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Music-dance-imaging training for young adults with Tourette Syndrome

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Abstract

Tourette Syndrome (TS) is a childhood-onset neurobehavioral disorder, which is characterized by motor and sound tics. Current studies have identified some specific factors that lead to tic reduction, such as relaxation, concentration, musical activities, and the execution of voluntary and finalistic movements. Patients with TS show a higher level of creativity than other people, which can be channeled, together with their excessive motor energy, into various functional activities that favor the reduction of tics. Moreover, in the last decades, music has been used as a rehabilitative tool, since it has shown to induce a positive effect on TS patients' mood and to facilitate the performance of fluid and rhythmic voluntary movements. The present study refers to "Imagine, Tourette!", a motor imagery, music-based intervention aimed at reducing the manifestation of motor and sound tics in adult TS patients. To test the specific effect of such a kind of training, 8 TS patients were exposed to one of two interventions: the experimental group performed motor tasks based on music whereas the control group performed motor tasks without the accompaniment of music. The hypothesis tested was that performing motor tasks accompanied by music could reduce the severity of tics and have an effect on patients' mood more than simply performing motor

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tasks alone. The results supported the hypothesis: music played a specific effect on the manifestation of tics and on the patients' mood, confirming its potentially positive role in motor interventions addressed to TS.

Keywords: Tourette; Tic; Music; Music Therapy; Dance; Voluntary movement; Imaging; Mood; Training.

1. Introduction

Tourette Syndrome (TS) is a childhood-onset neurobehavioral disorder, which is characterized by motor tics and at least one sound tic (American Psychiatric Association, 2013). Tics are repetitive, arrhythmic, semi-voluntary, and bring to non-finalistic movements. TS is a common syndrome (1% of the general population) with a complex etiology, which is mostly genetic and infective. Most patients (90%) present comorbidities with psychopathologies, including depressive symptoms as well as a reduced quality of life (Robertson, 2011; Zanaboni Dina & Porta, 2019).

Tics can be triggered by stressors (Lees, Robertson, Trimble, & Murray, 1984; Bornstein, Stefl, & Hammond, 1990; Robertson, Banerjee, Eapen, & Hixley, 2001; Caurín, Serrano, Fernández-Alvarez, Campistol, & Pérez-Dueñas, 2014) and by positive or negative emotional states, such as anxiety (Lees *et al.*, 1984; Bornstein *et al.*, 1990; Silva, Munoz, Barickman, & Friedhoff, 1995), repressed anger (Shapiro, Shapiro, Young, & Feinberg, 1988), euphoria, boredom, or fatigue. Some studies also identified factors leading to the reduction of tics, which include relaxation and concentration (Silva *et al.*, 1995; Robertson *et al.*, 2001; Eapen, Fox-Hixley, Banerjee, & Robertson, 2004; Caurín *et al.*, 2014). Based on these grounds, the present study involved two activities, which can induce relaxation and concentration, and, therefore, bring to a possible improvement in TS symptoms: music-based motor activities and motor imagery activities.

1.1. Music-based motor activities

It has been demonstrated that the performance of specific voluntary movements can induce a tic reduction in people with TS (Thomalla, Jonas, Bäumer, Siebner, Biermann-Ruben, Ganos *et al.*, 2014). More specifically, if voluntary motor activities involve the muscular districts affected by tics, a replacement of the tic with the voluntary gesture is possible, following the rationale of the Habit Reversal Training, i.e. a worldwide evidence-based therapy method addressed to TS patients (Azrin & Nunn, 1973; Woods, Piacentini, Chang, Deckersbach, Ginsburg, Peterson *et al.*, 2008).

TS individuals show higher levels of creativity than neurotypical people (Zanaboni Dina, Leckman, & Porta, 2011; Espert, Gadea, Alino, & Oltra-Cucarella, 2017; Zanaboni Dina, Porta, Saleh, & Servello, 2017). Their creative skills can be channeled, together with their excessive motor energy, into different functional activities, promoting a decrease in tics while being

productive (Caurín *et al.*, 2014). Within motor and creative activities, these patients should be addressed to opt for musical activities, because music induces them to perform fluid and rhythmic movements that contrast their tics (Bodeck, Lappe, & Evers, 2015; Scataglini, Andreoni, Fusca, & Porta, 2017). In fact, according to several studies (Zatorre, Halpern, Perry, Meyer, & Evans, 1996; Terry & Karageorghis, 2011), musical rhythm facilitates the coordination, by giving harmony to movements during a performance. More precisely, the temporal component of music leads the individual to follow the sequential structure and to "drag" movements.

