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**DOI**
10.1016/j.actpsy.2021.103417

**Publication date**
2021

**Document Version**
Final published version

**Published in**
Acta Psychologica

**License**
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Acta Psychologica 220 (2021) 103417

Contents lists available at ScienceDirect

Acta Psychologica

journal homepage: www.elsevier.com/locate/actpsy

# Do you listen to music while studying? A portrait of how people use music to optimize their cognitive performance

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ARTICLE INFO

*Keywords:*
Background music
Cognitive performance
Music perception

ABSTRACT

The effect of background music (BGM) on cognitive task performance is a popular topic. However, the evidence is not converging: experimental studies show mixed results depending on the task, the type of music used and individual characteristics. Here, we explored how people use BGM while optimally performing various cognitive tasks in everyday life, such as reading, writing, memorizing, and critical thinking. Specifically, the frequency of BGM usage, preferred music types, beliefs about the scientific evidence on BGM, and individual characteristics, such as age, extraversion and musical background were investigated. Although the results confirmed highly diverse strategies among individuals regarding when, how often, why and what type of BGM is used, we found several general tendencies: people tend to use less BGM when engaged in more difficult tasks, they become less critical about the type of BGM when engaged in easier tasks, and there is a negative correlation between the frequency of BGM and age, indicating that younger generations tend to use more BGM than older adults. The current and previous evidence are discussed in light of existing theories. Altogether, this study identifies essential variables to consider in future research and further forwards a theory-driven perspective in the field.

## 1. Introduction

Music is omnipresent in the current society. In 2018, an average Dutch person spent 152 min every day listening to music (The Statistical Portal, 2019) and the number of active users of music streaming services has significantly increased. For example, from 2015 to 2020, the number of Spotify users increased almost fivefold, from 68 to 320 million (The Statistical Portal, 2020). Thus, access to music at any time and place becomes more and more common. Occasions of simultaneous music listening while engaging in other tasks are increasing accordingly. Nevertheless, research is not conclusive about the effect of background music (BGM) on the performance of daily cognitive tasks: there appears a vast variability depending on the task, the type of music, and the characteristics of the listener, as well as complex interactions between those factors. It appears hard to draw general conclusions from the divergent evidence. For example, some report systematic negative effects of BGM on memory and reading (Ferreri & Verga, 2016; Kämpfe et al., 2011), while more recent studies presented a positive effect (e.g. Borella et al., 2019; Gonzalez & Aiello, 2019; Lemaire, 2019; Li et al., 2012). Motivated by this discrepancy and with the increasing relevance of the issue, our study takes an approach complementary to controlled experimental investigations and explores how people use BGM during daily cognitive tasks, specifically those involved in studying, by means of a survey. We expect that people have fine-tuned when and which BGM works best for them, hence asking for their best strategies could help us understand the previously found complex interaction effects and potentially disclose previously overlooked but influential factors. Ultimately, our goal is to guide theory-driven future research and hence contribute to the understanding of and ability to predict the relationship between BGM and performance of non-musical cognitive tasks in various contexts. Inspired by previous literature, the current study explores the usage of BGM on reading comprehension, memory, reasoning, writing, as well as general attention, while also considering individual differences in extraversion, music proficiency and age.

### 1.1. Reading

Many studies report detrimental effects of BGM on reading, where

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https://doi.org/10.1016/j.actpsy.2021.103417
Received 4 May 2021; Received in revised form 11 August 2021; Accepted 10 September 2021
Available online 20 September 2021

participants perform worse on a reading comprehension task when they simultaneously listen to music, compared to their performance in a silent condition. However, a number of factors have been found to modulate this effect. First, working memory capacity (WMC) of individuals appears to play a role (Christopher & Shelton, 2017; Fogelson, 1973; Lehmann & Seufert, 2017). Evidence suggests that individuals with higher WMC are less negatively influenced by BGM during reading than those with lower WMC. Furthermore, the influence of personality, specifically of extraversion on the effect of BGM has been demonstrated multiple times. Furnham and Bradley (1997) were the first to show that introverts perform worse when pop music is present during reading, while BGM does not affect the performance of extroverts. Other labs have successfully replicated that effect (e.g. Daoussis & Mc Kelvie, 1986; Furnham & Strbac, 2002) but an equally large body of studies has failed to show it (e.g. Avila et al., 2012; Holmes, 2019; Johansson et al., 2012).

The third aspect that is important for the effect of BGM on reading is the characteristics of the BGM. Studies confirm that many musical elements modulate the effect. For example, music with lyrics leads to more distraction than its instrumental counterpart (Avila et al., 2012), and pop and hip-hop tend to reduce performance more than instrumental classical music (Chou, 2010; Li et al., 2012; Perham & Currie, 2014). Also, the tempo and loudness of the music can modulate the effect, where loud and fast music provokes the most impairment (Thompson et al., 2012). Moreover, the complexity of BGM seems to matter as well. Participants perform a reading task better in a condition with highly repetitive music with a narrow tonal range, as compared to conditions with more complex, or no music (Kiger, 1989). Lastly, individuals' preferences and musical training play a role, too. For example, non-preferred music impairs reading comprehension when compared to conditions with preferred music, noise, or silence (Johansson et al., 2012). Also, Patston and Tippett (2011) found that BGM during reading is more detrimental for individuals with high, rather than low musical training, although this effect has not always been replicated (Haning, 2016).

Even though it seems like the majority of literature suggests negative effects of BGM on reading, there is some evidence for the opposite. A facilitating effect on reading comprehension has been demonstrated with classical BGM (Li et al., 2012). Also, classical BGM has been found to improve reading efficiency and the speed of reading (Kallinen, 2002). Notably, a number of studies report neither positive nor negative effects of any BGM on reading comprehension (Doyle & Furnham, 2012; Furnham et al., 1999; Furnham & Allass, 1999; Haning, 2016; Harmon et al., 2008). Thus, interpreting the overall evidence on the effects of BGM on reading comprehension is not straightforward. Even though studies have successfully identified a number of influential factors, many of them need further systematic explorations.

### 1.2. Memory

A large-scale meta-study by Kämpfe et al. (2011) suggests a slight detrimental effect of simultaneous music listening on memory tasks. Indeed, many reports agree with this (Alley & Greene, 2008; Cassidy & MacDonald, 2007; de Groot & Smedinga, 2014; Echaide et al., 2019; Gao & Bai, 2018; Gonzalez & Aiello, 2019; Liu et al., 2012; Perham & Sykora, 2012; Reaves et al., 2016; Zhang et al., 2009; Salamé & Baddeley, 1989), but a similarly large number of studies report positive effects of BGM on memory tasks (Anderson & Fuller, 2010; Borella et al., 2019; Bottiroli et al., 2014; De Groot, 2006; Ferreri et al., 2015; Kang & Williamson, 2014; Küssner et al., 2016; Lehmann et al., 2018; Lemaire, 2019; Mammarella et al., 2007; Oakes & North, 2006; Proverbio et al., 2015). Positive effects are demonstrated with various memory tasks, such as vocabulary learning (Chew et al., 2016; De Groot, 2006), second language learning (Kang & Williamson, 2014), as well as word recall and recognition (Anderson & Fuller, 2010). Recent studies further suggest that such beneficial effect of BGM might be due to the modulation of prefrontal cortex (PFC) activity: The PFC shows significantly reduced activity when participants learn items while listening to music, suggesting a reduced demand on the PFC and hence facilitation of performance through BGM (Ferreri et al., 2013; Ferreri et al., 2014; Ferreri et al., 2015).

