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Music improvisation enhances neutral verbal and visual memory in musicians and non-musicians alike

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A R T I C L E I N F O

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Musicianship

A B S T R A C T

Music is a complex activity with great cognitive potential. A specific type of research involves the use of focal music-based interventions implemented only once before, during, or after a task to improve cognitive performance. In the present research, we employed music-based interventions to explore their effects as a memory modulator. We conducted two studies: Study 1, to evaluate neutral verbal memory, and Study 2 to evaluate neutral visual memory. Volunteers, aged 18–40, participated in this investigation (124 musicians and 111 non-musicians). After the acquisition of verbal or visual information, the volunteers were exposed to music improvisation, music imitation, or a rest condition for 3 min. We evaluated memory through free recall and recognition tasks, with immediate and deferred measures. We found a significant improvement in memory among participants involved in music improvisation, who remembered more verbal and visual information than the imitation and rest condition groups, especially in the deferred measures. We found no differences according to the musical experience. Our results reinforce the idea that music improvisation intervention modulates different types of memory.

Introduction

Music is characterized as a complex activity that integrates visual and auditory stimuli, kinesthetic control, recognition of patterns, and memory processes, all of which generate a distinctive stimulation of our brain (Herrero & Carriedo, 2018). Cognitive science of music has made great advances in the last years by investigating how music modulates our brain architecture with its consequent repercussion in cognitive functions (Justel & Diaz Abrahan, 2012; Zuk & Gaab, 2018). Nonetheless, it is still an emerging science that needs more specificity (Dumont, Syurina, Feron, & van Hooren, 2017; Talamini, Altoè, Carretti, & Grassi, 2018). Some studies have indicated that music may modulate our cognitive functions (Benz, Sellaro, Hommel, & Colzato, 2016; Fauvel et al., 2014; Hanna-Pladdy & Gajewski, 2012; Wang, Ossher, & Reuter-Lorenz, 2015). However, music is such a broad concept that it is necessary to specify what is meant by music as a modulator of cognition. Undoubtedly, music cognition is an extremely valuable function that should be explored intensely because music produces great joy and motivation in people, generating high adherence, and could therefore be employed as a tool in educational and clinical settings and in the promotion and promotion of health (Ballarini, Martínez, Pérez, Moncada, & Viola, 2013; Strong & Midden, 2018; Thaut & Hoemberg, 2014).

Regarding specificity, our team compared the effect of improvisation versus imitation of a rhythmic pattern (Diaz Abrahan, Shifres, & Justel, 2019; Diaz Abrahan, Shifres, & Justel, 2018; Diaz Abrahan, Shifres, & Justel, 2020). In improvisation, the participants generated something novel and creative in groups, while in the imitation condition, they reproduced a rhythmic pattern. In both interventions, sound and music

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were present, the participants used instruments, and their voices and bodies were part of the musical process. Our results indicated that participating in musical improvisation and in musical imitation had different effects. Specifically, we found that those participants who performed an improvisation after acquiring visual information improved their mnesic performance, evaluated immediately and a week later, while those who imitated the pattern had a decrement in their memory, i.e. musical improvisation enhanced and musical imitation diminished memory. One possible explanation for these results is related to cognitive involvement, that is, the cognitive functions that are activated in each musical task. While musical improvisation includes creativity and the induction of positive emotional states, in reproduction the cognitive demands necessary to synchronize with external rhythms, such as divided attention and working memory to fit the pattern, could disrupt the process of memory formation. These results were found in young and older adults, especially in memory with emotional content. Other memory systems could be of interest to researchers in the field of neuropsychology and neuroscience.

As for the concept of musical improvisation that we used (Abrahan & Justel, 2015) was associated with the music therapy perspective of improvisation, in which music improvisation is considered a musical experience that is flexible enough to adapt to people with and without musical skills (Diaz Abrahan et al., 2018). During these musical experiences, different sounds, melodies, and rhythms are created and combined spontaneously with the resources available, according to the possibilities of the subject in musical interaction with other people (Bruscia, 1998, 1999). In this sense, music improvisation is not only performed by musicians; it is also a real-time ability that all people own (Wigram, 2004).

In this study, we evaluated the possible effect of music on memory, investigating music from two different perspectives. On the one hand, we compared the performance of musicians with that of non-musicians since extensive research indicates that these two populations differ in their structure and brain function. In other words, the anatomical changes involved in becoming a musician impact the cognitive function of the subject. On the other hand, we compared the effect of a focal, acute intervention on memory, regardless of whether the subject was a musician or not. Specifically, we evaluated both the effect of long-term music training and the effect of a focal, acute intervention.

Some studies have evaluated the effect of music training on behavioral tasks and divided them into near- and far-transfer effects (Sala & Gobet, 2017). The near-transfer concept is employed when the abilities affected by music training are closely related to the musical area, e.g. the recognition of melodic contour (Fujioka, Trainor, Ross, Kakigi, & Pantev, 2004). Far-transfer is employed when the benefits of music training go beyond the musical area, e.g. music training impacts mathematical knowledge (Vaughn, 2000). In the near-transfer domain, the results of some studies were overwhelming, and musicians outperformed non-musicians (Parbery-Clark, Strait, Anderson, Hittner, & Kraus, 2011; Zendel & Alain, 2012). In the far-transfer domain, the results were not as clear (Rodrigues, Loureiro, & Caramelli, 2013; Sala & Gobet, 2017). Some studies found that musicians performed better than non-musicians (Bugos, Perlstein, McCrae, Brophy, & Bedenbaugh, 2007; Talamini et al., 2018) but other studies found no such difference (Fauvel et al., 2014; Strong & Midden, 2018). Besides, the bulk of the research has focused on the learning and recall of verbal information (Franklin et al., 2008; Ho, Cheung, & Chan, 2003), with few antecedents in the visual domain (Jakobson, Lewycky, Kilgour, & Stoesz, 2008). In addition, few studies evaluated the effect of musical activities in the general population, and they focused on music perception, not on music production, although some research indicated that music production is more effective than music perception as far as modulation of functions is concerned (Fancourt, Ockelford, & Belai, 2014).

We present two studies in which the effect of music improvisation was compared with imitation and rest conditions in a verbal (Study 1) and a visual (Study 2) memory task. These interventions were implemented in musician and non-musician samples. According to our previous studies, we expected music improvisation to improve memory of both verbal and visual information. Regarding musicianship, we expected musicians to have a better mnemonic performance than non-musicians.

Study 1: verbal memory

Participants

One-hundred and eight volunteers (61.4 % female participants) between the ages of 18 and 40 (M = 29.4; $SD = .7$) participated in this study. Fifty-three were musicians (M) with more than five years of formal music training (schools, institutes, music conservatories). Fifty-five were considered non-musicians (NM). An a priori power analysis suggested that N = 78 would be adequate to provide .60 power (Faul, Erdfelder, Lang, & Buchner, 2007). The participants were recruited from online announcements, educational institutions, and music bands. Participant exclusion criteria included visual or hearing impairment, amusia, or any music-related pathology, cognitive impairment, and depression. Each participant signed a written informed consent form and completed a questionnaire where socio-demographic and musical expertise information was requested. The studies were anonymous and complied with the Helsinki Declaration, Convention of the Council of Europe on Human Rights and Biomedicine.

Verbal memory evaluation

The Rey Auditory Verbal Learning Test (RAVLT) was used to evaluate verbal memory (Dalmás, 1993; Rey, 1941, 1964; Ryan & Geisser, 1986). RAVLT is a widely-used, reliable, and valid assessment of auditory verbal learning and memory (Tierney, Snow, Reid, Zorzitto, & Fisher, 1987), which was validated for the Argentinian population (Burin, Drake, & Harris, 2013; Burin, Ramenzoni, & Arizaga, 2003). RAVLT reliability varied from 0.70 for List A to 0.38 for recall of List B. Moderate test-retest reliability of 0.55 was found a year after the first test administration (Tierney et al., 1987). The test consists in a list of 15 semantically unrelated words (e.g. perro [dog], hermano [brother], martillo [hammer]). The list was reproduced in wma format, with a Flip 3 JBL speaker, at an inter-word-interval of 7 s for the acquisition task and 5 s for the recognition task. At the beginning of the study, participants listened to the list of words once (acquisition phase).

