2022-12-06

Eye Closure Interacts with Music to Influence Vividness and Content of Directed Imagery

Herff, SA

http://hdl.handle.net/10026.1/20271

10.1177/20592043221142711
Music & Science
SAGE Publications

50th sempre: Society for Education, Music and Psychology Research Anniversary
MUSIC & SCIENCE

Music and Mental Imagery – Research Article

Music & Science
Volume 5: 1–14
© The Author(s) 2022
DOI: 10.1177/20592043221142711
journals.sagepub.com/home/mns
SAGE

Eye Closure Interacts with Music to Influence Vividness and Content of Directed Imagery

Steffen A. Herff[1,2], Sophie McConnell[3], Julie L. Ji[4,5] and Jon B. Prince[3]

Abstract

Goal-directed, intentional mental imagery generation supports a range of daily self-regulatory activities, such as planning, decision-making, and recreational escapism. Many clinical interventions for mood and anxiety disorders also use imagery and their effectiveness can be affected by an individual's ability to manipulate vividness and content of mental imagery. Prior literature points towards music as a promising candidate to influence imagination in such settings, but basic questions remain regarding how music affects mental imagery and how it interacts with basic, well-established parameters, such as facilitatory effects of eye closure. One hundred participants listened to music and a silent control whilst performing a guided mental imagery task. Specifically, participants saw a short video of a figure journeying towards a landmark and imagined a continuation of the journey with either closed or open eyes. After each trial, participants reported vividness and content of their imagined journeys. Bayesian Mixed Effects Models obtained strong evidence of greater vividness, duration, as well as distance travelled in music conditions compared to silent conditions. Additionally, interactive effects of music and eye closure were found for both vividness and the emotional valence of imagined content, where music effects were disproportionately amplified by eye closure. Findings further support music's potential to manipulate the perceptual, spatial-temporal, as well as emotional sentiment of deliberately generated mental imagery.

Keywords

Imagination, mental imagery, mind-wandering, music, vision

Submission date: 12 August 2022; Acceptance date: 15 November 2022

Introduction

Deliberate mental imagery generation plays a key role in action planning (Keller, 2012), simulating past and future events (D'Argembeau & Van der Linden, 2006), and escapism (Schäfer, Sedlmeier, Städtler, & Huron, 2013). Such mental imagery is also a feature of evidence-based psychotherapeutic treatment for mood and anxiety disorders (Hackmann, Bennett-Levy, & Holmes, 2011; Hirsch & Holmes, 2007; Pearson, Naselaris, Holmes, & Kosslyn, 2015; Blackwell, 2019; Holmes, Arntz, & Smucker, 2007; Lang, 1977; McEvoy, Saulsman, & Rapee, 2018; Mendes, Mello, Ventura, De Medeiros Passarela, & De Jesus Mari, 2008; Pile, Williamson, Saunders, Holmes, & Lau, 2021; Saulsman, Ji, & McEvoy, 2019). A key concern is that whilst these therapies are remarkably effective (Arntz, 2012), their efficacy may be affected by patients' ability to alter vividness and content of mental imagery (Johnsen & Lutgendorf, 2001; Mota et al., 2015; Richardson & Taylor, 1982; Stopa, 2011). Consequently, there is both basic and clinical utility in identifying methods to scaffold vividness as well as imagery content, and music has been identified as a promising candidate for influencing both undirected mind-wandering as well

[1] École Polytechnique fédérale de Lausanne, Switzerland
[2] The MARCS Institute for Brain, Behaviour and Development, Western Sydney University, Australia
[3] School of Psychology, Murdoch University, Australia
[4] Centre for the Advancement of Research on Emotion, School of Psychological Science, University of Western Australia, Australia
[5] School of Psychology, University of Plymouth, UK

Corresponding author:
Steffen A. Herff, École Polytechnique fédérale de Lausanne, Switzerland.
Email: s.herff@westernsydney.edu.au

as directed, intentional mental imagery (Dahl, Stella, & Bjørner, 2022; Herff, Cecchetti, Taruffi, & Déguernel, 2021; Küssner, Eerola, & Fujioka, 2019; Taruffi & Küssner, 2019). However, much is still unknown about how music affects mental imagery, and how it interacts with other core parameters of interest. Here, we are particularly concerned with exploring how music affects directed, intentional (predominantly visual) mental imagery with and without concurrent external visual information.

Music and Mental Imagery Generation

Mental imagery, both directed and undirected, is the representation and accompanying experience of sensory information without the direct concurrent external stimulus (Kosslyn, Ganis, & Thompson, 2001; Pearson et al., 2015). A large proportion of music listeners report that they experience spontaneous imagery when listening to music (Day, Thompson, & Boag, 2019; Küssner & Eerola, 2019; Vuoskoski & Eerola, 2015). Music is a reliable inducer of spontaneous, undirected mind-wandering (Herbert, 2013; see Taruffi & Küssner, 2019 and Küssner, Eerola, & Fujioka, 2019 for reviews) and listening to music increases the likelihood of mind-wandering episodes to occur (Taruffi, 2021). The characteristics of the music also shapes the content of such mind-wandering episodes (Dahl et al., 2022), with heroic music, for example, being predictive of exciting and positive thoughts, whereas sad music is predictive of demotivating thoughts (Koelsch, Bashevkin, Kristensen, Tvedt, & Jentschke, 2019). A large online survey study found that spontaneous music-induced imagery often contains common themes such as concrete (e.g., landscapes) and abstract (e.g., patterns and shapes) visual imagery (Küssner & Eerola, 2019). Furthermore, this music-induced undirected mind-wandering can also result in imagined narratives whose content is more similar between listeners of similar enculturation (Margulis, Wong, Simchy-Gross, & McAuley, 2019). A study showing that engagement with music is a predictor of concurrent visual mental imagery further reinforces the causal link between music and imagination (Presicce & Bailes, 2019). The strong empirical support for spontaneous music-induced mental imagination secured mental imagery a central role in current models of music perception, theorizing that the evoked images contribute to music's ability to communicate complex emotions (Balteș & Miu, 2014; Juslin & Sloboda, 2001; Juslin & Vastfjall, 2008; Vuoskoski & Eerola, 2015).

In addition to music's effect on non-directed mind-wandering, music can also affect imagination in goal-directed mental imagery tasks, highlighting its utility for clinical settings (Nanay, 2018; for a review see Pearson et al., 2015). This is because established and emerging evidence-based interventions utilize goal-directed deliberate mental imagery to expose clients to feared stimuli (Mendes et al., 2008; Rothbaum & Schwartz, 2002), rescript traumatic memories (Arntz, 2012; Holmes et al., 2007), train more positive and concrete memory and future thinking (Hallford et al., 2020; Hitchcock et al., 2021; Pile, Smith, et al., 2021), modify interpretation biases (Blackwell et al., 2015; Blackwell & Holmes, 2010; Hirsch et al., 2021; Ji et al., 2021), regulate mood instability (Holmes, Hales, Young, & Di Simplicio, 2019), and reduce engagement in harmful behaviors (Andrade, May, & Kavanagh, 2012; Di Simplicio et al., 2020). Directed and intentional mental imagery generation also underpins decision-making and motivated behavior, as it enables individuals to experience a hypothetical future situation to evaluate and prepare for possible outcomes and potential reactions (Bulley & Irish, 2018; Lang, 1979; Moulton & Kosslyn, 2009; Schacter, Addis, & Buckner, 2008; Taylor, Pham, Rivkin, & Armor, 1998).

Within the context of music, in a recent study participants engaged in a directed mental imagery task that required imagining the continuation of a visual inducer, namely a figure walking towards a landmark (Herff, Cecchetti, et al., 2021). These imagined continuations occurred either during concurrent music or a silent control condition. Similar to studies exploring undirected mind-wandering, vividness ratings were significantly higher when accompanied by task-irrelevant background music. Furthermore, the music also affected the content of the mental imagery, both in terms of sentiment as well as physical properties of the imagined content, such as the travelled distance and imagined time passed. Accordingly, the effects of music are not limited to an emotional coloring of the same mental imagery but extend to altering basic attributes such as imagined orientation in both time and space (see Herff, Cecchetti, Taruffi, & Déguernel, 2021, for an in-depth discussion). This finding generalizes music's ability to influence imagination from undirected mind-wandering to goal-directed mental imagery generation. This generalization is an important step for establishing music's potential to support evidence-based clinical psychological interventions that utilize mental imagery, which are effective (Arntz, 2012), but their efficacy can be influenced by the client's ability to deliberately generate and manipulate mental imagery (Mota et al., 2015; Stopa, 2011). Interestingly, in the aforementioned directed mental imagery paradigm, participants were asked to close their eyes, which is also a common instruction for mental imagery therapies that are music-based (e.g., Goldberg, 2013).

