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# Music improvisation modulates emotional memory

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## Abstract

Music improvisation is a technique frequently used in the music therapy field. Its application involves emotional support, cognitive evaluation or cognitive/motor rehabilitation. However, its effect as a valid treatment to moderate memory has not been studied. The aim of the present study is to investigate the effect of music improvisation on emotional memory, in adults with or without musical training. Participants watched emotional or neutral images, and rated simultaneously how emotional they felt the images were, from 0 to 10 (*nothing* to *highly arousing*). Later, participants were exposed to a treatment (music improvisation, imitation, or silence). Immediately afterwards, recall and recognition were evaluated. After a week, free recall and recognition were tested again. The main findings of this study were that music improvisation improves free recall and recognition of neutral and emotional images. The results also indicated that musicians showed better emotional memory performance than non-musicians.

## Keywords

*emotions, memory, music improvisation, music therapy, musical training*

Linked to music, the term improvisation refers to a multiplicity of performative practices that have in common a high degree of spontaneity and a low level of preconception. It is a rather diffuse concept whose scope depends on the scope and cultural context in which it is applied. Thus, the characterizations of musical improvisation can be very diverse and even present opposing characteristics depending on the practices of jazz (Berkowitz, 2010), contemporary

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academic music (Barrett, 1998), music from multiple cultures throughout the world (Nettl & Solis, 2009), music education (Biasutti, 2017) or music therapy (Abrahan & Justel, 2015) among many others. This work adheres to the music therapy use of improvisation, in which music improvisation is considered a musical experience: the therapeutic agent is not only music but also the subject's experience with music. In this sense, music improvisation is not only performed by musicians, it is also a real-time ability that all people own (Wigram, 2004). According to this perspective, music improvisation is conceived as the combination of sounds created in a specific framework inside an environment of trust that is established to address the needs of the client (Wigram, 2004). During these musical experiences, melody and rhythm are created spontaneously with the resources that are available at the moment, allowing for the possibilities of the client (Bruscia, 1998, 1999).

However, scientific research about the use of improvisation in music therapy, particularly from the neuropsychological point of view, is still emerging. In recent years, investigations have shown the effect of improvisation in several cognitive domains and populations, such as attention (Kim, Wigram, & Gold, 2008), working memory (Lopez-Gonzalez & Limb, 2012), executive functions, and motor skills (Pinho, Manzano, Fransson, Eriksson, & Ullen, 2014). However, most of them were case studies (Gilbertson, 2013), had a psychodynamic perspective, or were focused on neuroanatomical topics, omitting behavioral areas (Abrahan & Justel, 2015). Improvisation in music therapy has been applied as a technique for giving emotional support during clinical treatments (Schulkind, Hennis, & Rubin, 1999) and for perceptual and orientational evaluation in patients with brain lesions (Aldrige & Gilbertson, 2008), among others. This technique has also been systematically employed for the rehabilitation of cognitive functions (Thaut et al., 2009). In order to learn more about the clinical effects of improvisation on cognitive functions, such as memory, it is necessary to explore the capacity of this technique for modulating these functions.

Most of what we know about the relation between music and declarative memory concerns music listening rather than music performance activities (Janata, 2009; Rickard, Wing Wong, & Velik, 2012). Listening to music has been identified as a valid method to moderate arousal and emotion (Rickard, 2004), and these components can regulate both recall and recognition (Judde & Rickard, 2010). According to these and other studies, listening to music can enhance or diminish memory. Therefore music *modulates* this cognitive function (Deason, Simmons-Stern, Frustace, Ally, & Budson, 2012; Groussard et al., 2012; Miles, Miranda, & Ullman, 2016; Rickard, Toukhsati, & Field, 2005; Simmons-Stern et al., 2012). Modulation is understood here as a way of influencing a cognitive function by regulating or controlling a treatment. This corpus of studies does not focus on details of musical processing, but on memory. Thus, music is taken as a whole, as a treatment. This research follows this concept.

Studies on modulation of memory by music perception yielded different results according to the type of memory under evaluation. For instance, Rickard et al., (2012) showed that relaxing music causes emotional memory to deteriorate. As a subcategory of explicit memory, emotional memory is the consequence of the storage of information strongly consolidated due to stress or alarm factors (Bermúdez-Rattoni & Prado-Alcalá, 2001). Other studies found that an activating piece of music enhances emotional and neutral memory (Justel & Rubinstein, 2013; Justel, O'Conor, & Rubinstein, 2015). The mechanism involved in this modulation also underlies the modulation of memory by stress. This means that relaxing music diminishes arousal while activating music elevates it. In that way, relaxing music decreases blood pressure and heart rate while activating music elevates these parameters (Knight & Rickard, 2001).