Two tasks were used to evaluate memory: free recall and recognition (immediately and after a week). In free recall, participants were asked to write (pencil and paper task) the words that they remembered. After the free recall task, the participants did the recognition task, in which they were asked to identify the 15 target words from a pool of 30 words. False recognitions were subtracted from the total recognition score to obtain the recognition index.

Instrumental setting

For the musical experiences (improvisation or imitation), participants were allowed to choose percussion instruments (e.g. drums, maracas, bells, woodblocks, shakers, tambourine) or melodic/harmonic instruments (e.g. guitar, melodica, xylophone, flute). These instruments were used in the study because they were easy to handle.

Interventions

Music improvisation (MUS)

The first author (a music therapist) performed a rhythmic pattern repeatedly for three minutes as a base for an improvised performance by the participants playing their instruments. This pattern was performed with a percussion instrument at a medium volume (Fig. 1; Diaz Abrahan et al., 2018, 2019). Participants chose any instrument and improvised

Fig. 1. Rhythmic base-pattern.
Note. Rhythmic base-pattern presented by the researcher to guide the music reproduction and improvisation that participants were asked to perform with a set of basic instruments. Adapted from Music improvisation modulates emotional memory by Diaz Abrahan et al. (2018). Psychology of Music, 9, page 3.

musical patterns with it or their voices or bodies, spontaneously creating some musical feature according to the context provided by the base pattern. Such a rhythmical baseline was introduced to guide non-musician participants because pilot studies had shown that, without such guidance, participants could not follow the improvisation directions.

Imitation (IMI)

The same researcher who conducted the musical improvisation performed the same rhythmic pattern repeatedly for three minutes as a model to be imitated by the participants with their instruments. This pattern was performed with the same percussion instrument as that used in the improvisation at a medium volume. In this intervention, the participants imitated the pattern for three minutes (Gilbertson, 2013). The instructions included imitating the pattern heard as faithfully as possible, avoiding variations or new musical materials. This intervention was meant to control for possible effects of movements, music perception, and musical instruments, among others, that could explain the results.

Rest (REST)

The participants remained silent for three minutes. They were asked not to use cell phones, write in their notebooks, or have conversations with other participants. The aim of this intervention was to take into account a passive control condition.

Experimental design

Because there were three interventions (MUS, IMI, REST) and the participants had different musical expertise (M and NM), a 3(Intervention) x 2(Training) experimental design was run, with six groups with the following number of subjects: (1) M/MUS: musicians' improvisation group ($n = 21$); (2) M/IMI: musicians' imitation group ($n = 15$); (3) M/REST: musicians who remained silent ($n = 17$); (4) NM/MUS: non-musicians' improvisation group ($n = 19$); (5) NM/IMI: non-musicians' imitation group ($n = 16$); (6) NM/REST: non-musicians who remained silent ($n = 20$). Participants were randomly and blindly assigned to the different groups, and they were always tested in groups, with a minimum of four and a maximum of ten participants. This number of participants per group was implemented to control the involvement of the subjects and corroborate that each one participated in the music performance.

Procedure

The study was divided into two sessions with a one-week inter-session interval. The first session consisted of four immediately consecutive phases.

In the first phase (information phase, about 15 min), the participants signed the informed consent form and completed the socio-demographic and musical expertise questionnaire.

In the second phase (acquisition, 9 min), the participants listened to the list of words from the RAVLT once. This task was individual.

In the third phase (treatment phase, about 3 min), the participants were exposed to the interventions (music improvisation, imitation, or rest). The following directions were given during the music improvisation intervention: *"We will listen to a rhythmic base, from which you have to create something musical as a group. This rhythmic base will help you to start the improvisation at any time you want. You can use instruments, your voice, or your body. It is important to listen not only to the base but also to your own group*". In the imitation intervention, the following directions were given: "*We will listen to a rhythmic base and, anytime you want, you can start to imitate me. You can use instruments, your voice, or your body"*. In the rest condition, the following directions were given: "*Please remain silent and do not do anything for a few minutes"*. Before starting, the researcher corroborated that all the participants had understood the instructions. Then, the participants freely chose the musical instrument that they wanted to play (MUS and IMI conditions), and they performed the improvisation or imitation task in groups for three minutes while the REST group remained silent for three minutes.

Soon afterward, in the fourth phase (test phase, about 11 min), a two-task test was run. Participants were given paper and pencil to write down as many words as they could remember from the RAVLT (*Immediate Free Recall* task). Then, the 15 words from the RAVLT were mixed with 15 new words and the participants were asked to indicate, using a printed spreadsheet, whether they had seen the item before or not (*Immediate Recognition* task).

The second session (11 min) was held a week later, when the two-task test was run again (*Deferred Free Recall* task and *Deferred Recognition* task; see Fig. 2 for a schematic design of the procedure).

Data analysis

Age, years of formal education, and years of musical education were analyzed independently via univariate analysis of variance (ANOVA), where *Intervention* (Improvisation versus Imitation versus Rest) and *Training* (Musicians versus Non-musicians) were the between-factors.

The dependent variable for free recall was the number of words recalled by each participant, while in the recognition task the dependent variable was the number of words correctly recognized. Free recall and recognition (immediate and deferred) were analyzed independently with an analysis of co-variance of 2 factors. The between factors were Intervention (Music Improvisation versus Imitation versus Rest) and Training (musicians versus non-musicians). An ANCOVA was employed because academic education was a relevant variable (see more details in sample characteristics).

Post-hoc least-significant difference (LSD) pairwise comparisons were conducted to analyze significant main effects and significant interactions. The partial Eta square (η^2p) was utilized to estimate effect size. The alpha value was set at 0.05, and the SPSS software package was used to compute descriptive and inferential statistics.

Results

Sample characteristics

There were no differences between groups in age $p > .05$. However, there were differences depending on musical education $F(1, 101) = 158.33$, $p < .0001$, $\eta^2p = .611$, validating the sample selection (musicians had more expertise than non-musicians). Further, there were differences in academic education related to the Training factor $F(1, 98) = 15.98$, $p < .0001$, $\eta^2p = .14$, i.e., the musicians had a higher academic level than the non-musicians. For this reason, academic education was used as a co-variable in the statistical analysis. Table 1 shows the demographic and musical information.

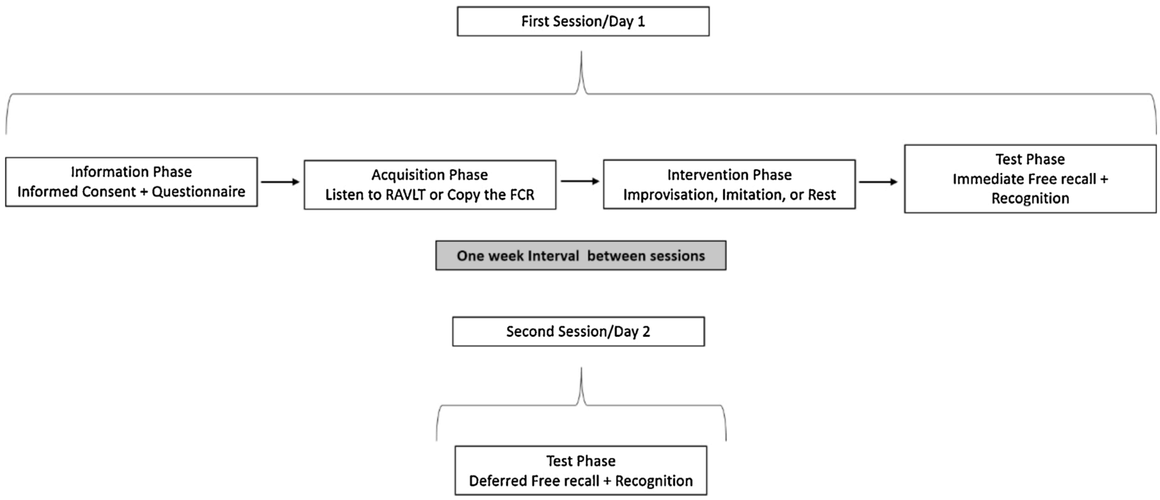

Fig. 2. Scheme of the experimental procedure.

