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Musical and verbal memory dissociation in a patient with autoimmune encephalitis

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Abstract

Music is emotionally arousing and activates different brain areas. Musicians with encephalitis spare musical memory. However, no prior studies have used delayed verbal and musical memory tasks in a patient with thalamic damage. The aim of the present study is to analyse a possible dissociation between verbal and musical memory in a patient with autoimmune encephalitis, who was an amateur musician. JC is a 67-years-old amateur musician with autoimmune encephalitis. He and 8 participants (musicians and non-musicians) were assessed through musical (novel excerpt recognition) and verbal memory tasks (word learning, recall and recognition), including a delayed memory task, a week later. The results showed JC had spared musical memory and impaired verbal memory, and a significant dissociation between them. The dissociation found could be due to the musical training brain plasticity. These findings support the idea of music stimuli as therapeutic tools for these patients.

Keywords: memory; music; autoimmune encephalitis; emotion

1. Introduction

Emotionally arousing stimuli are better remembered than neutral stimuli (Judde & Rickard, 2010; Justel et al., 2013; Quevedo et al., 2003). This effect has been observed in both young and older adults (Gomez-Gallego & Gomez-Garcia, 2017; Joubert et al., 2018).

Music is a strong emotional stimulus: listening to music produces emotional arousal, whether it is a novel or familiar musical excerpt (Lundqvist et al., 2009; Vieillard et al., 2008). Moreover, highly pleasurable and intense emotional musical excerpts are better remembered (Eschrich et al., 2005; Ferreri & Rodriguez-Fornells, 2017). In other words, the greater the emotional arousal, the better the memory.

Listening to and remembering novel and recently learned musical pieces involves several brain areas, including the hippocampus, prefrontal cortex, and parietal cortex (Rauschecker, 2014). Being exposed to recently heard music is associated with bilateral activations of the middle and superior frontal gyrus and precuneus (Platel et al., 2003; Thaut et al., 2020). Listening to familiar musical pieces activates the bilateral thalamus (Janata, 2009), especially ventral lateral nucleus of the left thalamus, and is associated with activation of the left superior frontal gyrus (Freitas et al., 2018). Music also generates emotional responses processed by several cortical and subcortical areas, especially by the reward circuit (Hernandez-Ruiz, 2019).

Music, as an emotionally arousing stimulus, can be used to modulate memory. Several studies found better recall and recognition of pictures and words after a post-learning musical treatment (Judde & Rickard, 2010; Justel et al., 2013; Moltrasio et al., 2020). Some of them performed a delayed recall and recognition test, a week later (Justel et al., 2013; Moltrasio et al., 2020), using pictures as the material to learn and recall. Participants exposed to arousing music performed better in both immediate and delayed tasks (Justel et al., 2013; Judde & Rickard, 2010): participants exposed to arousing music recalled a greater amount of pictures, compared to control subjects. This has also been reported in patients with episodic memory impairment, such as Alzheimer's Disease: arousing music decreased false picture recognition, a week later (Moltrasio et al., 2020). These and other studies show the importance of using a delayed memory task. Memory enhancement through music and other arousing stimuli is sometimes absent in immediate memory tasks (Quevedo et al., 2003). Emotionally arousing events increase memory consolidation, which may take place hours or days after encoding (Justel et al., 2013; Quevedo et al., 2003; Schumann et al., 2018).

Musical memory is a perception-based memory system for music, which allows us to remember previously learned musical stimuli (Peretz & Zatorre, 2005). Musical semantic memory is defined as memory for familiar musical excerpts learned throughout someone's life, without any knowledge of the spatial or temporal circumstances of learning (Groussard et al., 2010). Episodic musical memory, on the other hand, involves memory of recently learned musical (novel or unfamiliar) excerpts (Platel et al., 2003; Vanstone et al., 2012). These memory modalities can be independently impaired or spared (Cuddy & Duffin, 2005; Esfahani-Bayerl et al., 2019). Single case studies show dissociations between musical memory and other cognitive functions (Cuddy & Duffin, 2005; Tirigay et al., 2022).

Patients with Korsakoff syndrome, Alzheimer's Disease and other neurological conditions showed spared discrimination of familiar musical pieces (i.e., musical semantic memory), while showing severe deficits in other cognitive functions, such as language (Cuddy & Duffin, 2005; Johnson et al., 1985; Tirigay et al., 2022). However, the memory of recently learned musical excerpts (i.e., episodic musical memory) is not always preserved (Vanstone et al., 2012). Ménard & Belleville (2009) reported that patients with Alzheimer's Disease had recognition memory deficits with both unfamiliar musical excerpts and pseudowords.

