Acta Psychologica 212 (2021) 103206

Contents lists available at ScienceDirect

Acta Psychologica

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

Memory improvement in aging as a function of exposure to mood-matching music

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ARTICLE INFO

Keywords:
Aging
Recall
Working memory
Music
Mood

ABSTRACT

This study examined the effect of matching musical emotion and the mood of the listener on working memory and free recall in normal aging. Memory measures were taken at baseline in healthy young and older participants, and, following a happy or sad mood induction, again after exposure to both mood-matching and -mismatching music in a counterbalanced repeated measures design. Compared to baseline, [i] recall was greater following mood-matching than mood-mismatching music in both groups, and was reduced following mood-mismatching music in older adults, [ii] working memory was greater in the mood-matching condition, but did not differ from baseline in the mismatching condition. The results have significant implications for the increasingly popular forms of intervention involving music used with older populations experiencing cognitive decline.

1. Introduction

Aging is associated with memory decline, and this is not limited to individuals with dementia (Kausler, 1994; Light, 1991; Ward et al., 2013). With the proportion of the population aged 65 years and over steadily rising, a vital challenge is to uncover innovative and cost-effective methods of preserving and enhancing memory function with age.

A great deal of research developed following Rauscher et al.'s (1993) discovery that performance on a spatial task was superior in participants exposed to Mozart's sonata for two pianos (K448) for 10 min compared to those who were exposed to verbal relaxation instructions – (in) famously named "the Mozart effect". However, subsequent studies have varied considerable in relation to the effect on other cognitive tasks/ measures, procedures (listening before/during task), and type of music (e.g., Chabris, 1999; Franco et al., 2014; Schellenberg, 2012). Nevertheless, there is evidence that music can bolster memory in healthy older individuals and individuals with Alzheimer's disease (AD) (e.g., Calvert & Tart, 1993; McElhinney & Annett, 1996; Palisson et al., 2015; Rainey & Larsen, 2002; Simmons-Stern et al., 2010). In studies with both AD patients and healthy older adults, promising outcomes have been reported on tests of autobiographical memory (Foster & Valentine, 2001; Irish et al., 2006; Meilan Garcia et al., 2012), immediate and delayed recall (Chu et al., 2014; Palisson et al., 2015; Särkämö et al., 2014), and recognition (Simmons-Stern et al., 2010, 2012). For example, Palisson et al. (2015) showed that immediate and delayed recall were enhanced for passages of texts that were encoded with a musical association (sung) rather than no musical association (spoken) in AD patients and healthy controls, and Simmons-Stern et al. (2010) showed greater recognition of novel texts following encoding with a recording of an unfamiliar song rather than a spoken (non-musical) recording. However, Moussard et al. (2014) compared immediate and delayed recall for sung and spoken lyrics, and reported a benefit of musical encoding only on delayed and not immediate recall.

Although most studies have focussed on long-term measures of memory, there is evidence that music can also have a positive effect on short-term memory. For example, using a repeated measures design, Mammarella et al. (2007) reported enhanced working memory performance (forward digit span and phonemic fluency) in healthy older adults when listening to classical music (Vivaldi's Four Seasons) relative to no music or white noise. In both the music and white noise conditions, the sound started 1 min before the working memory tasks and continued throughout the tasks.

The function of music in the enhancement of memory in aging

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https://doi.org/10.1016/j.actpsy.2020.103206
Received 19 July 2019; Received in revised form 1 September 2020; Accepted 23 October 2020

warrants further investigation of the underlying mechanisms, in order to recommend successful initiatives. One possible explanation is that the boost in memory associated with music is driven by the effect that music has upon or interaction with the listeners' mood. Music is known to elicit powerful emotions (e.g., Koelsch, 2014) and can improve the emotional state of older individuals (Chu et al., 2014; Clément et al., 2012; Guétin et al., 2009; Janata, 2012). Moreover, it is well-established that memory is greater for emotional relative to neutral information in a range of modalities (e.g., Humphreys et al., 2010; Kensinger & Corkin, 2003). So, it is possible that the emotional arousal associated with music may explain the positive effect on the cognitive processes supporting memory. Indeed, Mammarella et al. (2007) interpreted their finding of greater working memory performance in older adults while listening to classical music versus white noise on the basis of arousal-and-mood interactions with the music.