Imagination and Eye Closure

The use of eye closure to facilitate deliberate mental imagery generation is a widespread assumption that has also received scientific support. From a theoretical perspective, mental imagery is understood to rely on both memory recall from specific memories or ideas (Day & Thompson, 2019) as well as working memory to construct coherent imagery (Baddeley & Andrade, 2000; Gunter & Bodner, 2008). Closing one's eyes reduces cognitive load by freeing resources that would otherwise be occupied in monitoring the external environment (Vredeveldt, Hitch, &

Baddeley, 2011), thus facilitating visual imagery (Bartels, Harkins, Harrison, Beard, & Beech, 2018) as well as creativity (Ritter, Abbing, & Van Schie, 2018). Various studies have now investigated the detrimental effect of concurrent visual information on both vividness as well as emotional intensity (Andrade, Kavanagh, & Baddeley, 1997; Engelhard, van den Hout, & Smeets, 2011; Engelhard, van Uijen, & van den Hout, 2010; Kemps, Tiggemann, Woods, & Soekov, 2004; Littel, van den Hout, & Engelhard, 2016; van den Hout, Engelhard, Beetsma et al., 2011; van den Hout, Engelhard, Rijkeboer, et al., 2011). For example, in a study by Bartels et al. (2018), participants performed a guided imagery task in which they were instructed to imagine a sexual fantasy. The results demonstrated that bilateral eye movement led to significantly less vividness and sexual arousal in the imagery task. Indeed, all the aforementioned studies report that closed-eyes facilitates mental imagery compared to open-eyes. The disruptive effect of concurrent visual information on mental imagery has been harnessed by therapeutic techniques such as Eye-Movement Desensitization and Reprocessing (Shapiro, 1989; van den Hout & Engelhard, 2012; van den Hout, Engelhard, Beetsma et al., 2011) and Tetris gameplay (James et al., 2015) to reduce intrusive distressing mental imagery. Whilst the facilitative effect of eye closure on mental imagery is well established, its interaction with other parameters that affect imagination, such as music, has received far less scientific attention.

The studies reviewed above establish that both music and eye closure seem to have facilitatory effects on mental imagery. Whether these are simply additive or interactive, however, is unclear. The study closest related to the topic is recent work by Hashim, Stewart, and Küssner (2020). In their study, 35 participants listened to music whilst either focusing on a blank screen or performing an eye-movement distractor task that required visually tracking a flashing white square (Kemps & Tiggemann, 2007). They found significantly higher prevalence of incidental visual imagery as well as increased imagined vividness when participants were not performing the concurrent visual tracking task. This is an important finding, as it shows that the aforementioned studies investigating the disruptive effect of concurrent visual information on mental imagery also generalize to music-induced imagination. However, as the interaction of music with concurrent visual information was not a research question in the study by Hashim et al. (2020), there was no silent control condition. Furthermore, the study was concerned with undirected rather than directed mental imagery and compared the effect of a cognitively taxing and distracting visual task (Kemps & Tiggemann, 2007; Kemps et al., 2004) with another (less demanding) visual condition. Therefore, their findings may not necessarily generalize to the question of interest in the present study, which is whether the absence of concurrent visual information (closed-eyes) interacts with the presence of music to influence vividness and content in a directed imagination task.

Aims and Hypotheses

This study aims to further our understanding of the impact of music and eye closure on deliberate mental imagery generation, a process used in cognitive therapies as well as self-regulation. Specifically, the study investigates the main and interactive effects of music and eye closure on the perceptual vividness, spatial-temporal characteristics, and emotional sentiment of imagined content. For this, we borrow a previously published music-based directed mental imagery paradigm (Herff, Cecchetti, et al., 2021) that requires participants to imagine the continuation of a journey, but add an additional within-subjects manipulation whereby participants perform the task with their eyes either open or closed. As in the previous study, we operationalize content both through the sentiment of the description of participants' imagined journey, as well as through physical properties of the journey in form of imagined time and distance travelled. This study first tests whether prior findings of the effects of music as well as eye closure can be replicated. Additionally, this study design enables testing whether effects of music and closed-eyes on imagination are purely additive or whether they interact with one another. Based on the reviewed literature, we hypothesise the following (foreshadowing the findings in parentheses):

1. Imagery vividness is greater when listening to music than silence (supported)
2. Closed-eyes trials show more vivid imagination than open-eyes trials (supported)
3. Eye closure affects music conditions more than silent conditions (supported)
4. Music (supported) and eye closure (supported) can affect imagined travel distance
5. Music (supported) and eye closure (not supported) can affect imagined time passed
6. Music (supported) and eye closure (supported) can affect imagined sentiment

Method

Design

This study utilized a 2 × 3 within-subject design with the factors *Eye Closure* (open-eyes vs. closed-eyes) and *Stimulus* (silent control vs. relaxing music vs. arousing music). Each participant performed the mental imagery task once for each factor combination. The order was fully randomized between participants. After the completion of the experiment, participants were asked to fill out additional questionnaires as detailed below.

Participants

We collected data from $N = 100$ participants online from the student population of Murdoch University, Perth, Australia. The sample size was based on a prior study using the same paradigm (Herff, Cecchetti, et al., 2021).

Thirteen participants skipped through the experiment and did not answer all the questions. These participants were removed from the sample and 13 new participants were recruited. The final sample of 100 participants had a median age of 21 years (ranging from 17 to 59; the self-identified gender distribution comprised 83 females, 11 males, two others, and four preferred not to disclose). All participants provided informed consent. Participants were reimbursed with course credit.

Stimuli

The auditory stimuli comprised two musical pieces and a silent control condition. The musical stimuli were chosen from a prior study (Kuan, Morris, & Terry, 2017): *Gli uccelli: II La colomba* (*The Birds: The Dove*, composed by Ottorino Respighi, performed by I Solisti Veneti, conducted by Claudio Scimone, published by Erato Classics S.N.C in 1988), *Music from the Gadfly: XII The finale* (composed by Dimitri Shostakovich, performed by the Ukraine National Symphony Orchestra, conducted by Theodore Kuchar, published Naxos in 1997). The two musical pieces were chosen as they adhere to the Western classical music style, and representative of the same idiom have previously shown strong effects in music-induced imagination studies (Herff, Cecchetti, et al., 2021). That said, other genres have also shown strong effects of music on imagination, making this choice somewhat arbitrary (Herff, Cecchetti, et al., 2021; Herff, Taruffi, Cecchetti, & Déguernel, 2021; Koelsch et al., 2019; Taruffi, 2021). More importantly, the pieces were selected to be associated with a relaxing (piece by Respighi) and an arousing (piece by Shostakovich) emotional state, confirmed in the prior study for the two aforementioned pieces (Kuan et al., 2017). We chose these two emotional states because prior research has shown that perceived arousal in music can have profound effects on guided mental imagery tasks during music listening. Specifically, if a guided mental imagery task is used to practice an athletic task, relaxing background music during imagery tends to facilitate later real-world performance (Kuan, Morris, Kueh, & Terry, 2018). Whilst no real-world athletic performance is required here from our participants, we want to account for the possibility that relaxing music simply facilitates imagination more than arousing music does. Consequently, and based on prior literature, the relaxing song (Respighi) can be considered more likely to produce an observable effect than the arousing song (Shostakovich). By including both, we explored whether potential effects are limited to ideal conditions, that is, a relaxing musical background. To strike a balance between trial number, mental imagery periods, and study duration, participants heard the first 1 min 45 sec of each piece, with a 100 ms fade-out to avoid clipping. The pyloudnorm Python library (Steinmetz, 2019) was used to normalize the loudness of all stimuli to the common value of $-23 \pm 5*10^{-7}$ LUFS, as per EBU R-128 (EBU, 2014). Both the duration choice and normalization process were based on a previous study (Herff, Cecchetti, et al., 2021).

A short visual inducer was used to guide participants' imagination. We used the visual inducer from Herff et al. (2021), namely a 15-s long video of the opening sequence of the video game 'Journey' (with written permission of Jenova Chen, CEO of ThatGameCompany, https://thatgamecompany.com, see Figure 1). In the video, a figure ascends a small hill (see Figure 1a). Once the figure reaches the top of the hill, a vague (low-contrast) landmark in the form of an illuminated mountain appears in the far distance (see Figure 1b). The purpose of the visual inducer is to provide a general frame to participants' mental imagery by offering a clear start and direction for the guided mental imagery task. After the short video, participants saw either a black screen with a white fixation cross, or the instructions 'Please close your eyes'. Note that in previous studies investigating the effect of concurrent visual information on imagination, the disruptive test condition required participants to track a moving target

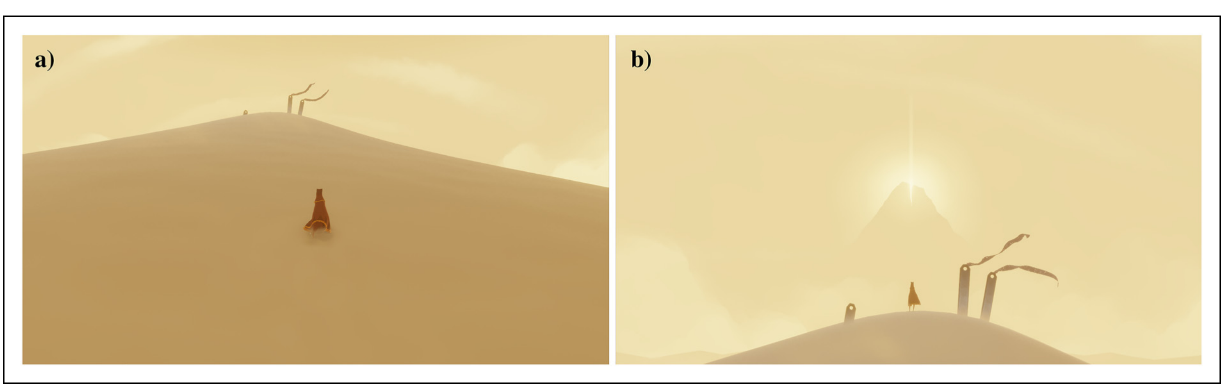

Figure 1. Images from the visual inducer video. A figure ascending a small hill was visible (a). Shortly after the figure reached the top of the small hill, a large but barely visible mountain (b), appeared in the far distance, and participants were instructed to imagine a continuation of the journey towards the landmark, with their eyes either closed or fixated on a cross. Reproduced with permission from Herff, Cecchetti, et al. (2021).