Musicians with memory deficits, such as encephalitis, showed the ability to learn novel pieces of music (Cavaco et al., 2012; Valtonen et al., 2014). Encephalitis is characterised by a subacute onset and rapid progression of memory or mental status impairment, along with psychiatric symptoms (Graus et al., 2016). Although the neurocognitive profile is heterogeneous and depends on the affected brain areas, episodic memory deficits are often reported (Witt & Helmstaetder, 2021). Autoimmune encephalitis can affect the limbic system and surrounding areas, including thalamus and hippocampus (Ding et al., 2021), which are related to episodic memory and learning (Ruetti et al., 2009; Kopelman, 2015). The damage in these areas is related to false recognition in memory tests (Edelstyn et al., 2002). Limbic encephalitis has been associated with accelerated long-term forgetting, i.e., newly acquired information can be initially remembered for a limited period, but is forgotten after a few days (Healmstaetder et al., 2019; Witt et al., 2015).

Autoimmune encephalitis often causes long-term cognitive deficits following months and years after the acute phase (Kvam et al., 2024). Cognitive stimulation and external aids can be useful and help either reduce deficits or improve autonomy, as reported by single-case studies (Langenbahn et al., 2013; Mori et al., 2021; Perna & Arenivas, 2020). These studies show the importance of employing personalised interventions based on spared abilities and preferences of the patients (Langenbahn et al., 2013; Mori et al., 2021).

Patients with encephalitis are able to learn how to play new musical pieces (Cavaco et al., 2012; Valtonen et al., 2014), even retaining the recently learned material two weeks later (Valtonen et al., 2014). This was attributed to spared procedural memory, which is necessary for the learning of motor skills, and to the fact that musical practice involves various brain regions related to rhythmic, visual and motor processing (which were intact in these patients). Moreover, studies show that musicians with encephalitis have spared recognition of recently learned musical excerpts, despite having a severe amnesic deficit (Esfahani-Bayerl et al., 2019; Finke et al., 2012). The authors suggest that learning and consolidation of musical information depends on different brain networks from those involved in other types of episodic and semantic memory (Esfahani-Bayerl et al., 2019).

Musical training is associated with brain plasticity and generates functional and neuroanatomic changes (Herholz & Zatorre, 2012). Some of these changes are greater development of auditory and motor areas and differentiated brain activation of the hippocampus during musical memory tasks (Herholz & Zatorre, 2012; Justel & Diaz Abrahan, 2012). When musicians recognize familiar musical excerpts, they show greater hippocampal activation, which enhances their musical memory (Groussard et al., 2010). Moreover, musical expertise enhances the recruitment of the hippocampus during melody familiarity judgement (i.e., semantic musical memory) (Gagnepain et al., 2017). Brain plasticity associated with musical training generates a cognitive reserve that could protect against neurological damage (Stern, 2009) and may help preserve musical memory (Esfahani-Bayerl et al., 2019).

Musical memory has been studied in patients with encephalitis with hippocampal damage (Esfahani-Bayerl, 2019). However, it has not been studied in musicians with autoimmune encephalitis with thalamic damage and memory deficits. Additionally, musical episodic memory assessment in patients with encephalitis did not include a delayed recognition task (e.g., one week after learning) (Esfahani et al., 2019; Finke et al., 2012). Adding such a task could demonstrate the retention and consolidation of musical episodic memory not only in an immediate recognition task. This would be crucial considering patients with encephalitis can show specific long-term deficits (observed in delayed memory recall, a week after learning) (Healmstaetder et al., 2019). Although patients with encephalitis are able to learn how to play new musical pieces, this ability seems to be linked to procedural rather than episodic memory. There are no single case reports of patients with autoimmune encephalitis with severe verbal memory impairment and spared delayed episodic musical memory. The aim of the present study is to analyze a possible dissociation between verbal and musical memory in a patient with autoimmune encephalitis, who was an amateur musician.

2. Method

2.1 Participants

This is a single-case study. We assessed patient JC, who was diagnosed with autoimmune encephalitis (Graus et al., 2016).