Individuals' habits appear to modulate the effect of BGM on memory performance. For example, presenting BGM during an associative learning task reduces the performance of individuals who usually do not listen to music while studying, but it does not reduce task performance of those who are used to listening to music while studying (Crawford & Strapp, 1994). Furthermore, although findings are not consistent, evidence suggests that the age of participants might play a role in the effect of BGM on memory. For example, older individuals are found to benefit from BGM (Bottiroli et al., 2014) as well as listening to music prior to a test session, when performing declarative and semantic memory tasks (Borella et al., 2019). However, Reaves et al. (2016) report negative effects of BGM on associative memory only in older adults (aged 60-75 years), while young adults are not distracted. Another study shows that performance on a source memory task with classical BGM is especially reduced in older adults (El Haj et al., 2014).

Finally, the type of music is important as well. Vocal BGM is often reported to hinder memory performance more than instrumental BGM (e.g. Alley & Greene, 2008; Zhang et al., 2009), especially when the lyrics of a piece are in a familiar language (De Groot & Smedinga, 2014). Notably, however, the latter study only showed detrimental effects of vocal BGM on short-term recall, while performance on a delayed recall task was not affected. Lastly, similar to reading comprehension, memory performance is specifically enhanced in the presence of classical and calming instrumental BGM (e.g. De Groot, 2006; Lehmann et al., 2018; Mammarella et al., 2007; Oakes & North, 2006). A recent study corroborates the significance of music characteristics, e.g. showing that performance of a simple task is only facilitated by complex, not by simple BGM (Gonzalez & Aiello, 2019).

### 1.3. Critical thinking and reasoning

The effect of BGM on critical thinking and reasoning has been studied using diverse tasks, such as arithmetic (Cockerham et al., 2019; Dolegui, 2013; Reynolds et al., 2014; Tucker & Bushman, 1991), verbal (Kou et al., 2018; Tucker & Bushman, 1991), spatial and logical reasoning tasks (e.g. Angel et al., 2010; Dobbs et al., 2011; Furnham & Allass, 1999; Schellenberg & Hallam, 2005), as well as measures of general cognitive ability and fluid intelligence (Cockerton et al., 1997; Yang et al., 2016). However, similar to reading comprehension and memory performance, the evidence does not yield a clear picture of the effect. For example, while some studies report that BGM with lyrics impairs performance of logical or spatial reasoning (Dobbs et al., 2011; Furnham & Allass, 1999), other studies either failed to replicate the effect (Angel et al., 2010; Kou et al., 2018; Reynolds et al., 2014), or found positive effects using the same task (Avila et al., 2012; Furnham et al., 1999; Schellenberg & Hallam, 2005). Similar contradicting results are reported with regard to arithmetic tasks (see Tucker & Bushman, 1991; Crawford & Strapp, 1994; Dobbs et al., 2011; Dolegui, 2013 vs. Reynolds et al., 2014; Yang et al., 2016; Cockerham et al., 2019) as well as tasks measuring general cognitive ability (see Cockerton et al., 1997; Dobbs et al., 2011; Reynolds et al., 2014; Yang et al., 2016). The type of music and personality of the listener are shown to play a role here too, albeit inconsistently (Avila et al., 2012; Dobbs et al., 2011; Furnham & Allass, 1999).

To summarize, while some influential factors are identified, how these interact with the effect of BGM on tasks involving critical thinking and reasoning is largely unknown. Again, the variability in type of music and task, as well as individual differences seems to create a complex pattern of results.

### 1.4. Writing

Studies investigating the effect of BGM on writing are scarce and even the few existing papers disagree with the direction of the effect. For example, Ransdell and Gilroy (2001) show that writing fluency is disrupted in the presence of vocal and instrumental BGM. Yet, another study demonstrates facilitating effects of BGM on L2 writing, specifically for writers classified as highly proficient in the language (Cho, 2015). Thus, the evidence suggests that the effect is most likely moderated by individual differences as well as the writing language.

### 1.5. Attention

Attention is not a cognitive task but included here because it plays a crucial role for successful execution of abovementioned tasks. A number of studies suggest a positive effect of BGM on attention and concentration, e.g., when listening to BGM during tasks measuring selective attention (Darrow et al., 2006; Herlekar & Siddangoudra, 2019) or sustained attention (Wu & Shih, 2019). The effect appears to be further influenced by the musical preferences of a listener, although it is yet to be investigated whether liked or disliked music is more beneficial (e.g. Huang & Shih, 2011; Mori et al., 2014). Evidence from another study shows that BGM genre as well as genre preference during a visual oddball task is related to the strength of electrophysiological responses associated to pre-attentive processing and WM maintenance (Caldwell & Riby, 2007). Thus, again, it appears crucial to consider the role of individual differences and music characteristics, and overall, the current evidence does not tell whether the presence of BGM positively or negatively influences attention and hence task performance.

### 1.6. The present study

Clearly, the effect of BGM on cognitive performance is a popular research topic and it is remarkable that findings are not converging even after a long history of research. Task variability as well as individual differences appears as consistent and crucial factors contributing to different experimental outcomes in all activities reviewed here.

In general, experimental studies are suitable for highlighting causal relations, but they can only test a limited number of variables and conditions at a time. Alternatively, survey studies can highlight interesting associations among many variables, while it is difficult to confirm causalities (e.g. Lonsdale & North, 2011; North et al., 2004; Randall & Rickard, 2017; Schäfer et al., 2013). In this study, we take the latter approach to compare the personal usage of BGM on four cognitive performance tasks to explore associations between different variables. We assume that people have developed certain strategies and habits regarding BGM usage that help to improve performance. Exploring those strategies could provide new insights complementing some of the contradicting experimental findings, as well as confirm known effects. Apart from questions regarding the frequency of BGM usage, preferred music types, and people's beliefs about the scientific evidence on BGM, we fathomed the potential role of extraversion and music proficiency - factors that have been suggested to be influential in previous experimental studies. A noteworthy strength of our study is the systematic comparison of aforementioned task types: in contrast to meta-studies, here, the same individuals report their usage of BGM on all four tasks.