It has been found that music with certain characteristics, such as fast tempi and major mode (features that statistically characterise 'happy' music), are associated with optimized arousal, which may affect mood and cognitive functioning (see Schellenberg, 2012, for a review of the 'arousal and mood' hypothesis). This arousal-and-mood model, however, still considers the music listener as a passive receiver, hence implying that 'sad' music would depress arousal and induce sadness (for a review of parameters associated with musical emotions see Coutinho & Cangelosi, 2011; Eerola & Vuoskoski, 2013; Gabrielsson & Lindstrom, 2010). However, Vuoskoski and Eerola (2012) and Vuoskoski et al. (2012) found that there were significant individual differences in participants' appreciation of music as 'pleasant' or 'beautiful' in relation to its affective characteristics, suggesting that for some exposure to their preferred 'sad' tracks was associated with well-being, not depressed mood. Recent research has examined the interaction between music and mood, and the effect on cognition in healthy young adults and children. This approach sees the listener as an active participant in the music listening event, rather than a passive receiver. It has been found that the interaction between the emotional cues in music (e.g., the mode and tempo) and the mood of the listener plays a mediating role in the effect on cognition (Franco et al., 2014; Swaine, 2014). Specifically, when there is a match between the emotion expressed by the music and the listeners' mood (sad musical expression matched with a sad mood, or a happy musical expression matched with a happy mood), this leads to improved performance on various cognitive tasks, whereas a mismatch between the mood expression of the music and the listeners' emotional state can be detrimental to performance. In Franco et al. (2014), working memory was improved in young adults and children when the music extract that they listened to matched their induced mood state (happy/angry/sad). Following baseline memory testing, participants listened to mood-matching or mismatching music prior to follow-up memory testing. The mood-matching effect was particularly strong in adult females who were in an angry mood and were given matching music, and in young children with both happy and sad mood-matching music. Importantly (and differently from what is predicted by the 'arousal and mood' hypothesis, Schellenberg, 2012), the mood-matching facilitation effect on cognition was also found for negative emotions. That is, individuals in a sad mood showed cognitive benefits when exposed to 'sad' music, not 'happy'/arousing music.

The mood-matching effect is distinct from a 'congruency' effect consistent with Bower et al.'s (1981) model of enhanced recall of information congruent with the emotional valence of the participant - the content of Franco et al.'s tests was not related with either a participant's mood or the musical emotion, and measured level of ability rather than selective recall of semantically consistent items. Such congruence effects have also been found in musical tasks, for example Tesoriero and Rickard (2012) showed that sad words are more easily recalled following a 'sad' musical prime, highlighting enhanced *selective* recall of semantically congruent items compared to incongruent semantic items. Furthermore, Tesoriero and Rickard used music to *induce* emotion in the participants whereas our framework is viewing the listener as active in the interaction with music, rather than a passive recipient (Franco et al., 2014; Swaine, 2014). In other words, the mood-matching effect is expected to emerge specifically from the interaction between a listener's mood state and the emotion expressed by the music.

The aim of this study was to examine the effect of matching mood and music on short and long-term memory in normal aging. To our knowledge the role of the mood of the listener has never been systematically studied in normal aging, yet this has large potential implications for cognitive interventions involving music. In the present study, immediate free recall (of a word list) was used as the long-term memory measure as this form of memory is particularly susceptible to the deleterious effects of aging, and as outlined above a number of prior studies have reported improvement in this form of memory as a function of music. By contrast, fewer studies have examined the effect of music on working memory, so we included a backward digit span measure to make this extension. Building on the design used by Franco et al. (2014), a happy or sad mood was induced in groups of healthy young and older participants, and memory measures were taken at three intervals: at baseline prior to mood induction, and, following an image-based mood induction procedure (e.g., happy), after exposure to both emotionally matching ('happy') and mismatching ('sad') music. Based on the findings of Franco et al. (2014), we anticipated that exposure to mood-matched music would be associated with enhanced memory in young adults, while mismatched mood and music would be detrimental. Key points of interest were whether this pattern would also be evident in older adults, and the relative magnitude of the effect.