The employment of music as a therapeutic tool has started to be explored over the last decades. Nowadays, many music-based methods are under investigation and they are applied in quite a wide range of disturbances, such as in the neurorehabilitation field (Bonacina, Cancer, Lanzi, Lorusso, & Antonietti, 2015; Cancer, Bonacina, Lorusso, Lanzi, & Antonietti, 2016; Cancer & Antonietti, 2017; Cancer, Stievano, Pace, Colombo, & Antonietti, 2019; Cancer, Bonacina, Salandi, Antonietti, Molteni, & Lorusso, 2020), but especially in cases of motor and speech disorders and emotional dysfunctions (Paul & Ramsey, 2000; Aldridge, 2005).

Music can be used in the rehabilitation aimed at reaching general goals (to motivate the patient, to induce a specific psychological state, to establish social relationships, etc.) or it can play a specific role. In the first case, music can be used to activate a psychophysiological state, an emotion, or to introduce interventions such as a psychotherapeutic session (Antonietti, 2009). For example, it has been found that music is a motivational input for elderly people in performing rehabilitation exercises and improving their quality of life (Sorrell & Sorrell, 2008). Music is also a tool to develop interpersonal contacts (Magee & Bowen, 2008): while listening to music, singing, or playing an instrument in group, people express feelings and thoughts that they could not be able to perform or verbalize without music. Music can trigger specific behaviors or cognitive processes that need to be rehabilitated (DeNora, 2000). This can be achieved with music accompanying motor/speaking tasks or it can be the exclusive rehabilitation task in itself (Antonietti, 2009; Antonietti, Colombo, & DeRocher, 2018). In this respect Särkämö and colleagues (2008) noticed that patients in post-stroke recovery who listened to music on a daily basis had more positive cognitive outcomes than patients who listened to audiobooks. Music was employed by Gervin (1991) in a study conducted on patients with motor disorders, who were affected by brain damage and, therefore, were characterized by an impairment in the areas of initiation, sequencing, and

motor planning; music was thus shown to encourage the synchrony between sounds and the patients' gestures during a training session of getting dressed by themselves. Concerning tics, many patients reported a total absence of symptoms while being involved in a music task, such as playing an instrument, singing, or performing a musical piece, especially when the music task was active (e.g., playing guitar) rather than when it was a passive one (e.g., listening to music) (Lees *et al.*, 1984; Sacks, 1995, 1998; Roessner, Banascheswki, & Rothenberger, 2004; Sacks, 2006, 2007; Robertson & Cavanna, 2008; Devlin, Alshaikh, & Pantelyat, 2019).

Besides motor activities, mood is another psychological state (see above, current subparagraph) that can also benefit from activities based on music (Lundqvist, Carlsson, Hilmersson, & Juslin, 2009; Schäfer, Sedlmeier, Stadtler, & Huron, 2013), which, in turn, can help to reduce tics when considering TS people. In the same way, the level of pleasure experienced by patients for a certain music piece (Bodeck *et al.*, 2015) and for the type of task proposed with music (e.g., dancing) impacts on the mood (Groarke & Hogan, 2019) and, consequently, on the severity of tics when considering TS patients. In agreement with these findings, in the present study the choice of music and of the motor tasks were modulated by considering the possible effects on patients' tics and on mood.

1.2. Motor imagery activities

Evidence in the literature (Jackson, Lafleur, Malouin, Richards, & Doyon, 2001; Sharma, Pomeroy, & Baron, 2006) has also suggested that the practice of motor imagery, in the absence of the actual execution of the movement, also improves the motor performance in patients with movement disorders. The same brain structures are indeed activated both when a person performs an action and when the person imagines to perform it (Jeannerod, 2001; Johnson-Frey, 2004). For this reason, mental practice sessions induce neuromodulation, similar to what happens following physical training (Trobia, Gaggioli, & Antonietti, 2011).