## 2. Methods

### 2.1. Participants

A total of 140 participants filled in an online questionnaire on their use of BGM during every day cognitive tasks (age range: 17–75 years old, $M = 32.56$, $SD = 13.11$; 50% female, 1.4% non-binary). Their average score on the EPQR-S (short-form revised Eysenck Personality Questionnaire) extraversion scale was 6.39 [0−12] ($SD = 3.6$) and the average music proficiency (a subscale of Goldsmiths Musical Sophistication Index) was 29.49 [7–49] ($SD = 10.4$) (see Materials for measurement details). Among them, 39.29% had a finished university bachelor's degree, 37.14% a university master's degree, and 15.71% had a PhD degree. Participants were recruited by a convenience sampling method, via social media and institute mailing lists. Participation was voluntary without any compensation for their participation. All participants gave informed consent. The questionnaire was approved by the ethics committee of the Faculty of Humanities of the University of Amsterdam.

### 2.2. Materials

The survey included questions about people's usage of BGM during daily life cognitive activities, namely, reading, writing, memorizing, and critical thinking. The same set of questions regarding the following five aspects were asked: the frequency of the BGM usage while engaging in these tasks, the reasons why they do or do not use BGM, the kind of music they prefer listening to when performing tasks of varying difficulties, and their belief about the effect of BGM while performing the corresponding task. In a separate section, a few additional questions were included on the impact of BGM on their focus and attention (see Appendix 1). At the end of the survey, three sets of questions regarding individual characteristics were asked: one asked standard demographic information (age, gender, education level), another set asked the level of music proficiency by a subset of Goldsmiths Musical Sophistication Index (Gold-MSI; Müllensiefen et al., 2014; see Appendix 1). The last set of questions consisted of the extraversion (“E”) scale of the short-form revised Eysenck Personality Questionnaire (EPQR-S; Appendix 2; (Eysenck et al., 1985). The survey was created with Qualtrics (https://www.qualtrics.com).

## 3. Results

### 3.1. BGM usage differs between tasks

The first question asked how often participants listen to music when they are engaged in one of the four tasks (reading, writing, memorizing, critical thinking). Participants indicated their usage using a slider ranging from 0 to 100%. As expected, there were large individual differences. For example, while 46 participants indicated that they listen to BGM during reading in less than 10% of the time, 6 participants stated to listen to music every time they read. Fig. 1 shows the mean frequency of the BGM usage. People tend to use more BGM during reading and writing, and the least while memorizing materials. A Friedman's two-way ANOVA by ranks confirmed that the usage of BGM significantly differs among the four tasks ($Q(3) = 71.9$, $p < .0001$, Kendall's $W = 0.176$). Significant pairwise comparisons are indicated in Fig. 1.

### 3.2. Reasons (not) to listen to BGM

This section analyzes why people do or do not listen to BGM when they are engaged in the four tasks. Tables 1 and 2 respectively summarize what participants indicated as their primary reason (not) to listen to BGM during each task. Here, participants could choose (forced-choice) from 7 or 8 options (see the columns of Tables 1 and 2 for all response categories). Table 1 shows that the majority of participants uses BGM to help their concentration or boost their mood. In response to “other” reasons, multiple participants mentioned that they use music to mask other background noise in their environment, and to keep themselves awake or motivated. Table 2 shows that the most frequent reason why people do not listen to BGM is because music distracts their concentration. Here, in response to “other reasons”, some people mentioned that especially vocal music distracts their concentration.

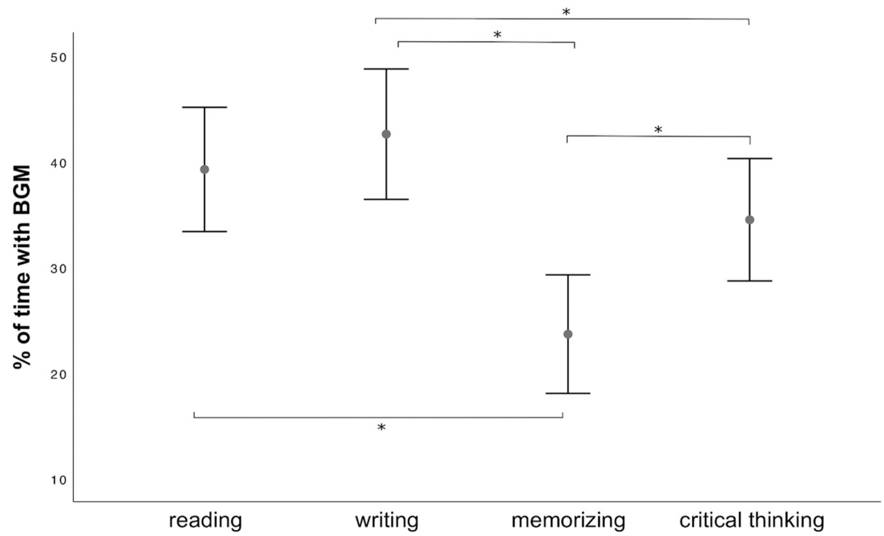


**Fig. 1.** Usage of BGM (background music) per task. Means and 95% confidence intervals are displayed for reading ($M = 38.96$, $SD = 34.70$), writing ($M = 42.58$, $SD = 36.38$), memorizing ($M = 23.99$, $SD = 33.19$) and critical thinking ($M = 34.64$, $SD = 34.07$). Asterisks indicate significant differences ($p < .001$; Bonferroni corrected for multiple comparisons).

**Table 1**
A frequency count of why people listen to music while engaged in each task. Please note that there is a category of "I never listen to music".

| | Music helps my concentration | Music boosts my mood | I feel that my performance is better when music is on | I don't know why but I like it | It is my habit to have music on | I never listen to music | Other |
|---|---|---|---|---|---|---|---|
| Reading | 19.3% | 22.9% | 3.6% | 4.3% | 7.9% | 17.9% | 24.3% |
| Writing | 16.9% | 28.7% | 10.3% | 4.4% | 9.6% | 19.9% | 10.3% |
| Memory | 11.4% | 15% | 6.4% | 2.9% | 7.9% | 50.7% | 5.7% |
| Critical thinking | 14.3% | 24.3% | 8.6% | 9.3% | 11.4% | 25.7% | 6.4% |

**Table 2**
A frequency count of why people do not listen to music while engaged in each task. Please note that there is a category of "I always listen to music".

| | Music distracts my concentration | Music interferes with my mood | I feel that my performance is worse when music is on | I don't know why but I don't like it | It is my habit to not have music on | I am not able to find a space where music is on | I always listen to music | Other |
|---|---|---|---|---|---|---|---|---|
| Reading | 60% | 2.1% | 7.1% | 1.4% | 4.3% | 1.4% | 15.7% | 7.9% |
| Writing | 56.6% | 0.7% | 9.6% | 0.7% | 2.9% | 3.7% | 19.1% | 6.6% |
| Memory | 71.4% | 0% | 5% | 2.9% | 5% | 2.1% | 10.7% | 2.9% |
| Critical thinking | 59.3% | 1.4% | 8.6% | 2.1% | 4.3% | 3.6% | 13.6% | 7.1% |

### *3.3. Preferred music genres*

Participants indicated their preferred type of BGM when performing the four tasks at different difficulty levels. Our BGM type options were based on previous studies (Christopher & Shelton, 2017; Ferreri et al., 2015; Lehmann & Seufert, 2017; Perham & Currie, 2014; Thompson et al., 2012; Yang et al., 2016). Fig. 2 summarizes responses for each activity type. Here, we report the frequency counts because participants could select multiple music types. The difficulty of the task is indicated on the x-axis, from easy to more challenging (except for memorizing).

