Université de Montréal

Effet de la musique d'ambiance sur les fonctions exécutives : une revue systématique de la littérature

Par
Catherine Houde-Archambault

Département de psychologie
Faculté des arts et des sciences

Essai présenté en vue de l'obtention du grade de Doctorat en psychologie (D.Psy)
Option neuropsychologie clinique

Dépôt initial: 8 mai 2023

Résumé

La musique d’ambiance a la capacité de moduler les émotions et ses effets en particulier sur les fonctions exécutives est de plus en plus exploré, d’où l’intérêt de rassembler les connaissances actuelles et d’identifier les paramètres déterminants de ce phénomène qui constitue l’objectif central de cette revue systématique. Pour cela, quatre bases de données systématiques et trois non systématiques ont été sondées jusqu’au 22-07-2022 pour répertorier les études examinant l’effet de la musique d’ambiance instrumentale sur les trois fonctions exécutives centrales, soit l’inhibition, la mémoire de travail et la flexibilité cognitive, d’adultes âgés entre 17 et 65 ans en bonne santé, non musiciens professionnels. La méthode de sélection d’articles *PRISMA* a permis de retenir 35 articles qui ont été évalués avec une adaptation de l’outil d’estimation de la qualité *Critical Appraisal Skills Programme*. Au total,16 études concernaient l’inhibition (n=858) et 23 la mémoire de travail (n=1748). Puisque seulement 3 études concernaient la flexibilité cognitive (n=681), cette fonction n’a donc pas fait l’objet d’analyse subséquente. Pour la majorité des articles (65,7%), le score de qualité était élevé, alors qu’il était modéré pour 34,3% d’entre eux. La plupart des méthodologies employait la musique classique et recrutait des jeunes adultes, les universitaires étant représentés de manière prédominante. Dans l’ensemble, les résultats sont hétérogènes, certains démontrant que la musique d’ambiance exerce un effet bénéfique, néfaste ou non significatif sur la performance exécutive. La qualité des études, l’adéquation entre les tâches et la fonction exécutive mesurée, les caractéristiques émotionnelles et le tempo des extraits musicaux semblent déterminants dans l’effet de la musique d’ambiance sur l’inhibition et la mémoire de travail, du fait de sa propension à avoir un effet facilitateur ou nuisible en fonction de ces éléments. Pour la mémoire de travail, l’intensité sonore et la personnalité semble aussi des facteurs influents. Certaines limitations méthodologiques ont réduit la capacité à comparer les études entre elles, telles que des imprécisions dans la description des paramètres musicaux et des caractéristiques des participants, puis des inconsistances à travers les études concernant l'adéquation des tâches pour évaluer les fonctions exécutives. Nos recommandations d'utiliser des instruments de mesures standardisés ou des paradigmes expérimentaux reconnus pour évaluer ces fonctions et de rapporter de manière exhaustive les paramètres musicaux, entre autres, devraient permettre d'uniformiser les méthodes et la qualité des recherches futures, afin d'optimiser la compréhension de l'effet de la musique d'ambiance sur l'inhibition et la mémoire de travail et se pencher davantage sur la flexibilité cognitive.

Mots-clés : musique d'ambiance, émotions musicales, fonction exécutive, inhibition, mémoire de travail, adultes.

Abstract

Background music has the capacity to modulate emotions, and its effects on cognitive processes, specifically on executive functions, are increasingly explored. Hence the importance of gathering current knowledge and identifying the determining parameters of this phenomenon, which constitutes the central objective of this systematic review. To accomplish this, four systematic and three non-systematic databases were surveyed up to 2022-07-22 to find studies exploring the effect of instrumental background music on the three core executive functions, namely inhibition, working memory, and cognitive flexibility, in healthy adults aged between 17 and 65 years old who were non-musicians or non-professional musicians. The article selection method followed the PRISMA Statement and yielded 35 studies, which were evaluated with an adapted version for estimating quality of the *Critical Appraisal Skills Programme*. In total, 16 studies related to inhibition (n=858), 23 to working memory (n=1748). Since only 3 studies explored cognitive flexibility (n=681), this function was not analyzed further. For most of them (65.7%), quality score was rated high, whereas for 34.3% quality score was moderate. Most methods were characterized by classical music and recruited younger adults; university students were predominantly represented. Generally, study results are heterogeneous, some demonstrate that background music exerts a beneficial influence, a detrimental effect or no significant effect on performance. Study quality, adequacy of measurement tasks and the executive function evaluated, emotional characteristics of music, and tempo appear essential in understanding background music's effect on inhibition and working memory, as a result of its tendency to have a beneficial of impairing effect according to them. For the latter, sound intensity and personality also seem to be influential factors. Some methodological limitations lessened our ability to compare studies, such as imprecisions concerning the description of musical parameters or participant samples, and inconsistency across studies relating to adequacy of tasks used to evaluate executive functions. Our recommendations to use standardized measurement instruments or experimental paradigms recognized to assess these functions, and to comprehensively report musical parameters, among others, should help standardize the methods and quality of future research, allowing our understanding of the effect of background music on inhibition, working memory, and cognitive flexibility to be optimized.

Keywords: background music, musical emotions, executive function, inhibition, working memory, adults.

Table des matières

Liste des tableaux

Liste des figures

Liste des sigles et abréviations

ACC : Accuracy (Taux de réponses correctes)

APA : American Psychological Association (Association Américaine de psychologie)

BGM: Background music (Musique d'ambiance)

CF: Cognitive flexibility (Flexibilité cognitive)

EFs: Executive functions (Fonctions executives)

ERR : Error rate (pourcentage d'erreurs)

INH: Inhibition

RT : Response times (Temps de réponse)

WM: Working memory (Mémoire de travail)

À mers chers parents, en reconnaissance de leur soutien inconditionnel et encouragements constants. Cet essai doctoral vous est dédié.

Remerciements

J'adresse tous mes remerciements à ma directrice d'essai doctoral, Nathalie Gosselin, pour sa guidance soutenue et ses contributions précieuses tout au long de ce projet. Je suis extrêmement reconnaissante pour son engagement constant envers mon succès et mes aspirations. Sa rigueur, son expertise et sa passion m'ont inspirée à m'investir dans la réalisation de ce projet et me développer sur le plan de scientifique et clinicienne. Je suis ravie d'avoir reçu sa supervision et travaillé avec elle à travers les dernières années.

J'aimerais remercier chaleureusement les membres de mon jury, Docteure Lise Gagnon et Docteur Arnaud Saj, qui ont révisé mon essai avec soin et minutie. Leurs commentaires pertinents et suggestions d'approfondissements m'ont permis d'élever la qualité de mon travail. Je suis très reconnaissante envers eux d'avoir contribué leur expertise à ce projet.

Je tiens à remercier Adam Robacewski, Émilie Ponton, Jadziah Pilon, et Vincent Montpetit pour leur aide précieuse dans le tri et la sélection des articles à inclure dans la revue. J'aimerais également remercier Amélie Cloutier et Dawn Merrett pour leurs révisions attentives et leurs commentaires judicieux. Enfin, à ceux nommer ci-dessus et aux membres du laboratoire MUSEC, j'aimerais souligner que leur enthousiasme et leurs commentaires constructifs m'ont soutenue et motivée à travers les différentes étapes de l'essai, puis qu'ils et elles ont agrémenté les longues heures de travail de rires et d'humanité. Je m'estime chanceuse d'avoir pu me fier à cette équipe de qualité.

À ma famille, je vous remercie pour votre amour, votre confiance et votre soutien indéfectibles tout au long de ce parcours académique. Je vous suis éternellement reconnaissante.

À mes amies, merci pour vos encouragements et votre écoute à travers les aléas de ce long parcours, pour tous les bons moments partagés ensemble, les rires et la légèreté.

Enfin mes derniers remerciements vont à Édouard, qui a tout fait pour me soutenir au quotidien, avec amour et bienveillance.

Structure de l’essai

L’essai doctoral, présenté dans ce qui suit, prend la forme d’un article scientifique empirique explorant l’effet de la musique d’ambiance sur les fonctions exécutives selon la méthode de revue systématique de la littérature. Cet article sera soumis à une revue scientifique et pour favoriser la publication, il est rédigé en anglais pour rejoindre un auditoire plus large.

Article

The effect of background music on executive functioning – A systematic review

Catherine Houde-Archambault[a], Nathalie Gosselin[a,b]

[a] Department of Psychology, University of Montreal, Montreal, QC, Canada
The Music, Emotions and Cognition Research Laboratory (MUSEC Laboratory),
International Laboratory for brain, music and sound research (BRAMS) Pavilion Marie-Victorin,
University of Montréal, 90 Vincent D'Indy Ave, Room A-108, Outremont, Quebec, Canada,
The Centre for Research on Brain, Language and Music (CRBLM),
[b]Centre interdisciplinaire de recherche sur le cerveau et l'apprentissage (CIRCA).

Corresponding Author: Nathalie Gosselin, e-mail: nathalie.gosselin@umontreal.ca

(Article ready for submission)

Abstract

Background music has the capacity to modulate emotions, and its effects on cognitive processes, specifically on executive functions, are increasingly explored. Hence the importance of gathering current knowledge and identifying the determining parameters of this phenomenon, which constitutes the central objective of this systematic review. To accomplish this, four systematic and three non-systematic databases were surveyed up to 2022-07-22 to find studies exploring the effect of instrumental background music on the three core executive functions, namely inhibition, working memory, and cognitive flexibility, in healthy adults aged between 17 and 65 years old who were non-musicians or non-professional musicians. The article selection method followed the PRISMA Statement and yielded 35 studies, which were evaluated with an adapted checklist for estimating quality and risk of bias (Critical Appraisal Skills Programme, 2020). and yielded 35 studies, which were evaluated with an adapted version for estimating quality of the *Critical Appraisal Skills Programme*. In total, 16 studies related to inhibition (n=858), 23 to working memory (n=1748), and 3 to cognitive flexibility (n=681). For most (65.7%), the quality score was rated high, whereas for 34.3% the quality score was moderate. Most studies used classical music and recruited younger adults; university students were predominantly represented. Generally, study results are heterogeneous, some demonstrate that background music exerts a beneficial influence, an impairing effect, or no significant effect on performance. Study quality, adequacy between the selected tasks and executive function evaluated, emotional characteristics of music, and tempo appear essential in understanding background music's effect on inhibition and working memory, as a result of its tendency to have a beneficial of impairing effect according to them. For the latter, sound intensity and personality also seem to be influential factors. Some methodological limitations affected our ability to compare studies, such as imprecision in the description of musical

parameters or participant samples and inconsistency in the tasks used to evaluate cognitive functions. Thus, we recommend the use of standardized measurement instruments or well-established experimental paradigms to assess executive functions, as well as comprehensive reporting of musical parameters. These should help standardize the methods and quality of future research, allowing our understanding of the effect of background music on inhibition, working memory, and cognitive flexibility to be optimized.

Introduction

The ubiquity of music in everyday activities like driving, studying, and exercise intrigues researchers (Ellis et al., 2019). This common habit has likely increased because of the digital revolution that has multiplied listening devices, facilitated the individual access to music in different contexts, and broadened the settings were music can be enjoyed (Krause et al., 2015). We refer to background music (BGM) when it is listened to as an accompaniment to a main activity, such as commuting, working, reading, preparing food, or even doing chores and exercising (Krause and North, 2017). When questioned, individuals report listening to music for its ability to modulate emotions (Carlson et al., 2021; Juslin et al. 2010; Schäfer et al., 2013). Consequently, one of the pillars in the field of musical studies is the claim that the observed positive effect of music on cognition is explained by the **Arousal-mood theory** (Schellenberg and Weiss, 2013; Thompson et al., 2001), according to which music improves cognition by enhancing arousal (physiological activation and alertness; Niven and Miles, 2013) and inducing positive emotions. Evidence from the literature supports the idea that music influences physiological measures (e.g., heart rate, skin conductance) associated with arousal (Bradt et al., 2013; Chanda and Levitin, 2013; Juslin and Västfjäl, 2008; Juslin et al., 2015; Knight, 2001; Schaefer, 2017). This enhanced arousal brings energy and reactiveness which should support cognitive demands, combined with a positive mood which translates into eagerness and motivation and explains the effect on cognitive function. Chanda and Levitin (2013) collated the available evidence and identified tempo as the main musical parameter influencing arousal. Precisely, faster tempo increases arousal, and slower tempo decreases it. To describe music's arousal and the emotions it conveys, Eerola and Vuoskoki (2011) refer to musical emotions (e.g., joy, calm, sadness) which can be described by referencing Russel's two-dimensional model (see Russell, 1980), namely valence (i.e., positive vs negative emotions) and arousal (i.e., stimulating vs relaxing). How these musical emotions are experienced may depend on the emotional dispositions of the person at the time of listening (Hunter et al., 2011; Schaefer et al., 2013) and personal basal activation level (Schaëfer et al., 2013), among other factors.

Thereupon, the effect of BGM and musical emotions may vary individually as a function of the **Yerkes-Dodson law** (1908). This concept suggests that an intermediate level of activation leads to optimal performance, and excessively low or elevated levels of activation harm it. Therefore, this inverted-U curve traces the relationship between emotions and cognition in the performance of complex cognitive tasks (Blair and Ursache, 2011). Applied to musical activation, this model could explain BGM's effect on cognition (Husain et al., 2002), as musical activation for optimal cognitive performance would depend on individual initial activation.

Some authors have linked musical emotions and executive functions (EFs) since they rely on related neural circuits, such as the emotional networks. Musical emotions recruit the same neural systems associated with other human emotions (see Koelsch, 2010, 2014, 2020, and Vuust et al., 2022, for reviews), for example, the amygdala, the nucleus accumbens, the hippocampus and the anterior cingulate cortex (ACC; Koelsch, 2014, and see Koelsch, 2020 for a meta-analysis). These cerebral structures (limbic system) are involved in neural circuits that attend to emotional processing and attentional control (Blair and Ursache, 2011; see Lindquist et al., 2012, for a meta-analysis). Briefly, the gathered findings identify the ACC, lateral prefrontal cortex, ventrolateral prefrontal cortex and dorsolateral prefrontal cortex as regulating attentional control and the processing of emotional stimuli (Lindquist et al., 2012). Hence, musical emotions interact with executive functioning. Acknowledging this, the contradictory results from the scientific literature relating to the effect of BGM on EFs seem important to clarify.

An impressive number of studies have explored how BGM influences cognitive functioning. Several studies have shown that the presentation of music during the performance of a task is beneficial (Begum et al., 2019; Kampfe et al., 2011; Mammarella et al., 2007). However, this effect varies according to the cognitive function studied and sometimes turns out to be detrimental or non-significant. Mainly, BGM is reported to impair memory (Cheah et al., 2022; Kampfe et al., 2011), reading (Kampfe et al., 2011), and language-related tasks (Cheah et al., 2022; Kampfe et al., 2011). Other cognitive functions, such as reasoning, and attention, appear to be unaffected by BGM (Cheah et al., 2022). Concerning executive functioning, a contradiction exists relatively to stimulating music and inhibition (INH), some findings suggest a beneficial effect (Fernandez & al., 2020; Marca et al., 2014) and others point to a detrimental effect (Rowe et al., 2007; Xiao & al., 2020). Similar results appear for working memory, as music was found to impair performance (Kang et Lakshmanan, 2017; Wang et al., 2020; Mohammadzadeh, 2016). Others report an unsignificant effect for both stimulating and relaxing music on INH (Burkhard et al., 2018) and working memory (Lehmann et Seufert, 2017; Palmiero et al., 2016). Despite numerous studies, there is still no consensus on the impact of BGM on executive functioning specifically.

Overall, the current lack of synthesis makes it difficult to make conclusions about the precise effect of music on cognitive performance. It is possible that classifying these results according to music-specific, task-specific, and individual-specific parameters might clarify our understanding.

The present review will focus on instrumental music, in light of the general hindering effect of lyrical music on cognitive functioning (Cheah et al., 2022). Among the firsts to demonstrate this effect, Williamson, Baddeley, and Hitch (2010) exhibited that there is interference when the auditory condition is phonologically similar to the task being completed, i.e., listening to speech while recalling verbal series does impair working memory performances. Finally, other influencing factors relate to individual differences such as personality. For example, introverted and extroverted personalities impact cognitive performances (Cassidy and Macdonald, 2007; Furnham and Allass, 1999; see Küssner, 2017 for a review), and stimulating music is more detrimental to introverts' performance than extroverts' (Cassidy and Macdonald, 2007). Furthermore, the initial cognitive capacities also modulate the effect of BGM on performance, specifically concerning working memory (WM). For example, Palmiero and colleagues (2016) demonstrated that WM sex-differences where dependant on WM capacities rather than emotional context. Lehmann and Seufert (2017) similarly reported a positive correlation between a higher WM capacity and learning with BGM. Additionally, musical expertise has often been positively correlated with EF performance as participants with more years of musical training perform better on executive functioning tasks (Criscuolo and al., 2019; Strait and Kraus, 2011; Tierney and al., 2020; Maturi and Sheridan, 2020; Barraza and Medina, 2019). Some authors explain this correlation since musicians attend to music more than non-musicians which amplifies their cognitive load and strain on cognitive resources (Patston and Tippett, 2011; Yoo and al., 2022). Hence, this review will focus on adults with no extensive musical.

EFs are central to goal-directed behaviors and decision-making (Eslinger, Flaherty-Craig, and Benton, 2004). In fact, as they organize complex information, cognitive and emotional resources to successfully reach intended goals (Barrasso-Catanzaro and Eslinger, 2016; Eslinger, 1996; Fuster, 2002). EFs represent the conductor of goal achievement by controlling initiated and inhibited actions appropriate to future goals (Blair and Ursache, 2011) defying distractions and competing responses. They represent attentional control as opposed to automatic processing (Diamond, 2013; Blair and Ursache, 2011; Burgess and Simons 2005; Espy 2004; Miller and Cohen 2001). The three core EFs are supported by the parietal lateral and superior prefrontal cortices (Collette et al., 2005). Maturation of EFs is characterised by increased connectivity between the prefrontal cortex and the area regulating emotions and cognition (Barrasso-Catanzaro and Eslinger, 2016) such as the ACC and the limbic system (Blair and Ursache, 2011). Hence, executive functioning encompasses emotional and attentional regulation (Blair and Ursache, 2011). In addition, EFs vary largely between individuals (Miyake and Friedman, 2012), and considering individual characteristics in the study of EFs is recommended (Blair and Ursache, 2011), such as age variance (Yuan and Raz, 2014). In fact, the cognitive decline that occurs in the later stages of adulthood (Glisky, 2007) does include EFs (as explained in Bherer, Erickson and Liu-Ambrose, 2013; and Bherer, L, 2015).

