Chapter 4
Music and *Stroke Rehabilitation*

Contents

4.1 Stroke

A stroke is a serious, life-threatening medical condition that occurs when the blood supply to a part of the brain is interrupted or severely reduced. This deprives brain tissues of essential nutrients and oxygen, and brain cells begin to die within minutes. There are two main types of strokes: ischemic and haemorrhagic. Ischemic strokes, which account for about 85% of all strokes, occur when the arteries to your brain become narrowed or blocked, causing a severely reduced blood flow. This can be due to blood clots, which can either form in the brain's blood vessels (thrombotic stroke) or elsewhere in the body and travel to the brain (embolic stroke). Haemorrhagic strokes occur when a blood vessel in your brain leaks or ruptures. This could be due to conditions such as hypertension, overuse of anticoagulants, or aneurysms.

Stroke is one of the most pre-eminent causes of mortality and morbidity in the world (Black et al. 2015). In 2017 alone, there were 1.12 million strokes in the European Union, 9.53 million stroke survivors, 0.46 million deaths, and 7.06

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million disability-adjusted life years lost because of stroke. The World Health Organization (WHO) has given special attention to the need to investigate and collect data on rehabilitation (Sauzet et al. 2015). Still, the rehabilitation of stroke patients remains a challenge, and there is a need for high-quality quantitative data. Although traditional physiotherapy and rehabilitation techniques have been shown to be effective in treating hemiparesis, such techniques present several limitations and are not always accepted by patients. Some of these techniques demand high tolerance, perseverance, and cooperation from the patients, which can lead to frustration (Pulman et al. 2013). Even well-established standard physiotherapies do not fully provide evidence of efficacy for motor behaviour improvement (Hakkennes and Keating 2005; Peurala et al. 2012; Stevenson et al. 2012). Therefore, new innovative, motivating, engaging, and goal-directed training protocols for stroke rehabilitation are necessary.

4.2 Music and Stroke Rehabilitation

Music and music-based interventions have been used in different clinical contexts producing positive effects in people with cognitive, emotional, and motor function impairments (Schlaug 2009; Schlaug et al. 2010). With the advent of brain imaging techniques such as electroencephalography (EEG), magnetoencephalography (MEG), and functional magnetic resonance imaging (fMRI), it has been shown that music activity, both music listening and music making, activates a broad and complex network of brain areas related to auditory, cognitive, sensory-motor, and emotional processes (e.g. Ellis and Thayer 2010; Särkämö et al. 2008). In particular, it has been shown that music playing can effectively improve motor skill recovery in stroke patients (Altenmüller et al. 2009; Altenmüller and Schlaug 2013; Schneider et al. 2007; Stevenson et al. 2012; Thaut and Abiru 2010). For instance, Schneider et al. (2007) studied stroke patient rehabilitation by comparing music-based training (piano and drum playing), constraint-induced movement therapy (CIMT, a therapy that focuses on the affected limb while restraining the unaffected limb) (Morris et al. 2006) and conventional physiotherapy. For motor rehabilitation, they found that music-based training was more effective than CIMT and conventional physiotherapy in terms of both a set of established motor tests and a computer-based motor analysis. In addition, patients described music-based training as an enjoyable and motivating activity, which has been identified as an important aspect of successful recovery (Schneider et al. 2007). It has been found that music (both listening and playing) positively affects mood and motivation in stroke and affective disorders patients (Koelsch et al. 2010; Forsblom et al. 2009; Särkämö et al. 2008).

Music-based therapy using traditional music instruments for stroke patients is often limited and restricted due to a lack of fine motor skills. Stroke patients with motor skills severely affected are often incapable of effectively playing a traditional musical instrument. Incorporating technology could prove to be advantageous in establishing a connection between music therapists and their clients. Many experts in the field have recognized the potential of technology to not only revolutionize the analysis of therapy sessions but also enhance the therapeutic journey for clients. In light of this, we suggest utilizing musical technologies as a part of daily music therapy practice, where interactive systems technology can capture user movements and translate them into audiovisual and haptic feedback. This way, technology can be effectively integrated into the appropriate domain of music therapy. In this context, accessible digital musical interfaces (ADMIs) provide a possible alternative for allowing stroke patients to enjoy music playing and its associated benefits. There have been several accessible digital musical interfaces (ADMIs) proposed for people with different types of motor disabilities, for instance, the EyeHarp (Vamvakousis and Ramirez 2016). For a description of some of them, please refer to Chap. 2.