The four panels show consistent patterns, although these trends are not always significant mainly due to a rather conservative *p*-value. The more challenging the task gets, the fewer people listen to BGM (see thick blue line indicating "no music"). Also, people are more selective when a task gets more challenging: the number of responses to "any type" (orange line) decreases with difficulty. Finally, people prefer non-vocal (i.e. instrumental), calm, and classical music in the background across the four tasks.

### *3.4. BGM and scientific belief*

This section analyzes the association between individuals' beliefs and their usage of BGM. Participants indicated whether they know or think that BGM has a positive, negative or no effect on the respective task performance. Table S1 (Supplementary Results) shows the responses of participants regarding their idea of scientific findings about BGM. It is interesting that even though the majority only indicates to think (rather than to know) about the effect of BGM, both negative and positive beliefs were observed similarly in our data.

Among six response types, we created three belief categories: positive, negative and no effects. Fig. 3 presents the average percentage of BGM usage per three belief categories for the four tasks. We performed a Kruskal-Wallis test with Scientific Belief as independent and Time spent listening to BGM as the dependent variable. There was a consistent and significant pattern between scientific belief and how much time people spend listening to BGM during reading ($H = 37.8$, $p < .001$), writing ($H = 41.1$, $p < .001$), memorizing ($H = 23.1$, $p < .001$) and critical thinking ($H = 25.2$, $p < .001$). The frequency of listening to BGM tends to be

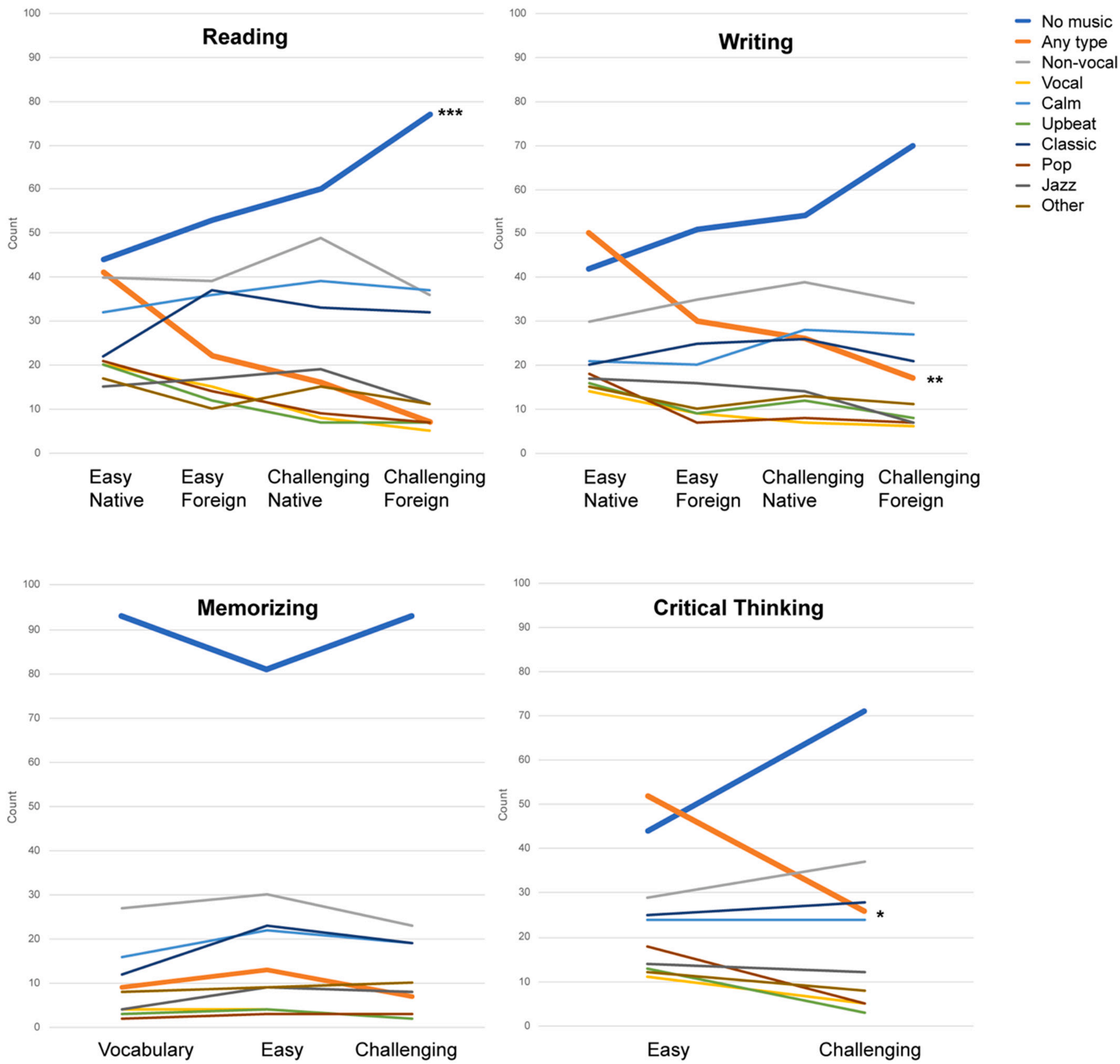


**Fig. 2.** Preferred music types while reading, writing, memorizing and critical thinking, $N = 140$. Y-axes indicates frequency count of the amount of people that choose the respective kind of music (or no music) while performing the task. Task difficulties are indicated on the X-axis. *Native* and *foreign* in upper two panels refer to the language choice. Each participant could select multiple answers. Asterisks indicate significant Bonferroni corrected *p*-values (10 comparisons) in a chi square-test, $^{***}p < .0001$, $^{**}p < .005$, $^{*}p < .05$.

significantly higher for people who believe in positive effects of BGM, compared to people who believe in negative or no effects in all tasks (Dunn's pairwise test; $p < .01$). There were no significant differences regarding the usage of BGM between people that believe in negative and no effects. See also Supplementary Results for more detailed interactions between BGM use and scientific beliefs.

### 3.5. Level of extraversion, music proficiency, and age

This section explores the association between individual differences and the usage of BGM. We found no significant correlations between people's music listening behavior and their level of extraversion (reading $\rho = 0.17$, writing $\rho = 0.039$, memorizing $\rho = 0.050$, critical thinking $\rho = -0.056$) or music proficiency (reading $\rho = -0.056$, writing $\rho = -0.071$, memorizing $\rho = -0.054$, critical thinking $\rho = -0.029$).