intensity (Andrade et al., 1997; Engelhard et al., 2011 , 2010; Kemps et al., 2004; Littel et al., 2016; van den Hout, Engelhard, Beetsma et al., 2011; van den Hout, Engelhard, Rijkeboer, et al., 2011), rather than fixating a stationary target. Indeed, meta studies demonstrated the additive disruptive effect of eye movement on mental imagery (Lee & Cuijpers, 2013). However, here we deliberately opted for the less disruptive effect of open-eyes without moving target tracking to avoid potential floor-effects in the silent control condition. We consider this a more conservative approach, as any disruptive effect of open-eyes observed in the present paradigm would likely be further exacerbated when done with moving target tracking.

Imagination Task

In each trial of the imagination task, participants were presented with the visual inducer and instructed to imagine a continuation of the figure's journey towards the landmark. After 15 s of the visual inducer, a gong sound was heard, indicating that the imagination period started. Ninety seconds later, the same gong sound was played, indicating that the imagination period was over. All instructions appeared written on the screen. Participants were also informed that after the video, they would either close their eyes (indicated with the written instructions 'Please close your eyes') between the two gong sounds or fixate on a white cross that appeared on-screen. In each trial, from the beginning of the video until the end of the imagination period, participants heard either one of the musical pieces or a silent control condition. Participants heard each musical piece and the silent control condition twice (in open- and closed-eyes conditions) for a total of six trials in fully random order. As with the previous study using the same paradigm (Herff, Cecchetti, et al., 2021), participants were instructed to 'please treat every repetition independently from one another. You can imagine a similar or a totally different journey every time. This is entirely up to you' and that 'there are no restrictions on your imagination, but please always keep the mountain in sight. This is because after your imagination you will be asked a few questions about the time and distance travelled in your imagination, and the mountain can help you orientate'. In each trial after the imagination period, participants were prompted to answer the following questions using the keyboard. The available inputs varied depending on the question and are indicated in brackets below:

1. How much time really passed between the two gong sounds? (minutes, seconds)
2. How far away do you estimate the mountain to be at the beginning of the journey? (kilometres, meters)
3. How much time passed in your imagination? (years, months, days, hours, minutes, seconds)
4. How far did you travel in your imagination? (kilometres, meters)
5. How vivid (clear) was the imagery you experienced compared to experiences in real life? (numeric response with 0 = not very clear and 100 = very clear)
6. Please describe your imagination in as much detail as possible. (free-format text box)

The first two questions were included to highlight the difference between real and imagined time and space, and indeed, all participants gave different responses to the real and imagined questions about time or space. Responses to the remaining questions were used to address the present research questions. Note, that we did not provide a formal definition of 'imagination' to the participants, but rather let participants interpret the instructions freely to avoid introducing biases. However, based on participants' free-format responses, every participant engaged in visual mental imagery, as intended. Additionally, some participants reported felt emotions as well as other imagined sensory experiences such as 'the sound of distant footsteps, accompanied with shouting'. All descriptive responses and task instructions can be found in the online supplement https://osf.io/b7wcr. The entire experiment took between 30 and 60 min, depending on how detailed participants' free-format responses were. After the last imagination trial, participants were prompted to fill out two additional questionnaires.

Questionnaires

The Goldsmith-Musical Sophistication Index (Gold-MSI) (Müllensiefen, Gingras, Musil, & Stewart, 2014) was the first questionnaire participants completed after the main experiment finished. It uses five subscales to determine participants' active and passive engagement with music. In this study, we did not have a hypothesis for musical training, but as some prior studies found such effects (Presicce & Bailes, 2019), we used the formal training subscale to control for them. Regardless, we did not find any evidence for an effect of musical expertise on the imagination task in the present study.

The second questionnaire was the Depression Anxiety Stress Scale (DASS) (Lovibond & Lovibond, 1995), and is not part of the present analysis. The results of this questionnaire will be reported elsewhere, together with the data of other imagination studies that also collected DASS-21 ratings to investigate the effects of mood symptoms on imagination across a series of multiple experiments.

Statistical Approach

We used Bayesian Mixed Effects Models to analyze the data. All models were implemented using the brms package (Bürkner, 2017, 2018) in R (R-Core-Team, 2013). Each model was provided with a weakly informative prior in form of a t-distribution with a mean of 0, a standard deviation of 1, and 3 degrees of freedom, and all continuous variables were standardized to have a mean of 0 and a standard deviation of 1 (Gelman, Jakulin, Pittau, & Su, 2008).

Both the prior and standardization are widely used in the auditory as well as music cognition literature (Beveridge, Cano, & Herff, 2021; Cecchetti, Herff, & Rohrmeier, 2021; Cecchetti, Herff, & Rohrmeier, 2022; Herff, Dorsheimer, Dahmen, & Prince, 2022; Herff, Harasim, Cecchetti, Finkensiep, & Rohrmeier, 2021; Herff et al., 2020; MacRitchie, Breaden, Milne, & McIntyre, 2020; Milne & Herff, 2020; Smit, Dobrowohl, Schaal, Milne, & Herff, 2020; Smit, Milne, Sarvasy, & Dean, 2022). Based on the research question at hand, each model then predicted a given dependent variable (vividness, distance, time, or emotional sentiment) whilst accounting for participant and trial effects through random intercepts. We initially also included the formal musical training subscale from the Gold-MSI in each model; however, as it did not carry predictive value in any model, we dropped this predictor for the final analyses. Each model ran on four chains with 1,000 warm-ups and 10,000 iterations. To assess the hypotheses, we report model coefficients (β), the estimated error of this coefficients (EE_β), as well as the evidence ratio in favour of a given hypothesis ($Odds_\beta > or < 0$). For convenience we denote effects than can be considered 'significant' under an alpha level of 5% with * (i.e., evidence ratio $\geq$ 19; see Milne & Herff, 2020)

To estimate participants' imagined sentiment, we used the National Language Tool Kit (NLTK) (Loper & Bird, 2002) to pre-process the free-format responses (filtering stop-words, lemmatizing, and stemming) and the Valence Aware Dictionary for sEntiment Reasoning (VADER) model (Hutto & Gilbert, 2014) implemented in Python to extract the sentiment from the pre-processed detailed descriptions of the mental imagery provided by the participants in each trial. Based on its inherent reference dictionary, VADER maps lexical features to emotion polarity (continuum from negative to positive) as well as intensity. These word-wise sentiment scores were then averaged within a given response and included in the statistical analysis, where more positive values indicate more positive sentiment. Participants varied greatly in their imagined distances and times travelled, with journeys ranging from 1 meter to 900 kilometres, and 1 s to 15 years. As we are here primarily concerned with relative imagined distance and time between conditions, rather than absolute imagined distance or time, we first log-scaled reported times and distances, and then standardized them (mean = 0, SD = 1) for each participant.

The statistical approach and experimental design were not pre-registered; however, they closely follow that of prior work (Herff, Cecchetti, et al., 2021). All data and scripts used for analysis are available through the Open Science Framework (https://osf.io/b7wcr).

Results

Imagery Vividness is Greater When Listening to Music Than Silence (supported)

Participants engaged in the task and used the full range of the vividness scale ($M = 44.60$, $SD = 28.42$, $Min = 1$, $Max = 100$). We predicted standardized *Vividness* using *Stimulus (*factor with three levels: Silence, Respighi, Shostakovich) as a predictor. As seen in Figure 2, both music conditions led to higher vividness ratings than the silence condition: Respighi ($\beta = .49$, $EE_\beta = .07$, $Odds(\beta > 0) > 9999$*), Shostakovich ($\beta = .62$, $EE_\beta = .07$, $Odds(\beta > 0) > 9999$*).

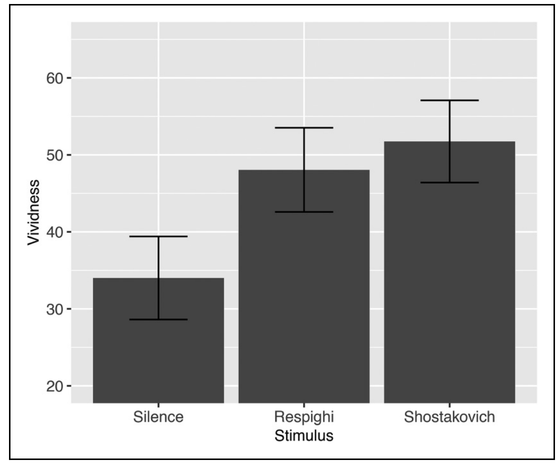

Figure 2. Raw mean vividness scores by stimulus. In all music conditions, participants reported more vivid imagery compared to the silence condition. Prior studies associated the Respighi piece with relaxing, and the Shostakovich piece with an arousing state. Error bars show 95% confidence intervals.