In the next section, we present a pilot study to investigate the effect of music therapy and adaptive digital music interfaces in the upper limb rehabilitation of stroke patients. We conducted a randomized, double-blind, controlled, longitudinal clinical study with chronic stroke patients. Patients in the control group (CG, N = 15) received 60 min of traditional physiotherapy, while for patients in the experimental group (EG, N = 15), 10 of these 60 min were replaced by music-based therapy using the MyoMusic adaptive digital interface. The MyoMusic is controlled by a motion capture (MoCap) sensor and eight electromyogram (EMG) sensors. All patients received 25 therapy sessions during 6 weeks. Patients were blindly evaluated at the beginning and at the end of the treatment by applying the Fugl-Meyer assessment for the upper extremities (FMA-UEs) as a primary outcome measure of motor recovery.

4.3 Research: Music and Motion Sensing for Stroke Rehabilitation

4.3.1 Participants

The research reported in this chapter is the result of a collaboration between the Rehabilitation Unit, Parc de Salut Mar, Hospital del Mar/Hospital de la Esperanza, Barcelona, and the Universitat Pompeu Fabra, Barcelona. Recruitment, interventions, and data collection are carried out at the Rehabilitation Unit. Data processing and analysis were carried out at the Universitat Pompeu Fabra. All stroke patients were assessed for eligibility according to predefined inclusion and exclusion criteria shown in Table 4.1.

Thirty adults (10 females and 20 males, mean = 67 years old, SD = 11) having suffered an (ischemic or haemorrhagic) stroke within the previous 3 months and with normal hearing participated in the study. Fifteen of them were randomly selected to participate in a music-based intervention consisting of playing an adaptive digital music interface with their upper limb affected by the stroke.

Table 4.1 Patients' inclusion and exclusion criteria

Inclusion criteria	Exclusion criteria
Admitted to physiotherapy Suffered from ischemic or haemorrhagic stroke within the previous 3 months Patients affected by emiparesia or monoparesia Understanding of Spanish or Catalan language	More than one stroke Cognitive impairment Deafness Restlessness and agitation

4.3.2 Materials

Music Material

Music used in the music therapy sessions included familiar music pieces with different degrees of difficulty:

- *Twinkle Little star*. Low difficulty level. Contiguous notes, mostly lower pitches (on the left in the interface) with quarter note rhythm.
- *Frére Jacques*. Medium difficulty level. Notes of a wider pitch range, mostly of high pitch (on the right side in the interface), but with some lower pitch (on the left side in the interface), with eighth notes rhythm.
- *Ode to Joy (Ludwig van Beethoven).* Medium/moderate difficulty level. Mostly contiguous notes but often played at faster tempi.
- *Children's Songs #1 (Chick Corea).* High difficulty level. Notes alternating between low and high pitch (i.e. wide range arm mobility), high difficulty level due to the ability required to concentrate in slow tempi sections and agility and precision of movements in fast tempi sections.

The pieces were chosen to ensure that participants were already familiar with them (except maybe *Children's Songs*). Songs were played at different tempi and with different spatial–pitch mappings, to match the abilities of each participant.

Data Acquisition and Processing

The Myo device, a highly sensitive nine-axis Inertial Measurement Unit (IMU) device, was used to acquire information from the affected forearm motion during the music intervention. The Myo device is a bracelet composed of a set of sensors for motion estimation and a haptic feedback motor. The bracelet size is between 19 and 34 cm adjustable to the forearm circumference. It weighs 93 g. The hardware comprises eight medical-grade stainless steel Electromyogram (EMG) sensors reporting electrical muscle activity. The IMU contains a three-axis gyroscope giving degrees of change in radians per second (angular velocity), a three-axis accelerometer as an estimation of −8 g to 8 g (1 g = 9.81 m/s2), a three-axis magnetometer giving an output a Quaternion reference of the imaginary rotation of the Myo in the space. It has an ARM Cortex M4 Processor, and it may provide short, medium, and long haptic feedback vibration. Its communication with a computer is based on Bluetooth with an included adapter, giving a sampling rate of 200 Hz (Hop time of 5 ms).