Table 1
Demographic and musical information.

Groups	Age	Education	Musical Educ.
M/MUS	28.24 ± 1.55	20.05 ± 1.15	14.14 ± 1.48
M/IMI	32.4 ± 2.87	19.21 ± 1.17	11.5 ± 1.26
M/REST	28.29 ± 1.72	17.12 ± .69	10.47 ± 1.58
NM/MUS	29.37 ± 1.5	16 ± .74	1.74 ± .39
NM/IMI	29.41 ± 2	15.07 ± .4	.76 ± .33
NM/REST	29.55 ± 1.3	16.5 ± .67	.7 ± .24

Note: M = Media; *SD* = Standard deviation. M/MUS: Musicians who performed musical improvisation; M/IMI: Musicians who imitated a rhythmic pattern; M/REST: Musicians who remained silent; NM/MUS: Non-musicians who performed musical improvisation; NM/IMI: Non-musicians who imitated a rhythmic pattern; NM/REST: Non-musicians who remained silent.

For musicians, the average musical expertise was 12.23 ± .86 years (range: 5–32 years), and all participants were musically active when the study was performed. Regarding instrument specialization, 71.42 % played string instruments (guitar, violin, bass, and piano), 14.28 % played wind instruments (e.g. traverse flute), while the remaining 14.28 % was equally divided into percussion instruments and vocal technique. Regarding the musical style of specialization, 26.33 % reported experience in classical music, 24.48 % rock, 16.32 % folk, and 10.2 % musical styles related to improvisation (e.g. jazz). Non-musicians had less than 1.05 ± .19 years of musical experience (range: 0–4 years). Of those who reported minimum musical experience, 52.63 % were acquainted with string instruments (mostly guitar), while the remaining 36.84 % had some experience singing in a choir or used the voice as their instrument.

Immediate measures

After the participants were exposed to the interventions, they were asked to write the words that they remembered from the RAVLT (free recall task). The results are depicted in Fig. 3. The ANCOVA indicated a significant difference in the double interaction of Intervention x Training $F(2, 104) = 4.43$, $p = .014$, $\eta^2p = .084$. The *Post-hoc* indicated that in the IMI group, musicians remembered more words than non-musicians. Further, non-musicians who imitated the pattern remembered fewer words than the other two groups. None of the other analyses yielded significant differences $p > .05$. After the free recall task, the participants did the recognition task. There were no significant differences in this task $p > .05$ (data not shown).

Deferred measures

After seven days, deferred memory was evaluated. One hundred volunteers participated in the deferred measures because nine volunteers were absent. The final sample for the deferred measures was as follows: M/MUS ($n = 19$); M/IMI ($n = 15$); M/REST ($n = 15$); NM/MUS ($n = 17$); NM/IMI ($n = 15$); NM/REST ($n = 19$). Initially, the free recall task was evaluated (Fig. 4A). The ANCOVA indicated a significant effect of Intervention $F(1, 90) = 10.9$, $p < .0001$, $\eta^2p = .195$. The *Post-hoc* showed that participants who improvised remembered more words than participants who imitated the rhythmic pattern or remained silent, while

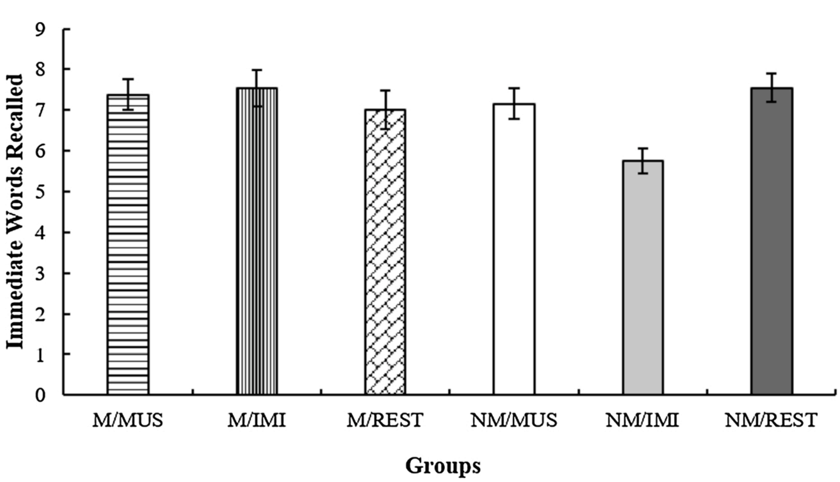

Fig. 3. Immediate verbal memory.
Note. Immediate Free Recall. Words that the participants remembered after they were exposed to the interventions. M/MUS: Musicians who performed musical improvisation; M/IMI: Musicians who imitated a rhythmic pattern; M/REST: Musicians who remained silent; NM/MUS: Non-musicians who performed musical improvisation; NM/IMI: Non-musicians who imitated a rhythmic pattern; NM/REST: Non-musicians who remained silent. The vertical lines indicate the standard error.