2. Materials and methods

2.1. Participants and design

Forty-eight young (seven male) and 48 older (eight male) adults participated, all fluent in English language and reporting good health (see Table 1 for participant characteristics). Young participants were students from Middlesex University, London, and older participants were members of the University of the Third Age (U3A) organisation. Participants received retail vouchers in exchange for their time. Twenty-four participants from each age group were randomly assigned to the happy mood condition, and 24 to the sad mood condition. The study was approved by the Middlesex University Research Ethics Committee.

Table 1
Participant characteristics.

	Young (n = 48) *M* (*SD*)	Older (n = 48) *M* (*SD*)
Age (years)	19.65 (1.59)	73.92 (5.80)
Education (years)	14.85 (1.44)	15.58 (2.32)
Visual acuity	28.83 (5.34)	39.71 (11.70)*
WAIS-III		
Vocabulary	35.98 (7.99)	55.67 (4.69)*
Processing speed	81.15 (11.92)	75.20 (15.97)*
WTAR	37.27 (6.74)	47.88 (3.74)*
Gold MSI	61.25 (12.64)	58.23 (19.54)
MMSE	–	29.46 (0.82)

Note. Visual acuity as measured using the Near Vision Test Card (Schneider, 2002), viewed at a distance of 16 in. while wearing corrective glasses if needed. Scores can range between 16 (highest acuity) to 160 (lowest acuity). WAIS-III = Wechsler Adult Intelligence Scale III (Wechsler, 1997). The Vocabulary and Processing Speed (Digit Symbol Substitution) subtests have maximum scores of 66 and 133, respectively. WTAR = Wechsler Test of Adult Reading (maximum score of 50). Gold MSI = Goldsmith Musical Sophistication Index (Dan-Glauser & Scherer, 2011). MMSE = Mini Mental State Exam (Folstein et al., 1975; maximum score of 30). No participant in this study scored below 27 on the MMSE.

* Significant difference between groups, $p < .05$.

2.2. Apparatus and stimuli

To test free recall, three sets of 20 individual words (concrete nouns, e.g. horse, grape, jumper) were used. A separate set of words was used at baseline, and follow-up tests 1 and 2, and the order in which the sets were presented was rotated between participants. Words were presented in black Calibri 25-point font in the centre of a white background, for 5000 ms, separated by a central fixation cross for 1000 ms. Participants were informed that they would see 20 words, one at a time, and that they would be asked to recall as many as possible afterwards. Immediately after presentation of the last word participants were asked to write down as many words as they could remember. No time limit was imposed, and the number of correctly recalled items was summed by the experimenter. Working memory was assessed using the Wechsler Adult Intelligence Scale III (WAIS-III) Backward Digit Span task (Wechsler, 1997). The experimenter read aloud sequences of digits of increasing length starting from two digits to a maximum nine digits, and the participants' task was to repeat them in reverse order (e.g., 7–2–8–6; correct response = 6–8–2–7). There were two trials for each length of sequence, to a maximum of 16 trials. One point was recorded by the experimenter for each correct trial, and a score of zero was recorded on trials in which the participant made an error or could not complete the trial. The task was discontinued when the participant obtained two consecutive scores of zero for a particular length of trial, or the maximum score of 16 was reached.