A group of age- and education-matched healthy controls took part in the study. The group included 8 participants: 5 non-musical (Age: M = 71; SD = 3), and 3 amateur musicians (Age: M = 68; SD = 3.5). The group of musicians were participants who had received at least 5 years of informal musical education. They were selected from acquaintances of the research team, all residing in Buenos Aires, as well as JC. Exclusion criteria were: depression, measured by Geriatric Depression Scale-15 (GDS-15) (Sheikh & Yesavage, 1986), neurological or psychiatric pathologies that affect cognition, and use of psychotropic drugs.

2.2 Case report

JC is a 67-year-old civil engineer with 18 years of education. Prior to the diagnosis of the disease, he worked as a civil engineer. He was an amateur musician who had been playing the piano since the age of seven.

During 2011, he started showing memory deficits for recent events and behavioral changes, in addition to episodes of disorientation in familiar places. Because of this, he went through several medical examinations. Functional magnetic resonance imaging (fMRI) showed hyperintense bithalamic lesions in T2 and FLAIR (Fluid-attenuated inversion recovery), which evolved stable every year. Likewise, in the neurocognitive assessment, he showed episodic verbal memory impairment, with a memory consolidation pattern. He showed false recognition of verbal material in logical memory tests, while his other cognitive functions were preserved (attention, executive functions, language).

The symptoms were progressing gradually and he was hospitalized in 2014. At that time, he had to abandon his work activities, since his memory deficit affected his performance. He was diagnosed with autoimmune encephalitis due to the presence of lesions visualized on fMRI and the presence of positive VGKC (voltage-gated potassium channel) antibodies. He was treated with corticosteroids as a result, showing a decrease in the bithalamic lesions. Subsequently, he underwent immunoglobulin treatment in 2015. There was no cognitive improvement and the fMRI showed an increase in the signal of both thalami.

The patient has received cognitive stimulation, piano lessons 3 times a week and choir practice once a week since 2015. He is functionally independent in activities of daily living, although he requires external aids (visual reminders, agenda) for carrying out instrumental activities (using transportation, remembering medical appointments, etc.). The last fMRI prior to the assessment, carried out in May 2017, indicated an increase in the signal of the right thalamus, mainly compromising its pulvinar and medial sector, and an increase in the signal from the tail of the right hippocampus.

JC was assessed in 2018. During assessment sessions, he was very collaborative and cheerful, especially when the tasks involved musical activities. Between one session and the other (one week apart), the patient did not remember the tasks done the previous week, although he remembered the assessor. In his daily life, he showed these verbal and visual memory deficits, e.g., he did not remember if he had already watched a movie or read a book a few days after. However, he did not report any issues with musical memory: he remembered novel musical pieces he had learned in choir practice or during piano lessons.

2.3 General assessment

2.3.1 Demographical Data

Participants filled in a personal data questionnaire (age, years of schooling, years of musical training, medical history, current medication, etc.) as well as a musical preferences questionnaire (Mercadal-Brotons & Augé, 2008).

2.3.2 Neuropsychological Assessment

The neuropsychological assessment included: Mini Mental State Examination (MMSE) (Allegri et al., 1999; Folstein et al., 1983) and Clock Drawing Test (CDT) (Freedman et al., 1994), Inverse and forward digit span (Artiola et al., 1999) and Boston naming Test (Goodglass & Kaplan et al., 1996).

2.3.3 Music Emotional Judgement

We assessed musical emotion recognition using 56 short musical excerpts that convey one of four intended emotions: happiness, sadness, threat and peacefulness (Vieillard et al., 2008). Participants listen to each excerpt through headphones after adjusting volume. They have to rate each excerpt according to arousal (on a scale from 1 to 5, being 1= relaxing and 5= arousing). They also have to choose an emotional category for each of them in a four-alternative forced-choice task: happiness, sadness, threat, peacefulness.

2.3.4 Verbal Memory

Verbal memory was assessed through California Verbal Learning Test (CVLT) (Artiola et al., 1999; Delis et al., 1987). Participants must learn a 16-word list (List A), followed by the presentation of a different list (List B). This is an incidental-learning phase. Immediately after, they perform a short-delay free and cued recall test of words from List A (immediate memory phase). 20 minutes later, they must again remember words from List A, through a free and cued recall and a recognition test (delayed memory phase).