The modulation of memory by music not only depends on the kind of music employed (relaxing vs. activating pieces) but also on participants' musical background (Gaser & Schlaug, 2003; Groussard et al., 2012; Justel, Diaz Abrahan, Castro, & Rubinstein, 2016; Miles et al., 2016). As some studies have reported that musicians show better memory scores than non-musicians (Groussard et al., 2010), it is possible to relate these findings to neuroanatomical and functional brain divergences between these populations (Justel & Diaz Abrahan, 2012) as the consequence of years of study involved in becoming a musician (Bermúdez & Zatorre, 2005; Gaab & Schlaug, 2003; Lappe, Herholz, Trainor, & Pantev, 2008; Lotze, Scheler, Tan, Braun, & Birbaumer, 2003; Schlaug, 2001).

Since listening to music can modulate emotional memory, can music improvisation modulate it as well? To offer an answer, we designed an experiment that ran an emotional memory test in an experimental group that received as a treatment a brief session of music improvisation, one control group that imitated a music pattern, and a second control group that remained in silence. Our predictions were: (1) Subjects who improvised will have higher memory scores than subjects in the other groups; (2) Arousing stimuli will be better remembered; (3) Musicians will have a better memory performance than non-musicians.

## Method

### Participants

One hundred and thirty seven volunteers (59% female participants) between the ages of 18 and 40 ($M$ = 24.5; $SD$ = 5.12) participated in this study, from different educational institutions. They were recruited through online announcements. Participants' exclusion criteria included visual or hearing impairment, amusia or any pathology related to music. Seventy-five of the subjects were musicians (M) with more than 5 years of formal musical training (schools, institutes, music conservatories). The average number of years of musical training was 9.8 + -4.31 years. Sixty-two participants were considered non-musicians (NM). They had less than 2.8 years of formal musical experience. Each participant signed an informed consent.

### Materials

*Memory task.* The material for the memory task consisted of 36 pictures selected from the International Affective Pictures System (IAPS; Lang, Bradley, & Cuthbert, 1995). Twenty-four were emotionally arousing (12 with a positive valence and 12 with a negative valence) and 12 were non-arousing, neutral images. According to previous works (Cahill, Gorski, & Le, 2003; Justel, Psyrdellis, & Ruetti, 2014) researchers selected the pictures. They covered a wide range of arousal (from 2.95 to 6.36) and valence (from 1.97 to 4.93) in line with the Lang et al. (1995) manual.

*Instrumental setting.* For the musical experiences, participants could choose to use percussion instruments (e.g. drums, maracas, bells, wood blocks, shakers, tambourine) or melodic/harmonic instruments (e.g. guitar, melodica, xylophone, flutes). All the instruments were selected because they were easy to handle/manipulate.

### Treatment conditions

*Silence condition (SIL).* The participants remained silent for three minutes.

*Imitation condition (IMI).* The first author (a music therapist) performed a rhythmic pattern repeatedly for three minutes as a model to be imitated by the participants with their instruments. This

**Figure 1.** Rhythmic base-pattern presented by the researcher to guide both imitation and music improvisation that participants had to perform with a set of basic instruments.

pattern was performed on a percussion instrument at a medium intensity level (see Figure 1; Berkowitz & Ansari, 2008, 2010; Manzano & Ullen, 2012; Pinho, Ullén, Castelo-Branco, Fransson, & de Manzano, 2016). Participants chose any instrument and imitated the pattern for 3 minutes (Gilbertson, 2013). The directives included imitating the pattern heard as faithfully as possible, avoiding variations or new musical materials. This condition was meant to control the possible effects of movement, music perception, previous experience playing musical instruments, etc., that could have altered the results.

*Music improvisation (IMP).* The same researcher performed the same rhythmic pattern repeatedly for 3 minutes as a base for an improvised performance by the participants playing their instruments. This pattern was performed on the same percussion instrument at a medium intensity level. In this situation, participants improvised musical patterns with instruments, their voices or bodies, spontaneously creating some musical feature according to the context provided by the base-pattern. The directives included playing without restrictions: the researcher proposed a free improvisation based on the same rhythmical pattern used in the IMI condition (Figure 1). This rhythmical baseline was introduced in order to guide non-musician participants because pilot studies had shown that without such guidance subjects could not follow the improvisation directions.

## *Experimental design*

Because there were three conditions (Silence, Imitation and Improvisation) and the participants were musicians and non-musicians, we ran a 3(condition) × 2(music expertise) experimental design, with six groups (1) M/SIL: musicians who remained in silence ($n = 33$); (2) M/IMI musicians who imitated ($n = 16$); (3) M/IMP: musicians who improvised ($n = 26$); (4) NM/SIL, non-musicians who remained silent ($n = 31$); (5) NM/IMI, non-musicians who imitated ($n = 16$); and (6) NM/IMP, non-musicians who improvised ($n = 15$). Participants were randomly and blindly assigned to the different groups, and were tested always in groups, with a minimum of four and a maximum of 10 subjects in order to control the involvement of each participant in the music performance. This participation was also monitored by video recording that was scored later.

## *Procedure*

The study was divided into two sessions with a 1-week intersession interval. The first session consisted of four immediately consecutive phases. In the first phase (information phase, about 10 minutes), the participants signed the informed consent and completed a questionnaire about age, gender and musical expertise.