Defining these functions poses a recurring challenge (Henrard, 2021), since many existing definitions overlap and multiple terms refer to the same function (Miyake and al., 2000a). For example, inhibition, inhibitory control, attentional control, and response inhibition are few of the terms used to refer to INH (see Miyake and al., 2000a). Similarly, working memory is sometimes named short-term memory, updating and monitoring. This reality raises a challenge when synthesising the existing literature, since the use of different terms to refer to the same function might disperse the scientific literature, conversely using the same terms for different concepts might lead to compiling evidence that should be considered separately and cause confusion (Miyake and al., 2000a). In the conceptualization of EFs (Anderson, 2010, chapter 1), a consensus has arisen surrounding inhibition (INH), working memory (WM), and cognitive flexibility (CF) as the three core EFs (Collette and al., 2005; Diamond, 2013; Henrard, 2021; Miyake and al., 2000b; Vaughan and Giovanello, 2010). The model presented by Miyake and his team (2000b) suggests that INH, WM, and CF (Miyake and al., 2000b) are both distinct and convergent entities, an idea that has been supported by several studies (see Collette and al., 2005 for a meta-analysis). Moreover, brain activation patterns for different executive processes are marked by overlapping regions, symbolizing this interrelation (for INH, WM, and CF; Collette and Van der Linden, 2002). The current study has classified the three core EFs according to the predominant definitions in the literature.

Inhibition. INH refers to the restraint in self-control (Diamond, 2013), relied on to voluntarily inhibit an automatic response (Miyake and al., 2000b). INH also allows us to focus our attention on a chosen target and resist to distractions from the environment or inner thoughts (Henrard, 2021), for example when reading a book, INH allows thoughts about chores to be ignored and attention to be focused on the text. When INH is lacking, behavior will reveal impulsivity, incorrect responses, automatisms, and sensitivity to distractions (Blair and Ursache, 2011; Henrard, 2021). For example, in class, INH makes it possible to refrain from answering automatically and allows to raise your hand and waiting to be chosen before given the answer out loud.

Working memory. WM allows to mentally manipulate information (Henrard, 2021) and update it with new information over a brief period (Blair and Ursache, 2011; Miyake et al., 2000b). For example, when listening to a conversation, WM helps retain, manipulate, and update information along with new information which allows us to understand what is explained. In doing so, it is possible to find meaning and adjust our behaviour accordingly (Henrard, 2021). WM thus allows to process information that is no longer available, for example, mentally calculating the amount of tip to give according to a bill (Diamond, 2013).

Cognitive flexibility. This EF refers to alternating between mental representations or actions (Miyake et al., 2000b). CF is the ability to adapt to change easily and is expressed through creativity, and changed perspectives (Diamond, 2013). In everyday life, individuals rely on CF when trying to understand someone else's perspective or adopting different paths to get to the same destination (Diamond, 2013).

Miyake et al. (2000a) also reported the diversity of cognitive tasks used to measure each function and their respective limits. Since tasks vary widely and solicit different cognitive processes, the adequacy of the tasks and the functions considered to be measured by these tasks could be interesting to analyse.

Considering the various findings summarized above and the lack of consensus apparent in the literature, the effect of BGM on core EFs remains unclear and reveals the need for a systematic literature review that also includes a scoping of the grey literature. This endeavour appears essential, as studies on the topic are emerging in growing numbers, and music is continuously spreading with the numeric revolution drawing back frontiers to music listening. A better understanding of BGM's effect is fundamental to frame future research exploring this theme and guide recommendations surrounding the already widespread use of music in the context of executive demand (e.g., while studying, working, driving). Compiling studies with particular attention paid to musical parameters, individual characteristics, and task-specific variables seems essential.

First objective of this review: Catalog performances on measures of INH, WM, and CF with BGM compared to a control (group or condition) in the healthy adult population. ***Second objective:*** Identify moderating variables of BGM's effect on EFs, such as musical parameters (e.g., tempo) and individual characteristics (e.g., musical expertise). ***Third objective:*** Examine the adequacy of the neuropsychological tasks or experimental paradigms used to measure EFs. ***Fourth objective:*** Guide future studies investigating the use of BGM in executive functioning contexts.

Methods

To ensure transparency and accuracy, the reporting of this systematic review is based on the Preferred Reporting Items for Systematic Review guidelines (PRISMA 2020; Page et al., 2020), an update of the PRISMA method (Moher et al., 2009). The Population, Intervention, Comparator, Outcome (or results) method, known by the acronym *PICO*, is commonly used to define eligibility criteria (see PRISMA 2020 for an introduction; Liberati et al., 2009; McKenzie et al., 2019) and is suitable for research questions targeting research practices (Santos et al., 2007). To establish what is known concerning the effect of BGM on core EFs in healthy adults, the PICO items below that define the eligibility criteria for the present review are inspired by the PRISMA (2020) recommendations and Santos and colleagues (2007):

Population.

- Healthy populations.
- Adults aged 17 to 65 and over. To allow for a broader inclusion of studies, a data-driven cut-off was set at 17 years of age in this review and included four additional studies. When studies had multiple groups only those of adults 65 or younger were reported.
- When studies explored distinct groups separately, only groups corresponding to the inclusion criteria (e.g., adults) were considered in the review.
- Participants with no extensive musical expertise, or non-professional musicians (no professional musicians or music students).

Intervention.

- Experimental or quasi-experimental study designs.
- Instrumental music (or instrumental versions of songs) presented during task completion.
- Tasks measuring EFs.

Comparators.

- Different control conditions (e.g., nature sounds, noise) or comparison to silence.
- Control conditions were not required but were favored in the quality assessment.

Outcomes.

- Performance reported on behavioural measures [e.g., response times (RT), error rates (ERR), correct answers].

Exclusion criteria.

- Reported psychiatric, neurological, or medical disorder.
- Musicians and university music majors.
- Music presentation solely before the task.
- Musical interventions (i.e., weekly program of musical intervention) or musical training (e.g., music practice over a given period).
- Case studies, systematic reviews, or meta-analyses.

Finally, studies written in French or English were included, which could be assessed by the main author and laboratory members. Studies in other languages were not included for analysis.

Information sources. *Databases.* First, a systematic review of the articles was carried out using four specialized databases, chosen for their relevance to the themes covered by this review and for the extent of this coverage: *PsycINFO (APA Psycnet),* specialized in psychology, *Web of Science (ISI),* a multidisciplinary database, *RILM Music (EBSCO)* and *Music index online (EBSCO),* which are specialized in music. Secondly, a non-systematic search was conducted with the help of the search engine *Journal Storage (JSTOR),* specialized in music. Finally, *Google Scholar* and *Proquest UdeM (ProQuest Dissertations & Theses Global),* listing dissertations and theses, were also surveyed to collect relevant studies of the field, including the grey literature. This set of databases was chosen in consultation with librarians Dominic Desaulniers and Christiane Melançon, respectively dedicated to psychology and music at the University of Montreal. This systematic review covers all years up to July 22nd, 2022.

Search strategy. The selected keywords made it possible to identify the most appropriate articles for the evaluation of the considered EFs (INH, WM, CF) in conjunction with BGM. The search formula used to probe the systematized databases contains English keywords separated with Boolean operators and truncators (see Appendix A for the full formula). The identification of keywords and decision rules for the inclusion of articles was carried out by the main author in collaboration with the supervisor of the systematic review, Nathalie Gosselin, and the librarians Dominic Desaulniers and Christiane Melançon.

Data collection process. *Screening and admission of studies.* After the search formula was launched in the different databases, the resulting data was imported into the EndNote bibliographic reference management tool (version X9.3.3; Clarivate Analytics, 2020). The decision-making process was based on the PRISMA 2020 flow diagram for new systematic reviews which included searches of databases, registers, and other sources (see Figure 1, Page et al., 2021). At each stage, the number of articles selected was indicated, allowing the step-by-step selection process to be detailed. In addition, articles collected through non-systematic research by consulting additional sources already known to the author that fit the topic were indicated in parallel. All references were screened independently by the main author and one of four laboratory members (AR, EP, JP, VM), referred to as interjudges hereafter. First, duplicates were removed both automatically by the software and manually verified. Second, screening was conducted based on titles and abstracts according to the inclusion and exclusion criteria. References were categorized as “included”, “excluded”, and “uncertain.” The studies retained and those rejected by each of the interjudges were compared. Those subject to indecision or conflict of decision were first discussed between the two interjugdes as an attempt to reach consensus. Eventually, if no consensus was reached, the third interjudge (NG), discussed the final decision with the main author and arbitrated the decision.

Finally, articles that reached interjudge agreement for inclusion were retrieved for full-text screening and to extract data. When necessary, the main authors were contacted by email to obtain missing information. References from articles admitted in the systematic review were also screened when relevant.

Data items. The references that were included based on the PRISMA decision-making flows and the interjudge consultations were exported into an analysis grid to collect data. For each reference, the following data was collected when available:

- Information concerning the study: authors, year of publication, journal of publication, title, written language.
- Population's characteristics: sample size, age, sex/gender, musical expertise.
- Objective.
- Study design.
- EF tasks: function evaluated; type of task: standardized tasks, experimental paradigms, laboratory-made tasks, or performance assessment tools.
- Auditory conditions (musical conditions, control conditions, e.g., nature sounds, noise, silence).
- Musical parameters (e.g., musical style, tempo, mode, intensity, instruments, music selection method).
- Outcome measures (e.g., mean and standard deviation, response time, error rate).

(Insert Figure 1 here.)

Risk of bias assessment. Reduction of potential biases is ensured by estimating the quality of the studies, thus preventing compromise of the review results and their interpretation. This critical analysis of the methodologies was conducted by the first author who extracted the data, then verified by the second (NG). The Critical Appraisal Skills Programme (CASP; 2020) was used to categorize studies according to a scale of risk based on the answers to the questions of a defined checklist. The checklist for randomized clinical trials (RCT; CASP RCT Checklist) seemed most appropriate for the present review, since it applies to quantitative experimental studies, including the comparison of outcome in different group conditions. Applies to our review, this checklist offers examination of studies comparing quantitative outcomes measured by EFs tasks in different auditory or musical conditions. The CASP RCT Checklist was modified for this review and a points allocation system used to judge the quality of the methods according to 11 items (see Table 1 for the full list). The following items cover topics such as randomisation, methodological transparency, and clarity: *1. clear and focused research question, 2. random presentation of conditions to participants / random assignment of participants to groups, 3. all participants counted from recruitment to results, 4. equivalence of initial groups (characteristics), 5. study protocol clearly defined and equivalent treatment of participants, 6) extensively reported effects of music, 7. confidence intervals or estimation of effect sizes, 8. sample size stated, 9) comparison to a non-musical baseline condition (control condition or group), 10. correspondence between the tasks used and the functions assumed to be measured by these tasks, 11. description of the musical material.* A point was awarded when the criterion was met by the study (using "yes," "no," "not applicable"), summing to a quality score ranging from 0-11. When an item was not applicable, a ratio was calculated to convert the score to the 11-point scale. Finally, quality was categorized as (a) high, if the score was greater than or equal to 9, (b) moderate, if the score was between 6 and 8 inclusively, or (c) low, if the score was less than or equal to 5.

(Insert Table 1 here.)

Results

Study Selection. A total of 35 studies met the inclusion criteria and were included in this review (see Figure 1 for the full PRISMA 2020 flow diagram). The four systematic databases provided 537 citations; after duplicates, records written in languages others than English or French, and authorless references were discarded, 404 citations remained. After reading the abstracts, 331 references were excluded because they did not concern our research topics and did not meet the criteria. Two studies were discarded because they could not be retrieved. The full text of the remaining 71 studies were reviewed, and 22 studies met the inclusion criteria for this systematic review. Additionally, 5 studies were identified through the reference sections of included papers, 2 studies were known references, and 3,470 studies were found on *Google Scholar*, *Proquest UdeM* and *JSTOR*. Of those, 57 records were assessed for eligibility and 13 references met the criteria, bringing the total of included studies to 35. A few authors were contacted for further information concerning their methods (i.e., age range, musical description) to elucidate inclusion or exclusion of their studies, and when possible, the clarifications were included (i.e., age range: Kumaradevan et al.; 2021, and Xiao et al., 2020). Studies that comprised participants older than 65 years old or that used lyrical music were selectively analysed and only groups (e.g., adults) and conditions complying with inclusion criteria (e.g., instrumental music or song without lyrics) were reported.

Study characteristics. All studies were randomized designs, except for two studies that were quasi-experimental (Kumaradevan et al., 2021; Villamizar et al., 2020). One article was a preprint (Villamizar et al., 2020), all others were published. Since some studies used more than one experiment, sometimes evaluating both INH and WM, the total experiments reported is greater than the number of included studies. Sixteen experiments had explored INH (n=858), and 21 (n=1748) had examined WM. Since only three studies had investigated CF, this function was not further analyzed. The main list of principal characteristics extracted from the 35 studies is summarized in Table 2. As you can see, most of them had tested the participants in an individual laboratory setting, while two studies tested in small groups, and one study tested all participants simultaneously. The population ranged from 17 to 48 years old, though some studies did not report this information. Gender was not systematically collected, but when data was available males and females were detailed in Table 2. The population of 46% of studies were constituted of students. Only two studies examined personality. Particularly these studied the effect of music on EFs and compared extroverted to introverted participants (Taheri et al., 2022) or compared participants with extroverted, introverted, and ambiverted traits (Barnes, 2002). Concerning interventions (or the musical material, and measures of the EF used), most studies used classical music (n=25), although pop, electronic, drum percussion, and film music were represented as well. Some musical materials were composed specifically for the experiment, most were original soundtrack (existing music), and others were manipulated to fit different tempi or remove lyrics of a song. INH and WM were measured with experimental paradigms, neuropsychological tests, tools created by the researchers, and performance examination tests that include College admission standardized tools (e.g., the Scholastic Assessment Test (SAT) or the Test of English as a Foreign Language (TOEFL), a reading comprehension tool). All tasks were visually presented. Comparators included primarily silence, followed by nature sounds (e.g., murmuring of a stream) and noise as controls for instrumental music. Studies examining the effects of different level of tempo (Burkhard et al., 2018; Chen, 2019; Cloutier et al., 2020; Dove, 2009; Du et al., 2020; Gann, 2021; Nadon et al., 2021; Petrucelli, 1987; Thompson et al., 2011; Xiao et al., 2020) compared performance between silence, slow tempo, and fast tempo. Reported outcomes often concerned response times (RT), error score (ERR) or accuracy (ACC), reading comprehension score relating to correct responses (for WM), and interference score (for INH, i.e., RT when resisting distraction - RT when there is no distraction to inhibit = interference score).

(Insert Table 2 here.)

Risk of bias within studies. The mean quality score for the 35 studies included is 8.91/11 (see Table 1 for detailed description of scores). Overall, the assessment of quality of these studies reveals a moderate to high quality in most studies. Specifically, a total of 23 studies (65.7%)

obtained a score equal to or higher than 9 and were ranked "High quality". Further, 11 studies (34.3%) were ranked as "Moderate quality" (i.e., scores between 6 and 8). When analyzing the different criteria more precisely, most studies described a clear and focused research question and defined their study protocol with precision. Additionally, most studied did randomly assign participants to groups or conditions and compared performance to a non-musical condition. Thus, studies could be replicated in the future. Sample size was declared, all participants were counted from recruitment to results, and treated equivalently, and effects of BGM were extensively reported. Most research teams demonstrated transparency and sufficient exploration of their results by reporting their statistical analysis and analysing each outcome presented. However, a few quality criteria were present in less than 70% of the studies, such as criterion 4. *"Extensive reporting of initial groups"* (63.89%), criterion 7. *"Confidence intervals or estimation of effect sizes"* (58.33%), and criterion 10, *"Correspondence between the tasks used and the functions assumed to be measured by these tasks"* (63.89%; see Table 1). This last criterion could be met with well-known experimental paradigms (e.g., listed by Diamond, 2013) or neuropsychological tasks recognized to assess three core EFs (e.g., cited in reference manuals in neuropsychology, like the *Neuropsychological Assessment Manual – fifth edition;* Lezak et al., 2012). However, in the studies reported here it seems those having a lower score could be bettered by reporting data with more precision. Overall, the quality of the methods employed is rated well and the evidence explored in this review is of satisfactory quality in general.

Results of included studies

The upcoming sections will present the findings and shed light on the musical factors influencing the observed effect of BGM on performance, along with factors related to tasks and population.

Firstly, the results will be presented according to EF and the impact of BGM, beginning with INH, and followed by WM.

Inhibition

As you can see in Table 3, BGM's effect on INH is non-consensual. BGM conditions were facilitative for 3 INH experiments, while a non-significant effect was represented in 9 experiments, and impairment was seen with 5 INH experiments. Globally, INH appears predominantly unaffected by BGM. Furthermore, Cloutier and colleagues' (2020) study reported multiple effects of BGM with 21 adults (M=23.95, SD=3.51) performing a Flanker Task and a study High-quality score. This study found no significant effect when stimulating and pleasant background music (with a fast tempo and composed in major mode) compared to silence (see Table 4). Performance was impaired, i.e., slower RT, when music was relaxing and pleasant (with a slow tempo and composed in a major mode) compared to silence and stimulating music. This article will be examined into distinct sections, separating the effects of music on INH in the non-significant and impairment sections. As you proceed, you will notice that certain task-specific factors, individual characteristics, or musical parameters are associated with more than one effect. Thus, subsequently INH studies will be examined in relation to music's effect on performance.

(Insert Table 3 here)

Facilitative effect

For three studies, a beneficial effect was observed with BGM (n=155, see Table 4). INH is facilitated by BGM with the Stroop Color and Word Test (Kumaradevan et al., 2021), a modified Attention Network Task (ANT; Fernandez et al., 2019), and a task of linguistic and spatial processing (Angel et al., 2010; see Table 4). The beneficial effect in Angel et al.'s study (2010) was shown with fast tempo classical music for accelerated RT and improved ACC. In Fernandez and colleagues' study (2019), acceleration of RT was observed with joyful rather than sad and compared to silence. This effect was noticed with soft classical music for Kumaradevan's team (2021). All these studies had tested younger adults.

