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Emotional memory and the effect of music on the memory of older adults

Memoria emocional y efecto de la música en el recuerdo de adultos mayores

Memória emocional e o efeito da música na memória de idosos

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Abstract

Older adults remember emotional stimuli to a greater extent than neutral ones. This would be higher for positive stimuli. Several studies used music to modulate emotional memories in young adults, in the consolidation stage. This was scarcely studied in older adults using negative, positive and neutral stimuli. The aim of this work is to study emotional memory in older adults and the effect of activating and relaxing music on emotional and neutral visual memory. Forty-four older adults were evaluated. They observed negative, positive, and neutral pictures. Then, a relaxing, activating or white noise musical treatment was applied to them, followed by a free recall and recognition task. A week later, the free recall and recognition tasks were repeated. The results indicated better memory free of emotional stimuli, and a greater number of emotional false positives. Relaxing music worsened delayed recognition, and white noise produced better immediate recall of positive pictures. The results indicate that emotional memory is preserved in older adults. Music modulates memories differently in older adults compared to younger adults, as only relaxing music produced the expected effect.

Keywords: older adults; music; emotions; positive stimuli

Resumen

Los adultos mayores recuerdan mejor los estímulos emocionales que los neutros, e incluso más los estímulos positivos. Diversos estudios utilizaron música para modular recuerdos emocionales y neutros en adultos jóvenes, en la etapa de consolidación. Esto fue poco estudiado en adultos mayores utilizando estímulos negativos, positivos y neutros. El objetivo del presente trabajo es estudiar la memoria emocional en adultos mayores y el efecto de la música activante y relajante sobre la memoria visual emocional y neutra. Se evaluaron cuarenta y cuatro adultos mayores. Observaron imágenes negativas, positivas y neutras. Luego se les aplicó un tratamiento musical relajante, activante o ruido blanco, seguido de una tarea de recuerdo libre y reconocimiento. Una semana después se repitieron las tareas de recuerdo libre y reconocimiento. Los resultados indicaron mejor recuerdo libre de estímulos emocionales, y mayor cantidad de falsos positivos emocionales. La música relajante empeoró

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el reconocimiento diferido, y el ruido blanco produjo mejor recuerdo inmediato de imágenes positivas. Los resultados indican que la memoria emocional está conservada en adultos mayores. La música modula los recuerdos de un modo diferente en adultos mayores en comparación con jóvenes, ya que sólo la música relajante produjo el efecto esperado.
Palabras clave: adultos mayores: música; emociones; estímulos positivos

Resumo

Os idosos se lembram mais dos estímulos emocionais do que dos neutros, e ainda mais estímulos positivos. Vários estudos utilizaram a música para modular memórias emocionais e neutras em adultos jovens, em fase de consolidação. Isso foi pouco estudado em idosos com estímulos negativos, positivos e neutros. O objetivo do presente trabalho é estudar a memória emocional em idosos e o efeito da ativação e relaxamento da música na memória visual emocional e neutra. Foram avaliados quarenta e quatro idosos. Eles observaram imagens negativas, positivas e neutras. Logo, um tratamento musical relaxante, ativador ou de ruído branco, foi aplicado a eles, seguido por uma tarefa de recordação livre e reconhecimento. Uma semana depois, as tarefas de recordação livre e reconhecimento foram repetidas. Os resultados indicaram melhor recordação livre de estímulos emocionais e um maior número de falsos positivos emocionais. A música relaxante piorou o reconhecimento diferido, e o ruído branco produziu uma melhor recordação imediata de imagens positivas. Os resultados indicam que a memória emocional está preservada em idosos. A música modula as memórias de forma diferente em idosos em comparação com adultos jovens, pois apenas a música relaxante produziu o efeito esperado.
Palavras-chave: idosos; música; emoções; estímulos positivos

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Emotionally activating stimuli are better remembered than neutral stimuli, which is known as emotional memory (Cahill & McGaugh, 1995; Justel et al., 2013). The emotional content of the stimuli modulates memory, since these stimuli are better remembered and, in more detail, than the neutral ones (Bradley et al., 1992). Several investigations showed the close relationship between emotions and memory (Bradley et al., 1992; Justel et al., 2013; Kensinger & Corkin, 2003).