On this basis, various motor imagery trainings for motor rehabilitation have been proposed. Page and co-workers (2001) compared the efficacy of a rehabilitation program, consisting of imaginative tasks and occupational therapy, with the efficacy of the occupational therapy alone. Patients were trained to motor imagery for 10 minutes three times a week after each therapy session, and twice a week at home, for a total period of six weeks. The imagination of movements (for example, the act of grabbing a cup)

improved motor performance in stroke patients. Moreover, Stevens and Stoykov (2003) confirmed the effectiveness of a motor imagery training in the rehabilitation of hemiparesis. They found an improvement in the movement of the paretic limb's wrist (e.g., manipulating objects) of patients who were involved in a rehabilitation program.

Only a handful of studies have employed motor imagery in the treatment of TS patients to date, to the best of our knowledge. Zago and colleagues (2014) investigated counterfactual thinking in a group of 48 TS subjects, who were instructed to perform unusual motor actions; counterfactual thinking resulted to be similar to that of healthy controls. Bodeck and colleagues (2015) employed music imagery tasks to improve tics, although motor imagery tasks were never employed for this goal.

In the present study we thus decided to include a motor imagery task with the aim of testing whether it could amplify the effect of the motor task on tics during the course of the training. The motor imagery task was not a variable of the study and for this reason it was carried out by all the participants. Given these premises (subparagraph 1.1, and current subparagraph), a motor imagery, music-based intervention, called "Imagine, Tourette!", was developed.

2. Aims and Hypothesis

The purpose of this pilot study was to test the effect of the "Imagine, Tourette!" intervention on tics and on mood in patients with TS. The training consisted in finalistic motor tasks (dancing), to be achieved with and without music, and in motor imagery tasks (on dancing). The hypothesis was that music could reduce the severity of tics and have an effect on patients' mood to a greater extent than the performance of the finalistic motor task alone, without the employment of music. References to music were deliberately omitted in the name of the training in order not to reveal the hypothesis of the study to the participants.

The improvement of tics and of mood could be expressed during and/or after the training sessions (refer, for example, to the previous studies on the effectiveness of music-based and music imagery trainings on tics during the session and for the following 15 minutes after the end of each session).

If this training led to positive results in the experimental subjects, it could be applied also to other individuals: young patients with Tourette Syndrome or patients with other motor disorders, such as stereotypies or mild

Parkinson's Disease. Not the least, the training was very simple in order to be administered also thanks to the online-based method (see Procedure). Actually the possibility to stay at home for patients with motor disabilities, with no caregiver who was asked to move to the trainer's office, made the training more feasible and easy to conduct. Furthermore, given the current COVID-19 pandemic, it was possible to perform the training without incurring in any risk of contagion also during lockdowns.

3. Methods

3.1. Participants

Eight TS patients from five Italian regions (Lombardy, Tuscany, Piedmont, Trentino-Alto Adige, and Emilia Romagna) volunteered to take part in the study. Inclusion criteria were the following: age between 20 and 35 and diagnosis of TS by a neurologist specialized in dealing with TS. All patients had already been engaged in cognitive-behavioral psychotherapy (CBT), i.e., Habit Reversal Training that is the gold standard CBT method for TS patients, for at least 4 months. Four participants were under pharmacological treatment (antipsychotics and antidepressants) for their TS, whereas in the others the medications were discontinued prior to enrollment in the study because of their improvements. The recruited patients were 6 males and 2 females (TS is predominant in males of the population with a 3:1 ratio; Leckman & Cohen, 1999), within the age range required by the study (*mean* age = 25.13 years; *SD* = 4.52). All participants received written and oral information about the study and signed the informed consent before the beginning of the intervention.

3.2. Procedure

A pseudo-randomized, control group design was applied.

First, two well known songs were selected to be used in the sessions of the training, i.e. "Gioca Jouer" by Cecchetto (song no. 1) and "Testa-spalla" by Don Lurio (song no. 2). Researchers opted for two songs, instead of only one, to limit the possibility that the musical experience was not pleasant enough: in fact, if one of the two songs, because of past experiences or idiosyncratic reactions, elicited negative emotions, the other one was thought to bring to a positive mood in the participants (it is unlikely that two songs had negative personal connotations for a same subject). An *ad hoc*

questionnaire was administered to all participants to assess their level of satisfaction regarding the two songs. Songs that were known were selected to promote a better control of the music variable: in this way, participants could not feel new and unexpected emotions. Moreover, the songs were also chosen because they both included pronounced movements the listener was invited to perform (e.g., song no. 1 quotes "sciare!" [ski!], which is an exhortation to make the skiing gesture).