Participants used MyoMusic, a motion capture system created by the Music and Machine Learning Lab at the Universitat Pompeu Fabra, which uses the Myo as an input device and implements a graphical interface that displays the position of the

Myo device (and therefore of the participant's arm in real time). The MyoMusic is used to trigger sounds depending on the Myo position. The interface displays notes arranged horizontally with a descending pitch order (higher notes on the right side). Once the exercise starts, a series of spheres fall into different positions, each one representing a musical note. Participants have to position their affected arm to "catch" the spheres in such a way that the position represented by their arm coincides with the falling spheres at the right time, which in turn triggers the corresponding sounds. When notes are "caught", they break into pieces, each of which represents a possible ornament of the performed melody. See Fig. 4.1 for a screenshot of the music interface.

The application allows you to change the speed, calibrate, and recalibrate the range of horizontal amplitude of the movement of the arm and select the piece, each with a different degree of complexity. At the end of each piece, an overall score is displayed (see Fig. 4.2) and the patient is encouraged to interact with small sonic objects as a reward. The score may be used for monitoring the difficulty of the task and the progress of the patient.

Recording: In order to record the gestures and synchronize the Myo device with video and audio data, a Max/MSP program was implemented, which sends Open Sound Control (OSC) events to the Myo application to generate a database of Comma Separated Values (CSV) files; it records the data at 60fps. These files are created with the format: timer in milliseconds, accelerometer (x, y, z), gyroscope (x, y, z), Quaternion (w,x,y,z), electromyogram (eight values), point_vector(x,y,z),

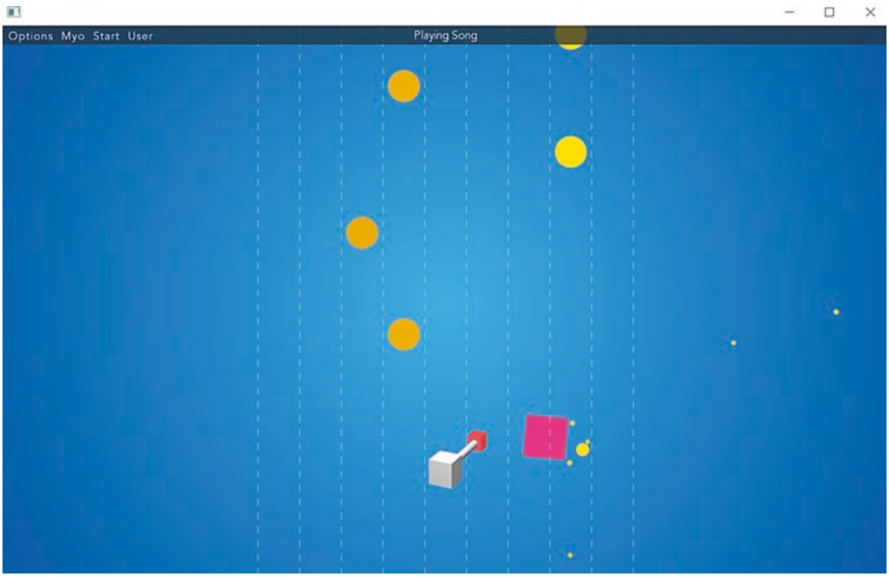

Fig. 4.1 The MyoMusic interface. Spheres represent notes; the square is the position of the patient's arm, and the task is to "catch" the spheres to trigger the corresponding notes. When notes are "caught," they break into pieces, each of which represents a possible ornament of the performed melody