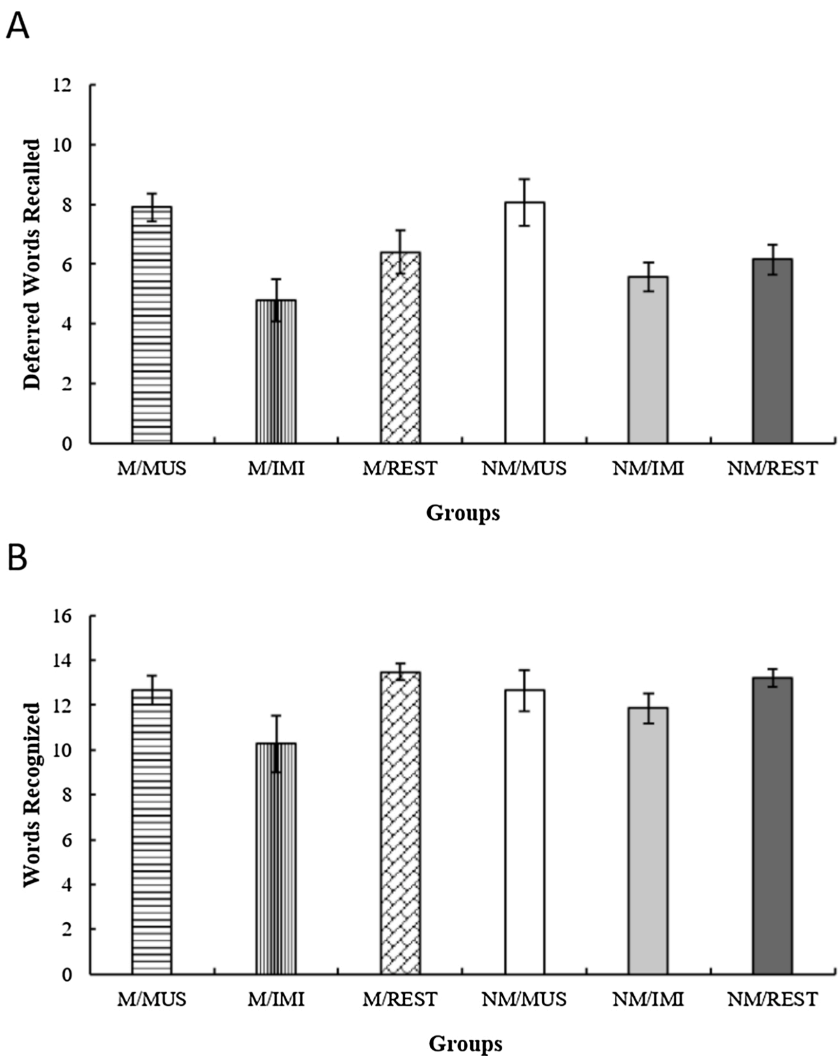

Fig. 4. Deferred verbal memory.
Note. A. Deferred Free Recall. Number of words that participants remembered seven days after they were exposed to the interventions. B. Deferred Recognition. Number of words that participants recognized after seven days. M/MUS: Musicians who performed musical improvisation; M/IMI: Musicians who imitated a rhythmic pattern; M/REST: Musicians who remained silent; NM/MUS: Non-musicians who performed musical improvisation; NM/IMI: Non-musicians who imitated a rhythmic pattern; NM/REST: Non-musicians who remained silent. The vertical lines indicate the standard error.

the REST group remembered more words than the IMI group.

The second deferred memory evaluation was the recognition task. The ANCOVA indicated a significant effect of Intervention $F(2, 90) = 3.95$, $p = .023$, $\eta^2p = .08$. The *Post-hoc* indicated that participants who performed an improvisation or remained silent recognized more words than the group who performed the imitation (Fig. 4B).

Study 2: visual memory

Participants

One-hundred and twenty-nine volunteers, aged between 18 and 50 ($M = 26.5$; $SD = .6$), who were naive, participated in this study (55.8 % female). Seventy-one were musicians (M) with more than 5 years of formal music training (schools, institutes, music conservatories) and 58 were non-musicians (NM). The recruitment and exclusion criteria were the same as those in Study 1. Each participant signed a written informed consent form and completed a questionnaire where socio-demographic and musical expertise information was requested.

Visual memory evaluation

The material for the neutral memory task was the Rey Complex Figure (RCF; Meyers & Meyers, 1995). RCF is a widely-used, reliable, and valid assessment of visuospatial construction and nonverbal memory learning and memory (Deckersbach et al., 2000), which was validated for general Spanish-speaking (Hartman & Potter, 1998; Mitrushina & Chervinsky, 1990; Palomo et al., 2013) and Argentinian populations (Burin et al., 2003, 2013). This is a figure with 18 different items that compose a larger image.

At the beginning of the study, participants were asked to observe the RCF and copy it with pencil and paper (acquisition phase). To evaluate this task, each participant's drawing was compared with the original 18 items of the RCF. According to the figure itself and the placement of the elements, 36 was the maximum possible score (see more details in data analysis).

Two tasks were used for memory evaluation (free recall and recognition). In free recall, participants were asked to draw the RCF from memory. Each participant's drawing was compared with the original 18 items of the RCF (36 was the maximum possible score; see more details in data analysis). In the recognition task, participants looked at 24 items, and they were asked to decide which ones were part of the RCF and which were new. False recognitions were subtracted from the total recognition score to obtain the recognition index.

Instrumental setting and interventions

The musical setting was the same as that used in Study 1.

Interventions

Interventions were the same as those used in Study 1.

Experimental design

Because there were three interventions (MUS, IMI, REST) and the participants had different musical expertise (M and NM), a 3(Intervention) x 2(Training) experimental design was run, with six groups with the following number of subjects: M/MUS: musicians' improvisation group ($n = 28$); M/IMI: musicians' imitation group ($n = 22$); M/REST: musicians who remained silent ($n = 21$); NM/MUS: non-musicians' improvisation group ($n = 22$); NM/IMI: non-musicians' imitation group ($n = 19$); NM/REST: non-musicians who remained silent ($n = 17$). The participants were randomly and blindly assigned to the different groups, and they were always tested in groups, with a minimum of four and a maximum of 10 participants. This number of participants per group was implemented to control the involvement of the subjects and corroborate that each one participates in the music performance.

Procedure

The study was divided into two sessions with a one-week inter-session interval (See Fig. 2). The first session was exactly the same as that in Study 1. In the second phase (acquisition, 9 min), the participants watched the RCF, and they were asked to copy it (they were supplied with pencil and paper).

The third phase was exactly the same as that in Study 1. Soon afterward, in the fourth phase (test phase, about 11 min), a two-task test was run. Participants were given paper and pencil to draw the RCF (*Immediate Free Recall* task) from memory. Then 12 target items from the RCF were mixed with 12 new items and participants were asked to indicate whether they had seen the item before or not (*Immediate Recognition* task).

The second session (11 min) was held a week later, when the two-task test was run again (*Deferred Free Recall* task and *Deferred Recognition* task; see Fig. 2 for a schematic design of the procedure).

Analysis

Age, years of academic education, and years of musical education were analyzed independently via univariate analysis of variance (ANOVA), where Intervention (Improvisation versus Imitation versus Rest) and Training (Musicians versus Non-musicians) were the between-factors.

Copy and free recall (immediate and deferred) of the RCF were evaluated as follows: Each of the 18 components of the RCF was evaluated according to whether it was well-drawn and correctly placed (2 points), well-drawn but incorrectly placed (1 point), badly-drawn but correctly placed (1 point), badly-drawn but recognizable (0.5 points), badly-drawn and incorrectly placed (0 points). The maximum final score was 36. Because there were differences regarding the age and academic education of the participants (data shown in the Results section), copy, recall, and recognition (immediate and deferred) were independently analyzed via ANCOVA with Intervention (Improvisation versus Imitation versus Rest) and Training (Musicians versus Non-musicians) as the between-factors, and Education and Age as the co-variables.

Post-hoc least-significant difference (LSD) pairwise comparisons were conducted to analyze significant main effects and significant interactions. The partial Eta square (η^2p) was utilized to estimate effect size. The alpha value was set at 0.05, and the SPSS software package was used to compute descriptive and inferential statistics.

Results

Sample characteristics

Regarding years of music education, a significant effect of Training was found $F(1, 127) = 138.66$, $p < .0001$, η^2p $= .534$, thus validating the sample selection because musicians had more years of musical education than non-musicians. There was a main effect for Intervention $F(1, 122) = 4.23$, $p = .017$, η^2p $= .065$, and Intervention x Training interaction $F(2, 122) = 3.49$, $p = .034$, η^2p $= .08$ related to the Age of the volunteers. A posteriori analysis indicated that musicians in the groups MUS and REST were older than non-musicians. Regarding years of academic education, there were main effects of the factors Training $F(1\ 119) = 15.25$, $p < .0001$, η^2p $= .114$, and Intervention $F(2\ 119) = 3.98$, $p = .021$, η^2p $= .063$. Musicians had more academic education than non-musicians, and volunteers in the Imitation condition had more academic education than the other two conditions. Because of the differences found in the socio-demographic information, Age and Academic Education were used as co-variables in the analyses (Table 2).

For musicians, the average musical expertise was 10.85 ± .7 years (range: 5–32), and all were musically active when the study was performed. As regards instrument specialization, 73.61 % played string instruments (guitar, violin, bass, and piano), 8.33 % played wind instruments (e.g. traverse flute) while 18 % used their voice as an instrument or played percussion instruments. Non-musicians had musical expertise of .94 ± .2 (range: 0–4), 94.44 % were familiar with string instruments (guitar mostly), and the remaining 5.56 % played percussion instruments.

Copy of the RCF

There were no differences between groups in the copy of the RFC.