According to Russell's circumplex model (Russell, 1980) an emotional stimulus has two dimensions: valence, i.e., positive (pleasant) or negative (unpleasant); and arousal, i.e., exciting (high arousal) or relaxing (low arousal; Bradley & Lang, 2000). Highly arousing positive or negative stimuli are better remembered than neutral stimuli (low arousal; Cahill & McGaugh, 1995; Crowley et al., 2019).

Emotional memory is associated with changes in neuronal activity that are generated during memory encoding and consolidation: increased activation of subcortical structures, such as the amygdala and hypothalamus (Cahill & McGaugh, 1998; Kensinger & Corkin, 2003; Richardson et al., 2004). Encoding is the process of knowledge acquisition, while consolidation is the later process, when information is stored in a long-term memory system

(Carlson, 2014). The emotional content of the stimuli can modify both processes (Crowley et al., 2019; McGaugh, 2018; Ruetti et al., 2009).

There is a cognitive decline in the ability to acquire new information, which is associated with age, especially from the age of 60 (Denburg et al., 2003). Emotional memory is spared in older adults. Several studies found better immediate and delayed recall of emotional visual stimuli in older adults (Charles et al., 2003; Denburg et al., 2003; Gomez-Gallego & Gomez-Garcia, 2017; Hamann et al., 2000; Justel & Ruetti, 2014; Kensinger et al., 2002; Leal et al., 2017), using pictures from the International Affective Picture System (IAPS; Lang et al., 1997). Some other studies did not find emotional enhancement of memory in older adults (Justel et al., 2015; Murphy & Isaacowitz, 2008).

Neuroanatomically, the preservation of emotional memory could be due to the sparing of brain areas related to emotional processing and the reward circuit, such as the amygdala, striatum, and medial prefrontal cortex (Brabec et al., 2010; St. Jacques et al., 2013). In addition, older adults exhibit an increased activity in the prefrontal cortex when perceiving positive and negative stimuli, which could reflect greater recruitment of controlled processes during emotional encoding (St. Jacques et al., 2013).

Some studies even found that older adults better recall positively valence pictures compared to negative pictures (Charles et al., 2003; Joubert et al., 2018), while young adults better recall negative material (Charles et al., 2003). This positive emotional enhancement of memory, known as the "positivity effect", is related to a greater allocation of cognitive resources during the encoding of emotional stimuli (Mather & Carstensen, 2005), greater influence of the amygdala and the medial prefrontal cortex in the hippocampus during encoding of positive stimuli (Addis et al., 2010), and less amygdalin activation with negative stimuli (St. Jacques et al., 2010). Older adults rate positive valence IAPS pictures as more positive than young adults (Grühn & Scheibe, 2008), and negative ones as less arousing (St. Jacques et al., 2010).

Although the emotional enhancement of memory has been studied in older adults, they also show greater false recognition scores of emotional stimuli (Gallo et al., 2010; Gomez-Gallego & Gomez-Garcia, 2017). This effect is related to the fact that emotions increase the familiarity or conceptual relationship between similar old (previously seen) and novel stimuli (for example, if both are activating and positive stimuli). Older adults would rely on memory retrieval strategies based on familiarity more than explicit item recall or recollection (Koen & Yonelinas, 2014). Therefore, during recognition tasks, they show an increase in both hits and false alarms (false recognition; Gallo et al., 2010). However, Kensinger and Corkin (2004) found decreased emotional false recognition in young and older adults, and suggested that emotional stimuli, since they are more arousing, generate a richer encoding, and, therefore, a more accurate recognition.

Like other emotional stimuli, music can generate emotional arousal, and listening to it is related to the activation of limbic and paralimbic areas (Blood & Zatorre, 2001; Koelsch, 2014). Therefore, several studies used music to modulate the memory of different stimuli. A brief presentation of activating music after visual or verbal stimuli, that is, during the consolidation stage, improves recall of visual stimuli in younger adults, compared to a control condition of white noise (Judde & Rickard, 2010; Justel et al., 2016; Justel & Rubinstein, 2013). This effect has been studied even with delayed recall tasks (one week later; Justel & Rubinstein, 2013). Relaxing music produces the opposite effect (less emotional activation), and this would generate a decrease in the emotional enhancement of memory, in delayed free recall (one week later; Rickard et al., 2012).