2.3.5 Musical Memory

To assess episodic musical memory, we used the Montreal Battery of Evaluation of Musical Abilities (MBEMA) (Peretz et al., 2013), which assesses musical processing and musical memory. This test was chosen since it is adequate for assessing musical abilities and musical memory in both musicians and non-musicians. Moreover, it assesses incidental memory in a similar way as the verbal memory task: it includes a learning phase, followed by a recognition phase. Participants must listen to pairs of musical excerpts and decide whether they are similar or different (learning phase). The excerpts differ in terms of melodic (Melody sub-test) or rhythmic aspects (Rhythm sub-test). At the end of the test, they perform a recognition test (memory phase): they listen to 20 musical excerpts, 10 of which are novel, and must decide whether they heard them throughout the test.

2.4 Procedure

The tests were carried out in 4 different sessions, one week apart one from another. We assessed each participant individually. During the first session, each participant was informed about the key aspects of the research and signed a written informed consent. Then, they filled in the questionnaires and performed the verbal and musical memory tests. A week later, during the second session, they completed delayed memory tests: free recall, cued recall and recognition from the CVLT, and the MBEMA recognition test. This was assessed in this way, since memory modulation using music has been reported in delayed memory tests (one week later) (Judde & Rickard, 2010; Justel & Rubinstein, 2013). We intended to see if the dissociation between music and verbal memory followed this pattern as well.

During the following two sessions (third and fourth), JC was assessed through the remaining neuropsychological tests. During the final session, we assessed musical emotional judgement as well.

2.5 Statistical analysis

We first compared JC and musicians and JC and non-musicians raw scores in neuropsychological tests.

For the musical emotional recognition test, JC was compared with 3 controls. We compared the arousal score of the different musical stimuli (happy, sad, scary and peaceful excerpts) and the correct answers of each emotional category (e.g., the amount of happy excerpts considered as happy, etc.).

Regarding verbal and musical memory, we compared JC's raw scores with both musicians and non-musicians (since all of them completed these tasks) separately. Verbal memory scores included delayed (20 minutes after learning) free and cued recall and recognition tasks, and delayed (one week after) free and cued recall and recognition tasks. For the recognition tasks, the scores of true recognition (correctly recognized words from list A) and false recognition (novel words that the participant considered as part of list A) were analyzed separately. Musical processing and musical memory raw scores were taken from the MBEMA: melody and rhythm sub-test (musical processing), and true and false recognition scores from immediate and delayed recognition test (musical memory).

We performed case-control comparisons with Crawford's modified t-test (Crawford & Howell, 1998) using a two-tailed hypothesis test. This test calculates whether the difference between the single case and the controls is statistically significant (Crawford et al., 2010). Size effect was also calculated.

Furthermore, to test whether the single case met the criteria for a dissociation between musical and verbal memory, we used the Bayesian Standardized Difference Test (BSDT) (Crawford & Garthwaite, 2007). BSDT is a modification of a paired t-test that compares the difference between case scores on two tasks with the analogous difference in the control sample. It tests whether the standardized difference between the patient's scores in both tasks is sufficiently large to render it unlikely ($p < .05$) that it is an observation from the standardized differences in the control population (Crawford & Garthwaite, 2007). According to the authors, the BSDT tests whether a patient's scores on two tests meet Bayesian criteria for a dissociation, putatively classical, when task X meets criterion for a deficit and task Y fails to meet criterion for a deficit, and the difference between tasks X and Y for the patient is statistically different to the difference observed in the control group. We report the estimated size effect for the difference between case and controls (Z-DCC). The comparisons of immediate and delayed true recognition between JC and non-musicians were not performed, because correlation of true recognition scores (for verbal and musical memory) was equal to zero, which made it impossible to carry out the analysis. We used the following programs: Singlims_es.exe and DiffBayes_ES.exe (Crawford et al., 2010).

3. Results

3.1 Demographical data

Compared with the non-musician controls, JC did not show significant differences in age ($t(4) = -1.217$, $p = .29$) and years of schooling ($t(4) = .079$, $p = .94$). Neither with respect to musicians ($t(2) = -.247$, $p = .82$ and $t(2) = .241$, $p = .83$, respectively).

3.2 Neuropsychological Assessment

Regarding the screening tests, we found no differences in the CDT score between JC and non-musicians ($t(4) = -.228$, $p = .83$), and between JC and musicians ($t(2) = -.217$, $p = .84$). Differences were found between JC and both groups on the MMSE score (non-musicians: $t(4) = -6.573$, $p = .002$; musicians $t(2) = -5.340$, $p = .03$).