(Insert Table 4 here)

Non-significant effect

Nine studies reported non-significant effects of BGM on INH performance (n=604, see Table 4). In terms of chosen measures of inhibition, most of those studies had used a Stroop task (Villamizar et al., 2020; Kim, 2022; Nadon et al., 2021; Petrucelli, 1987; Venkata Krishnam Raju, 2018) or the similar Colour-Word Remapping from the Cambridge Brain Science Battery (Myles, 2017). Other studies opted for the Go/No-go task of the Visual Cognitive Performance Task (Burkhard et al., 2018) or the Flanker task (Cloutier et al., 2020; Oliver et al., 2021). Regarding the Population, samples concerned by the non-significant effect of BGM include adults aged 17 to 39 years old, or university students (age not reported). Finally, two studies with no significant impact on INH had used musical stimuli that had classical music with positive valence (Kim, 2020; Venkata Krishnam Raju, 2018). Another common factor was arousal, both stimulating classical music (Cloutier et al., 2020), and music at different levels of activation, ranging from very relaxing (60 bpm), relaxing (80-110 bpm), stimulating (110-150 bpm), to very stimulating (150 bpm or more; Petrucelli, 1987), were associated with non-significant influence of music on performance. Moreover, facilitated performance was reported with both slow and fast tempo (Burkhard et al., 2018; Nadon et al., 2021). Also, music with various sound intensities (dB) were associated with no significant effect, as music with low, optimal or high intensity was presented in Oliver et al.'s study (2021), Furthermore, this non-significant effect was observed with music that was unfamiliar, as Myles (2017), Petrucelli (1987) and Villamizar (2020) showed in their respective studies where performance was unchanged with unfamiliar music.

Impairment

Music was found to impair INH in five studies (n=130; see Table 4). Regarding selected INH measures, BGM has a detrimental effect on performance when tools such as the Flanker (Cloutier et al., 2020; Rowe et al., 2007), the Simon (Klempova et al., 2018), the Antisaccades (Strukelj et al., 2016) and the Go/No-go tasks (Xiao et al., 2020) are employed to measure INH. Firstly, a determinant variable is the relaxing aspect of music that is associated with slowed response times compared to stimulating music (Cloutier et al., 2020) and silence (Cloutier et al., 2020; Klempova et al., 2018; Strukelj et al., 2016). Moreover, a tendency to favor accuracy to speed in a speed-accuracy trade-off is observed, while slowed RT were associated with soft BGM, compared to silence (Strukelj et al., 2016). Possibly, this result might be explained by the study's methodology, which omitted the specific instruction to respond as fast as possible. Another determinant factor concerns tempo. When the tempo was manipulated to be very fast, music lessened the capacity to inhibit a response in the no-go condition and impaired response accuracy (Xiao et al., 2020) compared to slow tempo music. INH was also impaired as response times were faster in the no-go condition with fast tempo music compared to music with moderate tempo, slow tempo, and silence (Xiao et al., 2020). These results were also significant for moderate and slow tempo music compared to silence (Xiao et al., 2020). Besides, regarding musical emotions, a positively valenced jazzed-up classical music also slows response times (Rowe et al., 2007), as well as impairs INH as demonstrated by a larger interference effect compared to sad music and the condition inducing a neutral emotion, which would be moderately pleasant and arousing according to Russel's Model (in this case, facts about Canada). Regarding the participants, studies obtained impaired INH performances with young adults (range 18-35 years old) or university students.

Working Memory

Referring to Table 3, it was primarily observed that music had no significant effect on WM performance (n=14 experiments). Performance on most of the WM tasks was non-significantly affected when examined with BGM, with four studies indicating impairment, and seven studies reporting facilitation. Additionally, two studies documented more than one effect on WM performances. Namely, Thompson et al.'s (2011) article reported music in major mode with slow tempo/soft volume, slow tempo/loud volume, and fast tempo/soft volume had no significant effect on reading comprehension (WM) compared to silence, while scores were impaired with fast tempo and loud BGM compared to other musical conditions and silence (Thompson et al., 2011). In this study, the loudness of music (measured in decibels, dB) and tempo seem to play a determinant role on reading comprehension test from the Graduate Management Admission Tests (GMAT; Thompson et al., 2011). Palmiero et al.'s study (2016) also showed both facilitated and not significantly affected performance. They found music with positive mood facilitated performance on the Corsi block-tapping task backward condition compared to music inducing neutral mood and negative mood (Palmiero et al., 2016). Whereas performance on the Corsi walking test backward condition, where participants recall a path by moving across blocks arranged on the floor (Palmiero et al., 2016), was not significantly affected by BGM. As previously stated in the INH section, these articles will be examined into distinct sections according to BGM's effect. As you continue, you will notice that determinant factors and parameters might be linked to multiple effects, as WM experiments are described by BGM's effect.

Facilitative effect

Seven studies presented findings in which WM was facilitated by musical background (n=317, see Table 5). Of these samples, the majority concerned participants aged between 18 and 42 years old, and some samples included undergraduate and graduate students. Relatively to instrument selection, studies opted for the N-Back paradigm (Gann et al., 2021; Sun et al., 2011; Taheri et al., 2022), the standardized Corsi block-tapping task and Corsi walking task (Palmiero et al., 2016). Fewer studies elected laboratory-made tools comprising a written verbal reasoning task (Sutton and Lowis, 2008), spatial processing tasks (Angel et al., 2010), and an Algebra ability instrument (Namwamba, 2012). One determinant variable underlining the facilitative effect for WM across these studies is the classical genre (Angel et al., 2010; Gann et al., 2021; Namwamba, 2012; Sun et al., 2011; Sutton and Lowis, 2008; Taheri et al., 2022). Also, a few elements associated with a facilitative effect are the same for WM than for INH, namely music inducing a positive mood (Palmiero et al., 2016), and music composed in major mode (the written verbal reasoning task; Sutton and Lowis, 2008). Furhtermore, similar to INH, WM was facilitated with music characterized by fast tempo (Angel et al., 2010; Gann et al., 2021), and slow tempo (Gann et al., 2021). Lastly, a musical variable associated with a facilitative effect on WM was loud volume (dB; Namwamba, 2012).

(Insert Table 5 here)

Non-significant effect

Music was presented with a non-significant effect on WM in thirteen studies (n=1240, see Table 5). Samples concerned by these results include adults aged 17 to 33 years old, and college students. Regarding the assessment tools selected to examine WM, most experiments related to reading comprehension such as the SAT (Barnes, 2007), the TOEFL (Chou, 2007), the Nelson Denny Reading Test (Dove, 2009), the Graduate Management Admission Tests (GMAT) reading comprehension test (Thompson et al., 2011) and a reading comprehension test similar to the GRE (Haning, 2016). A few studies opted for linguistic processing task created for their studies (Du et al., 2020; Mairal et al., 2015; Patston et al., 2011) and visual comparison of the lateralization and composition of a picture and the retained sample pattern (Yang et al., 2016). These tasks rely on the manipulation aspect of WM to process the retained information for a short period, updating it with new information, and selecting an answer accordingly. A small number of studies used standard WM tests, such as the N-back task (Bluelow et al., 2022; Chen, 2019), the Self-Ordered Pointing Task (Bluelow et al., 2022), the Corsi Walking test (Palmiero et al., 2016), and the verbal reasoning task and spatial rotation from the Cambridge Brain Science Battery (Myles, 2017).

Music from the classical genre was most represented (Barnes, 2002; Bluelow et al., 2022; Chou, 2007; Dove, 2009; Haning, 2016; Patston et al., 2011; Thompson et al., 2011) as not significantly influent. Additionally, music from the pop genre (Iwanaga et al., 2002; Mairal, 2015) had no significant effect on WM. Also, these studies reported that major mode (Haning, 2016; Thompson et al., 2011), stimulating and relaxing tempo (Dove, 2009; Du et al., 2020), and drumbeats at different tempos (120, 110-140) and tempo shifts (constant, gradual, syncopated, time signature shifts; Chen, 2019) were not significantly associated with and effect on performance. Moreover, WM measured by the Corsi walking test was not significantly affected by positive and negative moods, compared to the neutral mood condition (Palmiero et al., 2016).

Furthermore, the presence of errors manually added to the music did not affect WM (Patston et al., 2011) for non-musicians. Hence, musical stimuli that had non-significant effect on WM performance also comprised unfamiliar songs (Du et al., 2020; Myles, 2017). Moreover, complexity did not appear to be determining either, as evidenced by Barnes (2002) whose music described as high-complexity and low-complexity was associated with similar performance. Finally, RT were similar when performance was measured with tonal music in C major and atonal music composed for the study, which vary in tonality, i.e., have different organization of keys and tones (Yang et al., 2016).

Impairment

Four studies presented WM tasks where performance was impaired during BGM (n=153, see Table 5). The tools selected to assess WM in these studies comprised laboratory-made tasks relating to word recognition (Iwanaga et al., 2002), email comprehension and answering as a part of ecological deskwork tasks (Young and Nolan, 2015). One study relied on standardized tasks like the Self-Directing Signaling Test from the Executive and Frontal Lobes Battery (Villamizar et al., 2020), and another on a performance assessment test, namely the Graduate Management Admission Tests (GMAT) reading comprehension test (Thompson et al., 2011). Among those, one study reported music from the pop genre (Iwanaga et al., 2002) impaired ACC when compared to silence, and another observed that music in major mode from the classical genre impaired WM performance (Young and Nolan, 2015). Furthermore, loudness was also identified as impairing when music described by the authors as cinematic string (played by string instruments and composed for a film score) reached 74-78 dB compared to a no music condition (20-30 dB; Villamizar et al., 2020) and when music was identified as loud with a fast tempo, compared to baseline and other conditions (slow tempo/soft, slow tempo/loud, fast tempo/soft; Thompson et al., 2011). These results were obtained with participants aged 17 to 48 years old.

In the subsequent sections, results are revisited for INH and WM conjunctly, starting with an emphasis on quality score of studies. Then intervention-specific analysis (music followed by task specific), and finally population-specific analysis will be detailed.

Quality score analysis

Analyzing these findings according to quality estimation based on our adapted CASP checklist may weight confidence in the respective conclusions put forth. High-quality studies (n=23) mostly reported a non-significant effect of music across both INH (n=6) and WM (n=9), followed by impairment effect on task performance (INH n=4; WM n=2), and fewer high-quality studies reported a facilitative effect (INH n=1; WM n=3)[1]. Studies evaluated as moderate quality (n=11) were more dispersed. The reported effect of BGM on tasks was mainly beneficial (INH n=2; WM n=4) or non-significative (INH n=2; WM n=3), and fewer were impairing (INH n=1; WM n=3). Therefore, with higher quality methods, a smaller proportion of studies report beneficial effects of BGM compared to moderate quality, and studies who report no significant effect of BGM on EFs are prevalent.

In the following, results for INH and WM are analyzed together through the lenses of musical material specificities. These parameters are generally reported in a little number of studies and entail a cautious interpretation.

Music-specific analysis

In this section, experiments for both INH and WM are compiled together. Studies included in this review revealed disparities concerning reported musical parameters, which impacts the extent of comparability between experiments. Concerning tempo variations between conditions, slow tempo was associated with beneficial (n=1), but mostly detrimental (n=3) and non-significant (n=3) effect in the reported experiments. A similar pattern emerged for fast tempo/stimulating music. Experiments employing fast tempo as BGM reported beneficial effect (n=1), detrimental effect (n=3), and a null effect (n=4) on performance. Moreover, one study using BGM with moderate tempo concluded to its detrimental effect on performance. A single study examined the effect of different tempo shifts on performance, which was not a conclusive parameter as performance was undifferentiated between conditions. This parameter can be difficult to examine without also considering musical emotions. When examining emotions, very relaxing music was

[1] Sum of INH and WM studies for each quality category might differ from total studies because some studies have more than one task.

observed with no significant effect on performance (n=1), which was also reported with very stimulating music (with very fast tempo, n=1). Furthermore, studies where BGM was in major mode often induce a positive mood. These studies were sometimes associated with a beneficial effect on EF performance (n=7), yet positive mood and major mode were also shown to impair performance (n= 3) and have no-significant effect on EFs performance (n=4). Considering these parameters were not available for many studies even though they are potentially important in modulating emotions, the non-consensual effects collided here are partial.

On the other hand, when experiments were conducted using unfamiliar music or music specifically composed for the studies (n=4), BGM no significant effect was observed on performance. The authors did not verify the familiarity of participants with these excerpts, possibly because the excerpts were specifically composed for the studies. Since this factor is only scarcely reported in the included studies, the analysis of familiarity's influence on BGM's effect on EFs is incomplete.

Two studies (Nadon et al., 2021; Rowe et al., 2007) added an induction period before the task was completed with BGM. This rare design feature was associated with a beneficial effect on INH for Rowe and colleagues (2007) when realised with jazzed up classical BGM but had no significant influence on a WM task. Their induction phase was 10 minutes before task and a 2-minute induction booster between EFs tasks. Nadon et al. (2021) did introduce music before administering their EF measure, but an 8000ms duration is insufficient to be considered as an induction phase. Here again, studies including induction of emotions are scarce and interpretation is limited.

Lastly, one study manipulated the original pop song from Adele "Someone like you", removing lyrics and adding either a piano or violin melody (Mairal, 2015). This BGM had no effect on WM performance, meanwhile it's comparison with the remaining studies is strenuous since the removed lyrics factor is hardly interpretable without further comparable studies, considering lyrics's impairing effect on cognitive performance (Cheah et al., 2022).

After examining musical determinants, the following analyses proceed to examine the effect of BGM based on tasks-specific characteristics.

Task-specific analysis

When studies were examined addressing the task-specific variables, the origin of the tools used appeared to influence the outcome of BGM's influence on EFs (see Table 6 for details). In fact, studies were classified in order as standardized tasks, experimental paradigms, laboratory-made tasks, or performance assessment tools.

First, standardized tasks refer to tools that conform to a standard and are commonly used in the neuropsychological assessment, such as the Corsi block tapping test and the Stroop task. In total, 10 experiments were identified as falling under this category. Of these, 2 reported a beneficial effect of BGM on performance (INH n=1 and WM n=1). Impairment was reported with 1 standardized task assessing WM. Finally, BGM had no influence on performance for 8 experiments using standardized tasks, mostly for INH (n=6) and WM (n=2). Second, instrument measures were classified as experimental tasks when they were developed based on cognitive from the cognitive paradigms, i.e., study of cognition and how the brain works, and tested on participants. These tasks are generally comparable to neuropsychological tasks but are rather applied in the research contrary to standardized tasks which are frequently encountered in the clinical field. Popular experimental tasks include the Flanker task, the Go/No-go task, and the N-Back task, as listed by Diamond (2013). The studies included in this review presented 6 experimental tasks for which BGM had a facilitative effect (INH n=2 and WM n=4). BGM impaired performance in 4 instances, when INH was assessed. Finally, BGM had no significant effect on performance for 4 experimental tools, measuring INH n=2 and WM n=2. One study showed both impairment and no-significant effect of music on ING. Third, the laboratory-made tasks included tools developed for the study by the investigators, that are not based on known experimental paradigms per say. For example, in this review, a study included a desk-work environment were emails had to be read and correctly responded to, these instruments are not specifically supported by a cognitive paradigm per say. For these, BGM facilitated (n=2), impaired (n=2), and had no significant influence (n=3) on WM performance. Additionally, one study reported both no-significant effect or impairment of performance with BGM (WM). Fourth, five studies used performance assessment tests to record reading comprehension. These measures are standardized for academic classification and admissions, and not specifically for neuropsychological assessment, (e.g., the reading comprehension test from the Scholastic Aptitude Test). In this review, only one study found BGM had both impaired and had no significant effect on performance (WM). Finally, four studies found BGM had no significant effect on WM performance as measured by performance assessment tests. The majority of laboratory-made and performance assessment tools assessing WM also solicited arithmetic skills, reading comprehension skills, and verbal or spatial reasoning.

(Insert Table 6 here)

Population-specific analysis

In the present review, few studies reported results based on sex or gender. Sutton and Lowis (2008) concluded that females performed better on a verbal reasoning task (WM) when BGM expressing positive emotions in major mode was playing, compared to minor mode musical background. This influence of BGM was shown for females only and was not observed for males suggesting sex-differences in the effect of BGM. Taheri and colleagues (2022) have also identified modulations between males and females. Their results demonstrated gender differences, as accuracy (ACC) and response times (RT) in a WM task were facilitated to a greater extent for extraverted females when listening to classical BGM compared to extraverted males. They also observed extraverted participants had improved ACC and faster RT compared to introverts with BGM. However, Barnes' (2002) results did not vary according to personality (extroverts, introverts or ambiverts).

Having examined the findings, the discussion section will offer a comprehensive exploration of the main results and their relation to the existing literature and future perspectives.

Discussion

This systematic review aimed to clarify the effect of BGM on core executive functioning by offering an updated portrait of the current literature by describing the main reported outcomes, the musical and auditory conditions, EF tasks administered, and population. To this aim, results were first approached by function-specific analysis (INH, WM), then by music-specific analysis (e.g., genre, tempo, valence), and population-specific analysis (e.g., age, recruitment setting). Furthermore, quality-specific analyses were conducted as well as task-specific analyses (task source, correspondence between task and function).

As foreshown by the literature overview presented in the introduction, which encouraged the pursuit of this present review, the evidence gathered reflects a tripartite effect of BGM on EFs. Appropriately, facilitative, and impairing effects where gathered, and non-significant effects were predominant for INH and WM. Overall, examined according to study-quality, higher quality studies tended to present BGM as having no significant effect on executive performance. Facilitated EFs was the least represented outcome for INH, but did find some support among moderate and high-quality studies for INH and WM. BGM impairing performance was the least represented effect of music for WM. Since both INH and WM have shown all three influences of music, the effect of BGM on performance will be described for both functions jointly. A possible publication bias might contribute to the representation of significant results in the studies identified by this systematic review, even though non-published studies were sought through grey literature databases.

Describe the effect of BGM on EFs.