In older adults specifically, music was used to modulate recall during encoding (Bottiroli et al., 2014; Ferreri et al., 2013), and a decrease of false recognition scores was found (Simmons-Stern et al., 2012). Other studies applied musical treatments during memory consolidation, following a similar procedure previously used with young adults, using picture sets from the IAPS (Diaz Abrahan et al., 2019; Justel et al., 2015; Moltrasio et al., 2020). In a recent study, Diaz Abrahan et al. (2019) applied an active musical treatment (improvisation or imitation of rhythmic patterns), and found better free recall of total and negative pictures, better delayed recall of emotional pictures, and better delayed picture recognition, with the improvisation treatment. In addition, using the copy of a complex figure, that is, a neutral visual material, they found a better delayed recall of it with the improvisation treatment. In another study (Justel et al., 2015) only positive and neutral pictures were used, and a passive musical treatment: listening to activating or relaxing music. They found a decreased recall with relaxing music, compared to white noise (control condition), both in immediate and delayed recall and recognition. In another study, a musical treatment was applied to older adults with Alzheimer's disease (Moltrasio et al., 2020), and found less falsely recognized pictures with activating music, during a delayed recognition task.

Previous studies show that musical treatments in older adults modulate emotional and neutral memory. However, we found no studies that have assessed modulation of memory through music using positive, negative and neutral stimuli, and that analysed both true and false recognition scores.

The aim of this work is to study emotional memory in older adults and the effect of activating and relaxing music on emotional and neutral visual memory. The first hypothesis is that subjects will show an enhanced memory for emotional compared to neutral pictures. The second hypothesis is that the subjects exposed to the activating music treatment will show an increased memory compared to the other two, and subjects exposed to relaxing music treatment will show a decreased memory.

Method

Participants

Forty-four older adults (33 women, 11 men), between 64 and 97 years old (M = 73.7; SD = 7.9), residents of the province of Buenos Aires, participated in the study. They were recruited from various places: retirement centres; Cognitive Impairment Laboratory, from the hospital Eva Perón of San Martín, where participants went to perform a neurocognitive assessment; or they were companions or family members of patients and team members.

Older adults (from 60 years of age) without hearing problems were included. Subjects had a maximum of 12 years of formal education, and less than 5 years of formal or informal music training. Exclusion criteria included: depression (measured through the GDS-15) (Sheikh & Yesavage, 1986); cognitive impairment, measured through the Mini Mental State Examination (MMSE; Allegri et al., 1999; Folstein et al., 1975) and Clock Drawing Test (CDT; Freedman et al., 1994); and difficulties recognizing visual stimuli (assessed through the abbreviated version of the Boston Naming Test: Mini Boston; Serrano et al., 2001).

The present study was carried out in accordance with the WHO code of ethics on human experiments (Declaration of Helsinki). All participants voluntarily signed a written informed consent prior to their participation.

Instruments

Questionnaires

A personal data questionnaire was used to collect data on age, educational level, psychoactive substances (coffee, mate, tea, alcohol, cannabis, amphetamines) and psychotropic drugs use prior to the evaluation, psychiatric history, relevant illnesses, and years of musical training. In addition, they completed a Musical Preferences Questionnaire, where they were asked about musical preferences, and current and previous engagement in musical activities (Mercadal-Brotons & Augé, 2008).

Rey Complex Figure Test. We used the Rey Complex Figure Test (RCFT; Meyers & Meyers, 1995) as a measure of neutral visual memory. The original test consists of the copy of a complex figure, while watching the original figure. It has an immediate and delayed free recall task, in which the subject must draw what they remember of the figure. In addition, it has a recognition task, which consists of the presentation of 24 figures, of which 12 correspond to the original figure, and the subject must decide which ones were part of the original figure. The scoring of the figure (copy and recall) consists of dividing it into 18 parts, and giving a score of 0, 1 or 2 according to drawing and placement precision of each part.