Participants were divided into an experimental group and a control group of 4 subjects each, matching gender ($\chi^2 = 0$; $p = 1$), medication intake (y/n: $\chi^2 = .53$; $p = .46$), and level of satisfaction for the songs ($\chi^2 = 1.14$; $p = .28$).

The participants were exposed to a battery of standardized tests (see Assessment below) before, during, and after the intervention by a psychologist with a specific expertise in TS.

The intervention consisted of eight 15-minute individual sessions, within a two-week period. Sessions were online-based, using lap tops equipped with cameras. Trainers video-called patients on the web. Both the trainers and the patients were alone in a quiet room of their office/home. Trainers were two experts in TS treatment. The experimental group took part in motor activities based on music, whereas the control group was involved in the same tasks without music. The experimental group was asked to 1) watch a music video, in which dancers performed the dance moves along with the song and 2) repeat the movements of the dancers while re-watching the video. Controls were asked to perform the same two-step task but in the absence of music. From session 3 on, participants performed the movements while watching the video, i.e., the first step (watching without dancing) was not proposed anymore. During the training sessions the two songs were alternated ("Gioca Jouer" in sessions 1, 3, 5, 7; "Testa-Spalla" in the other sessions) in order to limit the impact of the emotions on the results that could be linked to a specific song.

The entire dataset of 8 participants also completed the same daily 3-minute motor imagery homework task. The task consisted in rethinking, into a private room, about the dancing of the last session. In this task participants were guided by a written list of sentences (e.g., "Try to recall the way you were dancing in the last session!").

3.3. Assessment

The following battery of tests was used:

- An *ad hoc pleasantness questionnaire* (3-point Likert scale) to assess patients' baseline pleasure in listening to songs 1 and 2.
- *Yale Global Tic Severity Scale* – YGTSS (Leckman, Riddle, Hardin, Ort, Swartz, Stevenson *et al.*, 1989). It is the most widely used clinical scale for the assessment of tic severity. It comprises an objective subscale, i.e., the severity of tics, and a subjective subscale, i.e., social impairment. It is completed by referring to the symptoms experienced during the previous week. Motor and sound tics are rated separately on 5 dimensions (e.g., tics' frequency, tics' intensity). The scale yields an objective double score for motor tics (0-25) and sound tics (0-25) and a subjective unified score for both motor and sound tics (0-50). It is important to notice that the two parts contribute equally to the global score, as social impairment is as fundamental as tic severity. At the end of each session, patients were assessed through tic objective (0-50) and subjective (0-50) scores. YGTSS scores were similar in the two groups at baseline (objective YGTSS: $t = .02$; $p = .85$; subjective YGTSS: $t = .08$; $p = .94$).
- *Beck Depression Inventory-Second edition* (BDI-II; Beck, Steer, & Brown, 1996) is a 21-item self-report depression inventory. Each item is rated on a 4-point Likert scale, ranging from 0 to 3, with 3 being the worst score when considering the severity of symptoms. Items refer to how respondents have been feeling throughout the previous 2 weeks (e.g., crying, self-efficacy, sleep disorders, etc.). The maximum total score is 63. According to the BDI-II manual, scores from 0 to 13 indicate the absence of depressive symptoms, whereas scores from 14 to 63 indicate depressive symptoms (14-19 = mild depressive symptoms, 20-29 = medium-severity depressive symptoms, 30-63 = severe depressive symptoms). The BDI-II was administered at baseline (t_0), at the end of the 4th session (t_1), and at the last session (t_2). The BDI-II was administered less frequently than the YGTSS because it is assumed that in two weeks TS patients should show a lower variability on mood than on tics. BDI-II scores were similar in the two groups at baseline ($t = .84$; $p = .43$).

4. Data analyses

Descriptive analyses of the YGTSS (objective and subjective scores) and BDI-II scores were first performed, considering patients as single cases. Each patient's outcome was reported. Considering the YGTSS, session 1 and session 7 were compared in relation to song 1 and session 2 and session 8 were compared in relation to song 2 (because these sessions were the first and the final session in which song 1 and song 2 were employed, respectively). Considering the BDI-II, the comparison was made between session 1 (t_0) and session 8 (t_2). Finally, group comparisons were performed using non-parametric statistics (Mann–Whitney U test; Alpha = .05), due to the small sample size, for all outcome variables (i.e., objective YGTSS, subjective YGTSS, and BDI-II).