Regarding the other neuropsychological tests, no significant differences were found between JC and both groups. No differences were found in the forward digit score between JC and non-musicians ($t(4) = 1.582$ $p = .18$); and JC and musicians ($t(2) = .217$ $p = .84$), and inverse digit score compared to non-musicians ($t(4) = .365$ $p = .73$) and musicians ($t(2) = -.489$ $p = .67$). Furthermore, no differences were found in the Boston Naming test scores between JC and non-musicians ($t(4) = .876$ $p = .4$), and JC and musicians: ($t(2) = -.26$ $p = .81$). Results are shown in Table 1.

Table 1. General assessment

	Controls		JC	
	Non-musicians	Musicians	Raw score	Z score
MMSE	29.5 ± .6	29.8 ± .5	26*	-
CDT	14 ± .8	14.5 ± 1	14	-
Forward Digit span	7 ± 1.4	9.5 ± 1	10	.1
Inverse Digit span	6.3 ± 2.4	7.8 ± 2.2	7	.5
Boston	51.3 ± 2.4	52.3 ± 3.4	53	.2

Mean ± deviation of musician, non-musician controls and JC's raw score in general assessment tests: Mini Mental State Examination (MMSE), Clock Drawing Test (CDT), Forward and Inverse digit span, and Boston Vocabulary Test (Boston).
Z score (normative data) of JC in Forward and Inverse digit span and Boston.
*Significant differences between JC and controls

3.3 Emotional Judgement

No significant differences were found between JC and controls in the arousal scores of happy ($t(2) = .26$, $p = .98$), sad ($t(2) = -1.949$, $p = .19$), scary ($t(2) = -.961$, $p = .44$) and peaceful excerpts ($t(2) = -.45$, $p = .70$). JC was as accurate as the controls to categorize the extracts according to their emotional category: happiness ($t(2) = .189$, $p = .87$), sadness ($t(2) = .247$, $p = .83$), scare ($t(2) = -.756$, $p = .53$), and peacefulness ($t(2) = .577$, $p = .62$).

3.4 Verbal Memory

We found significant differences between JC and non-musicians in all tasks, except for immediate and delayed false recognition tests. Compared to musicians, JC showed significant differences in most of the tasks, except for immediate false recognition and delayed false recognition tests. Results are shown in Tables 2 and 3.

Table 2. Verbal memory - comparison between JC and non-musicians

Task	Non-musicians	JC	t (3)	Estimated size effect (Zcc) Point	(95% CI)
Free Delayed recall	11 ± 1.6	1	-5.59*	-6.25	-11.116 to -1.544
Cued Delayed recall	12.8 ± 1.5	3	-5.844**	-6.533	-11.612 to -1.625
True Recognition	15.3 ± 1	8	-6.529**	-7.3	-12.957 to -1.844
False Recognition	3.8 ± 2.5	7	1.145	1.28	-.143 to 2.618
Free recall (one week later)	9 ± 1.4	0	-5.75*	-6.429	-11.429 to -1.595
Cued recall (one week later)	11 ± 2.2	0	-4.472*	-5	-8.929 to -1.176
True Recognition (one week later)	14.5 ± 0.6	10	-6.708**	-7.5	-13.309 to -1.901
False Recognition (one week later)	7.5 ± 2.4	12	2	1.875	.121 to 3.571

Mean ± deviation of non-musicians and JC's raw score of verbal memory tasks from California Verbal Learning Test (CVLT). Free delayed recall and cued delayed recall (20' minutes after word learning); True recognition: old words correctly recognized in memory recognition task; False recognition: new words categorized as old in memory recognition task; Free recall (one week later) and cued recall (one week later, one week after word learning); True recognition (one week later): old words correctly recognized, one week after word learning; False recognition: new words categorized as old, one week after word learning.
*Significant differences between JC and controls, $p < .05$. **Significant differences between JC and controls, $p < .01$

Table 3. Verbal memory - comparison between JC and musicians

				Size effect (Zcc)	
Tasks	Musicians	JC	t (3)	Point	(95% CI)
Free Delayed recall	13 ± 2.2	1	-4.879*	-5.455	-9.723 to -1.311
Cued Delayed recall	13.3 ± 2.2	3	-4.188*	-4.682	-8.375 to -1.080
True Recognition	15 ± .8	8	-7.826**	-8.75	-15.505 to -2.252
False Recognition	1.5 ± 2.4	7	2.05	2.292	.285 to 4.263
Free recall (one week later)	10 ± 1.8	0	-4.969*	-5.556	-9.9 to -1.341
Cued recall (one week later)	12.8 ± 2.6	0	-4.403*	-4.923	-8.795 to -1.153
True Recognition (one week later)	14.3 ± 1.7	10	-.262	-2.529	-4.664 to -.374
False Recognition (one week later)	2 ± .8	12	11.18**	12.5	3.286 to 22.107