Closed-eyes Trials Show More Vivid Imagination Than Open-eyes Trials (Supported)

To answer the second research question, we added *EyeCondition* (Open vs. Closed) and the *Stimulus x EyeCondition* interaction to *Stimulus* as predictors of *Vividness* to the model used to address the previous research question. Figure 3 shows that in all conditions, Silence ($\beta = .19$, $EE_\beta = .1$, $Odds(\beta > 0) = 36.46$*), Respighi ($\beta = .50$, $EE_\beta = .1$, $Odds(\beta > 0) > 9999$*), and Shostakovich ($\beta = .4$, $EE_\beta = .1$, $Odds(\beta > 0) > 9999$*), the closed-eyes trials showed more vivid imagination.

Eye Closure Affects Conditions With Music More Than Conditions With Silence (supported)

The above model further provided strong evidence that the facilitating effect closed-eyes had on vividness is stronger in both music conditions compared to the silence condition (Respighi vs Silence: $\beta = .31$, $EE_\beta = .14$, $Odds(\beta > 0) = 67.97$*; Shostakovich vs Silence: $\beta = .24$, $EE_\beta = .14$, $Odds(\beta > 0) = 23.67$*). This can be seen in Figure 4, which shows the model's predicted effects of closed-eyes on vividness when listening to the three different stimuli, expressed in standard deviations.

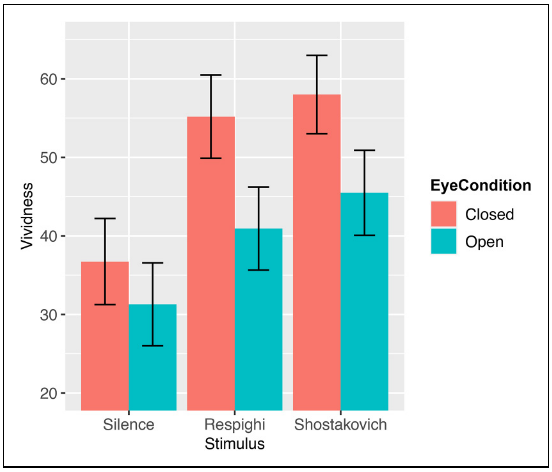

Figure 3. Raw mean vividness scores by stimulus and eye condition. In all stimulus conditions, participants reported more vivid imagery with closed- compared to open-eyes. This difference is much larger in the music compared to the silence conditions. Prior studies associated the Respighi piece with relaxing, and the Shostakovich piece with an arousing state. Error bars show 95% confidence intervals. Note that the mixed effects analysis can account for much of the variability contained in the error bars of the raw data depicted here.

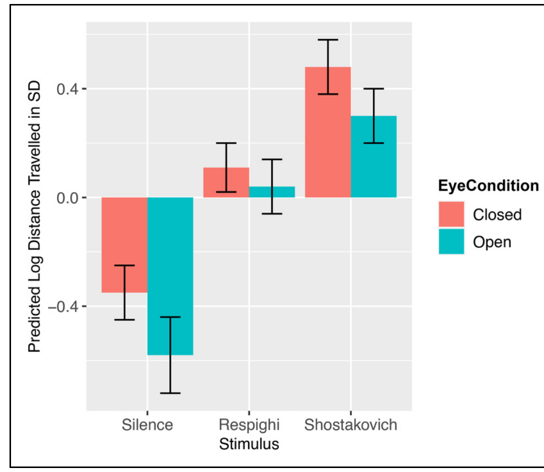

Figure 5. Model's predicted standardized log imagined distance travelled based on stimulus and eye condition, whilst controlling for participant and trial number random effects. The model obtains strong evidence that both music conditions show larger imagined distances travelled than the silence condition. The arousing Shostakovich piece also showed larger distances than the relaxing Respighi piece. Additionally, closed-eyes increased imagined distance travelled, but only in the silent condition. Error bars show 95% credible intervals of the model's coefficients.

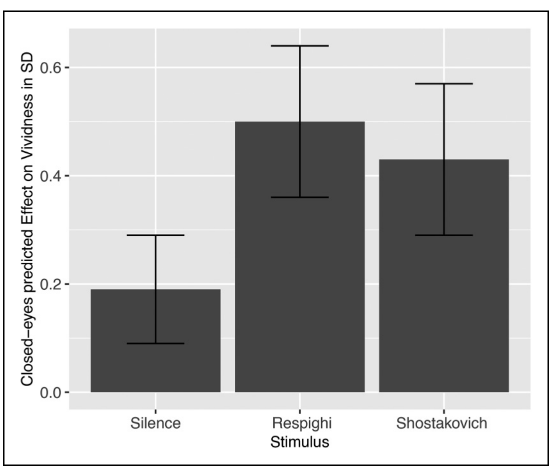

Figure 4. Conditional effects plot of the model's predicted effects (expressed in standard deviation) of eye closure on vividness for each stimulus, whilst controlling for participant and trial number as random effects. Prior studies associated the Respighi piece with relaxing, and the Shostakovich piece with an arousing state. The effect of eyes-closed is much stronger for music conditions than the silent condition. Error bars show 95% credible intervals of the model's coefficients.

Music (supported) and Closed-eyes (supported) Can Affect Imagined Travel Distance

Using the same model architecture as above but predicting standardized log distance travelled instead, we obtained strong evidence that in both music conditions, participants imagined longer distances travelled compared to the silence condition (Respighi vs Silence: $\beta = .54$, $EE_\beta = .09$, $Odds(\beta > 0) = 9999^*$; Shostakovich vs Silence: $\beta = .83$, $EE_\beta = .09$, $Odds(\beta > 0) > 9999^*$). Imagined travel distance also varied across music, with the arousing Shostakovich piece being predictive of larger distances travelled compared to the relaxing Respighi piece ($\beta = .38$, $EE_\beta = .12$, $Odds(\beta > 0) = 1160.29^*$). Closed-eyes is predictive of imagined distance travelled in the silence condition ($\beta = .23$, $EE_\beta = .12$, $Odds(\beta > 0) = 35.33^*$), but we did not obtain strong evidence for this to occur in either of the music conditions (Respighi: $\beta = .06$, $EE_\beta = .12$, $Odds(\beta > 0) = 2.34$; Shostakovich: $\beta = .18$, $EE_\beta = .12$, $Odds(\beta > 0) = 15.44$). Figure 5 shows the predicted changes in standardized log imagined distance travelled, expressed in standard deviations.

Music (supported) and Closed-eyes (not supported) Can Affect Imagined Time Passed

Using the same model architecture as above, but predicting standardized log time imagined instead, we observed strong evidence that both music conditions are predictive of greater time passed in imagination compared to the silence condition (Respighi vs Silence: $\beta = .39$, $EE_\beta = .09$, $Odds(\beta > 0) = 9999^*$; Shostakovich vs Silence: $\beta = .37$, $EE_\beta = .09$, $Odds(\beta > 0) = 9999^*$). We did not obtain strong evidence for closed-eyes to affect any of the three conditions (all $Odds < 13.57$). These results can be seen in Figure 6, where both music conditions show larger times travelled, but the height of the blue and red columns are comparable. The Shostakovich piece shows descriptively the largest difference between the closed-eyes and open-eyes condition.

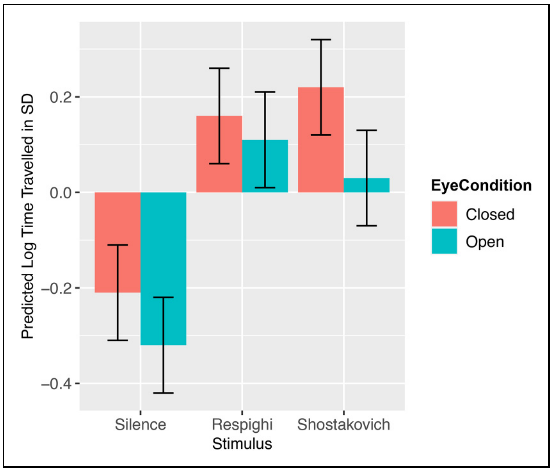

Figure 6. Model's predicted standardized log imagined time travelled based on stimulus and eye condition, whilst controlling for participant and trial number random effects. The model obtains strong evidence that both music conditions show longer imagined times travelled than the silence condition. Prior studies associated the Respighi piece with relaxing, and the Shostakovich piece with an arousing state. However, only weak to no evidence for an effect of closed-eyes was observed. Error bars show 95% credible intervals of the model's coefficients.