4.1. The descriptive analyses for single cases

The outcome of the experimental group (patients no. 1 to no. 4) is described below (refer to Fig. 1-3). The percentage of improvement in the YGTSS outcome was first presented for each patient, followed by the percentage of unvaried or worsening in the YGTSS outcome. Finally, the percentage of improvement/unvaried/worsening of the BDI-II was reported for each patient (Tab. 1).

4.1.1. Patient no. 1

The patient obtained an improvement of 14% and of 10% in the objective and subjective YGTSS scores, respectively, in relation to song 2. In contrast, the patient showed no variations in the subjective YGTSS score (0% of change) and even a worsening (-10%) in the objective YGTSS score in relation to song 1. In terms of mood, the patient positively passed from BDI-II *mild depressive symptoms* (t_0) to the *absence of depressive symptoms* (t_2) with an improvement of 40%.

4.1.2. Patient no. 2

Patient no. 2 improved by 20% in the subjective YGTSS score in both songs, while no difference was detected in the objective YGTSS score in both songs from the beginning to the end of the training session (0% of change). Mood also improved from the beginning to the end of the training (BDI-II improvement of 40%).

4.1.3. Patient no. 3

Patient no. 3 improved in both the objective YGTSS score (a tic reduction of 44% in song 1, and of 26% in song 2) and in the subjective YGTSS score (the impairment reduced of 36% in song 1 and of 38% in song 2). Moreover, the patient obtained an improvement of 21% from the beginning (t_0) to the end of the training (t_2).

4.1.4. Patient no. 4

Regarding the objective YGTSS score, patient no. 4 obtained an improvement of 6% in song 1 and of 4% in song 2. Concerning the subjective YGTSS score, the patient improved (8%) in song 2, whereas she worsened (-14%) in song 1. The patient's mood decreased (-21%), unfortunately, within the same BDI-II clinical range.

Table 1 – *Individual results*

	Patient no.	Song 1-improvement objective YGTSS	Song 2-improvement objective YGTSS	Song 1-improvement subjective YGTSS	Song 2-improvement subjective YGTSS	Improvement BDI-II
Experimental group	1	-10%	14%	0%	10%	40%
	2	0%	0%	20%	20%	40%
	3	44%	26%	36%	38%	21%
	4	6%	4%	-14%	8%	-21%
Control group	5	30%	10%	50%	10%	-16%
	6	0%	0%	11%	0%	25%
	7	26%	-6%	10%	-10%	-140%
	8	-2%	6%	2%	2%	57%