In the second phase, (acquisition phase, about 5 minutes) subjects watched the 36 selected pictures for 7 seconds each. Pictures were presented in random order, except for only two

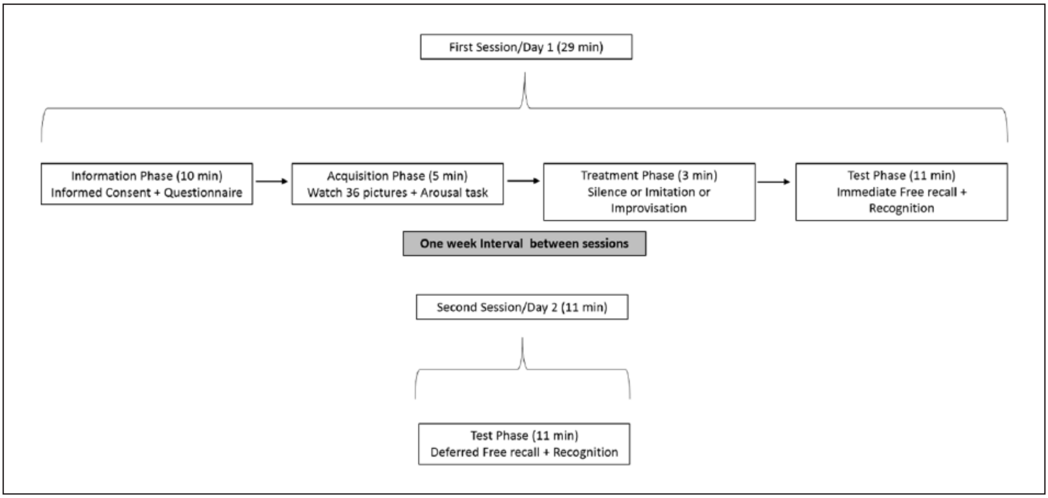


**Figure 2.** Scheme of the experimental procedure.

neutral pictures, which appeared as a first and last image in the series (Cahill et al., 2003). Simultaneously, the participant had to rate on a 0–10 scale how "emotional" or "activating" they felt about each image (0 = *nothing* to 10 = *highly arousing*). We included this behavioral task (*Arousal* task) in order to (1) ensure that the subjects attended to each and every one of the images; (2) validate the selection of IAPS images for this research context; and (3) compare the emotional impact of the images between M and NM groups prior to the treatment.

In the third phase (treatment phase, about 3 minutes), participants were exposed to the treatment condition (silence; imitation or music improvisation). In the silence condition, the instructions were as follows: "We ask you to remain silent for a few minutes. Please do not do anything during this period." In the imitation condition the following directions were given: "We will listen to a rhythmic base. At any time, you may start to imitate me. You may use instruments, your voice or your body." The following directions were given in the music improvisation condition: "We will listen to a rhythmic base, from which you have to create something musical in the group. This rhythmic base will help you to start improvising whenever you want. You may use instruments, your voice or your body. It is important to listen not only to the base pattern, but to your own group as well." Before starting, the researcher corroborated that all the participants understood the instructions. In the improvisation and imitation conditions, subjects chose freely the musical instrument they wanted. They performed the imitation or improvisation task in groups (silence conditions were also in groups) for 3 minutes.

Soon afterwards, in the fourth phase (test phase, about 11 minutes), a two-task test was administered. In it, participants had to describe in one word or short phrase the maximum number of pictures that they could remember (*Immediate Free Recall* task). Next, they observed the 36 original pictures combined with 36 new pictures in random order. While doing this they had to mark on a sheet of paper whether they had seen the images before (*Immediate Recognition* task).

After a week, the second session was held, in which the two-task test was run again (*Deferred Free Recall* task and *Deferred Recognition* task; see Figure 2 for a schematic design of the procedure, 11 minutes).

### Data analysis

Arousal, recall and recognition (immediate and deferred) were independently analyzed via a repeated measures Analysis of Variance (ANOVA) with *Condition* (Silence, Imitation,and Improvisation) and *Training* (Musicians vs. Non-musicians) as the between factors, and *Valence* (Neutral, Positive and Negative) as the repeated measures.

Post-hoc least-significant difference pairwise comparisons were conducted to analyze significant main effects and significant interactions. The partial Eta square ($\eta^2p$) was utilized to estimate effect size. The alpha value was set at .05 and the SPSS software package was used to compute descriptive and inferential statistics.

In order to be sure that subjects in the Imitation and Improvisation conditions fulfilled the directions for the entire 3-minute treatment, the treatment phases were videotaped for later scoring (in the Silence condition the participants were also videotaped, but those videos were not evaluated). For the music Improvisation and Imitation conditions two external researchers unrelated to the experiment watched the videos and rated the subjects according the following parameters: if the group could detach itself from the rhythmic base fragment, if melody patterns were present, the degree of participation of every subject, and new creations present in each group performance. Each of these items had a 5-point scale. According to those parameters the external researchers gave a final verdict about whether the production was an imitation or improvisation performance. Because these observers agreed that all participants were engaged in the treatments, every subject was included in the study. Inter-observer reliability was substantial and significant, $r(12) = .7$, $p < .05$.