Interestingly, there were slight but significant negative correlations between age and music listening behavior (reading $\rho = -0.225$, $p < .01$; writing $\rho = -0.279$, $p < .01$; memorizing $\rho = -0.196$, $p < .05$; critical thinking $\rho = -0.248$, $p < .01$), indicating that young participants tend to use BGM more than older participants. Fig. 4 visualizes this decreasing trend as a function of age. Due to the skewness of the age distribution in our data (more participants in the range of 17-25 years old), we opted for a graph with unequal age bins instead of scatter plots. The number of subjects in each bin is made similar.

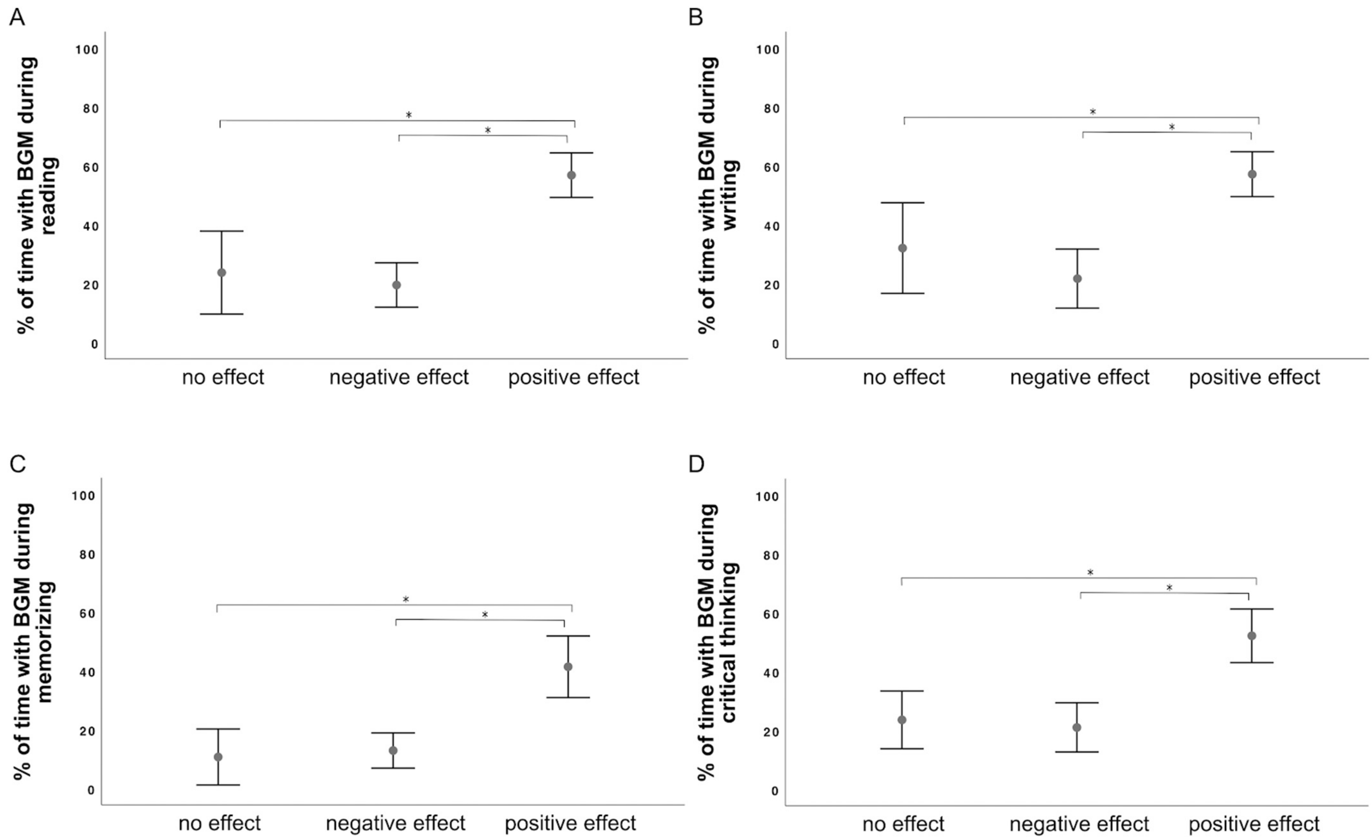


**Fig. 3.** Mean and 95% confidence intervals (CI) of background music usage, presented by scientific belief. Panel A, B, C and D show background music use in percentage of time during reading, writing, memorizing and critical thinking, respectively. Asterisks indicate significant differences ($p < .01$). BGM ~ background music.

### *3.6. BGM and attention*

A slightly different set of questions was asked to study the association between BGM and attention on a 7-point Likert scale. First, participants were asked whether BGM helps them to focus on studying. About half (50.71%) indicated that music helps them to focus their attention on studying, 20.7% of all participants even agreed strongly or completely ($M = 3.93$, $SD = 1.93$). The second question asked whether people are able to focus their attention without BGM. Here, 15.7% of participants agreed and 69.29% disagreed with the statement ($M = 2.65$, $SD = 1.60$). The third question explored preferred BGM types, where the majority of people indicated that non-vocal, calm and classical music rarely distract their attention, whereas jazz, upbeat, vocal and pop music appear to distract their attention always or often (Table 3).

## 4. Discussion

### *4.1. Summary of findings*

We explored how people use BGM while being engaged in daily cognitive tasks. The survey included questions about the frequency of BGM usage during different task types and difficulties, about preferred music types, beliefs about the scientific evidence on BGM, as well as individual characteristics. The results confirmed highly diverse strategies among individuals regarding the use of BGM. Nevertheless, several general tendencies emerged when systematically comparing the answers regarding reading, writing, memorizing and critical thinking.

The rate of BGM usage was different among the four tasks. Although such variability itself is in line with previous studies showing that the nature of the task interacts with the effect of BGM (e.g. Kämpfe et al., 2011; Avila et al., 2012; Bottiroli et al., 2014), it is interesting to note that the direction of the demonstrated effect does not always agree with experimental findings. For example, although many experimental studies report adverse effects of BGM on reading comprehension (e.g. Perham & Currie, 2014; Thompson et al., 2012), our participants appear to use BGM during reading relatively frequently. Also, many studies demonstrate positive effects of BGM on memory performance (e.g., Borella et al., 2019; Gonzalez & Aiello, 2019; Küssner et al., 2016; Lehmann et al., 2018; Lemaire, 2019) but our participants tend to use BGM the least during memorizing. Of course, such discrepancy is very well possible because we here report observational data, which are inherently distinct from experimental outcomes. Also, as we have reviewed in the introduction, not all experimental research agrees on the directionality of the effect of BGM. Nonetheless, such discrepancies may open the door to a new direction for future investigations, e.g. exploring the interaction of experimental effects and meta-awareness of these in one's daily life.