IAPS. We selected 36 IAPS pictures: 12 neutral (Arousal mean = 3.5), 12 positive (M = 6.3), 12 negative (M = 6). Subjects watched them in a Microsoft Office PowerPoint 2016 presentation, in a randomized manner (same order for all subjects). Another 3 pictures were used as an example of each type of picture (neutral, positive and negative), during the practice test. For each picture, subjects had to answer the level of arousal, that is, how arousing the pictures were for them, on a scale of 1 to 5, being: 1 = *non arousing*, 2 = *a little arousing*, 3 = *moderately arousing*, 4 = *very arousing* and 5 = *very much arousing*.

An additional 72 pictures were selected (same number of pictures for each emotional category) for immediate and delayed recognition tasks.

Treatment

As a post-learning treatment, we used musical stimuli and white noise. The latter has been used as a control condition in studies of memory modulation (Abrahan & Justel, 2019; Rickard et al., 2012). Haydn Joseph's Symphony No. 70 in D Major was used as an activating stimulus, previously used in similar studies (Justel et al., 2016; Justel & Rubinstein, 2013). We chose Pachelbel's canon in D major as a relaxing stimulus, which was used in other studies as a musical treatment (Justel et al., 2016).

Procedure

The assessment consisted of two sessions, a week apart one from another. During the first session, each subject read and signed the informed consent, in order to participate in the study. After that, they answered individually and orally a personal data questionnaire and musical questionnaire. They were assessed through the following exclusion tests: GDS-15, MMSE, CDT and Mini Boston.

Then, we applied the IAPS and RCFT protocols. We randomly assigned each subject to both procedures: some of them were exposed first to the RCFT protocol and then to the IPAS protocol, while others were exposed to the IAPS protocol first and then to the RCFT protocol. The treatment was also randomly assigned: a musical treatment (relaxing or activating) was applied in one of the protocols, and white noise in the other (for example: Subject 1 received the RCFT protocol with an activating music treatment, and the IAPS protocol with white noise). For the RCFT protocol, 24 subjects were exposed to white noise, 10 to activating music, and 10 to relaxing music. Whereas for the IAPS protocol, 22 subjects received white noise (control condition), 12 activating music treatment and 10 relaxing music treatment.

The RCFT protocol consisted in the administration of the test, with a slight modification. In the first session they had to copy the figure. Next, subjects listened to activating or relaxing music, or white noise (post-learning treatment). Then, they were assessed through immediate recall and recognition tasks. One week later, during the second session, subjects performed delayed recall and recognition tasks. For the recognition tasks, we computed the scores of both true and false recognition.

The IAPS protocol consisted of an explanation of the procedure, followed by a test trial (using 3 example pictures), in which we explained the misunderstandings that might appear. After that, subjects watched a set of 36 from the IAPS, one by one, on a computer screen, placed in front of the subjects at a comfortable distance adjusted during the test trial. Subjects watched each picture for as long as they needed, but we invited them to give a quick answer, without dwelling too much on each picture or making comments. Then, subjects listened to three minutes of activating or relaxing music (music treatment), or white noise (control condition). The assignment of each subject to each condition was random. Immediately afterwards, they were asked to describe briefly the pictures seen previously (immediate recall), followed by a recognition task (immediate recognition), where subjects watched the 36 initial pictures mixed with 36 new ones, and had to decide whether they were old or new. Both true and false recognition scores (pictures that are falsely recognized as old that were not part of the initial 36) were computed.

During the second session, one week later, participants were assessed through delayed free recall and delayed recognition tasks, with a new set of 36 pictures, different from the immediate recognition pictures.

Statistical analysis

We analysed the normality of the variables and used parametric statistics.

We used ANOVA to compare age and educational level, MMSE, CDT, being condition (treatment: activating music, relaxing music and white noise) the between-subject factor.

To analyse RCFT scores, we also used one-way ANOVA, with Condition (treatment) being the between-subject factor. We compared the raw scores of the copy, immediate recall and delayed recall tasks (according to the original scoring of the test). Scores for immediate and delayed recognition (correctly recognized stimuli), and immediate and delayed false recognition (new stimuli that are falsely recognized as old) were also analysed.

A repeated measures (RM) ANOVA was used to compare arousal scores (from IAPS protocol). We used condition as between-subject factor, and arousal score for each picture type (negative, positive, neutral) as the RM.