Immediate measures

After being exposed to the different musical interventions, the participants were instructed to draw from memory the RCF that they had seen in the acquisition phase (free recall test, Fig. 5A). The ANCOVA yielded a main effect of Intervention $F(2, 105) = 4.32$, $p = .016$, η^2p $= .082$. The *Post-hoc* indicated that the MUS and REST groups remembered more items of the RCF than the IMI group.

Recognition was the second task employed to evaluate memory. The results are depicted in Fig. 5B. The ANCOVA indicated a main effect of Intervention $F(2, 105) = 4.32$, $p = .016$, η^2p $= .08$, while the *Post-hoc* showed that participants that performed a musical improvisation or remained silent had a better recognition score than the group that imitated the rhythmic pattern.

Deferred measures

A week later, the free recall and recognition tasks were re-evaluated. One hundred and ten volunteers participated in the deferred measures, since 19 volunteers were absent. The final sample was as follows: M/MUS ($n = 23$); M/IMI ($n = 20$); M/REST ($n = 21$); NM/MUS ($n = 19$); NM/IMI ($n = 17$); NM/REST ($n = 16$). Fig. 6A illustrates the results of the free recall test. The ANCOVA indicated a main effect of Intervention $F(2, 105) = 7.02$, $p < .001$, η^2p $= .13$, and the *Post-Hoc* showed that participants who improvised remembered more items of the RCF than the groups who imitated a rhythmic pattern or remained silent. Regarding the deferred recognition (Fig. 6B), the ANCOVA yielded a main effect of Intervention $F(2, 99) = 3.48$, $p = .035$, η^2p $= .067$, and a posteriori analysis indicated that MUS groups recognized more items

Table 2
Demographic and music information.

Groups	Age	Education	Musical Educ.
M/MUS	28.21 ± 1.39	17.07 ± .7	10.75 ± 1.46
M/IMI	27.38 ± 1.43	19 ± 1.05	11.86 ± 1.07
M/REST	26.43 ± 1.44	16.44 ± .64	9.95 ± 1.05
NM/MUS	24.09 ± 1.53	14.91 ± .38	.91 ± .24
NM/IMI	29.84 ± 1.34	16.05 ± .45	.17 ± .12
NM/REST	22.12 ± 1.2	14.88 ± .32	1.53 ± .37

Note: M = Media; *SD* = Standard deviation. M/MUS: Musicians who performed musical improvisation; M/IMI: Musicians who imitated a rhythmic pattern; M/REST: Musicians who remained silent; NM/MUS: Non-musicians who performed musical improvisation; NM/IMI: Non-musicians who imitated a rhythmic pattern; NM/REST: Non-musicians who remained silent.

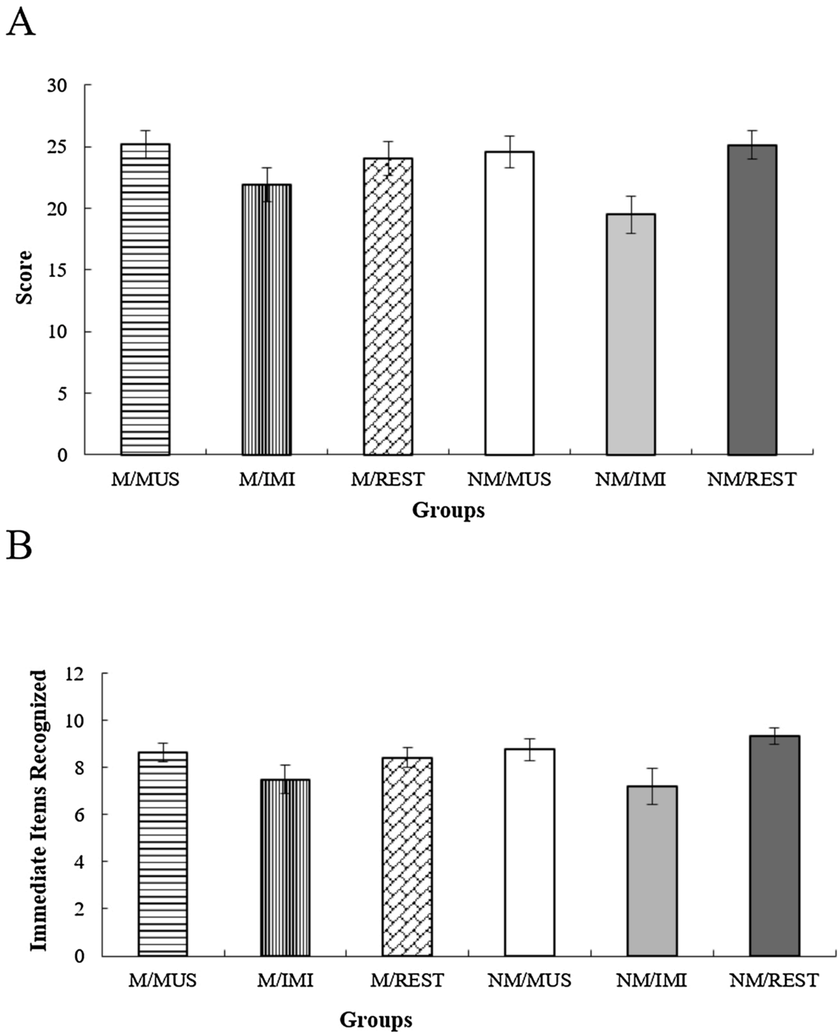

Fig. 5. Immediate visual memory.
Note. A. Immediate Free Recall: Score obtained according to the accuracy and location of the figure drawn from memory. B. Immediate Recognition. Number of items recognized from a set of 24 items. M/MUS: Musicians who performed musical improvisation; M/IMI: Musicians who imitated a rhythmic pattern; M/REST: Musicians who remained silent; NM/MUS: Non-musicians who performed musical improvisation; NM/IMI: Non-musicians who imitated a rhythmic pattern; NM/REST: Non-musicians who remained silent. The vertical lines indicate the standard error.

than IMI groups.

Discussion

The goal of these studies was to evaluate the effect of musical improvisation in the verbal and visual memory of musicians and non-musicians. We expected musical improvisation to enhance visual and verbal memory, in comparison to control conditions. We also expected musicians to perform better than non-musicians. The first prediction was corroborated but the second was not.

Specifically, we found that musical improvisation, in comparison with the imitation condition, enhanced the immediate recall and recognition of visual information and improved the deferred recall and recognition of verbal and visual material. Compared to the rest condition, musical improvisation enhanced verbal and visual memory in the deferred but not the immediate measures. This result was found for musicians and non-musicians alike. In improvisation as well as in imitation conditions, music was present, the participants listened to a rhythmic pattern, played instruments, used their bodies or voices, but the participants who improvised music showed better memory than the participants who imitated a rhythmic pattern. These results shed light on the specificity of musical cognition.

A possible explanation for this finding is that the improvisation condition, as opposed to the imitation of a pattern, involved a *creative process*, where the participants were instructed to create something musical as a group. Neuroscience considers musical improvisation an example of complex creative behavior, conceived as an original and novel process that requires divergent thinking. This means that improvisation involves the search for creative and different alternatives or possibilities for the resolution of a problem (Biasutti, 2017). The cognitive involvement, that is, the functions that are activated when someone is improvising music, is wide and it involves attention, working memory, autobiographical memory, executive functions, among others (Bengtsson, Csíkszentmihályi, & Ullén, 2007; de Manzano & Ullén, 2012).