Figure 1 – *Experimental group's objective YGTSS scores*

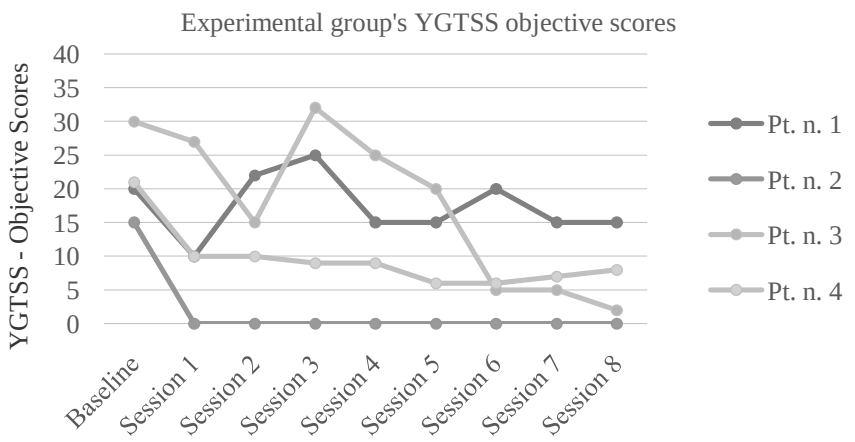


Figure 2 – *Experimental group's subjective YGTSS scores*

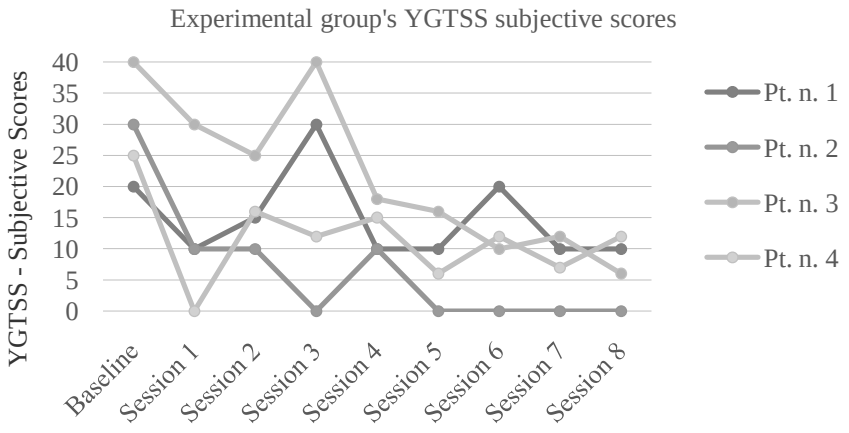
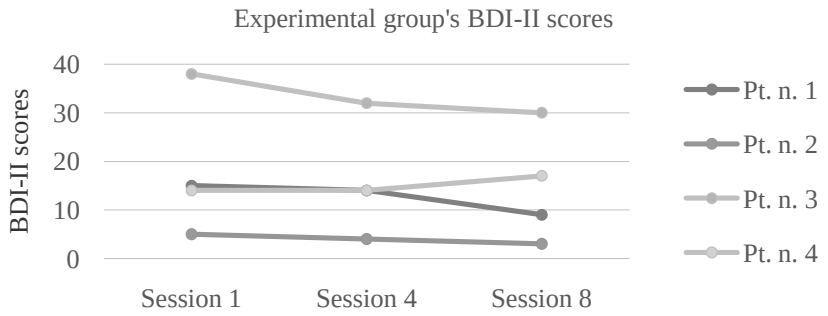


Figure 3 – *Experimental group's BDI-II scores*



The control group (patients no. 5 to no. 8) obtained the following results (see Fig. 4-6). Also in this case, the percentage of improvement in the YGTSS outcome was first presented for each patient, followed by the percentage of unvaried or worsening in the YGTSS outcome. Finally, the percentage of improvement/unvaried/worsening of the BDI-II was reported for each patient (Tab. 1).

4.1.5. Patient no. 5

The patient obtained an improvement of 10% in both the objective and subjective YGTSS scores in relation to song 2. The participant, instead, showed an improvement of 30% and of 50% in the objective and subjective

YGTSS score, respectively, in relation to song 1. Concerning the BDI-II scores, the subject worsened (-16%), however, within the same BDI-II clinical range.

4.1.6. Patient no. 6

Regarding song 1, participant no. 6 improved (11%) in the subjective YGTSS score, whereas no improvement was observed regarding the objective YGTSS score. Regarding song 2, the patient scored the same objective and subjective YGTSS results at the beginning and at the end of the training (0% of change). There was an improvement of 25% in BDI-II scores when comparing the first session (t_0) with the last session (t_2).

4.1.7. Patient no. 7

This patient scored positive results in the YGTSS measure in relation to song 1 (an improvement of 26% and of 10% in the objective and subjective YGTSS score, respectively), whereas the YGTSS score worsened in relation to song 2 (-6% and -10% in the objective and subjective score, respectively). The patient also worsened in the BDI-II score (-140%).

4.1.8. Patient no. 8

Patient no. 8 showed an improvement of 6% in the objective YGTSS score in relation to song 2 and of 2% in the subjective YGTSS score in relation to both songs. The objective YGTSS score slightly worsened (-2%) in relation to song 1. The patient improved of 57% in BDI-II scores from t_0 to t_2.