We found that task difficulty is related to the following two aspects, the frequency of BGM usage and the type of BGM that participants choose to listen to. Specifically, there was a consistent pattern across all tasks, namely, that people use BGM less often as a task gets more difficult. Also, while classical, calm, and non-vocal music were indicated as preferred genres when facing challenging tasks, people indicate to be less critical about the type of BGM when engaged in relatively easy tasks. This finding corresponds with previous research demonstrating that instrumental and calm music tend to have the least detrimental effect on cognitive performance (e.g. Alley & Greene, 2008; Avila et al., 2012; Thompson et al., 2012; Zhang et al., 2009).

Participants of this study had diverging ideas about the scientific evidence on BGM and cognitive task performance. Many participants believe in an enhancing effect of BGM, but a similar amount believe in the opposite. This is not too surprising, given the similarly diverging

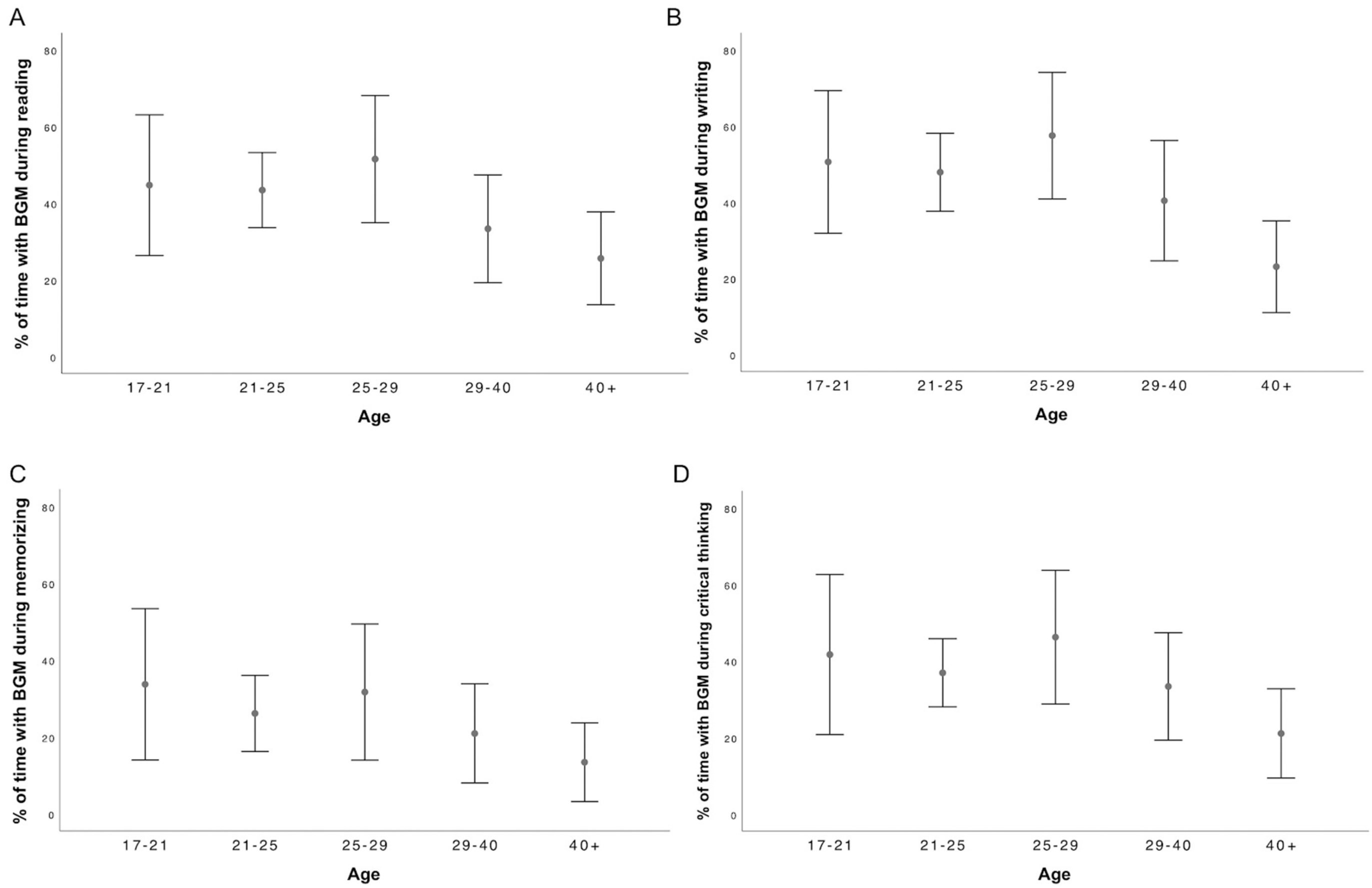


**Fig. 4.** Mean and 95% confidence intervals (CI) of BGM use are displayed for five distinct age groups. Panels A, B, C, and D show the relation for reading, writing, memorizing and critical thinking, respectively. Number of participants in each age group: $n1 = 16$, $n2 = 45$, $n3 = 22$, $n4 = 26$, $n5 = 31$. BGM ~ background music.

**Table 3**
Attention distraction during different background music, in percentages. All columns add up to 100%.

| Tell us which music tends to distract your attention while studying or work. | Non-vocal | Vocal | Calm | Upbeat | Classic | Pop | Jazz |
|---|---|---|---|---|---|---|---|
| Always | 9.3% | 41.4% | 6.4% | 34.4% | 10.7% | 40% | 22.9% |
| Often | 15.0% | 33.6% | 18.6% | 27.1% | 15.7% | 32.1% | 27.1% |
| Sometimes | 52.1% | 21.4% | 47.9% | 33.6% | 47.1% | 23.6% | 37.1% |
| Never | 23.6% | 3.6% | 27.1% | 5% | 26.4% | 4.3% | 12.9% |

evidence existing about the topic. We also found that beliefs of participants correspond well with their use of BGM: people who think that BGM has positive effects tend to use BGM more often than their counterparts. Importantly though, even those who believe in the positive effects of BGM do not always listen to BGM when performing a certain task (e.g., more difficult ones). Thus, although subjective belief appears as an essential motivation for the usage of BGM, people seem equally sensitive to other factors that are more related to the cognitive processes of listening to music and performing the target task.

Recent studies suggest that one's age interacts with the influence of BGM on memory tasks. However, while some associate ageing with negative effects of BGM (El Haj et al., 2014; Reaves et al., 2016), others show the opposite (Borella et al., 2019; Bottiroli et al., 2014). Here, we found slight but significant negative correlations between participants' age and their BGM usage frequency, suggesting that younger participants use BGM more often than older participants. This effect was not only found with regard to memory tasks, but also during reading, writing and critical thinking. While we should be careful not to overinterpret this finding given the skewed age distribution in our sample, some related observations and possible explanations are worth mentioning. Previous research found that increased age is associated with decreased multitasking performance (McAlister & Schmitter-Edgecombe, 2013; Zanto & Gazzaley, 2017). Also, our participants indicate that their primary reason not to listen to music is concentration distraction. Taken together, the underlying factor for the negative correlation between age and BGM use may be the challenge that is posed by declining multitasking efficiency. However, another likely factor is habit: due to the affinity to technology advancement, it may simply be more common and hence less distracting for younger generations to stream music in the background than it is for older participants. It would be interesting to investigate this further.