A synthesis of the qualitative observations provided by the independent experts can serve to reinforce the reliability of the treatment. The observers characterized music improvisation performed by the NM/IMP groups by using the following musical parameters: rhythms with division and offbeat patterns (according to the pattern played by the researcher) and melodic sequences highly varied over the performance. There was no clear structure due to its continuously modifying character. No harmonic patterns were observed.

Performances of the M/IMP groups were characterized also by rhythms with division and offbeat patterns (according to the pattern played by the researcher). Notably, a higher level of interaction among participants was observed. For example, there were melodic "dialogs" as antecedent–consequent phrases between two participants while a third played a harmonic accompaniment. Also noteworthy were the different ways of playing the musical instruments (beyond conventional). The music improvisations of the musician group were not performed in any particular genre.

Imitations in the NM/IMI and M/IMI groups were characterized by an exact imitation of the rhythmic base keeping the time rate proposed by the researcher. Participants began to imitate after about 30 seconds of listening to the rhythmic base presented.

## Results

### Arousal

Arousal was the first dependent variable analyzed. Participants had to watch neutral, positive, and negative images, and simultaneously rated how arousing the pictures were for them, from zero to ten. The results are depicted in Figure 3. The ANOVA indicated a significant effect for Valence, $F(2, 262) = 267.9$, $p < .0001$, $\eta^2p = .672$. A *post-hoc* test indicated that positive images were more activating than neutral ones, $p < .0001$, also negative images were more