To analyse the free recall of pictures, both immediate and delayed, we used RM ANOVA, using condition as the between-subject factor and the type of picture (neutral, negative, neutral) as the RM. Similarly, the analysis of immediate and delayed picture recognition was performed using a RM ANOVA, using condition as the between-subject factor and the type of pictures (neutral, negative, neutral) as the RM. We used the same method to analyse false immediate and delayed recognition, that is, the number of new pictures that were falsely recognized as old.

The p value was set at .05 and the partial Eta squared (η^2p) was calculated to estimate the effect size. We used the Statistical Package for the Social Sciences (IBM SPSS Statistics 25) to perform the statistical analysis.

Results

No group differences were found in age, $F(2, 41) = 0.269$, $p = .766$; educational level, $F(2, 41) = 1.659$, $p = .203$; MMSE, $F(2, 41) = 1.095$, $p = .344$; y CDT, $F(2, 41) = 1.684$, $p = .198$. Results are shown in table 1.

Table 1

Sociodemographic data and exclusion tests

Group	Age	Educational level (years)	MMSE	CDT
White noise	74.2 (7.4)	6.2 (2.2)	28.4 (1.5)	13.7 (1)
Activating	72.3 (7.8)	7.1 (2.5)	28.5 (1.1)	13.3 (0.9)
Relaxing	74.3 (9.7)	8.2 (2)	27.7 (1.4)	13.6 (0.9)

Notes. The means and standard errors (in parentheses) of the three groups (according to condition) in age, educational level (years), MMSE and CDT. White Noise: Subjects exposed to white noise as a control condition; Activating: Participants exposed to Haydn's Symphony No. 70 in D Major; Relaxing: Subjects exposed to Pachelbel's canon in D Major.

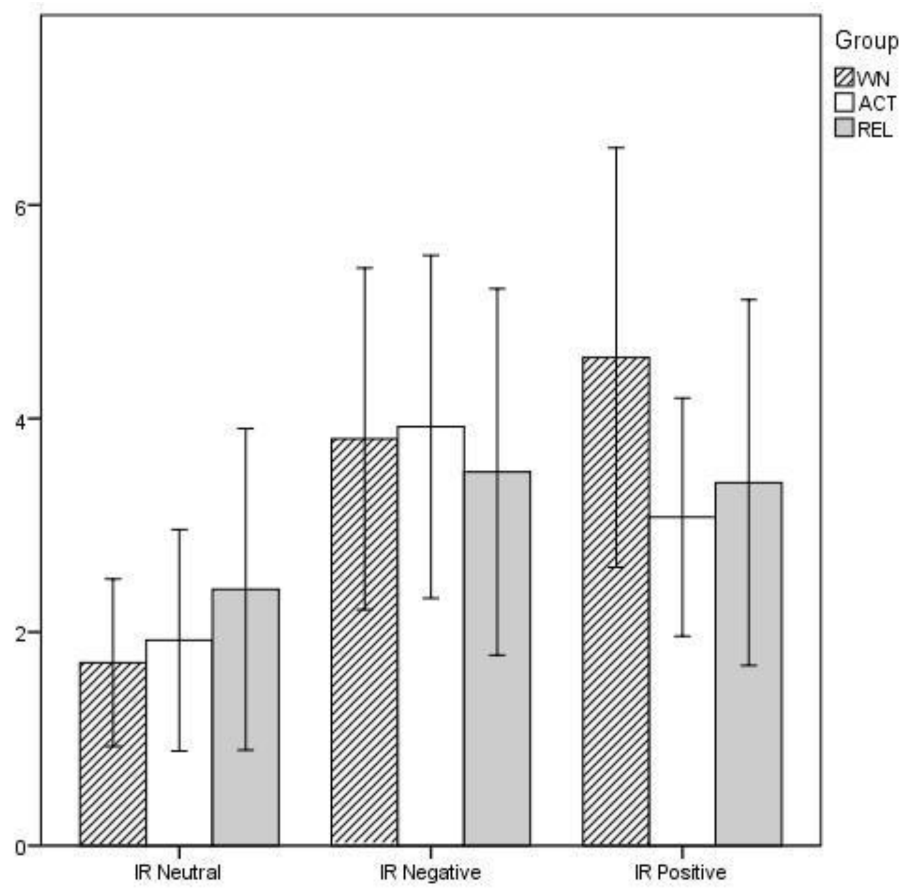
We found no group differences in the RCFT copy, $F(2, 41) = 0.978$, $p = .385$, that is, there were no differences between groups during the encoding of the figure. No differences were found in memory measures either: immediate recall, $F(2, 41) = 0.180$, $p = .836$; delayed recall, $F(2, 41) = 0.184$, $p = .832$; immediate recognition, $F(2, 41) = 0.649$, $p = .528$; delayed recognition, $F(2, 41) = 0.148$, $p = .863$; immediate false recognition, $F(2, 41) = 0.034$, $p = .967$; and delayed false recognition, $F(2, 41) = 1.702$, $p = .195$.