Mean ± deviation of musician controls and JC's raw score of verbal memory tasks, from California Verbal Learning Test (CVLT). Free delayed recall and cued delayed recall (20' minutes after word learning); True recognition: old words correctly recognized in memory recognition task; False recognition: new words categorized as old in memory recognition task; Free recall (one week later) and cued recall (one week later, one week after word learning); True recognition (one week later): old words correctly recognized, one week after word learning; False recognition: new words categorized as old, one week after word learning.
*Significant differences between JC and controls, $p < .05$ **Significant differences between JC and controls, $p < .01$

3.5 Musical memory

We found no significant differences in the MBEMA Melody sub-test scores between JC and non-musicians ($t(3) = .573$, $p > .05$), and JC and musicians (*t*(3)= .373, *p* > .05). No differences were found in the Rhythm sub-test scores between JC and non-musicians (*t*(3) = -1.068 *p* > .05) although there were differences between him and musicians (*t*(3) = -3.833, *p* < .05).

Regarding musical memory tasks, no differences were found between JC and the two groups on any of the tasks (tables 4 and 5).

Table 4. Musical memory - comparison between JC and non-musicians

	Non-musicians	JC	t (3)	p	Estimated size effect (Zcc) Point	(95% CI)
TR immediate	9 ± .8	9	0	1	0	-.98 to .98
FR immediate	2.3 ± 1.3	1	-.894	.437	-1.0	-2.197 to .285
TR delayed	8.5 ± .6	9	.7	.51014	.8	-.378 to 1.958
FR delayed	4.5 ± 2.9	2	-.8	.49683	-.9	-1.998 to .361

Mean ± deviation of non-musician controls and JC's raw score in musical memory tasks. TR immediate: true recognition (old excerpts correctly recognized) of the Montreal Battery of Evaluation of Amusia (MBEMA); FR immediate: false recognition (new excerpts categorized as old) of MBEMA; TR delayed: true recognition of musical excerpts (from MBEMA), one week later; FR delayed: false recognition of musical excerpts (from MBEMA), one week later

Table 5. Musical memory - comparison between JC and musicians

					Estimated size effect (Zcc)	
	Musicians	JC	t (3)	P	Point	(95% CI)
TR immediate	9.3 ± 1	9	-.268	.80584	-.3	-1.284 to .729
FR immediate	3.8 ± 1.5	1	-1.67	.19359	-1.9	-3.557 to -.117
TR delayed	9 ± 0	9	n/a	n/a	n/a	n/a
FR delayed	4 ± .8	2	-2.2	.11137	-2.5	-4.614 to -.363

Mean ± deviation of non-musician controls and JC's raw score in musical memory tasks. TR immediate: true recognition (old excerpts correctly recognized) of the Montreal Battery of Evaluation of Amusia (MBEMA); FR immediate: false recognition (new excerpts categorized as old) of MBEMA; TR delayed: true recognition of musical excerpts (from MBEMA), one week later; FR delayed: false recognition of musical excerpts (from MBEMA), one week later
n/a: non - analysed

3.6 Dissociations between musical and verbal memory

Figures 1 and 2 show musical and verbal memory scores of JC and controls. JC showed a significant dissociation between verbal and musical memory tasks, specifically in true and false delayed recognition tasks (p < .05), compared to non-musicians (Figure 1). Compared to musicians, JC showed a significant dissociation between musical and verbal tasks, in immediate true recognition and in delayed false recognition trials (p < .05 and p < .01) (Figure 2).