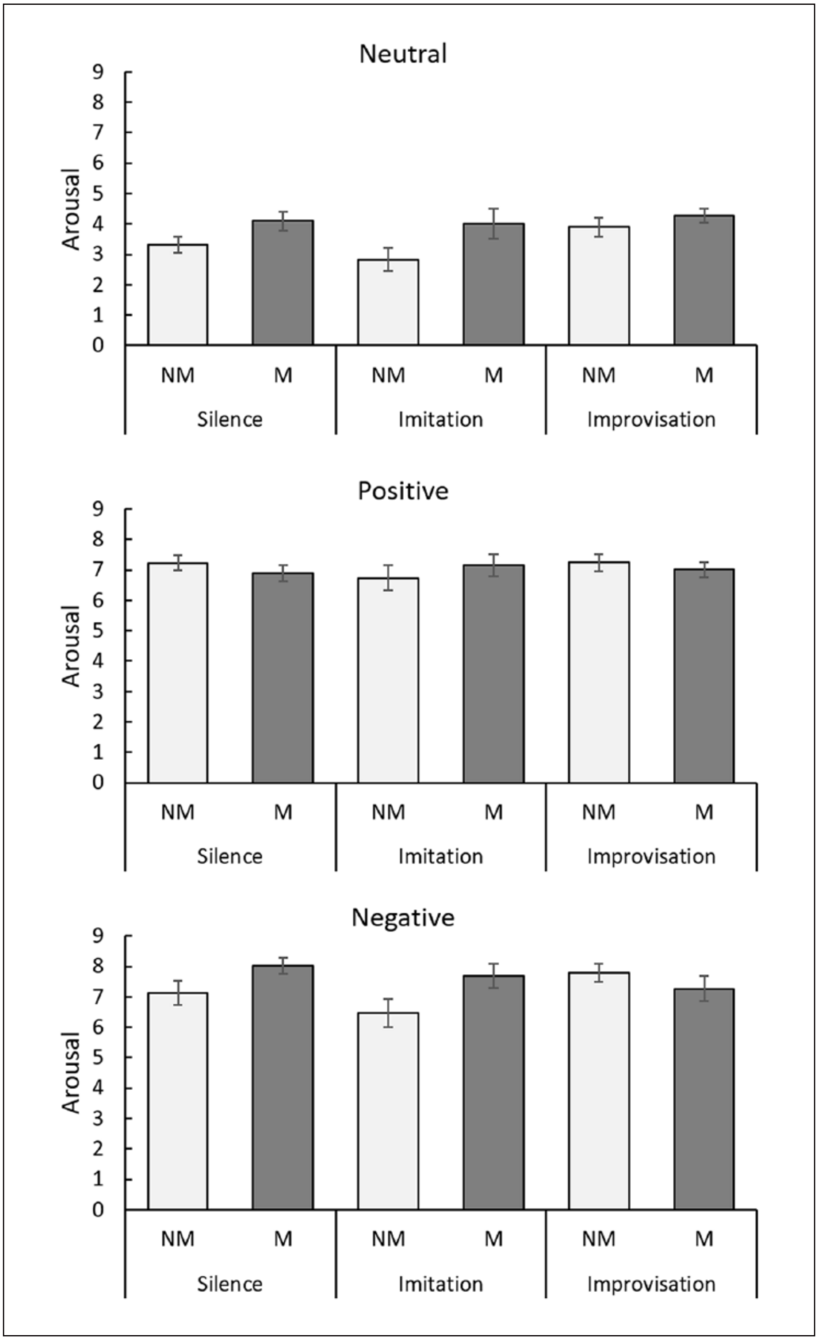


**Figure 3.** Assessment of neutral (top panel), positive (middle panel), and negative (bottom panel) images in a scale from 0 to 10 (0 = not arousing at all, 10 = the maximum that a picture could arouse the participant). NM: Non-musicians. M: Musicians. Silence: Participants who remained in silence; Imitation: Participants who imitated; Improvisation: Participants who improvised. Vertical lines represent standard errors of the mean.

activating than neutral ones $p < .0001$, finally the positive and negative images were the same $p > .05$. The ANOVA also indicated a significant effect of Training $F(1, 131) = 3.99$, $p < .05$, $\eta^2p = .03$: musicians rated the images as more arousing than non-musicians, $p < .05$. The Valence × Training interaction had a marginal significance, $F(2, 262) = 2.96$, $p = .053$, $\eta^2p = .022$, showing that differences between musicians and non-musicians occurred more when they rated neutral and negative images (top and bottom panel of Figure 3) than positive images (middle panel of Figure 3). The main factor, Condition, was not significant, indicating that the three groups rated Arousal at the same baseline.

## *Immediate free recall*

After participants were exposed to the treatment (Silence, Imitation, or Improvisation), they had to recall as many pictures as they could. Results are presented in Figure 4. The ANOVA indicated a significant effect of Valence, $F(2, 262) = 44.56$, $p < .0001$, $\eta^2p = .254$, which indicated that the arousing pictures were better remembered than the neutral ones. Negative pictures were the most remembered images, followed by the positive ones. Neutral images were the least remembered. Also, the ANOVA indicated a main effect of Condition, $F(1, 131) = 4.06$, $p = .02$, $\eta^2p = .058$. The Improvisation group showed a better recall than the Imitation group, $p = .028$; and the Silence group had a better recall than the Imitation group also, $p = .007$. There were non-significant differences between the Improvisation and Silence conditions, $p > .05$. No other statistical analyses yielded significant effects, $p > .05$.

## *Immediate recognition*

Afterwards, the free recall participants observed the 36 original pictures randomly intermixed with 36 new ones. They had to discriminate the new images from the old ones. Table 1 shows the means of the number of pictures that subjects could recognize in each experimental group. The ANOVA indicated no significant differences of Training, nor Valence or Condition, nor any of their interactions, $p > .05$.

## *Deferred free recall*

After a week, the test of free recall and recognition tasks was repeated. Figure 5 illustrates the results of the free recall task. The ANOVA indicated a significant effect of Valence, $F(2, 262) = 43.37$, $p < .003$, $\eta^2p = .249$. Arousing pictures were better remembered than neutral ones. Negative pictures were the best remembered, followed by positive ones. Neutral pictures were the least remembered. Also the ANOVA indicated a significant effect of Condition, $F(1, 131) = 8.28$, $p < .0001$, $\eta^2p = .112$. A *post-hoc* test showed that participants in the Improvisation condition recalled more images than participants in the Imitation and Silence conditions, $p < .05$. Between these last two groups there were no significant differences, $p > .05$.

## *Deferred recognition*

Regarding the pictures that the groups recognized after a week (Table 2), the ANOVA indicated a significant effect of Condition, $F(1, 131) = 9.08$, $p < .0001$, $\eta^2p = .122$. A *post-hoc* test indicated that participants in the Improvisation condition had better recognition than Silence, $p < .001$, and participants in the Silence groups had better recognition than those in the Imitation groups, $p < .05$. No other statistical analyses yielded significant effects, $p > .05$.

