (negative) music, which likewise matched. Every stimulus was trimmed to one minute and assembled into four blocks; each block was five minutes and had music that induced the same target emotion. Two rest blocks were included. The order of the six blocks was pseudo-randomized across participants (the rest blocks were intentionally ordered in such a way so that the second rest block would not immediately follow the first rest block). Participants were instructed to relax with eyes closed and listen to the music while undergoing fMRI scanning. After each block, participants received a questionnaire containing 10 questions rating each block using a six-point Likert scale. The questionnaire assessed if they only focused on the music, how much they were thinking about the music versus something else, meta-awareness, valence and arousal of thought content, if the thoughts were related to other people, if they were thinking about past or present or future, and how relevant the thoughts were to their current concerns. The fMRI data was analyzed to show functional connectivity images from the positive and negative conditions. The conditions were compared to see if there were any significant differences.

The researchers found that the rest and music blocks induced similar activity in several areas of the default mode network as well as other areas such as the medial temporal lobe (responsible for forming and retrieving memories), anterior cingulate cortex, hippocampal formation, parahippocampal cortex (crucial for forming and retrieving memories), temporoparietal cortex (responsible for spatial perception), and fusiform cortex (responsible for processing visual information such as object identification). Functional connectivity differences for positive and negative music were found in the posterior cingulate sulcus (with greater activity for negative music stimuli), and bilateral posterior superior frontal gyrus (responsible for working memory; greater activity for positive stimuli). The negative music block showed significantly higher functional connectivity in the posterior cingulate cortex compared to both the rest and positive music blocks.

Valence-specific functional connectivity analysis was conducted after the experiment to support the findings on negative music stimuli and the posterior cingulate sulcus. Functional connectivity was stronger during negative music stimuli compared to positive in the secondary somatosensory cortex (responsible for perceiving objects through touch), insula (responsible for integrating sensory experiences with emotional valence), medial orbitofrontal cortex (responsible for giving value of rewards during tasks), auditory cortex (responsible for integrating and processing auditory signals, such as language comprehension), and anterior hippocampal formation (responsible for recall of scenes and events).

Discussion

This thesis aims to look for a distinct neural signature for music-induced mind-wandering by reviewing functional neuroimaging studies on this matter. The findings from the two studies (Taruffi et al., 2017; Koelsch et al., 2021) reported that musical stimuli elicited activity in several brain regions associated with mind-wandering and emotions. Increased activity from the ventral medial prefrontal cortex, dorsomedial prefrontal cortex, and posterior cingulate cortex were reported in both studies. These regions are part of the default mode network, the same network to which mind-wandering has been closely linked (Christoff et al., 2009). Because of the overlap found in the default mode network between the music and rest conditions, and the consensus that mind-wandering episodes typically occur in resting conditions (Koelsch et al., 2021; Raichle et al., 2015), it is very likely that mind-wandering occurred because of the music stimuli, in line with what behavioural studies have suggested (see e.g., Koelsch et al., 2019; Taruffi et al., 2021).

The results from Taruffi et al. (2017) and Koelsch et al. (2021) show that sad, compared to happy music elicits stronger activity in the default mode network. These results are in line with previous findings regarding the effects that negative emotions have on mind-wandering (see e.g., Smallwood & Schooler, 2015; Poerio et al., 2013). As mentioned in the introduction, the orbitofrontal cortex is connected with the limbic network as well as the default mode network. Negative music elicited significant activity in the orbitofrontal cortex (Koelsch et al., 2021), which supports previous reports of increased activity in the orbitofrontal cortex during spontaneous emotional thought (see e.g., Fox et al., 2018; Dixon et al., 2017; Koelsch, 2014). Both Taruffi et al. (2017) and Koelsch et al. (2021) reported an increase in activity from the posterior cingulate cortex during both the negative and positive music-listening conditions. Koelsch et al. (2021) also found that positive music shows stronger functional connectivity in the bilateral posterior superior frontal gyrus compared to negative music; stronger functional connectivity during negative music stimuli was found between the orbitofrontal cortex, posterior cingulate sulcus, secondary somatosensory cortex, and insula. These regions (except for the orbitofrontal cortex) have been suggested to be active in response to pain (Xu et al., 2020; López-Solà et al., 2017). The results suggest that negative music can induce negative thought content during mind-wandering that is emotionally painful.