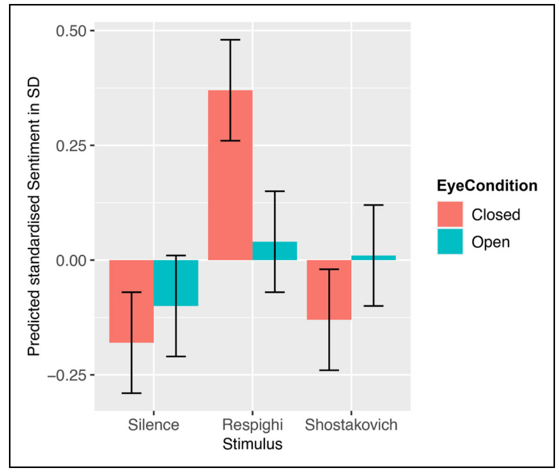

Figure 7. Model's predicted standardized sentiment of the imagined content based on stimulus and eye condition, whilst controlling for participant and trial number random effects. The model obtains strong evidence that the relaxing Respighi piece shows more positive sentiment than both the silence condition and the arousing Shostakovich piece. The Respighi is also the only condition in which closed-eyes affect imagined sentiment. Error bars show 95% credible intervals of the model's coefficients.

Music (supported) and Closed-eyes (support) Can Affect Imagined Sentiment

Using the same model architecture as above, but predicting standardized imagined sentiment instead, we observed strong evidence that imagined content during the relaxing Respighi piece shows much more positive sentiment compared to the silence condition (Respighi vs Silence: β = .34, EE_β = .1, $Odds(\beta > 0)$ = 2768.23*) and the arousing Shostakovich piece (Respighi vs Shostakovich: β = .26, EE_β = .1, $Odds(\beta > 0)$ = 250.75*). No strong evidence was obtained to set imagined sentiment apart during the Shostakovich piece and silence condition (Shostakovich vs Silence: β = .08, EE_β = .14 $Odds(\beta > 0)$ = 4.07). We obtained strong evidence for closed-eyes to affect sentiment positively in the Respighi piece (β = .34, EE_β = .14, $Odds(\beta > 0)$ = 160.43*), but no strong evidence was observed for an effect of closed-eyes on the Shostakovich piece (β = -.13, EE_β = .14, $Odds(\beta < 0)$ = .20, or the silence condition (β = -.08, EE_β = .14, $Odds(\beta < 0)$ = .38). This can also be seen in Figure 7, where the Respighi piece shows the most positive sentiment and is also the only condition where a large difference between the red and blue bar can be seen.

Discussion

That both music (Herff, Cecchetti, et al., 2021; Taruffi, 2021) and eye closure (Husnu & Crisp, 2011) can affect imagination is well established, but it is less clear whether/how they interact in the context of directed mental imagery generation. We addressed this in the present study and replicated as well as extended previous findings. Eye closure and music affected both vividness and content of mental imagery, but also interacted with one another. In the following, we discuss first the main effects of music and eye closure on mental imagery, then their interaction, followed by the potential clinical implications.

We replicate previous findings, showing that music can affect mental imagery (Day et al., 2019; Herbert, 2013; Herff, Cecchetti, et al., 2021; Herff, Taruffi, et al., 2021; Koelsch et al., 2019; Küssner & Eerola, 2019; Küssner et al., 2019; Taruffi & Küssner, 2019; Vuoskoski & Eerola, 2015). Specifically and similar to previous studies (Herff, Cecchetti, et al., 2021), we observe that music affects imagery vividness. In the present study this led to increased vividness compared to the silent control condition, though the direction of the effect is likely stimulus-specific. Here, we used two stimuli - one relaxing and one arousing musical piece. Prior work suggested that the relaxing piece might be more suited in supporting directed imagery (Kuan et al., 2017, 2018), however, for the purposes of the present study, we found that both pieces worked well in affecting imagination.

In the present study, we also replicated previous findings showing that music can be used to manipulate both emotional content (Taruffi, 2021) such as sentiment, as well as physical properties of the imagined content, such as imagined time and distance travelled (Herff, Cecchetti, et al., 2021). For the latter it is important to note that an imagery context does not distort representations of time and space (Decety & Jeannerod, 1995; Wong, Manson, Tremblay, & Welsh, 2013), making a systematic manipulation thereof meaningful and measurable. Music conditions systematically resulted in longer imagined time travelled and further imagined distances travelled. One music condition also showed significantly more positive sentiment than the silent condition. The findings highlight the profound impact that music can have on cognition as it manipulates fundamental systems, such as its well-established effects on listeners' emotion (Balteș & Miu, 2014; Juslin & Sloboda, 2001; Juslin & Vastfjall, 2008; Vuoskoski & Eerola, 2015), but also the somewhat more recent observation that it can be used to manipulate an individual's orientation in both real and imagined time and space (Droit-Volet, Bigand, Ramos, & Bueno, 2010; Herff, Cecchetti, et al., 2021; Schäfer, Fachner, & Smukalla, 2013).

Closed-eyes is widely assumed to facilitate imagination, likely because concurrent visual tasks impede imagination (Andrade et al., 1997; Bartels et al., 2018; Engelhard et al., 2010, 2011; Kemps et al., 2004; Littel et al., 2016; van den Hout, Engelhard, Beetsma et al., 2011; van den Hout, Engelhard, Rijkeboer, et al., 2011). Here, we also observe that across the silent and music conditions, closed-eyes led to higher vividness scores. This finding relates to prior research showing that demanding concurrent visual tasks disrupt undirected imagination during music listening (Hashim et al., 2020). Here, we generalize this finding from undirected mental imagery to directed imagery. Furthermore, we compared the removal of concurrent visual information (closed-eyes) with a less demanding visual condition (fixation, rather than target tracking) to disentangle the effects of visual information from those of task demand.

Closed-eyes increased reported imagery vividness in all conditions, however, this increase was substantially stronger when participants listened to music. This is a crucial observation, as this provides evidence that the effect of music and closed-eyes are not independent and simply additive, but instead interact with one another. This observation not only holds for vividness but imagined content as well. Closed-eyes increased travel distance in the silent, but not in the two music conditions. Curiously, closed-eyes increased sentiment for only one of the music conditions (compared to silence). We also did not obtain strong evidence that eye closure affected imagined time in any of the three conditions. Taken together, this pattern of results shows that vividness, sentiment, imagined distance, as well as time all capture different aspects of imagination and are also affected differently by both musical features, closed-eyes, and their interaction.

Potential Clinical Implications

Present findings on the impact of music and eye closure on the perceptual, temporal-spatial, and emotional sentiment of deliberately generated mental imagery may hold potentially important implications for clinical psychology. As outlined in the introduction, deliberate mental imagery generation is an important feature in a range of established and emerging evidence-based psychotherapeutic interventions (Andrade et al., 2012; Arntz, 2012; Blackwell et al., 2015; Blackwell & Holmes, 2010; Di Simplicio et al., 2020; Hallford et al., 2020; Hirsch et al., 2021; Hitchcock et al., 2021; Holmes et al., 2007 , 2019; Ji et al., 2021; Mendes et al., 2008; Pile, Smith, et al., 2021; Rothbaum & Schwartz, 2002). Depending on the treatment target, mental imagery can be employed to promote emotion and self-regulation by helping individuals upregulate helpful emotions, thoughts, and behaviors, or downregulate unhelpful ones. To upregulate affective and motivational impact, music and eye closure may be employed to increase vividness, duration, and psychological distance. Alternatively, silence and external visual distractors may be employed to reduce affective and motivational impact for downregulation purposes. Such tools may be particularly helpful for individuals at either end of the mental imagery ability spectrum. Critically, the interactive effects of music type and eye closure motivate future research to advance the understanding of their potential to be used in tandem to enable precise fine-tuning of internal mental representations (Arntz, 2020).

Limitations and Future Directions

As the present study was not designed to disentangle functional explanations, any proposed explanation for the present findings remains speculative at this point. It could be that the results are best described through a distraction-based account, whereby closed-eyes reduces potential visual distraction and non-invasive music blocks out potential distracting noise. Such a model would need to include diminishing returns of additional distraction, irrespective of modality, to account for the observed interactions between music and eye closure. If this were the case, then white-noise or noise-cancelling headphones without sound should lead to comparable results with the music condition here (an easily-testable hypothesis). However, such an explanation would struggle to explain the differences observed here between the two music conditions without strong assumptions about which song is more effective in blocking out distraction. Alternatively, visual information in the present task might indeed have functioned as a distractor (Lee & Cuijpers, 2013) with closed-eyes as a relief, whereas music might have affected listeners' emotional states (Juslin, 2013; Juslin & Sloboda, 2001; Smit et al., 2020) and associative memory (Jäncke, 2008). Accordingly, the observed effects would then be the result of a complex interaction between emotional, associative memory, and available cognitive resources. Regardless of the possible cause of the observed findings, it is likely that the strength and directionality of all effects observed here are always subject to the precise stimuli chosen. Ultimately, the ideal scenario would provide therapists with non-invasive, yet fine-tuned control over the imagined content and vividness of their clients. Obviously, this would require a detailed understanding of how various musical and acoustical features affect imagination and interact with eye closure. We think such an investigation would be a worthwhile endeavor, possibly resulting in accessible, cost-effective, and automated therapeutic tools that pre-select – or even generate in real-time – music with user-defined parameters such as induced imagined vividness and sentiment. It is important to note that this research is still in in its infancy, thus it is important to conduct future studies to better understand how exactly music affects imagination, and whether its effects could translate to therapeutic context.