The primary question seeking clarification was BGM's effect on EFs. Coherent with reviews on the effect of music on cognitive functioning published so far (Kampfe, 2011; Cheah et al., 2022), mixed effects were found with our systematic review. In whole, rather non-significant effects were reported for EFs, but still there are situations where beneficial and detrimental effects were observed. For INH and WM, this review enlightens the tendency that studies identified BGM's facilitative effect with positive and with stimulating music (fast tempo). Studies included in this review reporting impaired performances were most frequently associated with relaxing (slow tempo) BGM. Nevertheless, no characteristics were exclusively associated with a single effect on certain tasks or function, conversely multiple effects are observed with each variable for both EFs reviewed. As for detrimental effects, the slowing of response is one outcome identified in the context of the studies involved. However, in other contexts, the slowing of response could reflect a beneficial effect of BGM. For example, in the case of the stress response, the physiological activation attunes to the relaxing music and conveys a less stressed and more pleasant state to the listener (Bellier et al., 2020; Felszeghy et al., 2023) might support a beneficial slowing of response with BGM. In this optic, we are reminded that the intended use of BGM is context-dependant and so is its effect. As performance appears as one of many outcomes of interest seeking facilitation by BGM, it could be interesting to investigate stress and anxiety regulation (see de Witte & al., 2022 for a meta-analysis) and perception of effort (for example Devine, Vassena and Otto, 2022) during a cognitive task.

Interestingly, some **musical parameters** did influence EFs performance as tempo and mode (important parameters for musical emotions) were described in many studies. Hence, slow tempo and fast tempo were both mostly paired with null and detrimental effects, while beneficial impact was underrepresented. Sometimes, fast tempo music impaired accuracy in inhibitory control facilitating initiation of response (faster response times in no-go conditions). Nonetheless, music-specific analysis revealed that the following parameters were scarcely examined or reported, namely familiarity, sound intensity (volume, dB), and music manipulated to remove lyrics. With the available data, these factors seemingly had no influence on EFs performance.

Examining these findings prompts a reflection on the theories that underlie common assumptions in the field of music and cognition. According to the **Arousal-Mood Theory**, arousing and positively valenced music benefits cognition (Schellenberg and Weiss, 2013; Thompson et al., 2001). Results suggested by studies included in our review somewhat support that claim, for facilitative effect on INH has been observed with the elevated activation and positive valence of music. However, many studies reported no differential effect based on tempo and emotional characteristics of music. Some of this variability might be explained by individual characteristics, such as initial mood and emotional state at baseline. Nevertheless, as mentioned, these factors were not monitored prior to testing. Taken together, music-specific analysis reported results that only partly support the Arousal-Mood Theory and not specifically; by linking high arousal to a facilitated outcome in some instances, but not all. Additionally, positively valenced music was associated with a facilitative effect, although not exclusively. Perhaps, the fact that many parameters vary across studies, and sometimes the musical stimuli were described with only one of the two pillars of the Arousal-Mood theory complexified cross-study comparisons. Whether tempo (bpm), mode (minor, major), emotional valence, musical genre, sound intensity level (dB), instruments, musical determinants were not systematically reported, thereby limiting the comparability of conclusions and our understanding of BGM's effect.

Given this mitigated support for a well-established theory, conducting a comparison with **recent reviews** to determine if they yield similar conclusions could provide valuable insights and enhance our understanding. When comparing our review with Cheah and colleagues' (2022) recent review on the topic of BGM and cognitive performance, the overall quality of our 35 included studies appears alike their generally satisfactory quality of studies. Regarding executive domains, while some INH studies were reported in both our reviews, Cheah's and collaborators method for processing results concluded to no significant effect of BGM on performance of this EFs. In our review, results suggest mainly neutral effect of BGM and are consistent with those of Cheah and colleagues' (2022) review, which reported no significant effect of BGM for many cognitive domains including inhibition. However, memory-specific tasks in their review include various functions related to memory, such as encoding, retrieval, recognition, long-term memory and working memory and were found mostly impaired by BGM. Whereas WM in our review is found to be mostly unaffected (n=12) or facilitated (n=8) when examined in conditions with BGM, and impaired in only a few instances (n=5). Thus, our review does report beneficial and impairing effects as well and our conclusions are less categorical, but specific to WM in contrast with Cheah and collaborator's review.

Discrepancies between our reviews might emerge from specificity of cognitive domains explored and the fundamental conceptual models relied on. Some limits of Cheah et al.'s review concern the lack of theoretical perspective. While their description of the literature is remarkable, and their analysis and integration of included studies is exceptional, fundamental theories could have supported some methodological decisions. Precisely, their classification of WM in the memory domain with short-term and long-term memory, rather than in EFs is questionable. While many may argue WM should be considered an executive process (Collette et al., 2005; Diamond, 2013; Henrard, 2021; Miyake et al., 2000b; Vaughan and Gionavello, 2010), considering the manipulation of information essential in WM which is correlated with executive processes in Miyake's model (2000b) and their related brain activation (Colette and Van der Linden, 2002). On this topic, seemingly no conceptual model supported Cheah et al.'s classification of tasks and task difficulty. Directly, most studies in our review did not examine task-difficulty per say and reflecting on Cheah and colleagues' review (2022) conclusion that task-difficulty could impact the way BGM influences performance by modulating the available cognitive resources for the task at hand, perhaps adequacy of the task also modulates available cognitive resources.

Considering these inconclusive findings regarding the effect of BGM on executive functioning, which partly aligns with existing reviews and the Arousal-Mood Theory, the following section will discuss determinant variables that could potentially elucidate the observed variability thus far.

Determinant variables involved.

The present review's attempt to meet this objective was inconclusive. First, relative to population determinants, though interested in the adult population most studies were conducted with younger adults (18-30). Moreover, most studies with young adults are invested in the student population and educational setting, whether undergraduate or graduate scholars. Consequently, the samples examined represent only a portion of the adult-life span concerned by this review and participants' characteristics are unequally reported among studies. Additionally, musical perception has shown age-dependent variations, namely older adults rate positively valenced music more positively than younger adults (Cohrdes et al., 2020; Vieillard and Bigand, 2014). As aging leads to a non-clinical hearing loss or presbycusis in many adults, the musical perception of rhythm difference between young and older adults is subtle (Sauvé et al., 2022). This auditory decline is associated with a less distinctive musical perception and a deteriorated neural representation of the musical dissonance or consonance (Bones and Plack, 2015). Thus, throughout adulthood, musical perception varies and Moreno-Gomez and colleagues, 2017) have demonstrated that the neurodegeneration of the auditive system and brain circuits involved impairs musical perception as measured by the global accuracy score of the Montreal battery of evaluation of amusia. Hence, these considerations necessitate caution when generalizing our results and these factors could be taken into account when evaluating the effect of BGM in older adults. However, expanding the range of settings could enhance the inclusivity of adults and better represent the adult population at large. Regarding individual characteristics, the need for synthesis sometimes required a thinning of description which might have reduced valuable information concerning sample.

Second, population-specific analysis did underline sex (female) and personality (extraversion) as contributing to BGM's beneficial effect on performance, but only for a small number of studies. The hypothesis underlying the extraversion differences relies both on Eysenck's personality theory (as reviewed by Küssner, 2017) and the Yerkes-Dodson law (1908) of optimal arousal for cognitive performance, where too little or too elevated arousal are detrimental, and the optimal level varies for each individual and their context and the assumption that extroverted individuals have a higher basal activation level than introverts.

Third, the emotional state in which participants arrive prior to testing or how they evaluate the music (compared to how the experimenters previously have) was not systematically reported nor considered. Since individuals experience musical emotions depending on their emotional dispositions at the time of listening (Hunter et al., 2011; Schaefer et al., 2013) and personal basal activation level have an influence (Schaëfer et al., 2013) it is surprising that these variables are not investigated more systematically. Considering the underlying mechanisms, such as tempo influencing psychophysiological measures linked to arousal (e.g., Chanda and Levitin, 2013; Juslin et al., 2015; Shaefer, 2017), basal physiological baseline would modulate the arousal manipulation by BGM. Potentially, individual self-report of emotional state at baseline using the same model adapted for musical emotions (Eerola and Vuokoski's, 2011) could simplify comparison and clarify the effect of BGM's effect on individual's mood, arousal, and performance.

Fourth, concerning task-specific determinants, task difficulty was not labeled in most reviewed studies, and this might have confounded results. In fact, Cheah et al. (2022) found that task-difficulty, as classified by the authors of the reviewed studies, influenced the effect of BGM on performance since instrumental music significantly impaired difficult tasks. They recommended the inclusion of this variable in future studies. For example, including various levels of difficulty of the same task, tested in a pre-study, when planning experimental designs could allow the exploration of this conclusion.

Adequacy of the neuropsychological tests used.

Regarding executive task-specific parameters, the experimental paradigms were not all comparable in terms of methodological quality as rendered by the quality assessment. On one hand, sound neuropsychological assessment tools that most adequately measure the intended function were commonly used, such as the Stroop task, Corsi's backward span, as proposed in manuals such as Lezak and colleagues' *Neuropsychological assessment manual – 5th edition* (2012), the *Traité de neuropsychologie clinique de l'adulte - Tome 1 : évaluation* by Seron and Van der Linden (2014), or the *Compendium of Neuropsychological Tests: Administration, Norms, and Commentary* by Strauss et al. (2006). Advantages of using these assessment tools include tested and published measurement material that has been validated. Many studies relied on experimental tasks supported by neuropsychological and cognitive paradigms that may be found in laboratory settings, based on, and modified from tasks such as the Flanker task, Simon's task, Attentional Network Task, N-Back task, and the Go/No-Go paradigm (see Diamond, 2013 for a brief list of tasks). On the other hand, some studies employed performance assessment tests, and more ecological laboratory-made tasks such as composing emails, that might predominantly measure other functions such as reading comprehension, language skills, and reasoning skills that do solicit EFs, but not in a specific nor primary way. These results can hardly be presented as reflecting the executive domain purely and adequacy between the measurement tool and the assumed function being evaluated is inconsistent across studies.

Additionally, the alignment between the measure and the assumed function being measured by the task was most observed in tasks based on conceptual paradigms and the standardized tasks. Lastly, Miyake et al.'s (2000a) reported challenges, the diversity of the cognitive tasks used for each of the functions and their respective limits, the impurity of cognitive tasks, and the diversity of terms used to name EFs (Miyake et al., 2000a) remain to be addressed for a better understanding of BGM and EFs. Anyhow, the present review does underline the clear need for more rigorous studies interested in evaluating EFs in the context of BGM.

Future studies should follow the guidelines proposed in response to our fourth objective, which are presented hereafter.

Recommendations for future studies. To enhance the quality, fidelity and cross-study comparability of upcoming studies, the following considerations are recommended. Guidelines are presented according to the following *PICO* categories: population, interventions, and comparators.

Population. Future studies should report participant's age range in addition to means and standard deviations to ensure additional precision and facilitate decisions on inclusion according to cut-off criteria. Additionally, physical, neurological, and psychological health, and socio-economic status could be reported to allow a precise description of the population sample. A shift should occur where gender should be considered instead of the sexes attributed at birth in an effort to be more inclusive and respectful of participants and as a mean to adapt to social reforms. Personality and initial EF capacity (performance at baseline, e.g., WM or INH) should also be measured since few studies report these individual variables that have been associated with differential effects of BGM on EFs performance. Moreover, as presented, musical expertise has been shown to influence BGM's effect and the threshold of years of musical training defining musicians from non-expert musicians is hardly homogeneous across studies. In particular, the Goldsmiths Musical Sophistication Index (Gold-MSI) is a recent and easily accessible, open-sourced, self-report index (Müllensiefen et al., 2014) that goes beyond musical expertise and offers an evaluation of musical listening skills, musical expertise, singing abilities, and musical sophistication. Indeed, this tool could enhance our comprehension of participants' musical experience with continuous variable instead of discrete ones helping us define the samples. Future studies are also encouraged to collect musical listening habits with a self-reported questionnaire to clarify if the participants are familiarized and accustomed to working with BGM or not, which could moderate conclusions and influence participants according to their habits. The Gold-MSI also offers an emotional engagement scale and musical engagement which quantifies time and resources spent on music. Also, study designs should include a self-reported measure of emotions (e.g., relaxed vs stimulated, joy, sadness, tension, calm) at baseline and after experiencing each auditory conditions to assess the emotional impact of conditions in addition to impact on performance. Additionally, obtaining participants' emotional evaluations of the music or other auditory stimuli would enable researchers to verify whether the materials are indeed perceived as intended, eliciting stimulating/relaxing, positive/negative, or familiar/unfamiliar effects. A simple Likert scale could be administered for each question and each musical excerpt.

Interventions. Relative to the musical stimuli, the present review revealed a significant diversity of musical material, a lack of consistency in the reporting of these stimuli and their characteristics, and several effects for music grouped under the same categories (stimulating/relaxing) for both INH and WM experiments. For example, musical parameters involved in musical emotions like arousal (e.g., tempo) and mood were often highly variable across the musical selection of studies and their description was often missing or incomplete. Also, the heterogeneity of the musical stimuli characteristics reported in these studies limited the comparisons between papers and some studies grouped under a larger label (e.g., relaxing music) might have been better classified if the bpm's were given for every study. Thus, BGM interventions were not equivalent and future research should describe their selected BGM in more detail to allow for better comparison (see fourth objective for detailed recommendations). In general, musical interventions are poorly reported in the literature, which limits comparisons across studies (see Robb et al., 2019 for a review). Accordingly, an extensive reporting of musical parameters is fundamental, including genre, composer, interpret, title, duration, presence of lyrics, mode, tempo in bpm (e.g., 140bpm) and classification (e.g., slow/fast tempo; relaxing/stimulating), intensity levels in dB, tonality, instruments, and modifications made to the original musical piece when applicable. Familiarity of the musical stimuli should also be evaluated by listeners. For this, a self-reported questionnaire could be administered at the end of the experiment, while listening to the musical excerpts. Also, when songs with lyrics are used, adding a control condition consisting of an instrumental version of the song could revel interesting comparisons. However, music that is striped from lyrics might still induce interference if lyrics are mentally hummed by listener, which should be considered in the study design. Ultimately, study designs should favor within-subject, and between-conditions comparisons, to between-subjects comparisons, allowing individual differences to be considered. Lastly, study designs should control for a possible order effect by randomizing presentation of conditions.

Considering EFs assessment tools, studies should rely on executive measures suggested from neuropsychological guides that are known to measure the intended executive functions, or experimental designs which the processes are well described in the literature and present the following advantages: a) simplify comparison between studies, and b) clearly relate to specific cognitive functions. Recommendations put forth by Miyake, Emerson et Friedman (2000a) have yet been integrated in most studies and could elevate rigor and clarity in the assessment of EFs: a) evaluate executive function with more than one task for better reliability, b) select simpler executive tasks to limit the influence of non-specific tasks and favor tasks that selectively measure the ability of interest, and c) question participants on strategies deployed to perform the tasks.

Comparators. As stated by Grau-Sánchez et al. (2022), the selection of control conditions in studies involving music-based intervention poses a challenge. Hence, studies should include a non-musical control auditory condition (e.g., white noise, noise, nature sounds, coffee-shop sounds) that can be matched to musical conditions in terms of tempo and/or mode. Following recommendations, control group should replicate non-investigated aspects of the musical condition, which is aided by identifying essential intervention components (Grau-Sánchez et al., 2022). This way, the effect of auditory stimulation and the specific effect of music can be controlled adequately, in contrast to designs that compare to no intervention (i.e., silence). Lastly, study designs that compared noise conditions to multiple musical conditions differing in terms of tempo, valence, musical genre for example, offered multiple comparisons such as between and within-subjects analysis. An additional comparator could imply an independent measurement tool (different from the study intervention) to assess individual initial cognitive capacities and task performance in a no-music condition for baseline comparisons.

Future studies. The included studies' results have a limited outreach for generalisation as younger adults were predominantly represented. And even though some studies show similar effects for younger and older adults, the literature does suggest a cognitive decline in the later stages of adulthood (Glisky, 2007). Hence, a suitable representation of this population in studies would benefit our comprehension BGM's effect on executive functioning in adults, older adults, and the elderly. Moreover, the musical expertise criterion seems inconsistently reported and the variance in the cut-offs for extensive musical training should be considered. Regarding, music-specific reflections, though in the present review performance was not affected by the instrumental versions of pop music with lyrics, possibly, recognising the instrumental version of a song with lyrics might elicit the mental humming of lyrics and interfere with the task in similar ways to BGM with lyrics. Since music with lyrics appears to impair performance (see Cheah et al., 2022 for a review) possibly studies using instrumental versions of music with lyrics should be compared to instrumental music as well. This could heighten our understanding of the matter and reveal resourceful for broadening the scope of musical material beyond classical music. Eventually, the comparators and auditory conditions included in the study designs might also have influenced the results. Specifically, when studies compare different musical conditions to silence, the effect must significantly differ from silence to be classified as an effective moderator or modulator of performance. Whereas studies that compare musical or auditory conditions among themselves, with no active or passive comparators, a significant difference does not guarantee a differential effect to baseline. For thorough analysis, future studies are encouraged to include comparators (controls) in addition to different musical conditions. Implementing these recommendations might present a challenge due to the potential need for incorporating multiple tools, which could significantly extend the testing process. In sum, the hypotheses put forth with this review should be kept in mind for future research.

Strengths and limitations.

To our knowledge, this review is the first review dedicated to executive functioning to investigate the effect of BGM on the three core EFs specifically. Naturally, the limits of the cited included experiments, such as significant diversity of musical material, a lack of consistency in the report of musical and individual characteristics, and of task adequacy for measuring the intended function limit the conclusions reached by this review. Overall, these discrepancies among studies most probably contribute to the heterogeneous results conveyed in the literature and the lack of clarity. Additionally, the selection process was influenced by the linguistic resources available, hence some relevant studies might have suffered a linguistic bias by not being analyzed in the present review.

Furthermore, this review could not offer an analysis of the effect of BGM on CF, because of the few studies exploring this executive function, insufficient studies used recognized tests and a study design corresponding to our inclusion criteria. Hence, the effect of BGM on the EFs as described by Miyake's model is not fully represented in this review and underlines the need for future studies exploring CF in the context of BGM. Recommendations for future studies also extend to the study of CF, which is encouraged given the limited published material. Nevertheless, this review enlightens the recommendations future studies should tend to replicate. While this rigorous systematic review partially clarified the determinant variables (i.e., interventions: music-specific, task-specific; and population: population-specific) linked to the beneficial effect of BGM on EFs, its most valuable contribution is the synthesis of current knowledge. This systematic literature review also emphasizes several research challenges contributing to the heterogeneity of the conclusions, and dresses comprehensive recommendations for quality assessment (e.g., complete musical parameters) of the influence of BGM on core EFs in hopes of guiding best practices for future studies. In the longer term, standardized examination of the effect of BGM on EFs could generate clarifications and help frame the remediation of EF alterations present in the general population and associated with clinical disorders.