In relation to the arousal scoring of the pictures, we found a significant effect of the type of picture, $F(2, 41) = 274.073$, $p < .001$, $\eta^2p = 0.870$. Post-hoc tests indicated greater activation for positive pictures ($M = 3.9$, $SD = 0.4$) compared to neutral ones ($M = 2.7$, $SD = 0.5$), and for negative ($M = 4.1$, $SD = 0.4$) compared to the positive ones.

In relation to immediate recall, the ANOVA showed a significant effect of the type of picture, $F(2, 41) = 21.865$, $p < .001$, $\eta^2p = 0.348$, and an interaction of type of picture x condition $F(2, 41) = 2.964$, $p < .05$, $\eta^2p = 0.126$. Subsequent analysis indicated a better recall of positive pictures ($M = 3.9$, $SD = 1.8$) and negative pictures ($M = 3.8$, $SD = 1.6$) compared to neutral pictures ($M = 2$, $SD = 1.1$) in all groups. In relation to the picture type x condition interaction, subsequent analysis indicated a better recall for positive pictures with white noise condition, compared to subjects exposed to activating music (figure 1).

Figure 1

Immediate recall. Average of recalled neutral, positive and negative pictures

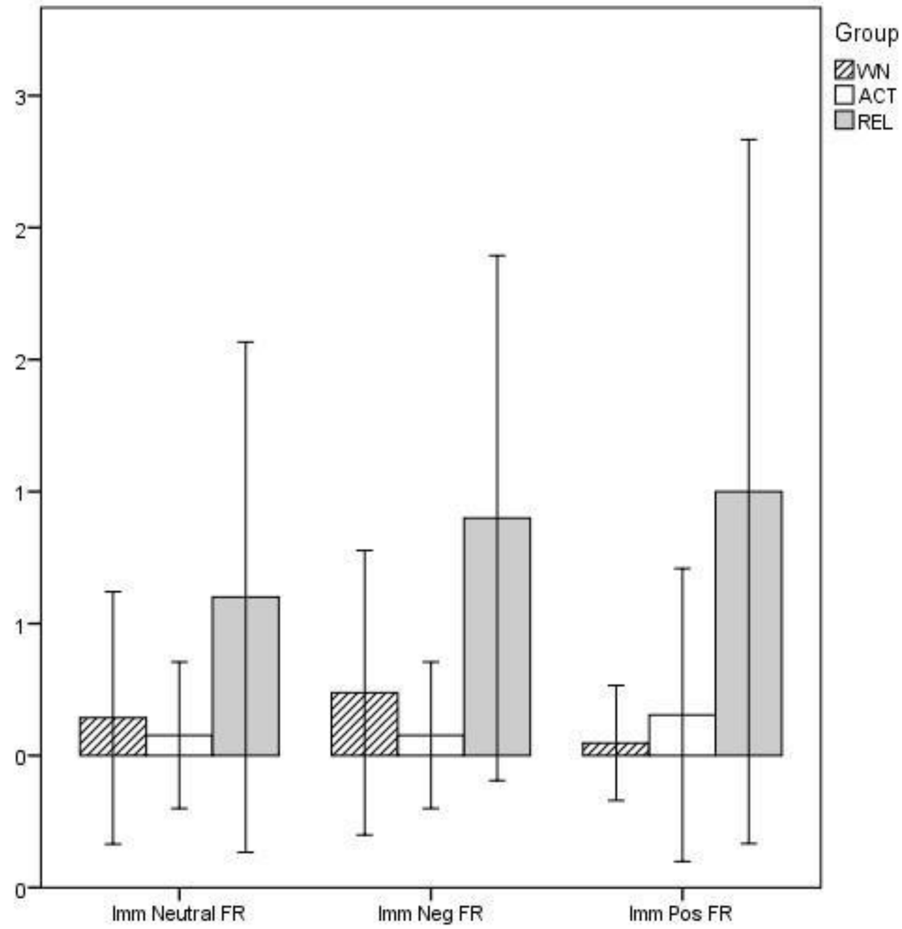


Note. WN: Subjects exposed to white noise as a control condition; ACT: Participants exposed to Haydn's Symphony No. 70 in D Major; REL: Subjects exposed to Pachelbel's canon in D major. The bars represent the standard deviation.