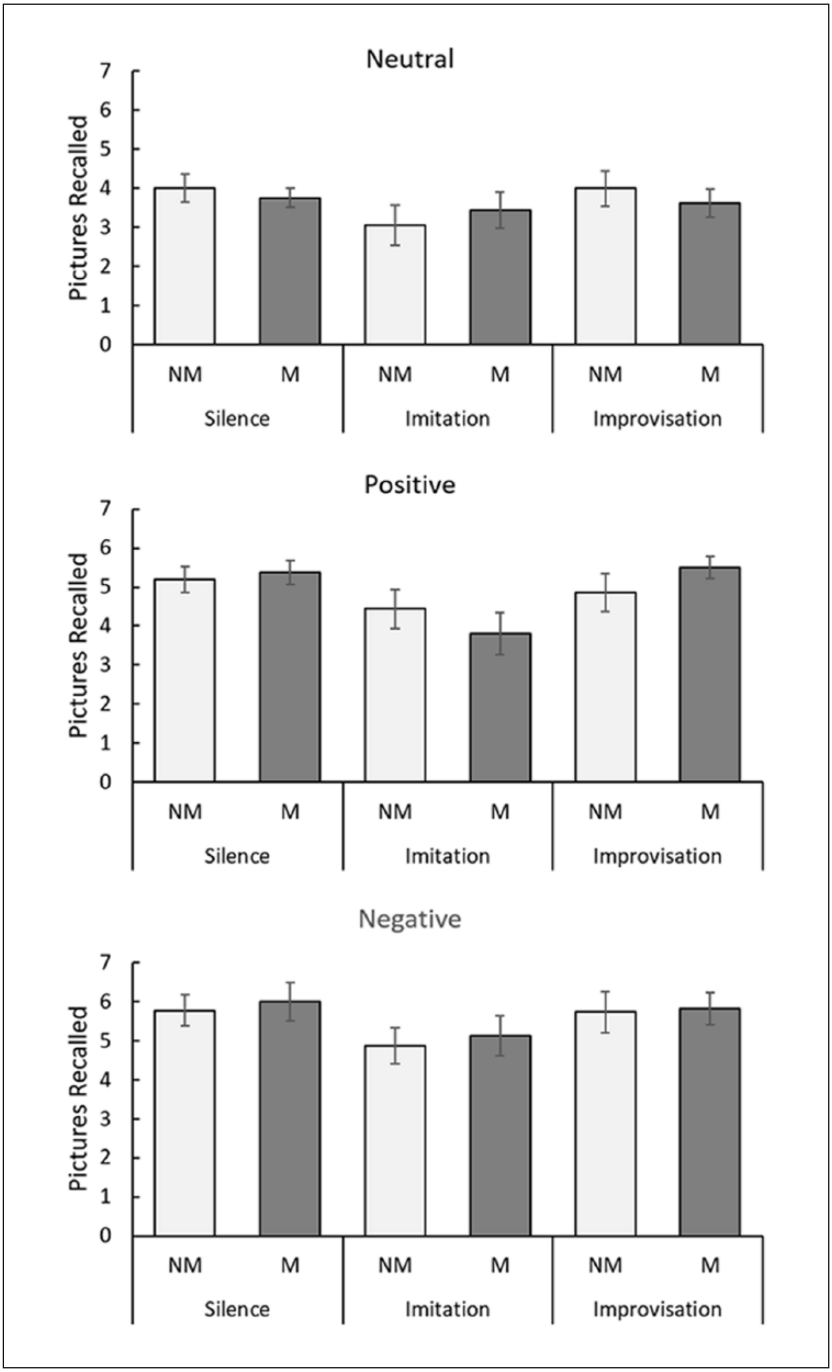


**Figure 4.** Immediate free recall. Number of neutral (top panel), positive (middle panel), and negative (bottom panel) pictures that groups could remember after the treatment. NM: Non-musicians. M: Musicians. Silence: Participants who remained in silence; Imitation: Participants that imitated; Improvisation: Participants who improvised. Vertical lines represent standard errors of the mean.

**Table 1.** Immediate recognition. Means and *SD* of the number of neutral, positive, and negative pictures that participants recognized as previously seen from a pool of 72 images. NM: Non-musicians. M: Musicians. Silence: Participants who remained in silence; Imitation: Participants who imitated; Improvisation: Participants who improvised.

| Groups | | Neutral | Positive | Negative |
|---|---|---|---|---|
| Silence | NM | 11.35 ± 0.39 | 11.25 ± 0.39 | 11.39 ± 0.39 |
| | M | 11.79 ± 0.18 | 11.84 ± 0.12 | 11.58 ± 0.08 |
| Imitation | NM | 11.75 ± 0.11 | 11.69 ± 0.11 | 11.5 ± 0.25 |
| | M | 11.87 ± 0.08 | 11.81 ± 0.10 | 11.69 ± 0.17 |
| Improvisation | NM | 12 ± 0 | 12 ± 0 | 11.93 ± 0.06 |
| | M | 12 ± 0 | 12 ± 0 | 12 ± 0 |

## Discussion

Most of the psychological studies about the relationship between music and emotion have examined this connection from the perceptual point of view rather than from the point of view of performance (McPherson, Lopez-Limb, Rankin, & Limb, 2014). However, some evidence has highlighted that performing music is more effective than merely perceiving it for improving certain cognitive functions (Fancourt, Ockelford, & Belai, 2014). Although some studies have investigated the effects of music perception on emotional memory, we know very little today about the specific consequences of musical performance (improvisation) on memory (Pinho et al., 2014). We investigated this issue here.

Evidence has shown that emotional stimuli are processed differently from non-emotional stimuli, being better remembered over time (Cahill & McGaugh, 1995, 1998; Erk, von Kalckreuth, & Walter, 2010; Justel, Psyrdellis, & Ruetti, 2013; McGaugh & Roozendaal, 2009). The present work adds to this growing body of evidence, since emotional pictures (both positive and negative images) were better remembered than the neutral ones. This result could be observed in both the short- and long-term recall assessments.