Conclusion

While the current literature exploring the effect of BGM on inhibition and working memory in healthy non-musician or non-professional musician adults is subject to growing exploration, heterogeneity relative to musical parameters, auditory conditions design, and participant's characteristics is predominant among these studies. Classical music is the genre most studied in this context, however musical material remains quite diverse and comparable with difficulty. Nevertheless, while multiple effects of music were reported and no definitive conclusion is reached, predominantly BGM was shown to have no significant effect on EF performance. However, some facilitative effect on executive functioning were collided, for which the determinant factors remain to be differentiated as the field is making progress. Most importantly, refining research methods and elevating quality of investigations appears essential for a better understanding of the variables implicated in the influence of BGM on executive function performances in the adult general population.

Acknowledgments

We are profoundly grateful for Adam Robacewski, Émilie Ponton, Jadziah Pilon, and Vincent Montpetit who assisted with the article screening and selection, Amélie Cloutier and Dawn Merrett for revising the article, and Dominic Desaulniers and Christiane Melançon for their help with determining databases and search strategy for this research.

References

(References preceded by an asterisk indicate studies included in the systematic review, references precede by a diamond-shaped bullet)

Anderson, V., Jacobs, R. & Anderson, P.J. (2010). Developmental trajectories of executive functions across the lifespan. Dans V. A. Anderson & R. Jacobs & P.J. Anderson (Eds.) *Executive Functions and the Frontal Lobes: A Lifespan Perspective* (pp. 23-56). Taylor & Francis. https://books.google.ca/books?id=f8p5AgAAQBAJ

Angel, L.A., Polzella, D.J. & Elvers, G.C. (2010). Background Music and Cognitive Performance. *Perceptual and Motor Skills*, 110(3_suppl), 1059-1064. https://doi.org/10.2466/pms.110.C.1059-1064

Bailey C.E. (2007). Cognitive accuracy and intelligent executive function in the brain and in business. *Annals of the New York Academy of Sciences*, *1118*, 122–141. https://doi.org/10.1196/annals.1412.011

*♦ Barnes, M.P. (2002). Individual differences in undergraduate reading comprehension as a function of extraversion -introversion level and background music complexity (publication no 3046285) [Ph.D., Hofstra University]. ProQuest Dissertations & Theses Global. https://www.proquest.com/dissertations-theses/individual-differences-undergraduate-reading/docview/305612017/se-2?accountid=12543

Barrasso-Catanzaro, C. & Eslinger, P.J. (2016). Neurobiological Bases of Executive Function and Social-Emotional Development: Typical and Atypical Brain Changes. *65*(1), 108-119. https://doi.org/https://doi.org/10.1111/fare.12175

Barraza, P., & Medina, D. (2019). Efficiency of attentional networks in musicians and non-musicians. *Heliyon, 5*, 1-17. https://doi.org/10.1016/j.heliyon.2019.e01315

Bellier, A., Secheresse, T., Stoeckle, A., Dols, A. M., & Chaffanjon, P. C. (2020). Impact of Background Music on Medical Student Anxiety and Performance During Anatomical Dissections: A Cluster Randomized Interventional Trial. Anatomical sciences education, 13(4), 427–435. https://doi.org/10.1002/ase.1918

Bersch-Burauel. (2006). *Development of musical preferences in adulthood.* ISBN 88-7395-155-4 © 2006 ICMPC. 9th International Conference on Music perception and Cognition.

Bherer, L. (2015). Cognitive plasticity in older adults: effects of cognitive training and physical exercise. *Annals of the New York Academy of Sciences, 1337*(1), 1-6. https://doi.org/https://doi.org/10.1111/nyas.12682

Bherer, L., Erickson, K. & Liu-Ambrose, T. (2013, 01/01). A Review of the Effects of Physical Activity and Exercise on Cognitive and Brain Functions in Older Adults. *Journal of aging research, 2013*, 657508. https://doi.org/10.1155/2013/657508

Blair, C., & Ursache, A. (2011). *A bidirectional model of executive functions and self-regulation.* In K. D. Vohs & R. F. Baumeister (Eds.), *Handbook of self-regulation: Research, theory, and applications* (p. 300–320). Guilford Press.

Bones, O., & Plack, C. J. (2015). Losing the music: aging affects the perception and subcortical neural representation of musical harmony. *The Journal of neuroscience : the official journal of the Society for Neuroscience*, *35*(9), 4071–4080. https://doi.org/10.1523/JNEUROSCI.3214-14.2015

Borella, E., Carretti, B., & Pelegrina, S. (2010). The specific role of inhibition in reading comprehension in good and poor comprehenders. *Journal of learning disabilities*, *43*(6), 541–552. https://doi.org/10.1177/0022219410371676

Bradt, J., Dileo, C., & Shim, M. (2013). Music interventions for preoperative anxiety. *The Cochrane database of systematic reviews*, (6), CD006908. https://doi.org/10.1002/14651858.CD006908.pub2

Brown, T.E., & Landgraf, J.M. (2010). Improvements in executive function correlate with enhanced performance and functioning and health-related quality of life: evidence from 2 large, double-blind, randomized, placebo-controlled trials in ADHD. *Postgraduate medicine*, *122*(5), 42–51. https://doi.org/10.3810/pgm.2010.09.2200

*Buelow, M.T., Jungers, M.K., Parks, C. & Rinato, B. (2022, Mar). Contextual Factors Affecting Risky Decision Making: The Influence of Music on Task Performance and Perceived Distraction. *Frontiers in Psychology*, 13, article no 818689. https://doi.org/10.3389/fpsyg.2022.818689

Burgess, P.W., Alderman, N., Emslie, H., Evans, J.J & Wilson, B.A. (1996). *Behavioural Assessment of the Dysexecutive Syndrome: The dysexecutive questionnaire*, Thames Valley Test Company.

*Burkhard, A., Elmer, S., Kara, D., Brauchli, C. & Jäncke, L. (2018, 2018-July-23). The Effect of Background Music on Inhibitory Functions: An ERP Study. *Frontiers in Human Neuroscience, 12*, 293. https://doi.org/10.3389/fnhum.2018.00293

Carlson, E., Wilson, J., Baltazar, M., Duman, D., Peltola, H.-R., Toiviainen, P. & Saarikallio, S. (2021, 2021-May-04). The Role of Music in Everyday Life During the First Wave of the Coronavirus Pandemic: A Mixed-Methods Exploratory Study [Original Research]. *Frontiers in Psychology, 12*. https://doi.org/10.3389/fpsyg.2021.647756

Cassidy, G., & MacDonald, R.A.R. (2007). The effect of background music and background noise on the task performance of introverts and extraverts. *Psychology of Music, 35*(3), 517-537. https://doi.org/10.1177/0305735607076444

Chanda, M.L., & Levitin, D.J. (2013). The neurochemistry of music. *Trends in Cognitive Sciences, 17* (4), 179-193. https://doi.org/10.1016/j.tics.2013.02.007

Cheah, Y., Wong, H.K., Spitzer, M. & Coutinho, E. (2022). Background Music and Cognitive Task Performance: A Systematic Review of Task, Music, and Population Impact. Music & Science, 5, 20592043221134392. https://doi.org/10.1177/20592043221134392

*♦ Chen, S. (2019). *When the Beat Drops: How Tempo Variation Influences Attention and Working Memory*. [Undergraduate senior thesis, Princeton University]. Psychology. http://arks.princeton.edu/ark:/88435/dsp01cr56n385r

Chew, A. S.-Q., Yu, Y.-T., Chua, S.-W., & Gan, S. K.-E. (2016). The effects of familiarity and language of background music on working memory and language tasks in Singapore. *Psychology of Music, 44*(6), 1431–1438. https://doi.org/10.1177/0305735616636209

Chini, M., & Hanganu-Opatz, I.L. (2021). Prefrontal Cortex Development in Health and Disease: Lessons from Rodents and Humans. *Trends in neurosciences*, 44(3), 227–240. https://doi.org/10.1016/j.tins.2020.10.017

*♦ Chou, P. (2007). The effects of background music on the reading performance of Taiwanese ESL students (publication no 3293448) [Ph.D., Indiana State University]. ProQuest Dissertations & Theses Global. https://www.proquest.com/dissertations-theses/effects-background-music-on-reading-performance/docview/304857770/se-2?accountid=12543

Clarivate Analytics. (2020). EndNote *(Version No.X9.3.3)* [Logiciel]. Clarivate. https://endnote.com/

*Cloutier, A., Fernandez, N.B., Houde-Archambault, C., & Gosselin, N. (2020). Effect of Background Music on Attentional Control in Older and Young Adults. *Frontiers in psychology*, *11*, 557225. https://doi.org/10.3389/fpsyg.2020.557225

Cohrdes, C., Wrzus, C., Wald-Fuhrmann, M., and Riediger, M. (2020). “The sound of affect”: age differences in perceiving valence and arousal in music and their relation to music characteristics and momentary mood. Music. Sci. 24, 21–43. doi: 10.1177/1029864918765613

Collette, F., & Van der Linden, M. (2002). Brain imaging of the central executive component of working memory. Neuroscience and biobehavioral reviews, 26(2), 105–125. https://doi.org/10.1016/s0149-7634(01)00063-x

Collette, F., Van der Linden, M., Laureys, S., Delfiore, G., Degueldre, C., Luxen, A., & Salmon, E. (2005). Exploring the unity and diversity of the neural substrates of executive functioning. *Human brain mapping*, *25*(4), 409–423. https://doi.org/10.1002/hbm.20118

Collette, F., Van der Linden, M., Delfiore, G., Degueldre, C., Luxen, A., & Salmon, E. (2001). The functional anatomy of inhibition processes investigated with the Hayling task. *NeuroImage*, *14*(2), 258–267. https://doi.org/10.1006/nimg.2001.0846

Criscuolo, A., Bonetti, L., Särkämö, T., Kliuchko, M., & Brattico, E. (2019). On the Association Between Musical Training, Intelligence and Executive Functions in Adulthood. *Frontiers in psychology*, *10*, 1704. https://doi.org/10.3389/fpsyg.2019.01704

Critical Appraisal Skills Programme (2020). CASP Randomized Control Trials Checklist. Repéré à https://casp-uk.net/casp-tools-checklists/

da Costa Santos, C.M., de Mattos Pimenta, C.A., & Nobre, M.R. (2007). The PICO strategy for the research question construction and evidence search. *Revista latino-americana de enfermagem*, 15(3), 508–511. https://doi.org/10.1590/s0104-11692007000300023

Davis, J.C., Marra, C.A., Najafzadeh, M., & Liu-Ambrose, T. (2010). The independent contribution of executive functions to health related quality of life in older women. *BMC geriatrics*, *10*, 16. https://doi.org/10.1186/1471-2318-10-16

Denckla, M.B. (1996). *A theory and model of executive function: A neuropsychological perspective.* In G.R. Lyon and N.A. Krasnegor, Eds., *Attention, Memory and Executive Function.* Paul Brookes Publishing Co., Baltimore, 263–278.

Devine, S., Vassena, E., & Otto, A. R. (2022, October 25). More than a Feeling: Physiological Measures of Affect Index the Integration of Effort Costs and Rewards During Effortful Decision-Making. https://doi.org/10.31234/osf.io/nmwya

de Witte, M., Pinho, A. D. S., Stams, G. J., Moonen, X., Bos, A. E. R., & van Hooren, S. (2022). Music therapy for stress reduction: a systematic review and meta-analysis. Health psychology review, 16(1), 134–159. https://doi.org/10.1080/17437199.2020.1846580

Diamond A. (2013). Executive functions. *Annual review of psychology*, *64*, 135–168. https://doi.org/10.1146/annurev-psych-113011-143750

*♦ Dove, M.K. (2009). The relationship of rhythmic and melodic perception with background music distraction in college level students (publication no 3358711) [Ph.D., University of Kansas]. ProQuest Dissertations & Theses Global. https://www.proquest.com/dissertations-theses/relationship-rhythmic-melodic-perception-with/docview/304917640/se-2?accountid=12543

Duncan, G.J., Dowsett, C.J., Claessens, A., Magnuson, K., Huston, A.C., Klebanov, P., Pagani, L.S., Feinstein, L., Engel, M., Brooks-Gunn, J., Sexton, H., Duckworth, K., & Japel, C. (2007). School readiness and later achievement. *Developmental Psychology, 43*(6), 1428–1446. https://doi.org/10.1037/0012-1649.43.6.1428

*Du, M., Jiang, J., Li, Z., Man, D. and Jiang, C. (2020, October). The effects of background music on neural responses during reading comprehension. *Scientific Reports*, 10(1), 18651. https://doi.org/10.1038/s41598-020-75623-3

Eakin, L., Minde, K., Hechtman, L., Ochs, E., Krane, E., Bouffard, R., Greenfield, B., & Looper, K. (2004). The marital and family functioning of adults with ADHD and their spouses. *Journal of attention disorders*, *8*(1), 1–10. https://doi.org/10.1177/108705470400800101

Eerola, T., & Vuoskoski, J.K. (2011). A comparison of the discrete and dimensional models of emotion in music. *Psychology of Music*, *39*(1), 18–49. https://doi.org/10.1177/0305735610362821

Ellis, C.L., & Salmoni, A.W. (2021). Descriptive analysis of university-student music preferences during different forms of physical activity. *Psychology of Music*, *49*(2), 177–192. https://doi.org/10.1177/0305735619847759

Espy, K.A., McDiarmid, M.M., Cwik, M.F., Stalets, M.M., Hamby, A., & Senn, T.E. (2004). The contribution of executive functions to emergent mathematic skills in preschool children. *Developmental neuropsychology*, *26*(1), 465–486. https://doi.org/10.1207/s15326942dn2601_6

Eslinger, P.J. (1996) Conceptualizing, Describing, and measuring components of executive function. In G.R. Lyon and N.A. Krasnegor, Eds., *Attention, Memory and Executive Function*. Paul Brookes Publishing Co., Baltimore, 367-395.

Eslinger, P., Flaherty-Craig, C., & Benton, A. (2004). Developmental outcomes after early prefrontal cortex damage. *Brain and Cognition*, 55, 84-103.

Felszeghy, S., Liukkonen, M., Tornero, C. S., Auvinen, O. M., Hämäläinen, K., Banafa, A., & Kurki, P. (2023). Influence of background music on stress reduction and impact on performances during students' simulation exercises. Journal of dental education, 10.1002/jdd.13235. Advance online publication. https://doi.org/10.1002/jdd.13235

*Fernandez, N.B., Trost, W. & Vuilleumier, P. (2019, Dec). Brain networks mediating the influence of background music on selective attention [Article]. *Social Cognitive and Affective Neuroscience*, 14(12), 1441-1452. https://doi.org/10.1093/scan/nsaa004

*Fernandez, N.B., Vuilleumier, P., Gosselin, N. & Peretz, I. (2021). Influence of background musical emotions on attention in congenital amusia. *Frontiers in Human Neuroscience*, 14. https://doi.org/10.3389/fnhum.2020.566841

Furnham, A. & Allass, K. (1999). The influence of musical distraction of varying complexity on the cognitive performance of extroverts and introverts. *European Journal of Personality*, 13(1), 27-38. https://doi.org/https://doi.org/10.1002/(SICI)1099-0984(199901/02)13:1<27::AID-PER318>3.0.CO;2-R

Fuster, J. (2002). Physiology of Executive Functions: The Perception-Action Cycle. In Principles of Frontal Lobe Function : Oxford University Press. Retrieved 17 Jun. 2021, from https://oxford.universitypressscholarship.com/view/10.1093/acprof:oso/9780195134971.001.0001/acprof-9780195134971-chapter-6.