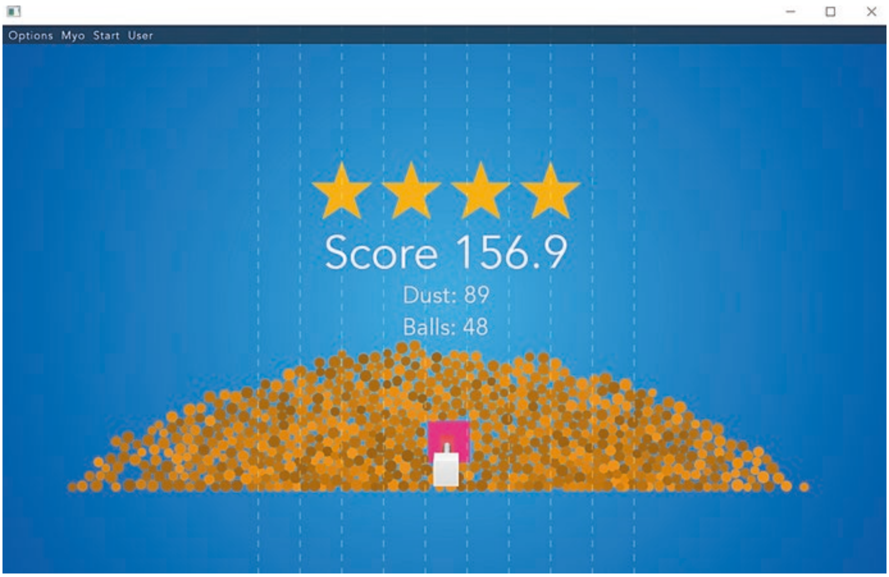

Fig. 4.2 At the end of each piece, an overall score is displayed to encourage the patient who interacts with small sonic objects as a reward

point_direction (x,y,z), point_velocity(x,y,z), and event (it is a marker during recordings). Those CSV files are recorded in the same time window range reference of the audio data, also created with Max.

Assessment tools. The Fugl-Meyer assessment (Fugl-Meyer et al. 1975; Gladstone et al. 2002) is a stroke-specific, performance-based impairment index. It is designed to assess motor functioning, balance, sensation, and joint functioning in patients with post-stroke hemiplegia. It is applied clinically and in research to determine disease severity, describe motor recovery, and plan and assess treatment. It is divided into four sections, shoulder/elbow/forearm, wrist, hand, and coordination/speed, in which different items are evaluated. It uses a quantitative scale from 0 to 2 points per item, with a total maximum total value of 66 points. The Chedoke Arm and Hand Activity Inventory is a rating scale consisting of 13 functional tasks. It is a measure of upper extremity functionality that uses a quantitative scale of 1 to 7 points per task, with a total sum of 91 points as the maximum score. Its purpose is to assess the functional capacity of the affected arm and hand, in conjunction with the unaffected side, in tasks that have previously been identified as important after a cerebrovascular accident. Its purpose is to promote bilateral function.

4.3.3 Methods

Patients eligible for inclusion in the study were contacted at the Rehabilitation Unit, Parc de Salut Mar, and informed about the procedures and objectives of the study. Patients received no information about which of the two interventions was the actual