For the mood induction, we used images from the Geneva Affective Picture Database (GAPED; Dan-Glauser & Scherer, 2011). At the start of the experiment, 36 neutral images (e.g., photographs of everyday objects and neutral scenes) were presented prior to baseline tests. The images were 640 × 480 pixels, presented in colour in the centre of a white background screen for 5000 ms each, separated by a central fixation point for 500 ms. Thus, the duration of the neutral preparation phase was approximately 3 min. Following baseline tests, participants were either subjected to happy or sad images (depending on the mood condition to which they were assigned) for 3 min. There were 36 images in total, 640 × 480 pixels in size, each presented in colour on a white background screen for 5000 ms., separated by a central fixation point for 500 ms. Happy images depicted scenes of children playing, people laughing and animals whereas sad images depicted lonely individuals, people crying and dead or mistreated animals.

In order to avoid confoundings due to familiarity and personal emotional associations (Cross, 2001), we used novel music in this experiment. The music stimuli were adjusted ad-hoc by J.S. Swaine, based on the music originally composed and validated as expressing the intended emotion for Franco et al. (2014). The 'happy' and 'sad' music tracks were differentiated on the basis of the following characteristics, respectively: mode (G-major vs. G-minor), tempo (fast BPM = 134 vs. slow BPM = 75), articulation (staccato vs. legato) (for a review of emotional parameters in music, see Eerola & Vuoskoski, 2013), both presented as piano music with a duration of 2 min.

2.3. Procedure

Participants were tested individually in a session that lasted approximately 1 h. In the preparation stage, participants viewed the 36 neutral images. After that, they performed their first recall and working memory task as a baseline condition. Immediately after, a happy (i.e., happy condition) or sad (i.e., sad condition) mood was induced by the presentation of the 36 happy or sad images. Then, participants were asked to put on headphones and click a button on the computer screen to listen a mood-matching music fragment (e.g., happy mood induction followed by happy music, or sad mood induction followed by sad music) or mood-mismatching music fragment (e.g., happy mood/sad music, or sad mood/happy music) for 2 min. Mood-matching was a repeated measures variable, so half of the participants performed the matched condition first and the mismatched condition second, and vice versa for the other half. After the first music exposure, there was a second recall and working memory task (i.e., follow-up test 1). Then there was a mood induction refresh (i.e., happy or sad images) followed by the second music exposure (mood-matching or mismatching, depending on the order of the conditions), and the final recall and working memory tasks (i.e., follow-up test 2). The order in which the memory tests were performed at baseline and follow-up tests 1 and 2 was counterbalanced between participants.

The repeated measure design was desirable in order to reduce noise in the data. However, given the duration of the experiment, and in order not to cue the participants about a critical design variable (what emotion/mood they felt when encountering the music), they were not asked explicit confirmation about the affect felt after the mood induction. We were confident that the mood induction would have the desired effect because in Franco et al. (2014) even 3–4 year olds reported with an explicit judgment the intended emotions felt after age-appropriate mood induction. Nevertheless, at the end of the present experiment the researcher questioned participants to confirm that the intended emotions were conveyed by the mood induction and music phases.

Upon completion of the experimental task participants completed a series of background tests, including [i] a near vision test (Schneider, 2002), [ii] the WAIS-III Digit Symbol Substitution and Vocabulary subtests (Wechsler, 1997) to examine processing speed and verbal comprehension, [iii] the Wechsler Test of Adult Reading to examine premorbid intelligence, [iv] the Goldsmith Musical Sophistication Index (Müllensiefen et al., 2014) to control for any differences between groups in musical expertise, and older adults also completed [v] the Mini Mental State Exam (Folstein et al., 1975) to assess general cognitive function (Table 1). We planned to exclude older participants with probable cognitive impairment evidenced by an MMSE score < 24 (abnormal), but no participant scored <27 on this test.