*Gann, C.L., Michener, P.N., Carney, S. & Schachtman, T.R. (2021). Effect of Music on Reaction Time Performance Using a Working Memory Task. *North American Journal of Psychology; Winter Garden*, 23 (2), 243-253. https://www.proquest.com/docview/2523170732

Gathercole, S.E., Pickering, S.J., Knight, C. & Stegmann, Z. (2004), Working memory skills and educational attainment: evidence from national curriculum assessments at 7 and 14 years of age. *Appl. Cognit. Psychol.,* 18: 1-16. https://doi.org/10.1002/acp.934

Glisky, E.L. (2007). Chapter 1 Changes in cognitive function in human aging. In Riddle DR (editor), *Brain Aging: Models, Methods, and Mechanisms*. CRC Press/Taylor & Francis. https://www.ncbi.nlm.nih.gov/books/NBK3885/

Grau-Sánchez, J., Jamey, K., Paraskevopoulos, E., Dalla Bella, S., Gold, C., Schlaug, G., Belleville, S., Rodríguez-Fornells, A., Hackney, M. E. & Särkämö, T. (2022). Putting music to trial: Consensus on key methodological challenges investigating music-based rehabilitation. *Ann N Y Acad Sci, 1518*(1), 12-24. https://doi.org/10.1111/nyas.14892

*Haning, M. (2016). The Association Between Music Training, Background Music, and Adult Reading Comprehension. *Contributions to Music Education, 41*, 131-143. http://www.jstor.org/stable/24711132

Henrard, S. (2021). De l'importance des fonctions exécutives dans la vie de tous les jours. *Revue francophone d'orthoptie*, 14 :7 – 11.https://doi.org/10.1016/j.rfo.2021.02.003

Hunter, P.G., Schellenberg, E.G., & Griffith, A.T. (2011). Misery loves company: mood-congruent emotional responding to music. *Emotion* (Washington, D.C.), 11(5), 1068–1072. https://doi.org/10.1037/a0023749

Husain, G., Thompson, W.F. & Schellenberg, E.G. (2002). Effects of Musical Tempo and Mode on Arousal, Mood, and Spatial Abilities. *Music Perception,* 20(2), 151-171. https://doi.org/10.1525/mp.2002.20.2.151

*Iwanaga, M. & Ito, T. (2002). Disturbance effect of music on processing of verbal and spatial memories [Article]. *Perceptual and Motor Skills*, 94(3), 1251-1258. https://doi.org/10.2466/pms.94.2.1251-1258

Jaschke, A.C., Honing, H., & Scherder, E. (2018). Exposure to a musically-enriched environment; Its relationship with executive functions, short-term memory and verbal IQ in primary school children. *PloS one*, *13*(11), e0207265. https://doi.org/10.1371/journal.pone.0207265

Juslin, P., & Västfjäll, D. (2008). Emotional Responses to Music: The Need to Consider Underlying Mechanisms. The Behavioral and brain sciences, 31, 559-575; discussion 575. doi:10.1017/S0140525X08005293Juslin, P. N., Barradas, G., et Eerola, T. (2015). From

Sound to Significance: Exploring the Mechanisms Underlying Emotional Reactions to Music. *Am J Psychol*, 128(3), 281-304. https://doi.org/10.1017/S0140525X08005293

Juslin, P.N., Liljeström, S., Västfjäll, D. & Lundqvist, L-O. (2010). How does music evoke emotions? Dans Juslin, P.N. (dir), Handbook of Music and Emotion: Theory, Research, Applications. *Oxford Scholarship Online*. http://dx.doi.org/10.1093/acprof:oso/9780199230143.003.0022

Juslin, P.N., Barradas, G., & Eerola, T. (2015). From Sound to Significance: Exploring the Mechanisms Underlying Emotional Reactions to Music. *The American journal of psychology,* 128(3), 281–304. https://doi.org/10.5406/amerjpsyc.128.3.0281

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

*Kim, A. (2022). The effect of music on accuracy in the Stroop test. *Psychology in the Schools*, 59(8), 1511-1520. https://doi.org/10.1002/pits.22689

*Klempova, B. & Liepelt, R. (2018). Barriers to success: physical separation optimizes event-file retrieval in shared workspaces. *Psychological Research-Psychologische Forschung*, 82(6), 1158-1176. https://doi.org/10.1007/s00426-017-0886-2

Knight, W.E., & Rickard, N.S. (2001). Relaxing music prevents stress-induced increases in subjective anxiety, systolic blood pressure, and heart rate in healthy males and females. *Journal of music therapy*, 38(4), 254–272. https://doi.org/10.1093/jmt/38.4.254

Koelsch, S. (2010). Towards a neural basis of music-evoked emotions. *Trends in Cognitive Sciences*, 14(3), 131-137. https://doi.org/https://doi.org/10.1016/j.tics.2010.01.002

Koelsch, S. (2014). Brain correlates of music-evoked emotions. *Nature Reviews Neuroscience, 15* (3), 170-180. https://doi.org/10.1038/nrn3666

Koelsch, S. (2020). A coordinate-based meta-analysis of music-evoked emotions. NeuroImage, 223, 117350. https://doi.org/https://doi.org/10.1016/j.neuroimage.2020.117350

Komlao, Norawat (2018) Variations Of Auditory Distractions: The Effect Of Familiarity With Background Music On Cognitive Performance On The Concept Shifting Task. Undergraduate thesis, Dublin, National College of Ireland. http://norma.ncirl.ie/id/eprint/3289

Kowarz, K.M. (2016). Background music in mindfulness practice: Associations with and among emotional arousal, state mindfulness, and psychological flexibility. *Dissertation Abstracts International: Section B: The Sciences and Engineering, 77*(1-B(E)).

Krause, A.E., North, A.C., & Hewitt, L.Y. (2015). Music-listening in everyday life: Devices and choice. Psychology of Music, 43, 3, 155-170. doi:10.1177/0305735613496860

Krause, A.E., & North, A.C. (2017). Pleasure, arousal, dominance, and judgments about music in everyday life. *Psychology of Music*, *45*(3), 355–374. https://doi.org/10.1177/0305735616664214

*Kumaradevan, K.S., Balan, A., Khan, K., Alji, R. M. & Narayanan, S.N. (2021). Modulatory role of background music on cognitive interference task in young people. *Irish Journal of Medical Science (1971 -), 190*(2), 779-786. https://doi.org/10.1007/s11845-020-02365-6

Küssner, M.B. (2017). Eysenck's Theory of Personality and the Role of Background Music in Cognitive Task Performance: A Mini-Review of Conflicting Findings and a New Perspective [Mini Review]. *Frontiers in Psychology*, 8(1991). https://doi.org/10.3389/fpsyg.2017.01991

Lehmann, J.A.M., & Seufert, T. (2017). The influence of background music on learning in the light of different theoretical perspectives and the role of working memory capacity. *Frontiers in Psychology, 8,* Article 1902. https://doi.org/10.3389/fpsyg.2017.01902

Lezak, M., Howieson, D., Loring, D., Hannay, H., & Fischer, J. (2012). *Neuropsychological Assessment*. (Fifth edition) Oxford University Press. ISBN 0195111214, 9780195111217

Liberati, A., Altman, D.G., Tetzlaff, J., Mulrow, C., Gøtzsche, P.C., Ioannidis, J.P., Clarke, M., Devereaux, P.J., Kleijnen, J., & Moher, D. (2009). The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate health care interventions: explanation and elaboration. *Journal of clinical epidemiology*, *62*(10), e1–e34. https://doi.org/10.1016/j.jclinepi.2009.06.006

Lindquist, K.A., Wager, T.D., Kober, H., Bliss-Moreau, E. et Barrett, L.F. (2012). The brain basis of emotion: a meta-analytic review. *The Behavioral and brain sciences*, 35(3), 121–143. https://doi.org/10.1017/S0140525X11000446

*♦ Mairal, S.V. (2015). *The Effect of Background Music on the Visual Categorization of Printed Words in Normal Younger and Older Adults* (publication nº 3711734) [Ph.D., The

University of Tennessee Health Science Center]. ProQuest Dissertations & Theses Global. https://www.proquest.com/dissertations-theses/effect-background-music-on-visual-categorization/docview/1707928838/se-2?accountid=12543

Mammarella, N., Fairfield, B., & Cornoldi, C. (2007). Does music enhance cognitive performance in healthy older adults? The Vivaldi effect. *Aging Clin Exp Res, 19*(5), 394-399.

Maturi, K.S., & Sheridan, H. (2020). Expertise effects on attention and eye-movement control during visual search: Evidence from the domain of music reading. *Atten Percept Psychophys*. https://doi.org/10.3758/s13414-020-01979-3

McKenzie JE, Brennan SE, Ryan RE, Thomson HJ, Johnston RV, Thomas J. Chapter 3: Defining the criteria for including studies and how they will be grouped for the synthesis. Dans: Higgins JPT, Thomas J, Chandler J, Cumpston M, Li T, Page MJ, Welch VA (Eds.). *Cochrane Handbook for Systematic Reviews of Interventions* (version 6.2, mise-à-jour Février 2021). Cochrane, 2021. Available from www.training.cochrane.org/handbook.

Miller, E.K. & Cohen, J.D. (2001). An Integrative Theory of Prefrontal Cortex Function. *Annual Review of Neuroscience*, 24(1), 167-202. https://doi.org/10.1146/annurev.neuro.24.1.167

Mischel, W., Ayduk, O., Berman, M.G., Casey, B.J., Gotlib, I.H., Jonides, J., Kross, E., Teslovich, T., Wilson, N.L., Zayas, V., & Shoda, Y. (2011). 'Willpower' over the life span: decomposing self-regulation. *Social cognitive and affective neuroscience*, 6(2), 252–256. https://doi.org/10.1093/scan/nsq081

Miyake, A., Emerson, M.J., & Friedman, N.P. (2000). Assessment of executive functions in clinical settings: problems and recommendations. *Seminars in speech and language*, 21(2), 169–183. https://doi.org/10.1055/s-2000-7563

Miyake, A., Friedman, N.P., Emerson, M.J., Witzki, A.H., Howerter, A., & Wager, T.D. (2000). The unity and diversity of executive functions and their contributions to complex "Frontal Lobe" tasks: a latent variable analysis. *Cognitive psychology*, *41*(1), 49–100. https://doi.org/10.1006/cogp.1999.0734

Miyake, A., & Friedman, N.P. (2012). The Nature and Organization of Individual Differences in Executive Functions: Four General Conclusions. *Current Directions in Psychological Science*, *21*(1), 8–14. https://doi.org/10.1177/0963721411429458

Moffitt, T.E., Arseneault, L., Belsky, D., Dickson, N., Hancox, R.J., Harrington, H., Houts, R., Poulton, R., Roberts, B.W., Ross, S., Sears, M.R., Thomson, W.M. & Caspi, A. (2011). A gradient of childhood self-control predicts health, wealth, and public safety. *Proceedings of the National Academy of Sciences*, 108(7), 2693. https://doi.org/10.1073/pnas.1010076108

Mohammadzadeh, A. (2016). The Effects of Music Presence on Auditory Verbal Working Memory. International Journal of Speech & Language Pathology and Audiology, 4. https://doi.org/10.12970/2311-1917.2016.04.02.3Ng, J.T. (2018). Analysis of cognitive flexibility by using EEG in the presence of background music. Final Year Project, UTAR. http://eprints.utar.edu.my/id/eprint/2833

Moreno-Gómez, F. N., Véliz, G., Rojas, M., Martínez, C., Olmedo, R., Panussis, F., Dagnino-Subiabre, A., Delgado, C., & Delano, P. H. (2017). Music Training and Education Slow the Deterioration of Music Perception Produced by Presbycusis in the Elderly. Frontiers in aging neuroscience, 9, 149. https://doi.org/10.3389/fnagi.2017.00149

Müllensiefen, D., Gingras, B., Musil, J., & Stewart, L. (2014). The musicality of non-musicians: An index for assessing musical sophistication in the general population. PloS One, 9, e89642. https://doi.org/10.1371/journal.pone.0089642.

* ♦ Myles, G. (2017) *Effects of Background Music on Cognitive Tasks.* [Honors psychology thesis, University of Western, Ontario London].

*Nadon, E., Tillmann, B., Saj, A. & Gosselin, N. (2021). The Emotional Effect of Background Music on Selective Attention of Adults. *Frontiers in Psychology*, 12, article no 729037. https://doi.org/10.3389/fpsyg.2021.729037

* ♦ Namwamba, J.-B.O. (2012). *The effect of classical instrumental background music volume on performance in mathematics tests, self efficacy, and test anxiety of college students* (publication nº 3521993) [Ph.D., Southern University and Agricultural and Mechanical College]. ProQuest Dissertations & Theses Global. https://www.proquest.com/dissertations-theses/effect-classical-instrumental-background-music/docview/1036462537/se-2?accountid=12543

Niven, K. & Miles, E. (2013). Affect Arousal. Dans M. D. Gellman et J. R. Turner (dir.), Encyclopedia of Behavioral Medicine (p. 50-52). Springer New York. https://doi.org/10.1007/978-1-4419-1005-9_1089

North, A.C., Hargreaves, D.J. et Hargreaves, J.J. (2004). Uses of Music in Everyday Life. *Music Perception*, 22(1), 41-77. https://doi.org/10.1525/mp.2004.22.1.41

*Oliver, M.D., Levy, J.J., & Baldwin, D.R. (2021). Examining the effects of musical type and intensity in performing the flanker task: A test of attentional control theory applied to non-emotional distractions. *Psychology of Music*, 49(4), 1017–1026. https://doi.org/10.1177/0305735620922599

Page, M.J., Moher, D., Bossuyt, P.M., Boutron, I., Hoffmann, T.C., Mulrow, C.D., Shamseer, L., Tetzlaff, J.M., Akl, E.A., Brennan, S.E., Chou, R., Glanville, J., Grimshaw, J.M., Hróbjartsson, A., Lalu, M.M., Li, T., Loder, E.W., Mayo-Wilson, E., McDonald, S., McGuinness, L.A., McKenzie, J.E. (2021). PRISMA 2020 explanation and elaboration: updated guidance and exemplars for reporting systematic reviews. *BMJ (Clinical research ed.)*, *372*, n160. https://doi.org/10.1136/bmj.n160

*Palmiero, M., Nori, R., Rogolino, C., D'Amico, S. & Piccardi, L. (2016). Sex differences in visuospatial and navigational working memory: The role of mood induced by background music. *Experimental Brain Research, 234*(8), 2381-2389. https://doi.org/10.1007/s00221-016-4643-3

*Patston, L.L.M. & Tippett, L.J. (2011). The effect of background music on cognitive performance in musicians and nonmusicians. *Music Perception, 29*(2), 173-183. https://doi.org/10.1525/mp.2011.29.2.173

*♦ Petrucelli, J. (1987). The effects of noise and stimulative and sedative music on stroop performance variables (publication nº 8802450) [Ph.D., St. John's University (New York)]. ProQuest Dissertations & Theses Global. https://www.proquest.com/dissertations-theses/effects-noise-stimulative-sedative-music-on/docview/303493969/se-2?accountid=12543

Robb, S.L., Hanson-Abromeit, D., May, L., Hernandez-Ruiz, E., Allison, M., Beloat, A., Daugherty, S., Kurtz, R., Ott, A., Oyedele, O.O., Polasik, S., Rager, A., Rifkin, J., & Wolf, E. (2018). Reporting quality of music intervention research in healthcare: A systematic review. *Complementary therapies in medicine*, *38*, 24–41. https://doi.org/10.1016/j.ctim.2018.02.008

*Rowe, G., Hirsh, J.B. & Anderson, A.K. (2007). Positive affect increases the breadth of attentional selection. *Proceedings of the National Academy of Sciences*, 104(1), 383-388. https://doi.org/doi:10.1073/pnas.0605198104

Russell, J.A. (1980). A circumplex model of affect. *Journal of Personality and Social Psychology*, 39(6), 1161–1178. https://doi.org/10.1037/h0077714

Sauvé, S. A., Bolt, E. L. W., Nozaradan, S., & Zendel, B. R. (2022). Aging effects on neural processing of rhythm and meter. *Frontiers in aging neuroscience*, *14*, 848608. https://doi.org/10.3389/fnagi.2022.848608

Schäfer, T., Sedlmeier, P., Städtler, C. & Huron, D. (2013-August-13). The psychological functions of music listening [Original Research]. *4*(511). https://doi.org/10.3389/fpsyg.2013.00511

Schaefer, H.-E. (2017). Music-Evoked Emotions—Current Studies [Review]. *Frontiers in Neuroscience*, 11(600). https://doi.org/10.3389/fnins.2017.00600

Schellenberg, E. & Weiss, M. (2013). Music and Cognitive Abilities (pp. 499-550). Dans D. Deutsch (Ed.). *Psychology of Music.*(p. 499-550). Elsevier Inc. https://doi.org/10.1016/B978-0-12-381460-9.00012-2

Seron, X. & Van der Linden, M. (2014). *Traité de neuropsychologie clinique de l'adulte - Tome 1 : évaluation* (2nd edition). DeBoeck supérieur. ISBN-13: 9782353272358

Strauss, E., Spreen, O. & Sherman, E. (2006). *A Compendium of Neuropsychological Tests: Administration, Norms, and Commentary*. Oxford University Press. ISBN: 978-0195159578

Strait, D.L., & Kraus, N. (2011). Can you hear me now? Musical training shapes functional brain networks for selective auditory attention and hearing speech in noise. *Frontiers in psychology*, *2*, 113. https://doi.org/10.3389/fpsyg.2011.00113

*Strukelj, A., Brannstrom, K.J., Holmberg, N., Mossberg, F. & Holmqvist, K. (2016). The impact of sound presentations on executive control: Evidence from eye movements [Article]. *Psychology of Music*, 44(5), 996-1011. https://doi.org/10.1177/0305735615604508

*Sun, C.A., Wei, H.T. & Yue, L.J. (2011). The ERP Research about the Influence of the Music of Chopin on Working Memory. Dans E. Zhu (dir.), 2011 International Conference on Photonics, 3d-Imaging, and Visualization (vol. 8205). *Spie-Int Soc Optical Engineering*. https://doi.org/10.1117/12.905967

*Sutton, C.J.C. & Lowis, M.J. (2008). The Effect of Musical Mode on Verbal and Spatial Task Performance. *Creativity Research Journal*, 20(4), 420-426. https://doi.org/10.1080/10400410802391884

*Taheri, S., Razeghi, M., Choobineh, A., Kazemi, R., Rasipisheh, P. & Vali, M. (2022). Investigating the effect of background music on cognitive and skill performance: A cross-sectional study. Work-a Journal of Prevention Assessment & Rehabilitation, 71(4), 871-879. https://doi.org/10.3233/wor-213631

Takeuchi, H., Taki, Y., Sassa, Y., Hashizume, H., Sekiguchi, A., Fukushima, A., & Kawashima, R. (2013). Brain structures associated with executive functions during everyday events in a non-clinical sample. *Brain structure & function*, *218*(4), 1017–1032. https://doi.org/10.1007/s00429-012-0444-z

Teffer, K. & Semendeferi, K. (2012). Human prefrontal cortex: evolution, development, and pathology. *Prog Brain Res*, 195, 191-218. https://doi.org/10.1016/b978-0-444-53860-4.00009-x

Tierney, A., Rosen, S., & Dick, F. (2020). Speech-in-speech perception, nonverbal selective attention, and musical training. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 46*(5), 968–979. https://doi.org/10.1037/xlm0000767

*Thompson, W.F., Schellenberg, E.G. & Letnic, A.K. (2012). Fast and loud background music disrupts reading comprehension. *Psychology of Music*, 40(6), 700-708. https://doi.org/10.1177/0305735611400173

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

Vaughan, L., & Giovanello, K. (2010). Executive function in daily life: Age-related influences of executive processes on instrumental activities of daily living. *Psychology and Aging, 25*(2), 343–355. https://doi.org/10.1037/a0017729

*♦ Venkata Krishnam Raju, S. (2018). *A Comparative Study of Effect of Music with Lyrics and Music Without Lyrics on Concentrating Ability of Students* (publication nº 28507812) [M.D., Dr. NTR University of Health Sciences (India)]. ProQuest Dissertations & Theses Global. https://www.proquest.com/dissertations-theses/comparative-study-effect-music-with-lyrics/docview/2555139692/se-2?accountid=12543

Vieillard, S., & Bigand, E. (2014). Distinct effects of positive and negative music on older adults' auditory target identification performances. *Quarterly journal of experimental psychology (2006)*, *67*(11), 2225–2238. https://doi.org/10.1080/17470218.2014.914548

* ♦ Villamizar, C.D., Guerrero Arenas, C., Orduña Bustamante, F. & Galicia Moyeda, I. (2020). The effect of listening to loud music in the performance of three higher-level cognitive functions. *Research Square.* Preprint (Version 1). https://doi.org/10.21203/rs.3.rs-105448/v1

Vuust, P., Heggli, O.A., Friston, K.J., & Kringelbach, M.L. (2022). Music in the brain. Nature reviews. Neuroscience, 23(5), 287–305. https://doi.org/10.1038/s41583-022-00578-5

Wang, S., Li, Y., Li, J., Wang, L., Yin, N. & Yang, S. (2020). [Research on the effect of background music on spatial cognitive working memory based on cortical brain network]. *Sheng wu yi xue gong cheng xue za zhi = Journal of biomedical engineering = Shengwu yixue gongchengxue zazhi, 37*(4), 587-595. https://doi.org/10.7507/1001-5515.201907065

Waxenbaum J.A., Reddy V, & Varacallo M. Anatomy, Autonomic Nervous System. [Updated 2022 Jul 25]. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2022 Jan-. Available from: https://www.ncbi.nlm.nih.gov/books/NBK539845/

Williamson, V.J., Baddeley, A.D. & Hitch, G.J. (2010). Musicians' and nonmusicians' short-term memory for verbal and musical sequences: Comparing phonological similarity and pitch proximity. *Memory & Cognition, 38*(2), 163-175. https://doi.org/10.3758/MC.38.2.163

*Xiao, R., Liu, C.H., Chen, J.J. & Chen, J. (2020). The Influence of Music Tempo on Inhibitory Control: An ERP Study [Article]. *Frontiers in Behavioral Neuroscience*, 14, 6, article no 48. https://doi.org/10.3389/fnbeh.2020.00048

*Yang, H., Lu, J., Gong, D.K. & Yao, D.Z. (2016). How do musical tonality and experience affect visual working memory? [Article]. *Neuroreport*, 27(2), 94-98. https://doi.org/10.1097/wnr.0000000000000503

Yerkes, R.M. & Dodson, J.D. (1908). The relation of strength of stimulus to rapidity of habit-formation. *Journal of Comparative Neurology and Psychology*, 18(5), 459-482. https://doi.org/https://doi.org/10.1002/cne.920180503

Yoo, G.E., Lee, S., Kim, A.J., Choi, S.H., Chong, H.J. & Park, S. (2022). Differential Background Music as Attentional Resources Interacting with Cognitive Control. *Int J Environ Res Public Health, 19*(22). https://doi.org/10.3390/ijerph192215094

*Young, E. & Nolan, J. (2015). Effects of Music Genre on Simple and Simulated Task Switching. *International Social Science Review, 91*(2), 1-19. https://www.jstor.org/stable/intesociscierevi.91.2.02

Yuan, P., & Raz, N. (2014). Prefrontal cortex and executive functions in healthy adults: a meta-analysis of structural neuroimaging studies. *Neuroscience and biobehavioral reviews*, 42, 180–192. https://doi.org/10.1016/j.neubiorev.2014.02.005

Appendix A

Search engine formula for probing systematic databases.