Moreover, concerning the nature of the arousal related to images, one of the most relevant results of this study indicated that musicians were *more emotional* than non-musicians when they had to rate the pictures. In addition, music improvisation was more effective at modulating memory than the other conditions. Regarding the first result, previous research revealed that musicians with a high domain of musical skills present greater activity in cerebral areas involved in emotion as a consequence of the deactivation of the cognitive control network (Beaty et al., 2016), allowing implicit and spontaneous processes (Pinho et al., 2016). Due to this background, it is expected that musicians give richer responses to stimuli involving emotional aspects than the general population. In the same vein, the evidence shows that the brains of musicians and non-musicians are different at both the structural and functional levels (Justel & Diaz-Abrahan, 2012). In addition, there are differences among musicians themselves, since the professionals who started their musical training earlier in life presented more changes in their brains than less experienced musicians (Elbert, Pantev, Wienbruch, Rockstroh, & Taub, 1995; Hutchinson, Lee, Gaab, & Schlaug, 2003; Schlaug, Jäncke, Huang, Staiger, & Steinmetz, 1995).

Regarding training, our prediction was that musicians would have better memory than non-musicians. However, this prediction was not fulfilled. One possible explanation is that our musician sample had a formal musical training mean of nine years, which raises the question of what the results would have been if more advanced musicians had been selected as a sample.

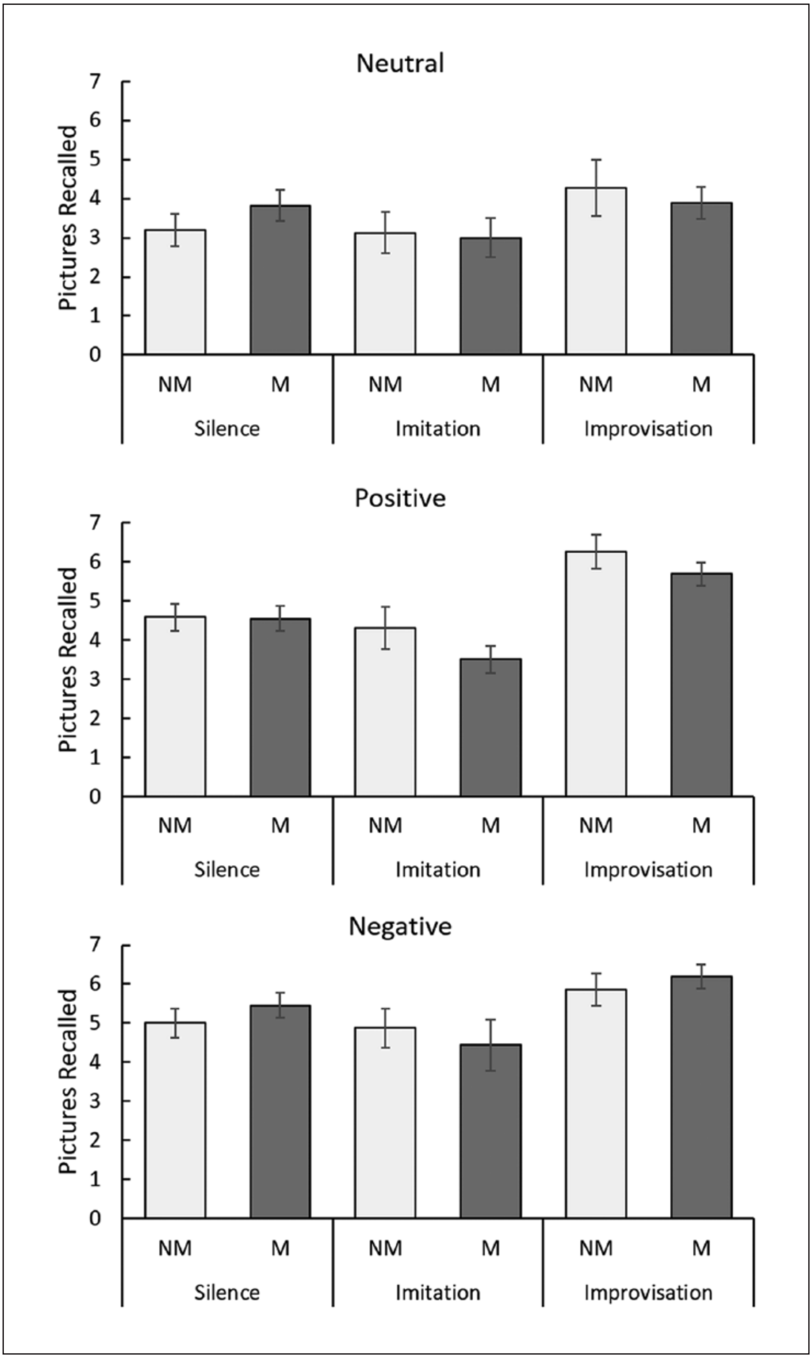


**Figure 5.** Deferred free recall. Number of neutral (top panel), positive (middle panel), and negative (bottom panel) pictures that groups could remember after a week between treatment and testing. NM: Non-musicians. M: Musicians. Silence: Participants who remained in silence; Imitation: Participants who imitated; Improvisation: Participants who improvised. Vertical lines represent standard errors of the mean.