3. Results

3.1. Recall

The number of words correctly recalled by young and older adults at baseline and following mood-matching and mismatching music is given in Fig. 1A. A 2 (age [young/older adult]) × 2 (mood [happy/sad]) × 3 (condition [baseline, matching, mismatching]) mixed analysis of variance (ANOVA) revealed a significant main effect of age, $F(1, 92) = 24.39$, $p < .001$, $\eta_p^2 = 0.19$, and no significant main effect of mood, $F(1, 92) = 0.28$, $p = .598$. Young adults' recall was consistently greater than that of older adults, and recall levels were generally similar in the happy and sad mood conditions. There was a significant main effect of condition, $F(2, 184) = 9.45$, $p < .001$, $\eta_p^2 = 0.09$, and no significant interactions (F's < 1, p's > 0.7). Collapsed across mood, recall was significantly greater in the mood-matching than the mismatching condition in both age groups, i.e., Young adults, $t(47) = 2.07$, $p = .042$, $d = 0.30$; Older adults, $t(47) = 3.69$, $p = .001$, $d = 0.51$, and older adults' baseline recall was significantly greater than recall following mood-mismatching music, $t(47) = 3.02$, $p = .004$, $d = 0.39$. No other comparisons were significant (t's < 1.86, p's > 0.05).

3.2. Working memory

Fig. 1B shows backward digit span scores in young/older adults at baseline and in mood-matching and -mismatching music conditions. There was no significant main effect of mood, $F(1, 92) = 0.21$, $p = .647$, or age, $F(1, 92) = 3.83$, $p = .053$, $\eta_p^2 = 0.04$, although performance was numerically superior in older relative to young adults. There was a main effect of condition, $F(2, 184) = 15.37$, $p < .001$, $\eta_p^2 = 0.14$, and no significant interactions, F's < 1, p's > 0.05. Collapsed across mood, working memory was significantly lower at baseline than in the matched condition in both groups, i.e., Young adults, $t(47) = 3.12$, $p = .003$, $d = 0.31$; Older adults, $t(47) = 3.38$, $p = .001$, $d = 0.45$, and was significantly