Finally, one should note that the majority of our participants are university students and researchers who are interested in the topic. A follow up replication with a larger sample size with various and yet balanced backgrounds would strengthen our findings.

### *4.2. Existing theories, our findings and future perspectives*

As we have reiterated many times, conflicting findings make it challenging to give a simple interpretation of how BGM influences cognitive task performance. A useful way to enhance our understanding of the issue is theory-driven research. In this section, we will focus and review four theories in the field. These theories are relatively old but are frequently adopted to explain the effects of BGM on performance. In addition, we will address one newer theory that may be relevant for future studies.

Individual differences appear in almost all studies in the field. Accordingly, one's personality, particularly extraversion, has been suggested to modulate the effect of BGM, an interaction predicted by Eysenck's theory of personality (Eysenck, 1967). According to the theory, introverts have higher levels of cortical arousal compared to extroverts, which means that they need less or no external stimulation to reach optimal levels of arousal and thereby maximal cognitive performance. Therefore, a moderate or high external stimulant like BGM should lead to decreased performance in introverts, while not negatively influencing the performance of extroverts. Küssner (2017) reports that, although there is much evidence in favor of Eysenck's personality theory (Daoussis & Mc Kelvie, 1986; Dobbs et al., 2011; Furnham & Allass, 1999; Furnham & Bradley, 1997; Furnham & Strbac, 2002), many other studies do not confirm it (Holmes, 2019; Johansson et al., 2012). Our results are in line with recent findings and do not suggest any relation between personality type and BGM use. However, one should note that our study was based on spontaneous responses and participants did not perform controlled experimental tasks. Therefore, our measure may be less sensitive to the effects of different personality types.

Another theory that is frequently mentioned in relation to the effects of BGM is the Cognitive Capacity Hypothesis (CCH, Kahneman, 1973). It states that one's cognitive capacity (or resource) is limited and therefore, if the cognitive load of a task exceeds one's capacity, task performance is hindered. There are persuasive findings that support this theory. For example, the effect of BGM on vocabulary learning is most detrimental when listening to BGM with lyrics of a familiar language, compared to an unfamiliar language or silence (De Groot & Smedinga, 2014; Gao & Bai, 2018). Listening to lyrics of a familiar language may rely on the same cognitive resources as vocabulary learning (e.g., the phonological loop), which may lead to an overload of processing capacity and thus to an interference effect. Such overload may be less likely when listening to lyrics of an unfamiliar language, as the processing load may tap into different resources than the target task. Other evidence suggests that specifically individuals with low WMC tend to demonstrate a substantial interference effect of vocal BGM when compared to instrumental music (Kang & Lakshmanan, 2017), again indicating that one's cognitive capacity interacts with the effect of BGM on performance. Because the definition of the resource is open and can be interpreted flexibly, the CCH offers a powerful way to explain a wide range of cognitive task performances. The theory can also elegantly explain our finding that people tend to use BGM differently depending on the task difficulty and type of activities, i.e. reading, writing, memorizing and critical thinking. People may be adjusting the cognitive load to an optimal level depending on the resources needed for the respective task. However, there is one caveat: the CCH does not explain the enhancing effect of BGM on cognitive performance. Therefore, it cannot be the sole explanation for the effects of BGM.

Interestingly, the following theories cover the enhancing effect of BGM. The Distraction-Conflict Theory (DCT) was initially proposed by Baron (1986) and recently adopted to interpret the impact of BGM on cognitive performance (Gonzalez & Aiello, 2019). Here, the key concept is the interaction between task difficulty and attention. The DCT assumes that a simple task needs less attention allocation to perform the task than a more complex task. Further, the theory proposes that one's mind starts to wander easily during a simple task, because not all attentional resources are engaged in the task. Now, let us assume another concurrent event, such as BGM, that could cause an attention conflict. Following the DCT, such a distractor would likely cause overstimulation when performing a complex task and hence deteriorate task performance (an explanation similar to the CCH). However, when performing a simple task, a distractor could facilitate performance by limiting undirected attention, boredom and mind-wandering. In other words, BGM could prevent attention distraction and could thereby enhance task performance. In favor of this theory, some recent studies indeed showed that different task difficulties modulate the impact of BGM (Gonzalez & Aiello, 2019; Lehmann et al., 2018). Similarly, the individual's task fluency is confirmed to have a similar effect. Individuals who are proficient in a task can benefit from BGM, while those with low task proficiency perform worse with BGM (e.g. Cho, 2015). Our finding that people tend to use BGM more when engaged in easier variants of the four tasks aligns well with this theory, too. Also, we found that one frequent reason to listen to BGM was to improve concentration, while the most popular reason not to listen to music was concentration distraction, which seems to agree with the DCT.

Unsurprisingly, there is some evidence contradicting the DCT, e.g. decreased performance of a simple task in the presence of BGM (Gao & Bai, 2018; Zhang et al., 2009) or no interaction between task difficulty and music condition at all (Angel et al., 2010). The load theory (LT) by Lavie (2005) may be relevant for understanding such discrepancies among studies. Similar to the DCT, the theory describes the impact of a task-irrelevant distractor depending on the loading of a task. Crucially, the theory differentiates between two types of task loads that each interact differently with potential distractors, perceptual load and cognitive-control load. Perceptual load is determined by the number of events that need to be perceived in a task. In response to high perceptual load, one may be fully focused on the task. In such a case, not much perceptual capacity would be left to process any task-irrelevant distractors; hence, distractors can have little or no detrimental effects. In contrast, when task loads are high on executive cognitive control functions like working memory, the task processing priorities are severely influenced by the concurrent task-irrelevant distractor. Thus, a similar distractor would be detrimental in a task with high cognitive-control load. Although there seem to be an effect of audio-visual modality interaction that is yet to be explored, and this theory does not cover the enhancing effect of BGM per se, incorporating such distinctions to further dissect task difficulties may shed light on the apparent disagreements among existing studies and guide future studies.

The last theory is the Arousal Mood Hypothesis (AMH; Thompson et al., 2001; Husain et al., 2002). The AMH was first introduced to account for the so-called Mozart effect, the temporally enhanced spatial IQ performance after listening to music by Mozart (Rauscher et al., 1993). Rauscher et al. proposed that the music by Mozart is especially suited to stimulate our brain to perform the task better. The AMH replaced this initial hypothesis by suggesting that music generally influences cognitive performance by altering one's state of arousal and mood (Davis & Thaut, 1989; Sloboda, 1992). Specifically, pleasant music would increase performance by improving one's mood and optimizing arousal levels, while unpleasant music would work against optimal performance by decreasing levels of mood and arousal. Also, pleasant but highly arousing music could lead to over-arousal and impairment of performance. Subsequent studies confirmed that the AMH is the most promising explanation for the Mozart effect (Schellenberg, 2005; Schellenberg et al., 2007).