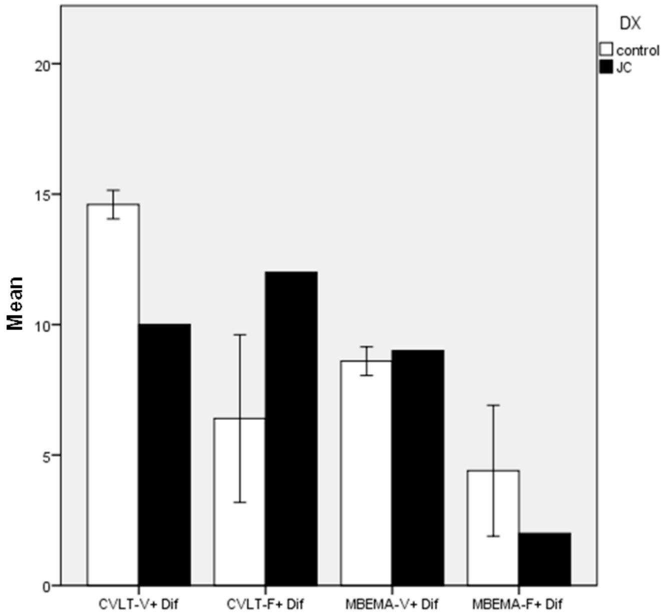

Figure 1. JC vs. non-musical controls – Comparison between verbal memory (CVLT) and musical memory (MBEMA), comparing delayed recognition scores (one week later). True delayed recognition scores correspond to verbal memory (CVLT-V + Dif) and musical memory (MBEMA-V + Dif) tests, as well as false delayed recognition scores (CVLT-F + Dif and MBEMA-F + Dif, respectively)

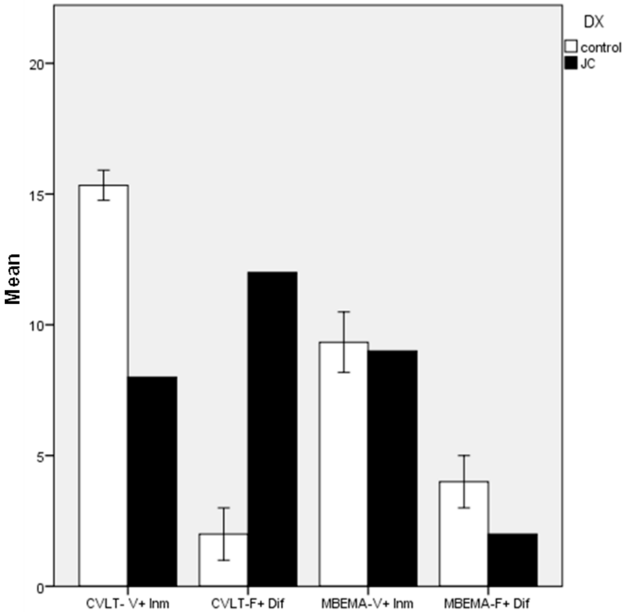

Figure 2. JC vs. musicians – Comparison between verbal and musical memory, comparing immediate true recognition (correctly recognized stimuli) and delayed false recognition (one week later). Immediate true recognition scores correspond to verbal memory (CVLT-V + Inm) and musical memory (MBEMA-V + Inm), as well as delayed false recognition (CVLT-F + Dif and MBEMA-F + Dif, respectively)

4. Discussion

The aim of the study was to analyze a possible dissociation between verbal and musical memory in a patient with autoimmune encephalitis, who is an amateur musician. JC showed severe episodic verbal memory impairment. However, he spared musical memory: even a week later, his performance was similar to both musician and non-musician participants. Moreover, we found significant dissociations between the patient and both musician and non-musician controls, in most musical and verbal memory tasks, including delayed memory tasks (one week later).

Previous studies suggest that amnesic patients show dissociations between verbal memory and musical memory (Esfahani-Bayerl et al., 2019; Finke et al., 2012). JC and both control groups differed in most verbal memory tasks. Despite that, we found no differences between JC and non-musicians in verbal false recognition, which may be explained by the presence of false recognition in older adults (Devitt & Schachter, 2016).

Despite his verbal memory deficits, he was able to remember novel musical pieces a week later. Previous studies have already shown the role of music as a memory enhancer for delayed recognition in adults (Judde & Rickard, 2010; Justel & Rubinstein, 2013) and patients with Alzheimer's Disease (Moltrasio et al., 2020; Ratovohery et al., 2019). Music improved delayed recall and recognition of visual and verbal stimuli (24 hour and a week later), when used during encoding (Ratovohery et al., 2019) or as a post-learning treatment (Judde & Rickard, 2010; Justel & Rubinstein, 2013; Moltrasio et al., 2020). Our results are in line with these findings, even though musical memory was not assessed in the aforementioned studies.

A dissociation between musical memory and verbal memory in a one-week delay memory task has not been previously reported. JC, who struggled with remembering the tasks he had done the previous session, was able to recognize new musical excerpts. JC's delayed recognition of novel musical pieces was even superior to non-musicians, although not statistically significant. Furthermore, he nearly showed no false recognition of musical excerpts. Previous studies have demonstrated preserved episodic musical memory in immediate tasks, yet not in delayed tasks (Esfahani et al., 2019; Finke et al., 2012). Only a single study demonstrated preserved delayed recall of a newly learned song. However, the task consisted in learning and performing novel musical sequences, which requires complex motor learning processes, not only episodic musical memory (Valtonen et al., 2014).