An alternative and complementary explanation is that the imitation condition may contribute to creating an interference effect. The restrictions, especially attentional ones, associated with replication, repetition of a pattern, adjustments in intensity, and synchronization efforts could diminish cognitive resources and lead to mnemonic deterioration (Diaz Abrahan et al., 2019; Miendlarzewska & Trost, 2014). The subjects who were imitating a rhythmic pattern may have been concerned about faithfully replicating or sharply *adjusting* to the model. Free improvisation involves other types of adjustment, which might demand different cognitive resources that do not interfere with memory but rather enhance it (Diaz Abrahan et al., 2018; Limb & Braun, 2008).

An important point for discussion, although it is not related to our main hypotheses, is the Rest condition. We found that Rest enhanced immediate visual memory and deferred verbal memory, in comparison to the imitation condition. This result was not completely unexpected since we had found similar results (Diaz Abrahan et al., 2018) and recent literature also supports the effect of rest on cognition (Humiston &

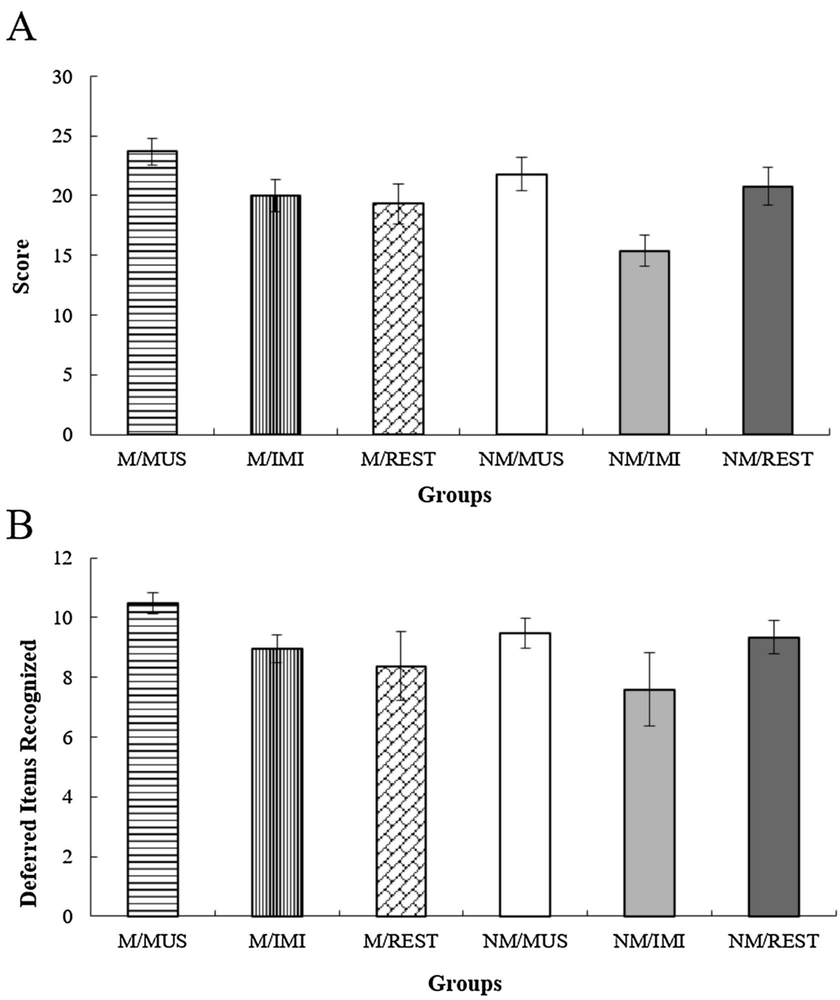

Fig. 6. Deferred visual memory.
Note. A. Deferred Free Recall: Score obtained according to the accuracy and location of the figure drawn from memory after seven days. B. Deferred Recognition. Number of components recognized in a set of 24 figures, after seven days. M/MUS: Musicians who performed musical improvisation; M/IMI: Musicians who imitated a rhythmic pattern; M/REST: Musicians who remained silent; NM/MUS: Non-musicians who performed musical improvisation; NM/IMI: Non-musicians who imitated a rhythmic pattern; NM/REST: Non-musicians who remained silent. The vertical lines indicate the standard error.

Wamsley, 2018; Wamsley, 2019). Over the last years, researchers have started to compare the effect of resting quietly in comparison to continuing with daily life after acquiring different types of information (episodic or procedural). This comparison originated in sleep literature, where sleep was compared with daily life but not with rest (Albert, Robertson, Mehta, & Miall, 2009; Tambini, Ketz, & Davachi, 2010). Brokaw et al. (2016) conducted a study where the participants acquired information and then rested or performed a distractor task, and the results indicated that rest enhanced memory almost as much as sleep did. The authors attributed their results to the interference caused by the mental effort in the distractor task. In the rest condition, the participants were not focused on anything in particular but rather mind-wandering while those in the control condition were focused on the performance of the distractor task. As stated in their discussion, the researchers explained "*Stimulus-oriented mental effort interferes with consolidation, whereas inwardly-focused mental activity does not. (…) The brain has entered an offline state conducive to consolidation*" (p. 23). This explanation is also suitable for the results found in our work because in the imitation condition the participants were focused on faithfully replicating the music pattern while in the improvisation condition they were not focused on strict requirements but rather playing together and creating something novel. This playful, light-hearted quality of our improvisation task could be associated with the mind-wandering state described by Brokaw et al. In addition, according to the study by Limb and Braun (2008), 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 is associated with autobiographical narrative and, therefore, one could argue that improvisation is a way of expressing episodic memory. It should be highlighted that even though we found an effect of rest in comparison to imitation, the improvisation intervention was more effective than the rest condition.

We found an effect of musical improvisation in the immediate and deferred tests, with stronger results in deferred outcomes, where improvisation was more effective than rest and reproduction. The results are concordant with the multifactor theory, according to which there are two different effects, one related to the immediate recall and another related to the deferred measures. Immediate memory benefits are thought to result from attentional mechanisms whereas delayed memory benefits are believed to result from post-encoding consolidation (Patil, Murty, Dunsmoor, Phelps, & Davachi, 2016).

We found no effect of musicianship. Some studies indicated that musicians have better mnemonic performance than non-musicians, especially in the verbal area (Chan, Ho, & Cheung, 1998; Cheung, Chan, Liu, Law, & Wong, 2017). These results could be interpreted as better performance in strategies or better use of rehearsal mechanisms and, therefore, of executive functioning rather than memory performance (Cheung et al., 2017; Franklin et al., 2008; Ho et al., 2003). Besides, other studies found no effect of musicianship on memory (Franklin et al., 2008; Hembold, Rammsayer, & Altenmuller, 2005). It is undeniable that musicians have different structural and brain functioning but these differences do not always impact cognition as expected and do not impact all cognitive functions (Wang & Schlaug, 2010; Strong & Midden, 2018). Nevertheless, the absence of a main effect for music training was a result found in our previous research in verbal (Diaz Abrahan & Justel, 2019) and visual emotional memory (Diaz Abrahan et al., 2018), except for one study with older musicians, where neutral visual memory was evaluated among musicians with mean music training of 17 years. By contrast, when we compared musicians with non-musicians, our sample did not have enough training to impact memory (Rodrigues et al., 2013, Cheung et al., 2017). Therefore, future research could study musicians with more years of music training.

Limitations and future directions

As expressed in the preceding paragraphs, one limitation of our study was the amount of training of our samples. In addition, our memory tasks may have been too simple and differences between groups could be observed in more challenging tests (Mandikal Vasuki, Sharma, Demuth, & Arciuli, 2016; Rodrigues et al., 2013).

Furthermore, many variables are involved in music training. Two of them are the number of hours played per week and the age at which the musician started taking music lessons (formal and informal). Considering these variables in the performance of memory could be an interesting point for future research.