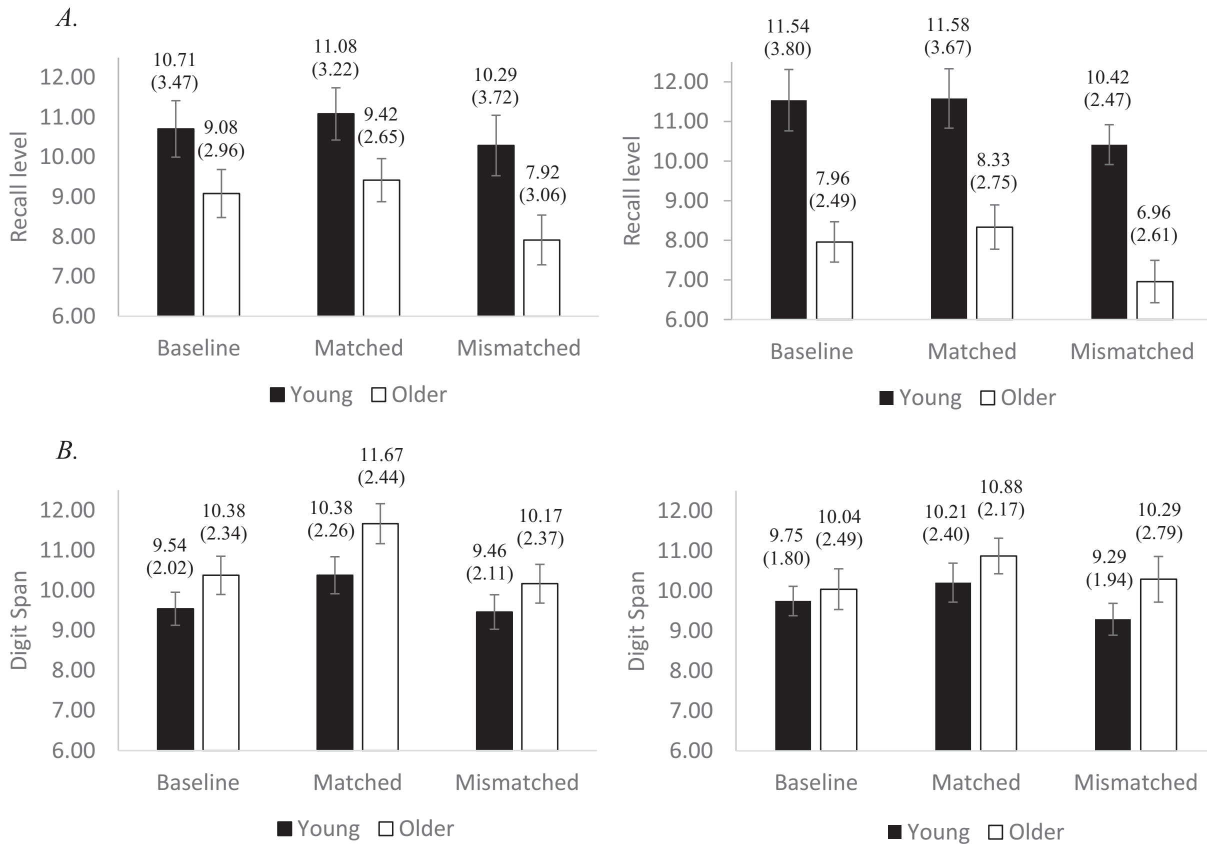

Fig. 1. Memory scores in the Sad condition (Left) and Happy condition (Right). *A.* Recall in Young and Older adults at baseline (neutral) and following mood-matched and -mismatched music. *B.* Backward digit span in Young and Older adults at baseline and following mood-matched and -mismatched music. Exact means and standard deviations (in parenthesis) are provided. Error bars indicate standard error of the mean (SEM).

greater in the matched than the mismatched condition in both groups, i.e., Young adults, $t(47) = 3.16$, $p = .003$, $d = 0.42$; Older adults, $t(47) = 3.47$, $p = .001$, $d = 0.43$. Performance in the mismatched condition did not significantly differ to performance at baseline in either group (t's < 1, p's > 0.05).

4. Discussion

This study highlights significant effects of mood-matching and -mismatching music on two separate aspects of memory: immediate free recall and working memory. Recall was significantly greater following mood-matching than -mismatching music in both young and older adults, and was reduced following mood-mismatching music compared to baseline in older adults. Furthermore, in both age groups working memory was greater following mood-matching music exposure compared to baseline, but did not differ from baseline in the mismatching condition.

Prior studies have reported improvements in memory as a function of music in aging (e.g., Chu et al., 2014; Palisson et al., 2015; Särkämö et al., 2014), but this is the first study to examine the role of the interaction between emotional cues in music and the emotional state of the listener, i.e., seeing the listener as an active participant rather than a passive recipient in a musical event. The findings suggest that a match between the emotional characteristics of the music and the mood of the listener has a facilitatory effect on working memory and immediate free recall in normal aging, whether the emotion is positive or negative. However, a mismatch between the two is particularly detrimental to recall in older adults. The idea that the mood of the listener plays a key role in the beneficial effect of music on memory was only recently proposed and empirically established (Franco et al., 2014; Swaine, 2014) but no prior study has tested this hypothesis with older adults, i.e. a group for which memory support may be of particular relevance. The current findings may therefore have implications for memory training initiatives: in order for music to be maximally beneficial, it should be matched with the mood of the listener. Moreover, these findings contribute to the empirical investigation of the benefits of music therapy in elderly care. Music therapy develops around a convergence of the expressive features of the music played by the therapist with the client's mood and behaviour, hence the mood-matching model elucidates the mechanism underlying aspects of music therapy. Specifically, the findings from this study corroborate the view that music-based activities benefit cognitive function in older adults.