Listening to music engages the default mode network to a similar degree as being at rest; positive music seems to put the participants in a similar state as in rest. However, negative music-induced mind-wandering seems to have a distinct neural signature when compared to mind-wandering at rest and positive music-induced mind-wandering. Both the posterior cingulate cortex and orbitofrontal cortex were significantly active during negative music listening compared to rest and positive music (Koelsch et al., 2021). This increased activity was only observed during negative music listening, which suggests that negative music-induced mind-wandering has a functional connectivity that can be distinguished from non-music-induced mind-wandering (being at rest).

This finding could have clinical implications since increased activity in the orbitofrontal cortex has been associated with increased rumination, which is a common symptom of major depressive disorder. If patients with major depressive disorder display stronger activity compared to healthy participants when exposed to sad music, and if there is a noticeable difference in functional connectivity from the orbitofrontal cortex, we could use sad music to assess if a patient may suffer from major depressive disorder by measuring the music-evoked activity from the orbitofrontal cortex.

Koelsch et al. (2021) found that positive music-induced mind-wandering reflected increased activity in the bilateral posterior superior frontal gyrus compared to negative music, this could be useful for future studies that compare the two conditions. Positive music-induced mind-wandering shows similar activity as the resting state which makes it hard to say if there is a distinct neural signature for positive music-induced mind-wandering. Further research on activity from the bilateral posterior superior frontal gyrus during positive music-induced mind-wandering is required to answer that question.

Limitations

There are several limitations for this review. First, the number of articles is low. Only two articles were found during the literature search, which could be a consequence of not using enough databases. It could also mean that this topic is relatively new and not a lot of research has been done. Second, both Taruffi et al. (2017) and Koelsch et al. (2021) included musicians and non-musician participants in their experiments, but neither looked for differences between the two groups. This is surprising since activity from the default mode network for non-musicians has been found to be greater compared to musicians (Alluri et al., 2017; Niranjan et al., 2019). This could be interpreted as musicians being more likely to focus on the details of the music (e.g., what notes are being played and the tempo of the music) rather than just listening and letting the mind wander. Neuroimaging data might have looked slightly different if only musicians or non-musicians were used instead of both. Third, Taruffi et al. (2017) only compared functional connectivity between sad and happy music-induced mind-wandering and did not use rest as a baseline, as Koelsch et al. (2021) did. It is hard to tell how the activity from the sad versus happy music-induced mind-wandering in Taruffi et al.'s study compares to resting state activity.

Societal implications and ethics

Most people encounter music daily through mediums such as music apps, radio, and television advertisements. Knowing that music can induce mind-wandering should raise concern when it comes to tasks that require a lot of attention but are often accompanied by music, such as driving a car. Shifting attention away from the road can be dangerous. If music is increasing the risk for mind-wandering during a ride, it might be recommended to turn the music off. This does not mean that you cannot listen to music during any task that requires a lot of attention, but listening to music may cause your mind to shift focus away from whatever you are doing. On the other hand, shifting focus away from a boring and low-effort task such as doing the dishes might make the task more enjoyable; listening to music can be a gateway to mind-wander away to somewhere pleasant instead. Workplaces that can be repetitive or boring can play music that induces empowering and motivating thoughts to the workers, which could improve work efficiency around the workplace. Advertisers could play music to induce more positive mind-wandering episodes, which could make the audience think more positively about whatever product is being advertised.

Because of the effects music has on mind-wandering, there is a possibility for music to be a manipulation tool. As mentioned previously, advertisers could play music to induce mind-wandering that would make the audience more likely to buy their product. Another concern would be the increased risk of music-induced mind-wandering while driving, since mind-wandering has been correlated with road traffic accidents (Burdett et al., 2019). Radio stations and music apps should implement a reminder after a certain amount of music has been played to keep drivers focused on the road. The reminder could be a simple voice message that reminds people to keep focus on the road; it could be used during times when traffic is the most intense such as rush hour. Pausing the music may help prevent some of the traffic accidents that take place today.

Conclusion

This thesis investigated if the existing literature supports the existence of a distinct neural signature for music-induced mind-wandering. The findings suggests that music engages the default mode network and that music causes mind-wandering in a similar fashion as being at rest. Negative music engages the orbitofrontal cortex and posterior cingulate cortex to a significantly greater degree than the resting condition or positive music. The results suggest – while not ruling out the possibility of a subtler effect for positive music-induced mind-wandering – a neural signature for negative music-induced mind-wandering. Positive music-induced mind-wandering had similar activity compared to rest, but it has stronger functional connectivity in the bilateral posterior superior frontal gyrus compared to negative music.

As of now, the literature used for this review points toward a distinct neural signature for music-induced mind-wandering, at least when it comes to music that has a negative valence. However, only two studies were used and as such, more studies need to be found before drawing conclusions.

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