("background music" OR "music* background" OR "musical environment" OR "music* listening" OR "musical activation" OR "musical arousal" OR "musical emotions") AND (neuropsycholog* OR "frontal lobes" OR "executive function*" OR "executive profile" OR "executive task" OR "executive process*" OR "executive deficit" OR "cognitive control" OR "executive control" OR inhibition OR "inhibitory control" OR "attentional control" OR "executive attention" OR "conflict resolution" OR "response inhibition" OR "behavioral inhibition" OR "working memory" OR "short term memory" OR "set shifting" OR "shifting" OR "task switching" OR "cognitive flexibility" OR "cognitive rigidity" OR "mental flexibility" OR "mental rigidity").

Figures and Tables

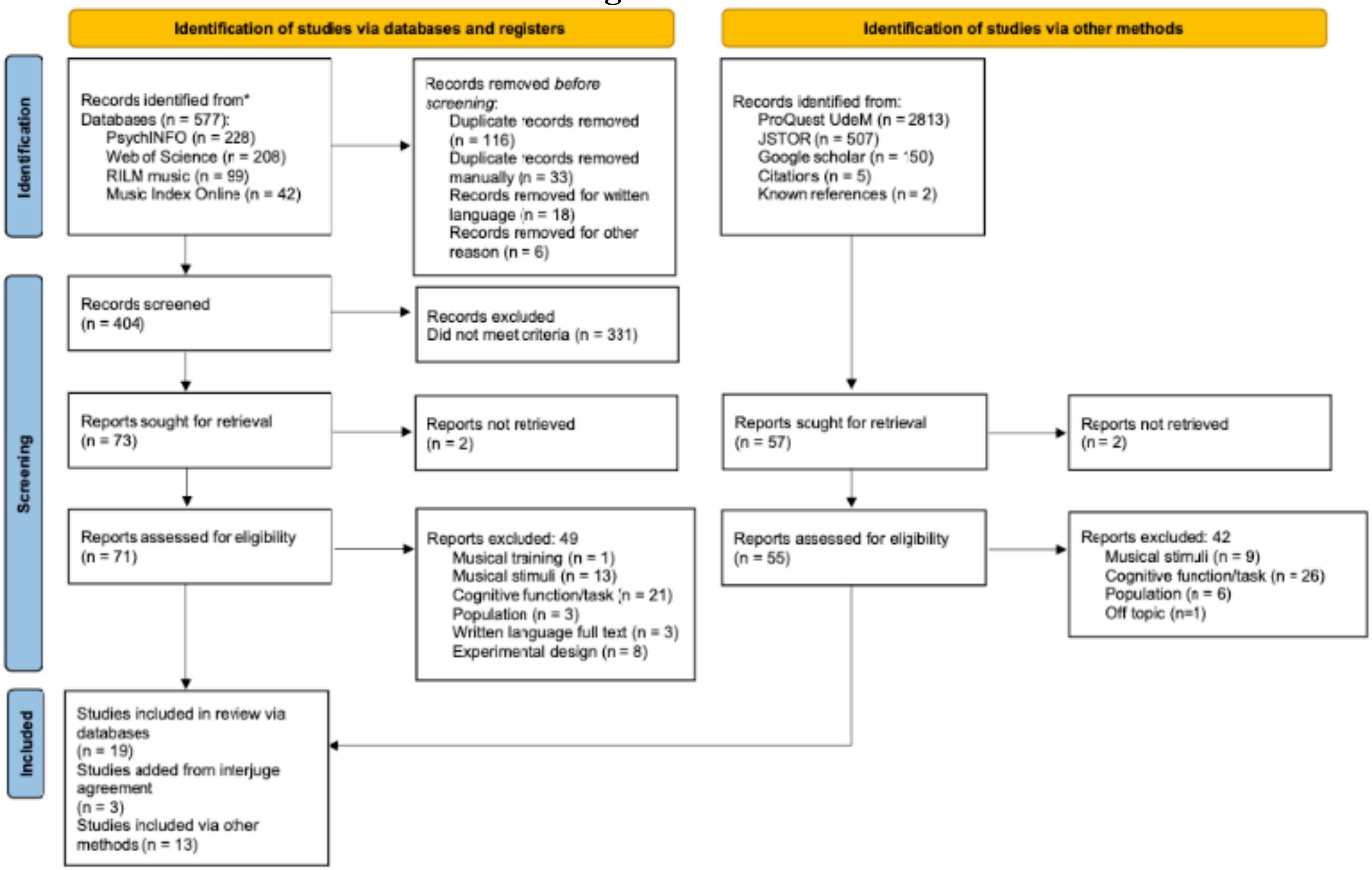

Figure 1. – PRISMA 2020 flow diagram for new systematic reviews which included searches of databases, registers, and other sources.

Table 1. – Quality assessment rating for each reference.

No.	Authors (Year)	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	Total score
1	Angel & al. (2010)	0	1	1	0	1	0	1	1	1	0	1	7
2	Barnes (2002)	0	1	1	1	1	1	0	1	1	0	1	8
3	Buelow & al. (2022)	1	1	1	1	1	1	1	1	1	1	0	10
4	Burkhard & al. (2018)	1	1	1	1	1	1	1	1	1	1	1	11
5	Chen (2019)	1	1	1	1	1	1	1	1	1	1	1	11
6	Chou (2007)	1	1	1	0	1	1	1	1	1	0	1	9
7	Cloutier & al. (2020)	1	1	1	1	1	1	1	1	1	1	1	11
8	Domínguez & al. (2020)	1	0	1	1	1	1	0	1	1	1	0	8
9	Dove (2009)	1	1	1	0	1	1	1	1	1	0	1	9
10	Du & al. (2020)	1	0	1	1	1	1	1	1	1	0	1	9
11	Fernandez & al. (2019)	1	1	1	1	1	1	0	1	1	1	1	10
12	Gann (2021)	1	1	1	0	1	1	1	1	1	1	1	10
13	Haning (2016)	1	1	0	0	1	1	0	0	1	0	1	6
14	Iwanaga and Ito (2002)	1	0	1	0	1	1	0	1	1	1	0	7
15	Kim (2022)	1	1	1	1	0	1	1	0	1	1	1	9
16	Klempova and Liepelt (2018)	1	1	1	1	1	1	1	1	1	1	1	11
17	Kumaradevan & al. (2021)	1	0	0	0	1	0	0	0	1	1	1	5
18	Mairal (2015)	1	1	1	1	1	1	1	1	1	0	0	9
19	Myles (2017)	1	1	1	1	1	1	1	1	1	1	1	11
20	Nadon & al. (2021)	1	1	1	1	1	1	1	1	1	1	1	11
21	Namwamba (2012)	1	1	1	0	1	1	1	1	1	0	1	9
22	Oliver & al. (2021)	0	1	1	1	1	1	1	1	0	1	0	8
23	Palmiero & al. (2016)	1	1	1	1	1	1	1	1	0	1	1	10
24	Patston and Tippett (2011)	1	1	1	1	1	1	1	1	1	0	1	10
25	Petrucelli (1987)	1	1	1	0	1	1	0	1	1	1	1	9
26	Rowe & al. (2007)	0	1	1	0	1	1	0	1	1	1	1	8
27	Strukelj & al. (2016)	1	1	1	1	1	1	0	1	1	1	0	9
28	Sun & al. (2011)	1	1	0	1	0	0	0	1	1	1	0	6
29	Sutton and Lowis (2008)	0	1	1	0	1	1	0	1	0	0	1	6
30	Taheri & al. (2022)	1	1	1	1	0	0	0	1	1	1	0	7
31	Thompson & al. (2011)	1	1	1	1	1	1	0	1	1	0	1	9
32	Venkata Krishnam Raju (2018)	1	1	1	1	1	1	1	1	1	1	1	11
33	Xiao & al. (2020)	1	1	1	1	1	1	1	1	1	1	1	11
34	Yang & al. (2016)	0	1	1	1	1	1	1	0	1	1	1	9
35	Young and Nolan (2015)	1	1	1	0	1	1	0	1	1	0	1	8
	Y (%) / Mean	**80,56**	**86,11**	**88,89**	**63,89**	**88,89**	**86,11**	**58,33**	**86,11**	**88,89**	**63,89**	**75,00**	**8,91**

Codes. 1 = present, 0 = not present

1. = clear and focused research question; 2. = random presentation of conditions to participants or random assignment of participants to groups; 3. = all participants counted from recruitment to results; 4.= extensive description of groups (characteristics); 5. = protocol clearly defined study and equivalent treatment of participants; 6. = extensively reported effects of music; 7. = confidence intervals or estimation of effect sizes; 8. = sample size stated; 9. = comparison to a non-musical basal performance (control condition or group); 10. = correspondence between the tasks used and the functions assumed to be measured by these tests; 11. = description of the musical material.

Y (%) = [n1/(n1+n0)]*100 (percentage of studies respecting the criteria).

Table 2. – Main list of extracted data: Population characteristics, study design, executive functions, task characteristics, and outcome

		Population characteristics						Task		Auditory stimuli				
No.	Reference	N	M	F	Age mean (SD)	Other	Design	Executive function	Measure	Music and sounds	Manipulation	Control condition	Other variables	Behavioural Outcomes
1	Angel et al. (2010)	56	28	28	Undergraduate students	Students in psychology	Mixed experimental design	INH	Linguistic processing (Criterion Task Set)	Classical : fast-tempo	na	Silence	na	Mean RT, Mean ERR%
								WM	Spatial processing (Criterion Task Set)					
2	Barnes (2002)	90	32	58	20.18 Undergraduate students	Extraverted=30 Ambiverted=30 Introverted=30	Mixed factorial design	WM	Scholastic Aptitude Test (SAT) Reasoning Test	1.High complexity 70-75dB 2.Low complexity 70-75 dB	na	Silence	Familiarity, prefered music listening and study, personnality questionnaire	Reading comprehension score
3	Buelow et al. (2022) study 3	258	109	149	18–25 18.66 (1.07)	68.6% White and 14.0% Black / African American	RDM, listened to the music more passively	WM	a) N-back; b) Self-ordered pointing task (SOPT)	Classical	na	Silence	Questionnaire assessing familiarity and self-reported level of distraction	Hits, False alarms, ERR
	study 4	341	154	187	18.70 (1.33)	64.3% White and 20.4% Black / African American	listened to the music more actively	WM	a) N-back; b) Self-ordered pointing task (SOPT)					
4	Burkhard et al. (2018)	25	8	17	20-30 23 (2.87)	Right-handed non-musicians	Design 3 X 4 ; RDM	WM	Go, No-Go: visual cognitive performance task (VCPT)	1.Relaxing music 70 dB 2.Stimulating music 70 dB	na	Silence	Self arousal, valence and mood rating and musical valence evaluation	RT, False alarms, Omissions
5	Chen (2019)	85	36	49	19.70 (1.50)	na	RDM, individual or two person tested	WM	N-back task	Drum beats 1.constant tempo 120bpm 2.syncopated tempo 120 bpm 3.gradual tempo shifts 100-140 bpm 4.time signature shifts 120bpm	Created for the study (unfamiliar)	Silence	Questionnaire music preferences and music listening habits	ERR, RT
6	Chou (2007)	123	27	96	>18	na	RDM; 1 testing room for each condition (3)	WM	TOEFL reading comprehension test	Classical	na	Silence	Questionnaire on musical listening habits, music attitude questionnaire	Mean comprehension score
7	Cloutier et al. (2020)	21	2	19	23.95 (3.51)	Young adults	2 mus X 2 cong/incong X 2 groups RDM	INH	Flanker task	Classical 1.stimulating 2.relaxing	na	Silence	Questionnaire assessing familiarity, pleasantness and activation of music	ERR, Interference, RT
8	Dove (2009)	84	nr	nr	nr	General college students	Counterbalance design	WM	Nelson Denny Reading Test, Form H, part II	Classical (Orchestral music), 55-70dB 1.relaxing 2.stimulating	na	Silence	Post testing familiarity questionnaire, music listening habits, familiarity	Reading comprehension score
9	Du et al. (2020)	39	15	24	Silence= 24.38 (1.1) Relax. music= 24.46 (1.13) Stim. music= 25.15 (1.72)	Preferred listening to music (n = 26) or a silent environment (n = 13)	3 × 2 mixed design; event-related potentials ; pseudo-randomised order	WM	Original Chinese sentences expressing + Seventy-seven sentences with world knowledge violations	Classical positive valence in major mode; orchestral music, 3 dB 1.fast-tempo 2.slow-tempo	Unfamiliar	Silence	Reading habits; self-reported arousal, familiarity and pleasantness of the music	ACC, RT
10	Fernandez et al. (2019)	52	NA	52	21 (2.60)	19 young adults	Mixed block design, pseudo-randomized order	INH	Modified Attention Network Test (ANT)	Classical 1.joy 2.tenderness 3.tension 4.sadness	na	Silence (in sub-study)	Valence and arousal dimensions	ACC, RT

(Table 2 continued)

No.	Reference	Population characteristics					Design	Task		Auditory stimuli			Other variables	Behavioural Outcomes
		N	M	F	Age mean (SD)	Other		Executive function	Measure	Music and sounds	Manipulation	Control condition		
11	Gann (2021)	29	19	9	nr	1 non-specified; psychology students; not color-blind	Within subject design	WM	N-back task	Classical major and minor mode 1.fast tempo 2.slow tempo	na	Silence	na	ERR, RT
12	Haning (2016)	15	nr	nr	>18	na	Testing in small groups; RDM	WM	a) Reading comprehension test (similar to the GRE: Graduate Record Examination test); b) sentence completion	Classical, major mode	na	Silence	na	ACC
13	Iwanaga and Ito (2002)	46	21	26	18-23	Undergraduate students	Counterbalanced among subjects	WM	a) The verbal memory task, b) The spatial memory task	1.Pop music (65dB) 2.nature sounds: murmurings of a stream (55dB)	na	Silence	Difficulty of task and disturbance by sounds	ACC, RT
14	Kim (2022)	66	19	47	19-23	2 subject's scores dismissed n=64 ; rock	RDM	INH	Stroop	Classical, stimulating, positive valence	na	Silence	Positively valenced, arousing music	ACC
15	Klempova and Liepelt (2018) experiment 1 and 2	24	1) 11 2) 3	1) 13 2) 21	1) 24.40 (2.90) 2) 19.90 (1.90)	na	Virtually separating action spaces of two co-actors	INH	Joint Simon task (referential coding et event-file processing)	Soft music	na	Silence	na	RT, Transition effect
16	Kumaradevan et al. (2021)	80	25	55	17–23	2 participants under 18 years of age, 78 participants were 18 and older	Quasi-experimental	INH	Stroop Colour and Word Test (SCWT)	Classical, major mode	na	Silence	na	ERR, RT
17	Mairal (2015)	22	10	12	18-33	Younger vs older adults; native speakers of English; normal speech and language	Mixed-design, RDM	WM	a) Categorization task of printed words, b) category selection	Pop song instrumental version 1.Piano Melody 2.Violin Melody	Lyrics removed, instrument manipulation	Silence	Music preferences and learning/studying/working habits	ACC, RT
18	Myles (2017) experiment 1	15	5	10	17-24 19.07 (1.94)	Undergraduate students	RDM Block design, one practice block, four blocks of testing	WM	Verbal reasoning task and spatial rotation (Cambridge Brain Science Battery (CBSB))	1.Instrumentland (140 bpm) 2.scrambled noise version (140 bpm)	Unfamiliar songs composed for the study	Silence	Participant's levels of preference, and affect rating (calm/excited and happy/unhappy)	Computerized score
	experiment 2	20	7	13	18-25 21.06 (1.78)	Undergraduate students		WM	Colour-Word Remapping (CBSB)					Computerized score
19	Nadon et al. (2021)	46	19	27	25.57 (4.33)	na	RDM, Block design	INH	Stroop	Classical 1.relaxing music 2.stimulating music 3.relaxing noise 4.stimulating noise	Noises were acoustically created and music-matched	Silence	Arousal, valence and familiarity evaluation of music	ERR, RT
20	Namwamba (2012)	30	23	**7**	18-30	Undergraduate students	RDM, 5 groups	WM	Algebra Ability Instrument (AAI)	Classical, 0dB to 79dB	na	Silence at 0 dB	na	Mathematics test scores
21	Oliver et al. (2021)	141	52	89	20.72 (3.26) all > 18	Undergraduate students, 83% Caucasian, Variations in WM	2X3 factorial study design	INH	Flanker task	Classical 1.No-Lyrics High intensity 2.No-Lyrics Optimal intensity 3.No-Lyrics Low intensity	Ajusted +/-10 dB according to group	na	Self-reported music preferences	Interference
22	Palmiero et al. (2016)	144	72	72	F=22.62 (2.80) M=22 (2.20)	Sex differences	Between-group design	WM	Corsi Block Task backward, Corsi Walking Task backward	Classical 1.positive 2.negative 3.neutral	na	Neutral music	Self-reported questionnaire of affect "right now"	Mean score
23	Patston and Tippett (2011)	36 non-mus	13	23	non-mus 24.14 (7.10)	Musical expertise	2X3 Mixed design	WM	Language comprehension, visuospatial search	Classical piano pieces minor or major mode 1.played correctly 2.played with errors	Errors added at constant frequencies throughout pieces	Silence	na	Total correct