Figure 4 – *Control group's objective YGTSS scores*

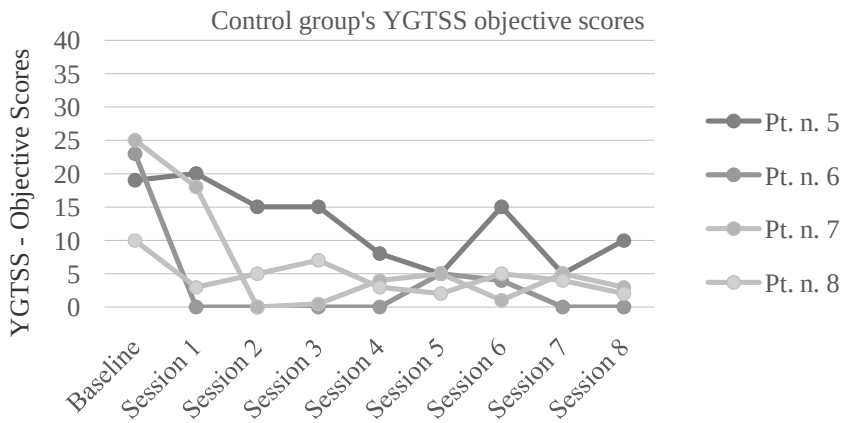


Figure 5 – *Control group's subjective YGTSS scores*

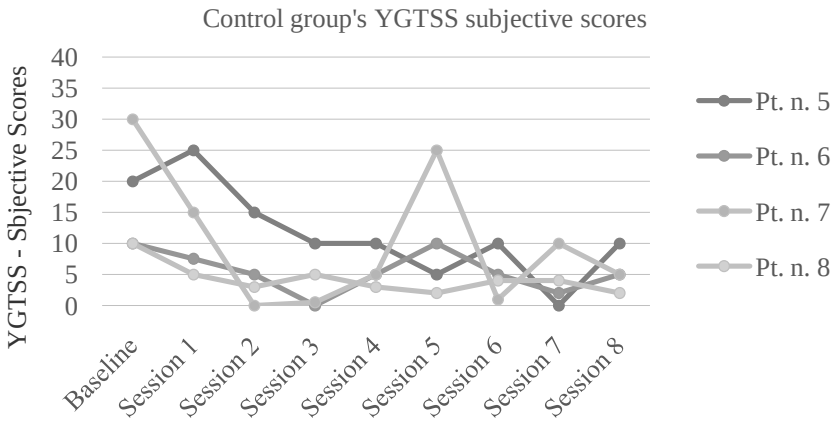
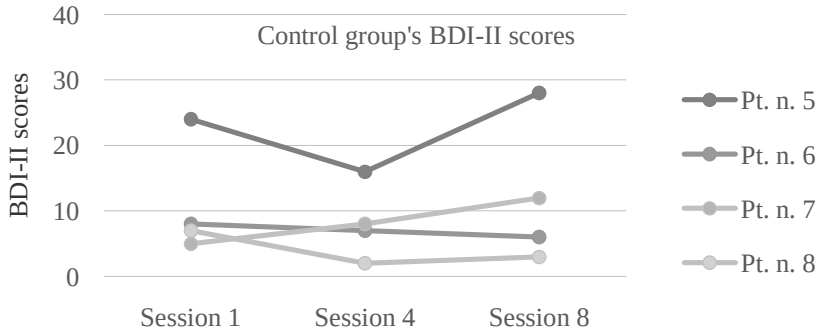


Figure 6 – *Control group's BDI-II scores*



4.2. Group comparisons

Song 2 produced a specific improvement in subjective YGTSS scores, which were significantly higher in the music group than in the control group with a large size effect (U = 1.50; p = .04; d = .81), but not in objective YGTSS scores for which group comparisons did not reach statistical significance (U = 4.5; p = .19; d = .44). On the other hand, song 1 did not produce any specific improvement, as was shown by the non-significant difference between music and non-music groups in the improvement of YGTSS scores in relation to song 1 (objective YGTSS: U = 7.5; p = .61; d = .06; subjective YGTSS: U = 6.00; p = .75; d = .25). Finally, music was found to have little effect on the BDI-II scores (U = 3.5; p = .12; d = .56).