Regarding musicianship, we focused on episodic memory (neutral, in this manuscript and previous studies, Diaz Abrahan et al., 2019; also emotional in Diaz Abrahan et al., 2018, 2019), but no studies have investigated the effect of music training on procedural memories or other implicit memories, with a far-transfer focus, which is a research gap. For this reason, future studies could compare the effect of music training on other types of memories. It would also be interesting to study different degrees of expertise (e.g. amateur versus professional musicians), and different types of expertise (wind instrumentalists compared to singers) since these different musical environments could lead to different brain changes and, therefore, different behavioral outcomes. Concerning the focal intervention, music improvisation could be studied in a different sample, such as adolescents or children, on whom, to the best of our knowledge, the effect of music improvisation has not been studied yet. Moreover, the effect of musical improvisation on other types of memory could be a topic of research, especially in non-musicians since most studies have evaluated musicians. Finally, further research could measure how long the effects of musical improvisation last.

Conclusions

This work intended to add specificity to the study of music as a modulator of cognition. We found that musical improvisation improves verbal and visual memory performance, in immediate and deferred measures, in musicians and non-musicians alike. Musical improvisation could be employed in different clinical or educational settings because this simple, safe, and enjoyable intervention modulates memory.

Author contributions

VDA and NJ contributed to the conception and design of the studies. VDA conducted the studies. VDA and NJ contributed to data analysis. VDA, FS, and NJ participated in the writing of the paper and interpretation of the data. FS and NJ supervised and integrated the information.

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Ethical approval

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional research committee (having approval from the Universidad de Buenos Aires) complying with the Helsinski Declaration, Convention of the Council of Europe on Human Rights and Biomedicine.

Availability of data and material

Not applicable.

Code availability

Not applicable.

Declaration of Competing Interest

The authors report no declarations of interest.

References

Abrahan, V., & Justel, N. (2015). La improvisación musical: Una mirada compartida entre la musicoterapia y las neurociencias. *Psicogente, 18*(34), 372–384. https://doi.org/10.17081/psico.18.34.512

Albert, N. B., Robertson, E. M., Mehta, P., & Miall, R. C. (2009). Resting state networks and memory consolidation. *Communicative & integrative biology, 2*(6), 530–532. https://doi.org/10.4161/cib.2.6.9612

Ballarini, F., Martínez, M. C., Pérez, M., Moncada, D., & Viola, H. (2013). Memory in elementary school children is improved by an unrelated novel experience. *PloS One, 8*(6), e66875. https://doi.org/10.1371/journal.pone.0066875

Bengtsson, S. L., Csíkszentmihályi, M., & Ullén, F. (2007). Cortical regions involved in the generation of musical structures during improvisation in pianists. *Journal of Cognitive Neuroscience, 19*(5), 830–842. https://doi.org/10.1162/jocn.2007.19.5.830

Benz, S., Sellaro, R., Hommel, B., & Colzato, L. (2016). Music makes the world go round: The impact of musical training on non-musical cognitive functions—A review. *Frontier in Psychology, 6*, 2023. https://doi.org/10.3389/fpsyg.2015.02023

Biasutti, M. (2017). Teaching improvisation through processes. Applications in music education and implications for general education. *Frontiers in Psychology, 8*, 911. https://doi.org/10.3389/fpsyg.2017.00911

Brokaw, K., Tishler, W., Manceor, S., Hamilton, K., Gaulden, A., Parr, E., et al. (2016). Resting state EEG correlates of memory consolidation. *Neurobiology of Learning & Memory, 130*, 17–25. https://doi.org/10.1016/j.nlm.2016.01.008

Bruscia, K. (1998). *Musicoterapia. Métodos y prácticas*. México: Editorial Pax.

Bruscia, K. (1999). *Modelos de Improvisación en Musicoterapia*. Gasteiz: Agruparte Victoria.

Bugos, J. A., Perlstein, W. M., McCrae, C. S., Brophy, T. S., & Bedenbaugh, P. H. (2007). Individualized piano instruction enhances executive functioning and working memory in older adults. *Aging & Mental Health, 11*(4), 464–471. https://doi.org/10.1080/13607860601086504

Burin, D., Drake, M., & Harris, P. (2013). *Evaluación neuropsicológica en adultos*. Editorial Paidos.

Burin, D., Ramenzoni, V., & Arizaga, R. L. (2003). Evaluación neuropsicológica del envejecimiento: normas según edad y nivel educacional. *Revista Neurología Argentina, 28*(3), 148–152.

Chan, A. S., Ho, Y. C., & Cheung, M. C. (1998). Music training improves verbal memory. *Nature, 396*(6707), 128. https://doi.org/10.1038/24075

Cheung, M., Chan, A., Liu, Y., Law, D., & Wong, C. (2017). Music training is associated with cortical synchronization reflected in EEG coherence during verbal memory encoding. *PloS One, 12*(3), Article e0174906. https://doi.org/10.1371/journalpone.0174906

Dalmás, F. (1993). Cap.: Semiología de la memoria. *En: La memoria desde la Neuropsicología.* Roca Viva Editorial.

de Manzano, O., & Ullén, F. (2012). Goal-independent mechanisms for free response generation: Creative and pseudo-random performance share neural substrates. *NeuroImage, 59*(1), 772–780. https://doi.org/10.1016/j.neuroimage.2011.07.016

Deckersbach, T., Savage, C. R., Henin, A., Mataix-Cols, D., Otto, M. W., Wilhelm, S., et al. (2000). Reliability and validity of a scoring system for measuring organizational approach in the complex figure test. *Journal of Clinical and Experimental Neuropsychology, 22*(5), 640–648. https://doi.org/10.1076/1380-3395(200010)22:5;1-9;FT640. To link to this article:.

Diaz Abrahan, V., & Justel, N. (2019). Propuestas musicales para modular la memoria verbal emocional de adultos jóvenes con o sin entrenamiento musical Epistemus. *Revista de estudios en Música, Cognición y Cultura, 7*(1), 49–69. https://doi.org/10.24215/18530494e003

Diaz Abrahan, V., Shifres, F., & Justel, N. (2018). Musical improvisation modulates emotional memory. *Psychology of Music, 48*(4), 1–16. https://doi.org/10.1177/0305735618810793

Diaz Abrahan, V., Shifres, F., & Justel, N. (2019). Cognitive benefits from a musical activity in older adults. *Frontiers in Psychology, 10*, 652.

Diaz Abrahan, V., Shifres, F., & Justel, N. (2020). Impact of music-based intervention on verbal memory: An experimental behavioral study with older adults. *Cognitive Processing, 22*(1), 117–130. https://doi.org/10.1007/s10339-020-00993-5

Dumont, E., Syurina, E., Feron, F., & van Hooren, S. (2017). Music intervention and child development: A critical review and further directions. *Frontiers in Psychology, 8*, 1694. https://doi.org/10.3389/psyg.2017.01694

Fancourt, D., Ockelford, A., & Belai, A. (2014). The psychoneuroimmunological effects of music: A systematic review and a new model. *Brain, Behavior, and Immunity, 36*, 15–26. https://doi.org/10.1016/j.bbi.2013.10.014

Faul, F., Erdfelder, E., Lang, A., & Buchner, A. (2007). G* Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods, 39*(2), 175–191.