It will be important for future studies to extend this line of enquiry to older individuals with dementia, and also examine other forms of memory. Further work is also needed to examine the mechanisms involved on both a cognitive as well as psychophysiological level. It may be that exposure to mood-matching music boosts the depth of encoding of new information to memory relative to when mood and music are mismatched (it is well-established that more elaborate or deeper encoding results in superior memory retrieval, e.g., Craik & Lockhart, 1972). The cognitive benefit of music has also been related to the actions of a bidirectional reciprocal neurovisceral circuit between the brain and the heart, in which cortico-subcortical structures serve as the link between psychological and physiological processes (Thayer et al., 2012). This cognitive regulation reflects on a physiological cardiorespiratory level, more specifically in the parasympathetic driven component of the autonomous nervous system (e.g., Thayer & Lane, 2009). In a recent pilot-study, it has indeed been shown that improved cognitive performance in 6–9-year-old children after a mood-music matching was related with increased parasympathetic regulation (Franco et al., 2015).

Considering that neurovisceral cognitive regulation appears to be at risk in older individuals due to prefrontal vulnerability of the brain (Thayer & Lane, 2009), it is warranted to further investigate parasympathetic activity as a promising underlying mechanism of cognitive regulation in musical contexts with aging groups (Mangiacotti et al., 2019).

In the current study, the findings on the recall and working memory tests were broadly similar in the happy and sad conditions. This means that the cognitive benefit does not only occur after listening to positively-valenced music as has been argued in earlier studies (i.e., the 'arousal and mood hypothesis', for a review see Schellenberg, 2012). Rather, irrespective of the emotional valence per se, a match between the music and the listener's state is critical, for example for reducing attentional costs incurred when current action tendencies associated with mood and emotional states are mismatched by those embodied in musical features (cf. Gross, 2002; Perlovsky, 2015). As expected, recall in young adults generally exceeded that in older adults. Free recall declines to a greater extent in aging than other forms of long-term episodic memory, such as recognition, possibly because it requires self-initiated and effortful memory search (e.g., see Craik & McDowd, 1987). In contrast, working memory performance in the current study was statistically equivalent between groups. Although it is generally accepted that working memory declines with age, a great many studies have also reported no effect (reviewed in Nyberg et al., 2012), and this has been attributed to various factors associated with high-performing older individuals (e.g., high levels of 'cognitive reserve', Meng & D'arcy, 2012). Indeed, the older participants in the current investigation were very high-functioning, socially and culturally engaged, and as a group their working memory performance was numerically greater than that of young adults.

In general, the results suggest that the effect of mood-matching and -mismatching music may have different nuances for recall and working memory, with recall being particularly negatively affected by mood-mismatching music and working memory being particularly positively supported by mood-matching music. Further research is needed to explore and consolidate this suggestion using a variety of cognitive tasks and musical stimuli.

5. Conclusions

This study provides novel evidence that mood-matching music is beneficial to recall and working memory in young and older adults, and the findings make an important advancement to our understanding of the mechanisms underlying the beneficial effect of music on memory in aging. A match between the emotional cues in music and the mood or affective state of the listener enhances recall and working memory, but a mismatch is particularly detrimental to recall in older adults. Thus, the music intervention approaches more likely to succeed in aging are those based on conceptualising both music listening and participation as forms of active engagement, hence taking into account the initial emotional state of the participants.

CRediT authorship contribution statement

Emma V. Ward: Conceptualization, Methodology, Software, Supervision, Formal analysis; Funding acquisition; Writing- Original draft preparation; Martine Van Puyvelde: Conceptualization, Investigation, Writing- Reviewing and Editing; Alex Isac: Investigation; Formal analysis; Maria Donnelly: Investigation; Formal analysis; Fabia Franco: Conceptualization, Methodology, Supervision, Writing- Reviewing and Editing.

Acknowledgements

This work was funded by an award from the Experimental Psychology Society. The authors would like to thank Joel S. Swaine (University of Hull) for creating the musical stimuli for this study, which are openly available: https://soundcloud.com/user-601027202/sets/happy-and-sad-piano-tracks/s-WhSMrTVVsoE.

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