Conclusion

The present study shows that background music and eye closure interact to affect directed mental imagery. Both affected vividness and imagined content, and their combination offers the prospect of non-invasively fine-tuning directed mental imagery. This prospect is promising and shows that both music and closed-eyes in their combination are well justified for escapism (Schäfer, Sedlmeier, et al., 2013), activities such as role play (Padovani, Ferreira, & Lelis, 2017), and potentially to further support evidence-based therapies that utilize mental imagery.

Acknowledgements

We thank all our participants. We thank Jenova Chen for allowing us to use content from the video game "Journey" to function as visual inducers.

Action Editor

Mats Küssner, Humboldt-Universität zu Berlin, Department of Musicology and Media Studies.

Peer Review

Simon Blackwell, Ruhr-Universität Bochum, Department of Clinical Psychology and Psychotherapy.
Sarah Hashim, Goldsmiths University of London, Department of Psychology.

Contributorship

SAH co-developed the study, coded and implemented the experiment, analyzed the data, and wrote as well as edited the manuscript. SM co-developed the study, prepared the stimuli, collected the data and contributed to the writing. JLJ contributed to writing the manuscript and provided insights from a clinical perspective. JBP co-developed the study, collected the data, and commented as well as edited the manuscript.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Ethical Approval

The study was conducted in accordance with the declaration of Helsinki and received ethics approved from the university's institutional review board (Approval code: 2021/069).

Funding

The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: This work was supported by the Swiss National Science Foundation (SNF) under the SPARK grant scheme awarded to Dr. Steffen A. Herff (CRSK-1_196567 / 1) and by the Australian Government through the Australian Research Council (ARC) under the Discovery Early Career Researcher Award (DECRA) awarded to Dr. Steffen A. Herff (DE220100961).

ORCID iDs

Steffen A. Herff https://orcid.org/0000-0001-8396-1306
Sophie McConnell https://orcid.org/0000-0002-9809-3254
Julie L. Ji https://orcid.org/0000-0003-1688-9708
Jon B. Prince https://orcid.org/0000-0002-8267-9963

References

Andrade, J., Kavanagh, D., & Baddeley, A. (1997). Eye-movements and visual imagery: A working memory approach to the treatment of post-traumatic stress disorder. *British Journal of Clinical Psychology*, *36*(2), 209–223. https://doi.org/10.1111/j.2044-8260.1997.tb01408.x

Andrade, J., May, J., & Kavanagh, D. (2012). Sensory imagery in craving: From cognitive psychology to new treatments for addiction. *Journal of Experimental Psychopathology*, *3*(2), 127–145. https://doi.org/10.5127/jep.024611

Arntz, A. (2012). Imagery rescripting as a therapeutic technique: Review of clinical trials, basic studies, and research agenda. *Journal of Experimental Psychopathology*, *3*(2), 189–208. https://doi.org/10.5127/jep.024211

Arntz, A. (2020). A plea for more attention to mental representations. *Journal of Behavior Therapy and Experimental Psychiatry*, *67*, 101510. https://doi.org/10.1016/j.jbtep.2019.101510

Baddeley, A. D., & Andrade, J. (2000). Working memory and the vividness of imagery. *Journal of Experimental Psychology: General*, *129*(1), 126. https://doi.org/10.1037//0096-3445.129.1.126

Balteș, F. R., & Miu, A. C. (2014). Emotions during live music performance: Links with individual differences in empathy, visual imagery, and mood. *Psychomusicology: Music, Mind, and Brain*, *24*(1), 58. https://doi.org/10.1037/pmu0000030

Bartels, R. M., Harkins, L., Harrison, S. C., Beard, N., & Beech, A. R. (2018). The effect of bilateral eye-movements versus no eye-movements on sexual fantasies. *Journal of Behavior Therapy and Experimental Psychiatry*, *59*, 107–114. https://doi.org/10.1016/j.jbtep.2018.01.001

Beveridge, S., Cano, E., & Herff, S. A. (2021). The effect of low-frequency equalisation on preference and sensorimotor synchronisation in music. *Quarterly Journal of Experimental Psychology*, https://doi.org/10.1177/17470218211037145

Blackwell, S. E. (2019). Mental imagery: From basic research to clinical practice. *Journal of Psychotherapy Integration*, *29*(3), 235. https://doi.org/10.1037/int0000108

Blackwell, S. E., Browning, M., Mathews, A., Pictet, A., Welch, J., Davies, J., & Holmes, E. A. (2015). Positive imagery-based cognitive bias modification as a web-based treatment tool for depressed adults: A randomized controlled trial. *Clinical Psychological Science*, *3*(1), 91–111. https://doi.org/10.1177/2167702614560746

Blackwell, S. E., & Holmes, E. A. (2010). Modifying interpretation and imagination in clinical depression: A single case series using cognitive bias modification. *Applied Cognitive Psychology: The Official Journal of the Society for Applied Research in Memory and Cognition*, *24*(3), 338–350. https://doi.org/10.1002/acp.1680

Bulley, A., & Irish, M. (2018). The functions of prospection–variations in health and disease. *Frontiers in Psychology*, *9*, 2328. https://doi.org/10.3389/fpsyg.2018.02328

Bürkner, P. (2017). brms: An R package for Bayesian multilevel models using stan. *Journal of Statistical Software*, *80*(1), 1–28. https://doi.org/10.18637/jss.v080.i01

Bürkner, P. (2018). Advanced Bayesian multilevel modeling with the R package brms. *The R Journal*, *10*, 1. https://doi.org/10.32614/RJ-2018-017

Cecchetti, G., Herff, S. A., & Rohrmeier, M. A. (2021). *Musical syntactic structure improves memory for melody: Evidence from the processing of ambiguous melodies.* Paper presented at the Proceedings of the Annual Meeting of the Cognitive Science Society.

Cecchetti, G., Herff, S. A., & Rohrmeier, M. A. (2022). Musical garden paths: Evidence for syntactic revision beyond the linguistic domain. *Cognitive Science*, https://doi.org/10.1111/cogs.13165

Dahl, S., Stella, A., & Bjørner, T. (2022). Tell me what you see: An exploratory investigation of visual mental imagery evoked by music. *Musicae Scientiae*. https://doi.org/10.1177/102986492211248

D'Argembeau, A., & Van der Linden, M. (2006). Individual differences in the phenomenology of mental time travel: The effect of vivid visual imagery and emotion regulation strategies. *Consciousness and Cognition*, *15*(2), 342–350. https://doi.org/10.1016/j.concog.2005.09.001

Day, R. A., & Thompson, W. F. (2019). Measuring the onset of experiences of emotion and imagery in response to music. *Psychomusicology: Music, Mind, and Brain*, *29*(2–3), 75. https://doi.org/10.1037/pmu0000220

Day, R. A., Thompson, W. F., & Boag, S. (2019). Characterizing experiences of music-evoked visual imagery in high prevalence contexts. *Psychomusicology: Music, Mind, and Brain*, *30*, 72–87. https://doi.org/10.1037/pmu0000251

Decety, J., & Jeannerod, M. (1995). Mentally simulated movements in virtual reality: Does Fitt's Law hold in motor imagery? *Behavioural Brain Research*, *72*(1–2), 127–134. https://doi.org/10.1016/0166-4328(96)00141-6

Droit-Volet, S., Bigand, E., Ramos, D., & Bueno, J. L. (2010). Time flies with music whatever its emotional valence. *Acta Psychologica*, *135*(2), 226–232. https://doi.org/10.1016/j.actpsy.2010.07.003

Di Simplicio, M., Appiah-Kusi, E., Wilkinson, P., Watson, P., Meiser-Stedman, C., Kavanagh, D. J., & Holmes, E. A. (2020). Imaginator: A proof-of-concept feasibility trial of a brief imagery-based psychological intervention for young people who self-harm. *Suicide and Life-Threatening Behavior*, *50*(3), 724–740. https://doi.org/10.1111/sltb.12620

EBU, R. (2014). 128, loudness normalisation and permitted maximum level of audio signals. *EBU Recommendation, Geneva*.

Engelhard, I. M., van den Hout, M. A., & Smeets, M. A. M. (2011). Taxing working memory reduces vividness and emotional intensity of images about the queen's day tragedy. *Journal of Behavior Therapy and Experimental Psychiatry*, *42*(1), 32–37. https://doi.org/10.1016/j.jbtep.2010.09.004

Engelhard, I. M., van Uijen, S. L., & van den Hout, M. A. (2010). The impact of taxing working memory on negative and positive memories. *European Journal of Psychotraumatology*, *1*(1), 5623. https://doi.org/10.3402/ejpt.v1i0.5623

Gelman, A., Jakulin, A., Pittau, M. G., & Su, Y. (2008). A weakly informative default prior distribution for logistic and other regression models. *Annals of Applied Statistics*, *2*(4), 1360–1383. https://doi.org/10.1214/08-AOAS191

Goldberg, F. S. (2013). The Bonny method of guided imagery and music. In *Art & science of music therapy* (pp. 134–150). Routledge.