The analysis of immediate recognition did not show significant effects of picture type, $F(2, 41) = 1.656$, $p = .197$, condition, $F(2, 41) = 0.913$, $p = .409$, or the interaction between both, $F(2, 41) = 0.487$, $p = .745$. Analysis of immediate false recognition, on the other hand, yielded no significant effects of picture type, $F(2, 41) = 1.718$, $p = .186$, or picture type x condition interaction, $F(2, 41) = 1.937$, $p = .112$. Although we found a significant effect of condition, $F(2, 41) = 6.019$, $p < .005$, $\eta^2p = 0.227$, and found a greater number of false recognition for the relaxing music group ($M = 2.5$, $SD = 3.1$), compared to white noise ($M = 0.4$, $SD = 1.2$) and activating music ($M = 0.3$, $SD = 0.6$; figure 2).

Figure 2

Immediate false recognition. Mean score of immediate false recognition of neutral, positive and negative pictures



Note. WN: Subjects exposed to white noise as a control condition; ACT: Participants exposed to Haydn's Symphony No. 70 in D Major; REL: Subjects exposed to Pachelbel's canon in D major. The bars represent the standard deviation.

Regarding delayed recall, we found a significant effect of the picture type, $F(2, 41) = 17.350$, $p < .001$, $\eta^2p = 0.297$. Post-hoc analysis indicated better recall of positive ($M = 2.64$, $SD = 1.4$) and negative pictures ($M = 2.3$, $SD = 1.7$), compared to neutral pictures ($M = 1$, $SD = 1.1$).

In relation to delayed recognition, the ANOVA did not show effects of picture type, $F(2, 41) = 1.1$, $p = .338$, condition, $F(2, 41) = 1.394$, $p = .260$, or the interaction picture type x condition, $F(2, 41) = 1.133$, $p = .347$.

Finally, we found a significant effect of the type of picture in delayed false recognition, $F(2, 41) = 6.719$, $p > .05$, $\eta^2p = 0.141$. Post-hoc analysis indicated more false recognition for positive ($M = 0.8$, $SD = 1.5$) and negative ($M = 0.8$, $SD = 1.4$) pictures compared to neutral ones ($M = 0. 3$, $SD = 0.9$).

Discussion

The aim of the work was to study emotional memory in older adults, and the effect of activating and relaxing music on emotional and neutral visual memory. The first hypothesis was partially verified. In both immediate and delayed free recall, we found a better recall of emotional pictures, compared to neutral ones, although no differences were found in recognition tasks. The second hypothesis was also partially confirmed. Although we found a better immediate recall of positive pictures with white noise, which goes against the proposed hypothesis and previous studies, a greater number of immediate false positives was found with the relaxing condition, in agreement with the proposed hypothesis. In addition, no modulation of neutral visual stimuli (RCFT) was found.

Older adults spared emotional memory enhancement, even a week later. All groups better recalled emotional pictures compared to neutral pictures in immediate recall, and better recalled positive pictures compared to neutral pictures in delayed recall. Previous studies reported immediate and delayed emotional memory enhancement in older adults (Charles et al., 2003; Denburg et al., 2003; Gomez-Gallego & Gomez-Garcia, 2017; Hamann et al., 2000; Justel & Ruetti, 2014; Kensinger et al., 2002). The sparing of areas related to emotional memory and emotion processing, such as the amygdala, explains the presence of this phenomenon even in older adults (St. Jacques et al., 2013).

In addition, the results show the preservation of emotional memory in delayed recall, previously reported (Denburg et al., 2003; Diaz Abrahan et al., 2019; Justel et al., 2015). However, the positivity effect (better recall of positive pictures), previously reported in older adults on immediate recall, was not found (Charles et al., 2003; Joubert et al., 2018).