Our findings show that musical episodic memory is retained and consolidated beyond immediate recognition tasks. This is important given that patients with encephalitis may exhibit specific long-term deficits (Witt et al., 2015). Healmstaetder et al. (2019) reported an association between encephalitis and accelerated long-term forgetting using one-week delayed recall measures. This association emphasises the relevance of performing delayed memory tasks in patients with encephalitis. Moreover, it highlights the study's critical findings for considering treatments that demonstrate long-term effects.

Regarding the anatomical areas involved, patients who show dissociation of musical and verbal memory have hippocampal damage, and the analysis and explanation of this phenomenon involves the role of the hippocampus (Esfahani-Bayerl et al., 2019). JC is the first reported case of autoimmune encephalitis with thalamic damage, who showed a dissociation between verbal and musical memory tasks. JC's thalamic damage is associated with verbal but not musical memory impairment.

It is important to note that JC had received musical training and continued his musical activities at the time of the assessment. Musical training generates changes in the brain (Justel & Diaz Abrahan, 2012). JC's musical background likely enhanced his musical memory compared to other memory modalities. JC had a similar performance to a group of musicians, which may imply that his musical memory did not change despite his disease. This could be related to cognitive reserve that protected him against the brain damage (Feldberg et al., 2019).

Music is emotionally arousing, unlike a list of neutral words. Musical pieces may be easier to remember (Eschrich et al., 2005; Ferreri & Rodriguez-Fornells, 2017). This difference could explain the dissociation we found. JC performed similarly to control participants in an emotional musical judgement test (Vieillard et al., 2008), which means he spared music emotion recognition. Therefore, musical stimuli may have been better remembered because of their emotional content. This aligns with findings from several studies that have explored the impact of emotionally arousing stimuli on memory modulation (Gomez-Gallego & Gomez-Garcia, 2017; Joubert et al., 2018).

Some limitations of the present work could be addressed in future studies. First, the number of musical and verbal memory stimuli were different: the musical memory task could have been easier because it contained fewer stimuli, generating an advantage for the patient. Using a task with a greater number of stimuli might help to address this limitation. A comparison between the patient's verbal emotional memory and musical memory, using similar emotional stimuli for verbal and musical material (e.g., negative stimuli and positive stimuli), could be very useful for future research. The second limitation is the small sample size. This could explain why we found no significant differences between JC and controls in tasks in which JC was clearly impaired (e.g., false recognition in verbal memory test). Finally and in line with this limitation, our findings correspond to the study of a single case. Additionally, JC may have been more motivated by the musical tasks than control participants, which could have benefited his performance. Further studies with larger samples are needed to assess the generalizability of the results.

In conclusion, this case study shows a dissociation between verbal and musical episodic memory, in both immediate and delayed recognition, which was not previously reported in a patient with encephalitis with a cognitive profile of moderate to severe memory deficits. This result supports the idea that music could play a very important role in the lives of amnesic musician patients. Music could almost be the only kind of stimulus that they are able to remember after the injury. Previous studies have shown the importance of using personalized interventions tailored to the preserved abilities and preferences of people with encephalitis (Langenbahn et al., 2013; Mori et al., 2021). Therefore, employing music as a therapeutic tool could be especially beneficial for patients who have a unique bond with it. Future investigations could focus on whether this could also be valid for amnesic non-musical participants and further study the role of emotional arousal in musical memory. Therefore, we would be closer to elucidating the role of musical training as a protective factor against neurological damage.

Data Availability

The data that support the findings of this study are available from the corresponding author, J.M., upon reasonable request.

Ethic Statement

All participants signed a written informed consent (in the case of JC, we obtained the oral authorization of the informal caregiver) in accordance with the principles of the Declaration of Helsinki.
This research was approved by the Committee for Responsible Conduct in Research of the Faculty of Psychology of the University of Buenos Aires.

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Authors' contribution

JM wrote the manuscript and conducted the assessment of the patient and control participants, WR designed the procedure and co-wrote the Discussion section, FC conducted statistical analyses and co-wrote the results section, DGP co-wrote the Materials and methods section. All authors reviewed the final manuscript.

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