**Table 2.** Deferred recognition. Means and *SD* of the number of neutral, positive and negative pictures that participants could recognize as previously seen from a pool of 72 images. NM: Non-musicians. M: Musicians. Silence: Participants who remained in silence; Imitation: Participants who imitated; Improvisation: Subjects who improvised.

| Groups | | Neutral | Positive | Negative |
|---|---|---|---|---|
| Silence | NM | 11.35 ± 0.18 | 11.67 ± 0.09 | 11.32 ± 0.19 |
| | M | 11.64 ± 0.13 | 11.82 ± 0.06 | 11.58 ± 0.13 |
| Imitation | NM | 11.25 ± 0.41 | 11.19 ± 0.37 | 11.5 ± 0.25 |
| | M | 10.94 ± 0.4 | 11.44 ± 0.24 | 11.06 ± 0.26 |
| Improvisation | NM | 11.87 ± 0.09 | 11.93 ± 0.06 | 11.73 ± 0.2 |
| | M | 11.96 ± 0.03 | 11.96 ± 0.03 | 12 ± 0 |

The vast majority of previous research had participants with a minimum of 13 years of musical training (Berkowitz & Ansari, 2010; Limb & Braun, 2008). Future research should address this issue.

Empirical investigations in both humans and animals converge in that modulation of arousal has been offered as a likely explanation for a facilitative effect of music on memory task performance (Chanda & Levitin, 2013). Whether due to its rhythmic properties or its capacity to elicit strong emotions, music can produce autonomic and neurochemical responses that are consistent with an aroused state, which in turn can result in enhanced task performance (Rickard et al., 2005). However, this is not the only factor responsible for the modulation of memory. In our work we had subjects who listened to and played a rhythmic pattern (imitation condition) who, although they were active, could recall fewer images than subjects in the Improvisation condition could remember. This indicates that the results do not merely depend on either the receptive or the active nature of the task. Additional factors appear to be interacting to enhance memory, and future studies should address these issues.

These findings could be interpreted differently if the cognitive demands of the dissimilar treatments are considered. It is possible to think that subjects who were imitating a rhythmical pattern were more concerned about faithfully replicating or *adjusting* sharply on the model. Free improvisation involves other types of adjustment, which might demand different cognitive resources. This could be related to the study by Limb and Braun (2008), who indicate that spontaneous improvisation, beyond any degree of musical complexity, is characterized by widespread deactivation of the lateral prefrontal cortex together with focal activation of the medial prefrontal cortex. This last example is associated with the autobiographical narrative and, as such, one could argue that improvisation is a way of expressing episodic memory. Emphasizing the privileged place of improvisation within the field of music therapy, this investigation thus intends to contribute to evidence-based techniques within this discipline.

It is important to stress that silence and imitation conditions were both control conditions but they were not the same. In the immediate free recall the worst memory performance was the one of the Imitation, not the Silence condition. A possible explanation is that participants

in the Silence condition were reviewing the pictures for those 3 minutes of silence and then they had better memory in immediate free recall than those in the Imitation condition. This explanation is appropriate because in deferred free recall the Imitation and Silence conditions had performed the same, and they had poorer memory than the Improvisation condition. Nonetheless, in future studies it would be interesting to ask the participants if they were reviewing the images while they were in silence, or were they thinking or doing something else. This is, therefore, an important contribution to clinical applications because there is a difference between asking a patient "to imitate the music therapist" and "to make music together." In improvisation, concern for replication and timing adjustment diminishes while increasing the likelihood of enjoying the activity. This enjoyment, loaded with emotion, could play an important role in modulating memory, since it is well documented that emotion moderates this cognitive function (McGaugh & Roozendaal, 2009).

Despite the widespread informal use of music as a memory enhancer in both patient and general populations, such anecdotal reports have not received adequate empirical investigation. It is important to note that research in the subjects addressed in this work is growing due to the empirical studies of the biological bases of music perception and cognition in participants with and without musical training, and because of the inclusion of music therapy in neurorehabilitation programs (Abrahan & Justel, 2015; Justel & Diaz Abrahan, 2012; Pantev & Herholz, 2011). Yet, music improvisation research is still scarce; and research techniques are addressed from a musical perspective rather than from the clinical experience of qualified music therapists. For this reason, our objective has been to contribute on the one hand to understanding basic behavioral and cognitive processes, and on the other hand to foster the implementation of music therapy techniques in a clinical context based on empirical evidence. Our aim as well has been to provide some specificity to the effects of improvisation techniques in music therapy and their possible use in the stimulation and rehabilitation of memory.

As music improvisation modulates emotional memory, music treatment may provide a simple, safe and effective method of preventing the potentially harmful physiological concomitants of memory impairment, with great potential for clinical application.

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