(Table 2 continued)

No.	Reference	Population characteristics					Design	Task		Auditory stimuli			Other variables	Behavioural Outcomes
		N	M	F	Age mean (SD)	Other		Executive function	Measure	Music and sounds	Manipulation	Control condition		
24	Petrucelli (1987)	48	24	24	nr	Undergraduate and graduate students	Within-subjects; balanced using a Latin Squares Design.	INH	Stroop (color-name page (CN), and incongruous color-word page (CW))	1.White noise 70-75db Electronic music 2.Highly Stimulating (150bpm or more) 3.Moderately Stimulating (110-150 bpm) 4.Moderately Sedative (80-110bpm) 5.Highly Sedative (60bpm)	Composed for the study	Silence White noise as baseline	Musical Preference Questionnaire	Total correct, Total errors
25	Rowe et al. (2007)	24	12	12	nr	University students	Repeated measures, 3 conditions x2 tasks	INH	Flanker task	1.Happy mood: jazzed-up version of classical piece 2.Sad mood : classical	Sad music played at half speed	Neutral mood : basic facts about Canada	Self-reported valence of their mood and arousal	Correct association, RT, Interference
26	Strukelj et al. (2016)	32	17	15	18-35 25.20 (3.76)	Normal hearing	Mixed block design	INH	Antissacades task	1.Classical 2.babble 3.crying baby 4.playing children 5.rolling river 6.traffic noise 7.generic nature sound	Babble noise	Silence	Perceived disturbance level during the sound presentations, musical preference questionnaire	Latency, Mean correct first saccade
27	Sun et al. (2011)	30	15	15	21-25	Non music majors; right-handed; good sight; no history of mental disease, drug abuse, brain external injury, neural disease or chronic body disease.	3*2 within subject design	WM	N-back task (1 back and 2 back)	1.Classical lower B flat minor, B major, E major, F Major 2.Pilot music	na	Silence	Task difficulty (easy: n-1back; hard: n-2back)	ACC, RT
28	Sutton and Lowis (2008)	48	24	24	18-42 (mostly 19-20)	na	Repeated measure	WM	Written verbal reasoning tasks	Classical: in F major and in F minor	Adapting mode	na	Rating of emotional impact	Mean correct response
29	Taheri et al. (2022)	52	26	26	19-30 22.46 (3.21)	Students; extroverts 82.73%	Cross-sectional study	WM	N-back task	Classical	na	Silence	Self-reported enjoyment of music, familiarity	ACC, ERR, RT
30	Thompson et al. (2011)	25	9	16	17-26 Mean= 19.7	Undergraduate students	RDM, mixed design	WM	Reading comprehension, based upon the Graduate Management Admission Tests (GMAT)	Classical 1.slow/soft (110 bpm/60 dB) 2.slow/loud (110 bpm/72.4 dB) 3.fast/soft (150 bpm/60 dB) 4.fast/loud (150 bpm/72.4 dB)	Tempo (bpm) and intensity (dB)	Silence	na	ACC
31	Venkata Krishnam Raju (2018)	202	107	95	17-25	Healthy, not color-blind, not myopic	Between-group design	INH	Stroop Test card	Classical	na	Silence	na	Total words correctly read in 1 minute
32	Villamizar et al. (2020)	22	10	12	22-39 29 (4.95)	na	Quasi-experimental and longitudinal design	INH	Stroop (from BANFE-2)	Unfamiliar cinematic string music (74 to 78 dB-A)	Lightly modified	Silence (24 to 30 dB-A)		Hits, Omissions, ERR, RT
								WM	Self-directing signaling test (SDST)					
33	Xiao et al. (2020)	26	16	10	18-25 19.50 (1.40)	na	Repeated measure design	INH	Go/No-go task	Classical 1.slow (54 bpm) 2.medium (104 bpm) 3.fast (154 bpm)	Recomposed, tempo (bpm) manipulation	Silence	Music-induced pleasure, arousal, preference	ACC, RT
34	Yang et al. (2016) experiment	47	nr	nr	23-28 Mean= 25	Non-musicians (musicians); graduate students	Between-participant design	WM	Visual processing of picture	C major composition music 1.tonal 2.atonal	Composed for the study (unfamiliar)	Silence	na	ACC, RT
35	Young and Nolan (2015)	60	28	32	19-48 Mean= 22.78	Small Midwestern liberal arts college	Second part of experiment: multiple tasks in a maximum time	WM	Answer emails and manage time	Classical	na	Silence	RDM groups	Emails correctly answered

Note. Not reported elements are identified as nr. Only conditions, groups and tasks relevant to the research inclusion criteria are reported. ACC: % correct response; ERR: error rate; INH: inhibition; RT: response time; WM: working memory.

Table 3. – Number of studies across executive function, as a function of task and effect of BGM on performance.

Executive functioning measures according to function	Number of studies		
	Impaired	Non-significant	Facilitated
Inhibition: total of experiments for each effect	**5**	**9**	**3**
Antisaccades task	1		
Color-word remapping-inhibition (CBSB)		1	
Flanker task	2	2	
Go/No-Go task	1	1	
Modified Attention Network Task			1
Simon task	1		
Spatial processing			1
Stroop color and word test		5	1
Working memory: total of experiments for each effect	**5**	**19**	**8**
Corsi Block-tapping task			1
Corsi Walking task		1	
Linguistic processing	1	5	1
Mathematical operations			
N-back task		2	3
Reading comprehension (GMAT, GRE-like, NDRT, SAT, TOEFL)	1	4	
Responding to emails	1		
Self-directing signaling test (SDST)	1		
Self-ordered pointing task (SOPT)		1	
Spatial memory task		1	
Verbal memory task	1		
Verbal reasoning task (CBSB)		1	
Visuospatial processing task		3	2
Visual rotation task (CBSB)		1	
Written verbal reasoning task			1

Note. Some studies may present more than one experiment and the total number of studies might not reflect the total number of experiments. Likewise, some studies present different conditions and report varied effects of background music for the same measure.

Table 4. – Inhibition studies as a function of the effect of background music on outcomes, musical conditions and comparators, task administered and sample description.

Reference	Effect	Music condition	Auditory comparator	Sample size
Angel & al. (2010)	+ RT and ACC	Classical fast-tempo	Silence/no music*	n=56
Fernandez & al. (2019)	+ RT	Classical happy music (joy)	1.Tenderness 2.Tension 3.Sadness* 4.Silence/no music*	n=19
Kumaradevan & al. (2021)	+ RT	Classical, major mode, soft	Silence/no music*	n=80
Burkhard & al. (2018)	=	1.Relaxing music (70 dB) 2.Stimulating music (70 dB)	Silence/no music	n=25
Cloutier & al. (2020)	=	Classical stimulating (fast tempo)	1.Classical relaxing (slow tempo) 2.Silence/no music*	n=21
Kim (2022)	=	Classical stimulating, positive valence	Silence/no music	n=64
Myles (2017)	=	Unfamiliar music (140 BPM)	1.Scrambled noise version, 140 bpm 2.Silence/no music	n=15, n=20
Nadon & al. (2021)	=	Classical 1.relaxing noise 2.relaxing music 3.stimlating noise 4.stimulating music	Silence/no music	n=46
Oliver & al. (2021)	=	Classical 1.high intensity 2.optimal intensity 3.low intensity	1.High intensity 2.Optimal intensity 3.Low intensity	n=141
Petrucelli (1987)	=	Electronic music composed for the study 1.highly stimulating (150bpm) 2.moderately stimulating (110-150 bpm) 3.moderately sedative (80-110bpm) 4.highly sedative (60bpm)	Silence/no music White noise	n=48
Venkata Krishnam Raju (2018)	=	Classical	Silence/no music	n=202
Villamizar & al. (2020)	=	Unfamiliar cinematic string composition	Silence/no-music (noise 24-30 dB)	n=22

(Table 4 continued)

Reference	Effect	Music condition	Auditory comparator	Sample size
Cloutier & al. (2020)	- RT	Classical and relaxing (slow tempo)	1.Classical stimulating (slow tempo)* 2.Silence/no music*	n=21
Klempova & Liepelt (2018)	- RT	Soft music	Silence/no music*	n=24
Rowe & al. (2007)	- RT	Jazzed-up version of classical music, happy (positive) mood	1.Classical sad mood* 2.Basic facts about Canada*	n=24
Strukelj & al. (2016)	- RT and interference	Classical slow/soft tempo	1.Babble 2.Baby crying 3.Playing children 4.Rolling river 5.Traffic noise 6.Nature sound 7.Silence/no music*	n=35
Xiao & al. (2020)	- ACC (no-go)	Classical fast tempo (154 bpm)*	1.Slow tempo (54 bpm)*,*** 2.Moderate tempo (104 bpm)*** 3.Silence/no music**,***	n=26
	- RT (no-go)	Classical 1.slow tempo** 2.moderate tempo)** 3.fast tempo ***		

Note . RT= response time, ACC= accuracy. Non-significant effect is marked (=); for auditory conditions that had a facilitative (+) or impairment (-) effect on performance, the significant difference is identified with an *.

Table 5. – Working memory studies as a function of the effect of background music on outcomes, musical conditions and comparators, task administered and sample description.

Reference	Effect	Music condition	Auditory comparator	Sample size
Angel & al. (2010)	Reasoning score	Classical fast tempo	Silence/no music	n=56
Gann & al. (2021)	RT	Classical, fast tempo and slow tempo	Classical major and minor mode 1.Fast tempo 2.Slow tempo 3.Silence/no music*	n=29
Namwamba (2012)	Algebra reasoning	Classical high dB (79dB)	Five conditions, 0dB (silence) to 79dB	n=30
Palmiero & al. (2016)	Visuospatial WM score	Classical with positive mood	Positive, neutral, negative moods	n=72
Sun & al. (2011)	RT	1.Pilot music 2.Classical minor or major mode	Silence/no music*	n=30
Sutton & Lowis (2008)	Reasoning score	Classical in F major	Classical in F minor*	n= 48
Taheri & al. (2022)	RT, ACC	Classical	Silence/no music*	n=52
Barnes. (2002)	=	1.high complexity (70-75 dB) 2.low complexity (70-75 dB)	1.High complexity (70-75 dB) 2.Low complexity (70-75 dB) 3. Silence/no music	n=90
Buelow & al. (2022)	=	Classical	Silence/no music	(A) n=258 (B) n=341
Chen (2019)	=	Drum beats 1.constant tempo 120bpm 2.syncopated tempo 120 bpm 3.gradual tempo shifts 100-140 bpm 4.time signature shifts 120bpm	Silence/no music	n=85
Chou (2007)	=	Classical	Silence/no music	n=123
Dove (2009)	=	Classical orchestral music 1.relaxing (55-70 dB) 2.stimulating (55-70 dB)	Silence/no music	n=84
Du & al. (2020)	=	Unfamiliar Classical, positive emotions/ major mode 1.fast (high-arousal) 2.slow (low-arousal) tempo	Silence/no music	n=39

(Table 5 continued)

Reference	Effect	Music condition	Auditory comparator	Sample size
Haning (2016)	=	Classical in major mode	Silence/no music	non-mus n=15
Iwanaga & al. (2002)	=	Pop music (65 dB)	1.Nature sounds: murmurings of a stream 55dB 2.Silence/no music	n=46
Mairal. (2015)	=	Pop song 1.Piano Melody 2.Violin Melody	Silence/no music	n=36
Myles (2017)	=	Unfamiliar instrumental music,140 bpm	Scrambled noise version, 140 bpm Silence/no music	n=15
Patston and Tippett (2011)	=	Classical piano pieces (minor/major mode) 1.played correctly 2.played with errors	Silence/no music	non-mus n=36
Thompson & al. (2011)	= score	Classical 1.Slow/soft (110 bpm, 60 dB) 2.Slow/loud (110 bpm, 72.4 dB) 3. Fast/soft (150 bpm, 60 dB)	Silence/no music	n=25
Yang & al. (2016)	=	C major composition music 1.tonal 2.atonal	Silence/no music	non-mus n=47
Iwanaga & Ito (2002)	- ACC	Pop music (65dB)	Silence/no music * Nature sounds 55 dB	n=46
Thompson & al. (2011)	- score	Classical fast/loud (150 bpm, 72.4 dB)	1.Slow/soft (110 bpm, 60 dB)* 2.Slow/loud (110 bpm, 72.4 dB)* 3. Fast/soft (150 bpm, 60 dB)* 4.Silence/no music*	n=25
Villamizar & al. (2020)	- score	Unfamiliar cinematic string music, lightly modified (74-78 dB)	Silence/no-music (noise 24-30 dB)*	n=22
Young & Nolan (2015)	- Emails correctly answered	Classical in major mode	Silence/no music*	n=60

Note . RT= response time, ACC= accuracy. Non-significant effect is marked (=); for auditory conditions that had a facilitative (+) or impairment (-) effect on performance, the significant difference is identified with an *.

Table 6. – Adequacy of task and function assumed to be measured by the task.

EF	Task	Adequacy	Test source	BGM effect	Reference
INH	Antisaccades task	Y	EXP	-	Strukelj et al. (2016)
INH	Colour-Word Remapping (CBSB)	Y	STD	ns	Myles (2017) experiment 2
INH	Flanker task	Y	EXP	ns	Oliver et al. (2021)
INH	Flanker task	Y	EXP	- ns	Cloutier et al. (2020)
INH	Flanker task	Y	EXP	-	Rowe et al. (2007)
INH	Go/No-go task	Y	EXP	-	Xiao et al. (2020)
INH	Go/No-Go task Visual cognitive performance task (VCPT)	Y	EXP	ns	Burkhard et al. (2018)
INH	Joint Simon task (referential coding et event-file processing)	Y	EXP	-	Klempova and Liepelt (2018) experiment 1 and 2
INH	Linguistic processing (Criterion Task Set)	N	EXP	+	Angel et al. (2010)
INH	Modified Attention Network Test (ANT)	Y	EXP	+	Fernandez et al. (2019)
INH	Stroop	Y	STD	ns	Kim (2022)
INH	Stroop	Y	STD	ns	Nadon et al. (2021)
INH	Stroop	Y	STD	ns	Petrucelli (1987)
INH	Stroop	Y	STD	ns	Venkata Krishnam Raju (2018)
INH	Stroop (from BANFE-2)	Y	STD	ns	Villamizar et al. (2020)
INH	Stroop Colour and Word Test (SCWT)	Y	STD	+	Kumaradevan et al. (2021)
WM	Algebra Ability Instrument (AAI)	N	LAB	+	Namwamba (2012)
WM	Answer emails and manage time	N	LAB	-	Young and Nolan (2015)
WM	Categorization task of printed words Category selection	N	LAB	ns	Mairal (2015)
WM	Corsi Block Task backward	Y	STD	+	Palmiero et al. (2016)
WM	Corsi Walking Task backward	Y	STD	ns	Palmiero et al. (2016)
WM	Language comprehension Visuospatial search	N	LAB	ns	Patston and Tippett (2011)
WM	N-back task	Y	EXP	+	Taheri et al. (2022)
WM	N-back task	Y	EXP	ns	Chen (2019)
WM	N-back task	Y	EXP	+	Gann (2021)
WM	N-back task Self-ordered pointing task (SOPT)	Y	EXP	ns	Buelow et al. (2022)
WM	N-back task (1 back and 2 back)	Y	EXP	+	Sun et al. (2011)
WM	Original Chinese sentences expressing Word knowledge violations	N	LAB	-	Du et al. (2020)
WM	Reading comprehension (Graduate Management Admission Tests (GMAT))	N	PAT	- ns	Thompson et al. (2011)
WM	Reading comprehension (Nelson Denny Reading Test, Form H, part II)	N	PAT	ns	Dove (2009)
WM	Reading comprehension (Scholastic Aptitude Test (SAT))	N	PAT	ns	Barnes (2002)
WM	Reading comprehension test Sentence completion	N	PAT	ns	Haning (2016)
WM	Reading comprension (TOEFL)	N	PAT	ns	Chou (2007)
WM	Self-directing signaling test (SDST)	Y	STD	-	Villamizar et al. (2020)
WM	Spatial processing (Criterion Task Set)	Y	EXP	+	Angel et al. (2010)
WM	Verbal memory task Spatial memory task	Y	LAB	- ns	Iwanaga and Ito (2002)
WM	Verbal reasoning task Spatial rotation (Cambridge Brain Science Battery (CBSB))	Y	STD	ns	Myles (2017) experiment 1
WM	Visual processing of picture	Y	LAB	ns	Yang et al. (2016) experiment 2
WM	Written verbal reasoning tasks	N	LAB	+	Sutton and Lowis (2008)

Note. EF=Executive function, INH=inhibition, WM=working memory, Y=yes, N=no. STD=standardized test, EXP=experimental paradign, PAT=performance assesment test for ranking and admissions, LAB=laboratory-made test.