5. Discussion and Conclusions

Music is an important rehabilitation tool. As a matter of fact, in the neurorehabilitation field the range of patients who could benefit from music interventions is broad, especially in cases of motor deficits (including TS), speech disorders, and emotional dysfunctions. The therapeutic use of music can induce a psychophysiological state of well-being and can improve mood. Motor and motor imagery tasks are indicated in TS in order to improve symptoms. The results of the current study are in line with this rationale. When considering the two groups, our study showed that music had a significantly positive effect on the impairment of tics in song 2. Some of the patients belonging to the experimental group of the "Imagine, Tourette!" training program showed a better outcome than the controls in the YGTSS measures (both objective and subjective scores), thus supporting the concept that music can be beneficial in the rehabilitation of motor impairments. Also considering the mood, the majority of individual cases in the experimental group showed a better outcome than the controls. In particular, a participant of the experimental group moved from BDI-II mild depressive symptoms to the absence of depressive symptoms and two other patients of the same group exhibited a large improvement.

During the course of the study, some unexpected outcomes also emerged. Participants showed different reactions based on the difficulty they perceived in performing the motor acts concurrently to the two songs. This depended on the speed of the songs (song 2 was faster than song 1), even though the required level of motor coordination to perform the dance movements was basic, and therefore comparable between the two songs. Furthermore, in most patients the motor imagery task re-evoked mood sensations they had experienced during the dance. The participants referred that the more they experienced positive mood sensations during the task, the fewer difficulties they had to learn the movements, and vice versa. We argue that the level of difficulty perceived affected the mood of the patients and had a potential positive or negative impact on self-esteem, and possibly on tic as well, during the activity. This variable needs to be further explored in future studies. Another unexpected outcome also emerged following the patients' comments. Participants reported that song 1 was more "fluid" and therefore it induced fewer tics than song 2, which was perceived as "jerky". Future considerations are needed in the selection of songs' rhythm. Actually, Devlin and colleagues (2019) found that a music tempo between 105 and 125 beats per minute, a duple time, a clear downbeat, a moderate pulse

clarity, and minimal key modulations are more effective in patients with movement disorders.

Although this is a pilot study and further research should be promoted, the positive findings regarding music-based interventions as reported in the literature (Gervin, 1991; Sorrell & Sorrell, 2008; Cancer *et al.*, 2016) together with the results of the training presented here should encourage clinicians to suggest music activities (e.g., dancing) as a good practice for their TS patients to be combined within psychotherapy. As a matter of fact, during psychotherapy it is difficult to lead a patient to start and maintain a hobby with the aim of contrasting depressive symptoms. Indeed, motor and musical hobbies are recommended for patients suffering from TS and/or depressive symptoms. In addition, since TS people are particularly creative, hobbies could also maximize their creative potential. Interestingly, regarding the creative potential, one of the participants of the present study decided to enroll in a painting course after the end of the "Imagine, Tourette!" intervention, whereas he had never showed any interest in a hobby over the last two years of psychotherapy. This was a remarkable success, which may, however, be extended to more subjects in upcoming research studies, if you also consider the limitations.

5.1. Limitations

This study has some limitations, which should be accounted for and due to which the generalization of the results should be cautious. First of all, the sample size was small and for this reason no parametric statistical analyses could be conducted. Further studies should lead to multicentric studies involving more TS patients, including samples of TS children. After having applied the training session, as described in this paper, to larger TS datasets, the research could be extended to patients affected by other motor disorders, such as patients suffering from stereotypies or mild Parkinson's Disease.

Another limitation of the current study is that four of the patients were medicated while the others were not. In future investigations, the variability of results due to drug administration should be measured and accounted for.

In addition, motor imagery tasks were not considered as a variable. Future studies should test the possible role of motor imagery as a therapeutic resource itself, given also the advantages of its practicality. Actually, motor imagery by itself, as opposed to listening to music and dance, can be used in absence of other tools (such as a tape recorder) and in public spaces without provoking embarrassment (because the individual does not have to dance).

Given the results, song 1 needs to be modified or proposed to different individuals. More in general, a refinement of the selection of songs is requested: offering songs with the appropriate features (e.g., rhythm, speed, and "fluidity" of music) could facilitate positive emotions and the performance of the motor tasks, and, consequent, reduction of TS symptoms.

Finally, considering the small number of participants, two pieces of music may have created a bias because it could have determined a further differentiation of the sample response, even by reducing the effect of pleasantness.

Notwithstanding, taking these conclusions and limitations into consideration, music-based motor and imagery tasks conducted with TS people have shown promising results and future investigations in this research field should be promoted in order to assess the efficacy of such an approach in the treatment of TS symptoms.

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