Regarding recognition of emotional pictures, we did not find a better recognition of emotional pictures, although a greater number of emotional false recognition was observed in delayed recognition. The first result could be due to a ceiling effect, i.e., neutral pictures recognition was high, reaching maximum values in several subjects. Other studies found the same result in relation to emotional picture recognition (Charles et al., 2003; Justel et al., 2015), except for one, in which they used a greater number of pictures to remember (Gomez-Gallego & Gomez-Garcia, 2017). The second result, increase in emotional false recognition, has also been reported previously. This result could be due to the fact that the emotionality of the stimuli generated a greater feeling of familiarity because of the emotional similarity of new and old pictures, making subjects mistakenly recognize new stimuli (Gallo et al., 2010; Koen & Yonelinas, 2014).

We did not find modulation of exclusively neutral memory (RCFT protocol) with music. In a previous study, authors found a better delayed recall of the RCFT, although they used an active musical treatment (improvisation vs. imitation; Diaz Abrahan et al., 2019). Another study, which assessed older adults with deficits, found no modulation of RCFT memories with musical treatments, showing similar results (Rubinstein et al., 2015). However, regarding emotional pictures, we found differences between groups, which will be discussed later. It is possible that this modulation difference is attributable to the fact that music modulates neutral and emotional stimuli differently. Another explanation is related to the differences in the demands of the tasks: the copy of the RCFT requires other cognitive functions, such as visual construction and planning (Burin et al., 2007; Meyers & Meyers, 1995), different from the demands of watching pictures; and both the task and the stimulus itself are much less frequent than the pictures. In other words, it is possible that the musical intervention was not strong enough to generate a memory modulation of such a complex stimulus.

Regarding the modulation of emotional memories, we found better immediate recall of positive pictures in the white noise (control) group, compared to the subjects exposed to activating music. This is inconsistent with previous studies: in young adults, activating music enhances visual and verbal stimuli (Judde & Rickard, 2010; Justel et al., 2016; Justel & Rubinstein, 2013); and, in older adults, white noise did not enhance memory for pictures (Justel et al., 2015). A possible explanation for this is the differences between groups in variables not considered in this study, such as personality and mood. It has been reported that personality traits such as Openness to experience and Conscientiousness are related to better performance in memory tasks in older adults (Luchetti et al., 2016). Moreover, differences in memory performance (Leal et al., 2017) and mood (Gomez-Gallego & Gomez-Garcia, 2017), could affect older adults' emotional memory.

Finally, subjects exposed to relaxing music showed more immediate false recognition. This memory modulation through music was not reported in false recognition scores: in a previous study they did not analyse these scores (Justel et al., 2015), although they found worse recognition of neutral and positive pictures with relaxing music. In addition, the modulation of memories through music, considering false recognition scores, has been reported in subjects with Alzheimer's disease (Moltrasio et al., 2020). In this study, the activating music group showed decreased delayed false recognition scores. These results suggest that music modulates memories differently in healthy older adults and subjects with neurodegenerative diseases.

The limitations of the study are related to the results that contradict previous studies that used activating music to modulate memories. As mentioned above, this could be overcome considering uncontrolled variables, which could be done in future studies. Participants in this study were not balanced in terms of sex (since they were mostly women): future studies could assess differences between sexes regarding memory modulation through music, in order to determine if this variable is influencing the results. However, it should be noted that, although the sample size is small, the hypothesis of emotional memory enhancement in older adults was corroborated, and the hypothesis of memory modulation through music was partially corroborated.

In conclusion, the results indicate sparing of emotional memory in older adults. Moreover, in relation to the modulation of emotional memory through music in older adults, musical interventions seem to modulate memories in a different way compared to younger adults and older adults with dementia: activating music did not enhance emotional memory, on the contrary, it worsened; but we found the expected effect with relaxing music. These findings support previous studies that indicate the preservation of emotional memory in older adults, although emotional stimuli also generate more false recognition. In addition, this study supports findings regarding memory modulation through music, since music can be used to modulate memories even in the context of age- related cognitive decline. Future studies could delve into how these stimuli (both the type of music and the emotionality of visual stimuli), can be used for cognitive stimulation in healthy older adults.

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