Fauvel, B., Groussard, M., Mutlu, J., Arenaza-Urquijo, E. M., Eustache, F., Desgranges, B., et al. (2014). Musical practice and cognitive aging: Two cross-sectional studies point to phonemic fluency as a potential candidate for a use-dependent adaptation. *Frontiers in Aging Neuroscience, 6*, 227. https://doi.org/10.3389/fnagi.2014.00227

Franklin, M. S., Moore, K. S., Yip, C. Y., Jonides, J., Rattray, K., & Moher, J. (2008). The effects of musical training on verbal memory. *Psychology of Music, 36*, 353–365. https://doi.org/10.1177/0305735607086044

Fujioka, T., Trainor, L., Ross, B., Kakigi, R., & Pantev, C. (2004). Musical training enhances automatic encoding of melodic contour and interval structure. *Journal of Cognitive Neuroscience, 16*(6), 1010–1021. https://doi.org/10.1162/0898929041502706

Gilbertson, S. (2013). Improvisation and meaning. *International Journal of Qualitative Studies on Health and Well-being, 7*, 20604. https://doi.org/10.3402/qhw.v8i0.20604

Hanna-Pladdy, B., & Gajewski, B. (2012). Recent and past musical activity predicts cognitive aging variability: Direct comparison with general lifestyle activities. *Frontiers in Human Neuroscience, 6*, 198. https://doi.org/10.3389/fnhum.2012.00198

Hartman, M., & Potter, G. (1998). Sources of age differences on the Rey-Osterrieth Complex Figure Test. *Clinical Neuropsychologist, 12*(4), 513–524.

Hembold, N., Rammsayer, T., & Altenmuller, E. (2005). Differences in primary mental abilities between musicians and non-musicians. *Journal of Individual Differences, 26* (2), 74–85. https://doi.org/10.1027/1614-0001.26.2.74

Herrero, L., & Carriedo, N. (2018). Differences in updating processes between musicians and non-musicians from late childhood to adolescence. *Learning and Individual Differences, 61*, 188–195. https://doi.org/10.1016/j.lindif.2017.12.006

Ho, Y. C., Cheung, M. C., & Chan, A. S. (2003). Music training improves verbal but not visual memory: Cross-sectional and longitudinal explorations in children. *Neuropsychology, 17*(3), 439–450. https://doi.org/10.1037/0894-4105.17.3.439

Humiston, G., & Wamsley, E. (2018). A brief perior of eyes-closed rest enhances motor skill consolidation. *Neurobiology of Learning and Memory, 155*, 1–6. https://doi.org/10.1016/j.nlm.2018.06.002

Jakobson, L. S., Lewycky, S. T., Kilgour, A. R., & Stoesz, B. M. (2008). Memory for verbal and visual material in highly trained musicians. *Music Perception: An Interdisciplinary Journal, 26*(1), 41–55. https://doi.org/10.1525/mp.2008.26.1.41

Justel, N., & Diaz Abrahan, V. (2012). Plasticidad cerebral: Participación del entrenamiento musical. *Suma Psicológica, 19*(2), 97–108. Available in: https://www.redalyc.org/articulo.oa?id=134225567007.

Limb, C., & Braun, A. (2008). Neural substrates of spontaneous musical performance: An fMRI study of jazz improvisation. *PloS One, 3*(2), e1679. https://doi.org/10.1371/journal.pone.0001679

Mandikal Vasuki, P., Sharma, M., Demuth, K., & Arciuli, J. (2016). *Hearing Research, 342*, 112–123. https://doi.org/10.1016/j.heares.2016.10.008

Meyers, J. E., & Meyers, K. R. (1995). *Rey complex figure test and recognition trial*. Psychological Assessment Resources, Inc.

Mitrushina, M., & Chervinsky, A. B. (1990). Efficiency of recall on the Rey-Osterrieth complex figure in normal aging. *Brain Dysfunction, 3*(3-4), 148–150.

Miendlarzewska, E. A., & Trost, W. J. (2014). How musical training affects cognitive development: rhythm, reward and other modulating variables. *Frontiers in Neuroscience, 7*, 279. https://doi.org/10.3389/fnins.2013.00279

Palomo, R., Casals-Coll, M., Sánchez-Benavides, G., Quintanaa, M., Manero, R. M., Rognoni, T., et al. (2013). Estudios normativos espanoles ~enpoblación adulta joven (proyecto NEURONORMA jóvenes): normas para las pruebas Rey—Osterrieth Complex Figure (copia y memoria) y Free and Cued Selective Reminding Test. *Neurología, 28*, 226–235. https://doi.org/10.1016/j.nrl.2012.03.008

Parbery-Clark, A., Strait, D. L., Anderson, S., Hittner, E., & Kraus, N. (2011). Musical experience and the aging auditory system: Implications for cognitive abilities and hearing speech in noise. *PloS One, 6*, Article e18082. https://doi.org/10.1371/journal.pone.0018082

Patil, A., Murty, V., Dunsmoor, J., Phelps, E., & Davachi, L. (2016). Reward retroactively enhances memory consolidation for related items. *Learning & Memory, 24*, 65–69. https://doi.org/10.1101/lm.042978.116

Rey, A. (1941). L'examen psychologique dans les cas d'encéphalopatie traumatique. *Archives de Psychologie, 28*(112), 286–340.

Rey, A. (1964). *L'examen Clinique en psychologia*. Presses Universitaires de France.

Rodrigues, A., Loureiro, M., & Caramelli, P. (2013). Long-term musical training may improve different forms of visual attention ability. *Brain and Cognition, 82*, 229–235. https://doi.org/10.1016/j.bancc.2013.04.009

Ryan, J. J., & Geisser, M. E. (1986). Validity and diagnostic accuracy of an alternate form of the Rey Auditory Verbal Learning Test. *Archives of Clinical Neuropsychology, 1*, 209–217.

Sala, G., & Gobet, F. (2017). Does far transfer exist? Negative evidence from chess, music, and working memory training. *Current Directions in Psychological Science, 26*(6), 515–520. https://doi.org/10.1177/0963721417712760

Strong, J., & Midden, A. (2018). Cognitive differences between older adult instrumental musicians: Benefits of continuing to play. *Psychology of Music, 20*, 1–17. https://doi.org/10.1177/0305735618785020

Talamini, F., Altoè, G., Carretti, B., & Grassi, M. (2018). Musicians have better memory than nonmusicians: A meta-analysis. *PloS One, 13*(1), Article e0191776. https://doi.org/10.1371/journal.pone.0191776

Tambini, A., Ketz, N., & Davachi, L. (2010). Enhanced brain correlations during rest are related to memory for recent experiences. *Neuron, 65*, 280–290. https://doi.org/10.1016/j.neuron.2010.01.001

Thaut, M., & Hoemberg, V. (2014). *Handbook of neurologic music therapy*. Oxford University Press.

Tierney, M. C., Snow, W. G., Reid, D. W., Zorzitto, M. L., & Fisher, R. H. (1987). Psychometric differentiation of dementia: Replication and extension of the findings of Storandt and coworkers. *Archives of Neurology, 44*(7), 720–722. https://doi.org/10.1001/archneur.1987.00520190032013

Vaughn, K. (2000). Music and mathematics: Modest support for the oft-claimed relationship. *Journal of Aesthetic Education, 34*(3/4), 149–166. https://doi.org/10.2307/3333641

Wamsley, E. (2019). Memory consolidation during rest. *Trends in Cognitive Science, 23*(3), 171–173. https://doi.org/10.1016/j.tics.2018.12.007

Wang, C., & Schlaug, G. (2010). Music making as a tool for promoting brain plasticity across the life span. *Neuroscientist, 16*(5), 566–577. https://doi.org/10.1177/1073858410377805

Wang, X., Ossher, L., & Reuter-Lorenz, P. A. (2015). Examining the relationship between skilled music training and attention. *Consciousness & Cognition, 36*, 169–179. https://doi.org/10.1016/j.concog.2015.06.014

Wigram, T. (2004). *Improvisation: Methods and techniques for music therapy clinicians, educators, and students*. England: Jessica Kingsley Publishers.

Zendel, B. R., & Alain, C. (2012). Musicians experience less age-related decline in central auditory processing. *Psychological Aging, 27*, 410–417. https://doi.org/10.1037/a0024816

Zuk, J., & Gaab, N. (2018). Evaluating predisposition and training in shaping the musician's brain: The need for a developmental perspective. *Annals of the New York Academy of Sciences*, 1–11. https://doi.org/10.1111/nyas.13737