Of course, the AMH can be applied to account for the effect of BGM listening on cognitive task performance (e.g. Bottiroli et al., 2014; Daoussis & Mc Kelvie, 1986; Lehmann & Seufert, 2017; Proverbio et al., 2015; Schellenberg & Hallam, 2005). Indeed, many studies show how the AMH can explain positive effects of BGM: stimulant music was found to boost both arousal and memory performance (Lemaire, 2019), classical music appeared to boost positive affect as well as multiple-choice test performance (Dosseville et al., 2012), and music had increased both blood pressure and the score on a divided attention test (Herlekar & Watve, 2016), to name a few. Recent evidence also shows that the AMH can account for the negative effects of BGM. For example, high tempo music hindered the executive control system by modulating the arousal responses during an inhibitory task performance (Mansouri et al., 2017), and non-preferred BGM was shown to increase arousal and had negative effects on reading comprehension (Johansson et al., 2012). Notably, the

AMH is often applied hand in hand with Eysenck's personality theory. Following Eysenck, baseline levels of arousal differ between extraverts and introverts. Accordingly, the AMH would predict that individuals with different degrees of extraversion would react differently to BGM in terms of cognitive performance. In the current study, results of two questions further support the AMH. Firstly, we found that the most popular reason to listen to BGM was mood improvement, which directly supports the AMH. Nevertheless, concentration improvement was a similarly popular choice, suggesting that mood is not the only driving factor to use BGM. Secondly, regarding the preferred music types, the number of people voting for upbeat BGM decreased as the investigated task got more challenging. This is in line with the assumption of over-arousal in response to highly arousing music proposed by the AMH. Calm, classical and jazz were the most popular genres - following the AMH, these may be highly pleasant and boost both mood and arousal to an optimal level. Finally, it is fair to mention again that our extraversion measure did not correlate with BGM use, which disagrees with the assumption of the AMH when incorporating Eysenck's personality theory.

In short, the AMH offers a plausible explanation to both positive and negative effects of BGM on cognitive performance, as well as individual differences. The challenge here may be to establish the causality between mood/arousal and the change in cognitive performance. Also, it is important to note that a number of experimental studies have failed to support the AMH in the past (Burkhard et al., 2018; Cockerton et al., 1997; Kang & Lakshmanan, 2017; Lehmann et al., 2018; Lehmann & Seufert, 2017). Especially, many could not confirm the effect of different music valence on task performance, which one would expect following the AMH, given the changes in mood and arousal (Borella et al., 2019; Bottiroli et al., 2014; Proverbio et al., 2015; Sayar, 2018).

To summarize, our results support four theories reviewed here, the CCH, DCT, LT and AMH. The former three partly share how they explain the interference effect of BGM: the processing of BGM may take up too much resources to optimally perform the main task. The AMH instead provides two explanations for potential negative effects of BGM. First, unpleasant BGM may interfere with mood/arousal and thereby with cognitive performance, or second, upbeat music may over-arouse the listener and like this hinder cognitive performance. For the enhancing effect of BGM, theories take different approaches. The CCH and LT do not account for the effect. The DCT proposes that BGM could effectively direct one's attention to perform a relatively simple task. The AMH proposes that BGM enhances mood and arousal, and thereby task performance. Unlike the DCT, the AMH does not explicitly differentiate between the effects of BGM on tasks with various difficulties. Thus, the current paper presents more supportive evidence than counter-evidence for most of the aforementioned accounts. This may imply that all four variables, i.e. cognitive capacity, attention, mood as well as arousal may be playing a part. A key for potential future research is to control for or to measure these variables simultaneously with the target task performance to explore their relevance for the effects of BGM. Furthermore, incorporating the potential effect of age-related change in the frequency of BGM usage may help to disentangle the issue, as ageing may systematically influence one of these variables.

## Declaration of competing interest

The authors declare no competing financial, professional, or personal interests that might have influenced the performance or presentation of the work described in this manuscript.

## Acknowledgements

The authors are grateful for Jannie de Leeuw and Rolinde Zievelink for their kind help with the recruitment of participants. We are also grateful for Rebecca Scarratt, Jordy Naus and Ada Örken for their comments on an earlier version of the manuscript. This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

## Appendix 1

Subset of Goldsmiths musical sophistication index (Gold-MSI).

- I have never been complimented for my talents as a musical performer. * (completely disagree / strongly disagree / disagree / neither agree nor disagree / agree / strongly agree / completely agree)
- I would not consider myself as a musician. * (completely disagree / strongly disagree / disagree / neither agree nor disagree / agree / strongly agree / completely agree)
- I engaged in regular, daily practice of a musical instrument (including voice) for __ years. (0 / 1 / 2 / 3 / 4-5 / 6-9 / 10 or more)
- At the peak of my interest, I practiced __ hours per day on my primary instrument. (0 / 0.5 / 1 / 1.5 / 2 / 3-5 / 5 or more)
- I have had formal training in music theory for _ years (0 / 0.5 / 1 / 2 / 3 / 4-6 / 7 or more)
- I have had _ years of formal training on a musical instrument (including voice) during my lifetime. (0 / 0.5 / 1 / 2 / 3-5 / 6-9 / 10 or more)
- I can play __ musical instruments. (0 / 1 / 2 / 3 / 4 / 5 / 6 or more)

*Mirrored question.

Questions about focus and attention

- Music helps me to focus my attention on studying (7 completely agree – 1 completely disagree)
- Focusing my attention on studying is harder without music on (7 completely agree – 1 completely disagree)
- Upbeat music distracts my attention while studying (always – often – sometimes – never)
- Calm music distracts my attention while studying (always – often – sometimes – never)
- Vocal music distracts my attention while studying (always – often – sometimes – never)
- Non-vocal music distracts my attention while studying (always – often – sometimes – never)

## Appendix 2

Extraversion scale of the short-form revised Eysenck Personality Questionnaire (EPQR-S)

- Are you a talkative person? (yes / no)
- Are you rather lively? (yes / no)
- Do you enjoy meeting new people? (yes / no)
- Can you usually let yourself go and enjoy yourself at a lively party? (yes / no)
- Do you usually take the initiative in making new friends? (yes / no)
- Can you easily get some life into a rather dull party? (yes / no)
- Do you tend to keep in the background on social occasions? * (yes / no)
- Do you like mixing with people? (yes / no)
- Do you like to have plenty of action and excitement around you? (yes / no)
- Are you mostly quiet when you are with other people? * (yes / no)
- Do other people think of you as being very lively? (yes / no)
- Can you get a party going? (yes / no)

*Mirrored question.

## Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.actpsy.2021.103417.

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