Gunter, R. W., & Bodner, G. E. (2008). How eye movements affect unpleasant memories: Support for a working-memory account. *Behaviour Research and Therapy*, *46*(8), 913–931. https://doi.org/10.1016/j.brat.2008.04.006

Hackmann, A., Bennett-Levy, J., & Holmes, E. A. (2011). *Oxford guide to imagery in cognitive therapy*. Oxford University Press.

Hallford, D. J., Yeow, J. J. E., Fountas, G., Herrick, C. A., Raes, F., & D'Argembeau, A. (2020). Changing the future: An initial test of future specificity training (fest). *Behaviour Research and Therapy*, *131*, 103638. https://doi.org/10.1016/j.brat.2020.103638

Hashim, S., Stewart, L., & Küssner, M. B. (2020). Saccadic eye-movements suppress visual mental imagery and partly reduce emotional response during music listening. *Music & Science*, *3*, https://doi.org/10.1177/2059204320959580

Herbert, R. (2013). An empirical study of normative dissociation in musical and non-musical everyday life experiences. *Psychology of Music*, *41*(3), 372–394. https://doi.org/10.1177/0305735611430080

Herff, S. A., Cecchetti, G., Taruffi, L., & Déguernel, K. (2021). Music influences vividness and content of imagined journeys in a directed visual imagery task. *Scientific Reports*, *11*(1), 1–12. https://doi.org/10.1038/s41598-021-95260-8

Herff, S. A., Dorsheimer, I., Dahmen, B., & Prince, J. B. (2022). Information processing biases: The effects of negative emotional symptoms on sampling pleasant and unpleasant information. *Journal of Experimental Psychology: Applied*, https://doi.org/https://doi.org/10.1037/xap0000450

Herff, S. A., Harasim, D., Cecchetti, G., Finkensiep, C., & Rohrmeier, M. A. (2021). *Hierarchical syntactic structure predicts listeners' sequence completion in music.* Paper presented at the Proceedings of the 43rd Annual Conference of the Cognitive Science Society.

Herff, S. A., Herff, C., Milne, A. J., Johnson, G. D., Shih, J. J., & Krusienski, D. J. (2020). Prefrontal high gamma in ecog tags periodicity of musical rhythms in perception and imagination. *eNeuro*, *7*(4), 784991. https://doi.org/10.1523/ENEURO.0413-19.2020

Herff, S. A., Taruffi, L., Cecchetti, G., & Déguernel, K. (2021). *Empirical characterisation of the effect of music on imagination*. Paper presented at the 16th International Conference on Music Perception and Cognition jointly organised with the 11th triennial conference of ESCOM, The University of Sheffield.

Hirsch, C. R., & Holmes, E. A. (2007). Mental imagery in anxiety disorders. *Psychiatry*, *6*(4), 161–165. https://doi.org/10.1016/j.mppsy.2007.01.005

Hirsch, C. R., Krahé, C., Whyte, J., Krzyzanowski, H., Meeten, F., Norton, S., & Mathews, A. (2021). Internet-delivered interpretation training reduces worry and anxiety in individuals with generalized anxiety disorder: A randomized controlled experiment. *Journal of Consulting and Clinical Psychology*, *89*(7), 575. https://doi.org/10.1037/ccp0000660

Hitchcock, C., Smith, A. J., Elliott, R., O'Leary, C., Gormley, S., Parker, J., & Hammond, E. (2021). A randomized, controlled proof-of-concept trial evaluating durable effects of memory flexibility training (memflex) on autobiographical memory distortions and on relapse of recurrent major depressive disorder over 12 months. *Behaviour Research and Therapy*, *140*, 103835. https://doi.org/10.1016/j.brat.2021.103835

Holmes, E. A., Arntz, A., & Smucker, M. R. (2007). Imagery rescripting in cognitive behaviour therapy: Images, treatment techniques and outcomes. *Journal of Behavior Therapy and Experimental Psychiatry*, *38*(4), 297–305. https://doi.org/10.1016/j.jbtep.2007.10.007

Holmes, E. A., Hales, S. A., Young, K., & Di Simplicio, M. (2019). *Imagery-based cognitive therapy for bipolar disorder and mood instability*. Guilford Publications.

Husnu, S., & Crisp, R. J. (2011). Enhancing the imagined contact effect. *The Journal of Social Psychology*, *151*(1), 113–116. https://doi.org/10.1080/00224541003599043

Hutto, C., & Gilbert, E. (2014). *Vader: A parsimonious rule-based model for sentiment analysis of social media text.* Paper presented at the Proceedings of the International AAAI Conference on Web and Social Media.

James, E. L., Bonsall, M. B., Hoppitt, L., Tunbridge, E. M., Geddes, J. R., Milton, A. L., & Holmes, E. A. (2015). Computer game play reduces intrusive memories of experimental trauma via reconsolidation-update mechanisms. *Psychological Science*, *26*(8), 1201–1215. https://doi.org/10.1177/0956797615583071

Jäncke, L. (2008). Music, memory and emotion. *Journal of Biology*, *7*(6), 1–5. https://doi.org/10.1186/jbiol82

Ji, J. L., Baee, S., Zhang, D., Calicho-Mamani, C. P., Meyer, M. J., Funk, D., & Teachman, B. A. (2021). Multi-session online interpretation bias training for anxiety in a community sample. *Behaviour Research and Therapy*, *142*, 103864. https://doi.org/10.1016/j.brat.2021.103864

Johnsen, E. L., & Lutgendorf, S. K. (2001). Contributions of imagery ability to stress and relaxation. *Annals of Behavioral Medicine*, *23*(4), 273–281. https://doi.org/10.1207/S15324796ABM2304_6

Juslin, P. N. (2013). What does music express? Basic emotions and beyond. *Frontiers in psychology*, *4*, 596. https://doi.org/10.3389/fpsyg.2013.00596

Juslin, P. N., & Sloboda, J. A. (2001). *Music and emotion: Theory and research*. Oxford University Press.

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

Keller, P. E. (2012). Mental imagery in music performance: Underlying mechanisms and potential benefits. *Annals of the New York Academy of Sciences*, *1252*(1), 206–213. https://doi.org/10.1111/j.1749-6632.2011.06439.x

Kemps, E., & Tiggemann, M. (2007). Reducing the vividness and emotional impact of distressing autobiographical memories: The importance of modality-specific interference. *Memory (Hove, England)*, *15*(4), 412–422. https://doi.org/10.1080/09658210701262017

Kemps, E., Tiggemann, M., Woods, D., & Soekov, B. (2004). Reduction of food cravings through concurrent visuospatial processing. *International Journal of Eating Disorders*, *36*(1), 31–40. https://doi.org/10.1002/eat.20005

Koelsch, S., Bashevkin, T., Kristensen, J., Tvedt, J., & Jentschke, S. (2019). Heroic music stimulates empowering thoughts during mind-wandering. *Scientific Reports*, *9*(1), 1–10. https://doi.org/10.1038/s41598-019-46266-w

Kosslyn, S. M., Ganis, G., & Thompson, W. L. (2001). Neural foundations of imagery. *Nature Reviews Neuroscience*, *2*(9), 635–642. https://doi.org/10.1038/35090055

Kuan, G., Morris, T., Kueh, Y. C., & Terry, P. C. (2018). Effects of relaxing and arousing music during imagery training on dart-throwing performance, physiological arousal indices, and competitive state anxiety. *Frontiers in Psychology*, *9*, 14. https://doi.org/10.3389/fpsyg.2018.00014

Kuan, G., Morris, T., & Terry, P. (2017). Effects of music on arousal during imagery in elite shooters: A pilot study. *PLoS One*, *12*(4), e0175022. https://doi.org/10.1371/journal.pone.0175022

Küssner, M. B., & Eerola, T. (2019). The content and functions of vivid and soothing visual imagery during music listening: Findings from a survey study. *Psychomusicology: Music, Mind, and Brain*, *29*(2–3), 90. https://doi.org/10.1037/pmu0000238

Küssner, M. B., Eerola, T., & Fujioka, T. (2019). Music, emotion, and visual imagery: Where are we now? *Special Issue: Music, Emotion, and Visual Imagery Guest Editors: Mats B. Küssner, Tuomas Eerola, Takako Fujioka*, https://doi.org/10.1037/pmu0000245

Lang, P. J. (1977). Imagery in therapy: An information processing analysis of fear. *Behavior Therapy*, *8*(5), 862–886. https://doi.org/10.1016/S0005-7894(77)80157-3

Lang, P. J. (1979). A bio-informational theory of emotional imagery. *Psychophysiology*, *16*(6), 495–512. https://doi.org/10.1111/j.1469-8986.1979.tb01511.x

Lee, C. W., & Cuijpers, P. (2013). A meta-analysis of the contribution of eye movements in processing emotional memories.

Journal of Behavior Therapy and Experimental Psychiatry, *44*(2), 231–239. https://doi.org/10.1016/j.jbtep.2012.11.001

Littel, M., van den Hout, M. A., & Engelhard, I. M. (2016). Desensitizing addiction: Using eye movements to reduce the intensity of substance-related mental imagery and craving. *Frontiers in Psychiatry*, *7*, 14. https://doi.org/10.3389/fpsyt.2016.00014

Loper, E., & Bird, S. (2002). Nltk: The natural language toolkit. *arXiv preprint cs/0205028*.

Lovibond, P. F., & Lovibond, S. H. (1995). The structure of negative emotional states: Comparison of the depression anxiety stress scales (DASS) with the Beck depression and anxiety inventories. *Behaviour Research and Therapy*, *33*(3), 335–343. https://doi.org/10.1016/0005-7967(94)00075-u

MacRitchie, J., Breaden, M., Milne, A. J., & McIntyre, S. (2020). Cognitive, motor and social factors of music instrument training programs for older adults' improved wellbeing. *Frontiers in Psychology*, *10*, 2868. https://doi.org/10.3389/fpsyg.2019.02868

Margulis, E. H., Wong, P. C. M., Simchy-Gross, R., & McAuley, J. D. (2019). What the music said: Narrative listening across cultures. *Palgrave Communications*, *5*(1), 1–8. https://doi.org/10.1057/s41599-019-0363-1

McEvoy, P. M., Saulsman, L. M., & Rapee, R. M. (2018). *Imagery-enhanced CBT for social anxiety disorder*. Guilford Publications.

Mendes, D. D., Mello, M. F., Ventura, P., De Medeiros Passarela, C., & De Jesus Mari, J. (2008). A systematic review on the effectiveness of cognitive behavioral therapy for posttraumatic stress disorder. *The International Journal of Psychiatry in Medicine*, *38*(3), 241–259. https://doi.org/10.2190/PM.38.3.b

Milne, A. J., & Herff, S. A. (2020). The perceptual relevance of balance, evenness, and entropy in musical rhythms. *Cognition*, *203*, 104233. https://doi.org/10.1016/j.cognition.2020.104233

Mota, N. P., Schaumberg, K., Vinci, C., Sippel, L. M., Jackson, M., Schumacher, J. A., & Coffey, S. F. (2015). Imagery vividness ratings during exposure treatment for posttraumatic stress disorder as a predictor of treatment outcome. *Behaviour Research and Therapy*, *69*, 22–28. https://doi.org/10.1016/j.brat.2015.03.003

Moulton, S. T., & Kosslyn, S. M. (2009). Imagining predictions: Mental imagery as mental emulation. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *364*(1521), 1273–1280. https://doi.org/10.1098/rstb.2008.0314

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*(2), e89642. https://doi.org/10.1371/journal.pone.0089642

Nanay, B. (2018). Multimodal mental imagery. *Cortex*, *105*, 125–134. https://doi.org/10.1016/j.cortex.2017.07.006

Padovani, R., Ferreira, L., & Lelis, L. (2017). *Bardo: Emotion-based music recommendation for tabletop role-playing games.* Paper presented at the Proceedings of the AAAI Conference on Artificial Intelligence and Interactive Digital Entertainment.

Pearson, J., Naselaris, T., Holmes, E. A., & Kosslyn, S. M. (2015). Mental imagery: Functional mechanisms and clinical applications. *Trends in Cognitive Sciences*, *19*(10), 590–602. https://doi.org/10.1016/j.tics.2015.08.003

Pile, V., Smith, P., Leamy, M., Oliver, A., Bennett, E., Blackwell, S. E., & Holmes, E. A. (2021). A feasibility randomised controlled trial of a brief early intervention for adolescent depression that targets emotional mental images and memory specificity (imagine). *Behaviour Research and Therapy*, *143*, 103876. https://doi.org/10.1016/j.brat.2021.103876

Pile, V., Williamson, G., Saunders, A., Holmes, E. A., & Lau, J. Y. F. (2021). Harnessing emotional mental imagery to reduce anxiety and depression in young people: An integrative review of progress and promise. *The Lancet Psychiatry*, *8*(9), 836–852. https://doi.org/10.1016/S2215-0366(21)00195-4

Presicce, G., & Bailes, F. (2019). Engagement and visual imagery in music listening: An exploratory study. *Psychomusicology: Music, Mind, and Brain*, *29*(2–3), 136. https://doi.org/10.1037/pmu0000243

R-Core-Team. (2013). R: A language and environment for statistical computing. Vienna, Austria: R Foundation for Statistical Computing. Retrieved from http://www.R-project.org/

Richardson, A., & Taylor, C. C. (1982). Vividness of memory imagery and self-induced mood change. *British journal of clinical psychology*, *21*(2), 111–117. https://doi.org/10.1111/j.2044-8260.1982.tb00539.x

Ritter, S. M., Abbing, J., & Van Schie, H. T. (2018). Eye-closure enhances creative performance on divergent and convergent creativity tasks. *Frontiers in Psychology*, *9*, 1315. https://doi.org/10.3389/fpsyg.2018.01315

Rothbaum, B. O., & Schwartz, A. C. (2002). Exposure therapy for posttraumatic stress disorder. *American Journal of Psychotherapy*, *56*(1), 59–75. https://doi.org/10.1176/appi.psychotherapy.2002.56.1.59

Saulsman, L. M., Ji, J. L., & McEvoy, P. M. (2019). The essential role of mental imagery in cognitive behaviour therapy: What is old is new again. *Australian Psychologist*, *54*(4), 237–244. https://doi.org/10.1111/ap.12406

Schacter, D. L., Addis, D. R., & Buckner, R. L. (2008). Episodic simulation of future events: Concepts, data, and applications. *Annals of the New York Academy of Sciences*, *1124*, 39–60. https://doi.org/10.1196/annals.1440.001

Schäfer, T., Fachner, J., & Smukalla, M. (2013). Changes in the representation of space and time while listening to music. *Frontiers in Psychology*, *4*, 508. https://doi.org/10.3389/fpsyg.2013.00508

Schäfer, T., Sedlmeier, P., Städtler, C., & Huron, D. (2013). The psychological functions of music listening. *Frontiers in Psychology*, *4*, 511. https://doi.org/10.3389/fpsyg.2013.00511

Shapiro, F. (1989). Eye movement desensitization: A new treatment for post-traumatic stress disorder. *Journal of Behavior Therapy and Experimental Psychiatry*, *20*(3), 211–217. https://doi.org/10.1016/0005-7916(89)90025-6

Smit, E. A., Dobrowohl, F. A., Schaal, N. K., Milne, A. J., & Herff, S. A. (2020). Perceived emotions of harmonic cadences. *Music & Science*, *3*, https://doi.org/10.1177/2059204320938635

Smit, E. A., Milne, A. J., Sarvasy, H. S., & Dean, R. T. (2022). Emotional responses in Papua New Guinea show negligible evidence for a universal effect of major versus minor music. *PLoS One*, *17*(6), e0269597. https://doi.org/10.1371/journal.pone.0269597

Steinmetz, C. (2019). Csteinmetz1/pyloudnorm (Version v0.1.0). Zenodo.

Stopa, L. (2011). *Imagery rescripting across disorders: A practical guide*. Elsevier.

Taruffi, L. (2021). Mind-wandering during personal music listening in everyday life: Music-evoked emotions predict thought valence. *International Journal of Environmental Research and Public Health*, *18*(23), 12321. https://doi.org/10.3390/ijerph182312321

Taruffi, L., & Küssner, M. B. (2019). A review of music-evoked visual mental imagery: Conceptual issues, relation to emotion, and functional outcome. *Psychomusicology: Music, Mind, and Brain*, *29*(2–3), 62. https://doi.org/10.1037/pmu0000226

Taylor, S. E., Pham, L. B., Rivkin, I. D., & Armor, D. A. (1998). Harnessing the imagination: Mental simulation, self-regulation, and coping. *American Psychologist*, *53*(4), 429. https://doi.org/10.1037//0003-066x.53.4.429

van den Hout, M. A., & Engelhard, I. M. (2012). How does EMDR work? *Journal of Experimental Psychopathology*, *3*(5), 724–738. https://doi.org/10.5127/jep.028212

van den Hout, M. A., Engelhard, I. M., Beetsma, D., Slofstra, C., Hornsveld, H., Houtveen, J., & Leer, A. (2011). EMDR and mindfulness. Eye movements and attentional breathing tax working memory and reduce vividness and emotionality of aversive ideation. *Journal of Behavior Therapy and Experimental Psychiatry*, *42*(4), 423–431. https://doi.org/10.1016/j.jbtep.2011.03.004

van den Hout, M. A., Engelhard, I. M., Rijkeboer, M. M., Koekebakker, J., Hornsveld, H., Leer, A., & Akse, N. (2011). EMDR: Eye movements superior to beeps in taxing working memory and reducing vividness of recollections. *Behaviour Research and Therapy*, *49*(2), 92–98. https://doi.org/10.1016/j.brat.2010.11.003

Vredeveldt, A., Hitch, G. J., & Baddeley, A. D. (2011). Eyeclosure helps memory by reducing cognitive load and enhancing visualisation. *Memory & Cognition*, *39*(7), 1253–1263. https://doi.org/10.3758/s13421-011-0098-8

Vuoskoski, J. K., & Eerola, T. (2015). Extramusical information contributes to emotions induced by music. *Psychology of Music*, *43*(2), 262–274. https://doi.org/10.1177/0305735613502373

Wong, L., Manson, G. A., Tremblay, L., & Welsh, T. N. (2013). On the relationship between the execution, perception, and imagination of action. *Behavioural Brain Research*, *257*, 242–252. https://doi.org/10.1016/j.bbr.2013.09.045