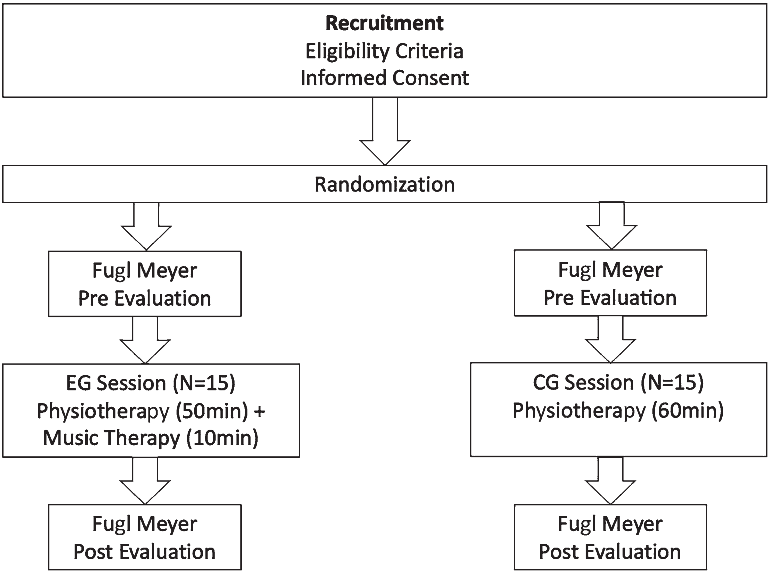

Fig. 4.3 Flow diagram of the study design

experimental condition. If patients agreed to participate, they were asked to sign the informed consent form. Participants were treated individually. Participants in the experimental group (EG) received physiotherapy sessions for 50 min and a music intervention with MyoMusic for 10 min, four times a week. The sessions were conducted by two professional music therapists with experience in rehabilitation care. Each music therapy session consisted of playing some of the music pieces (see above) with MyoMusic. Motion data was recorded during the music therapy session. Participants in the control group (CG) received 60 min of physiotherapy. All participants were receiving similar levels of medication at the moment of the study. Figure 4.3 shows a flow diagram of the study design.

In addition to motion data gathering, participants were blindly assessed using the Fugl-Meyer evaluation method, both before the first session (pre) and after the last session (post). Data were analysed by applying a t-test of pre- and post-values.

4.3.4 Results

Fugl-Meyer and Chedoke Assessment The experimental and control groups improved their rehabilitation of the upper limb. However, the improvement was more significant for the experimental group ($p = 0.0016$) than for the control group ($p = 0.0122$) as measured by the Fugl-Meyer assessment. Similarly, the improvement was more significant for the experimental group ($p = 0.0002$) than for the

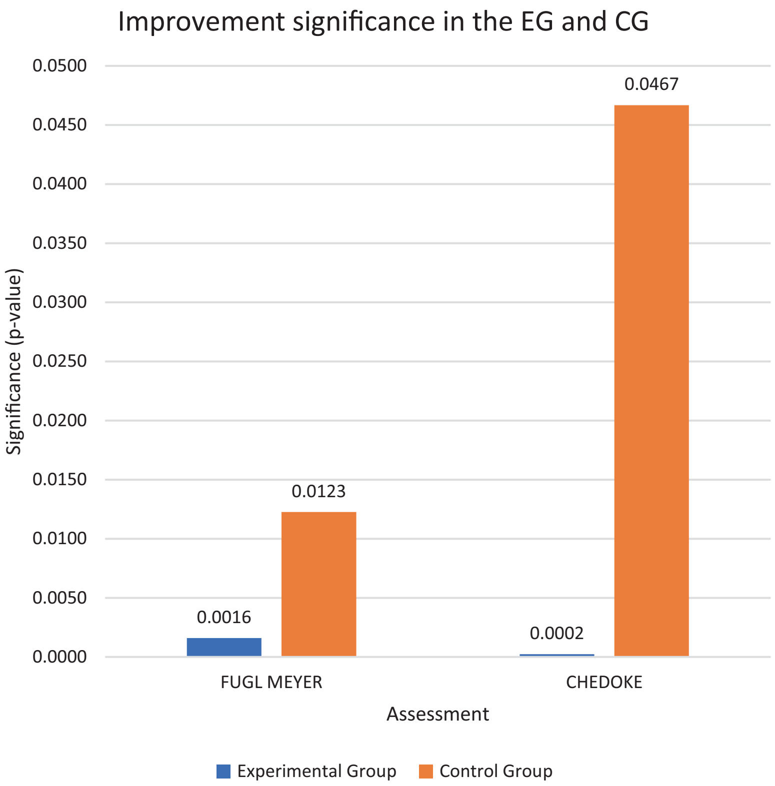

Fig. 4.4 Statistical significance of pre-post evaluation by the Fugl-Meyer and Chedoke assessments for the experimental group (blue) and control group (orange)

control group ($p = 0.0466$) as measured by the Chedoke assessment. Figure 4.4 shows the statistical significance of both groups for the Fugl-Meyer and Chedoke assessments.

4.3.5 Discussion

The Fugl-Meyer assessment results reveal that both the experimental and control groups experienced improvement post-rehabilitation. However, the experimental group exhibited a notably higher level of significance in improvement ($p = 0.001$) compared to the control group ($p = 0.01$). Although both traditional physiotherapy and the combination of physiotherapy with music therapy were anticipated to enhance upper limb rehabilitation, it was striking to see the experimental group achieve greater improvement by incorporating just 10 min of MyoMusic intervention per session.

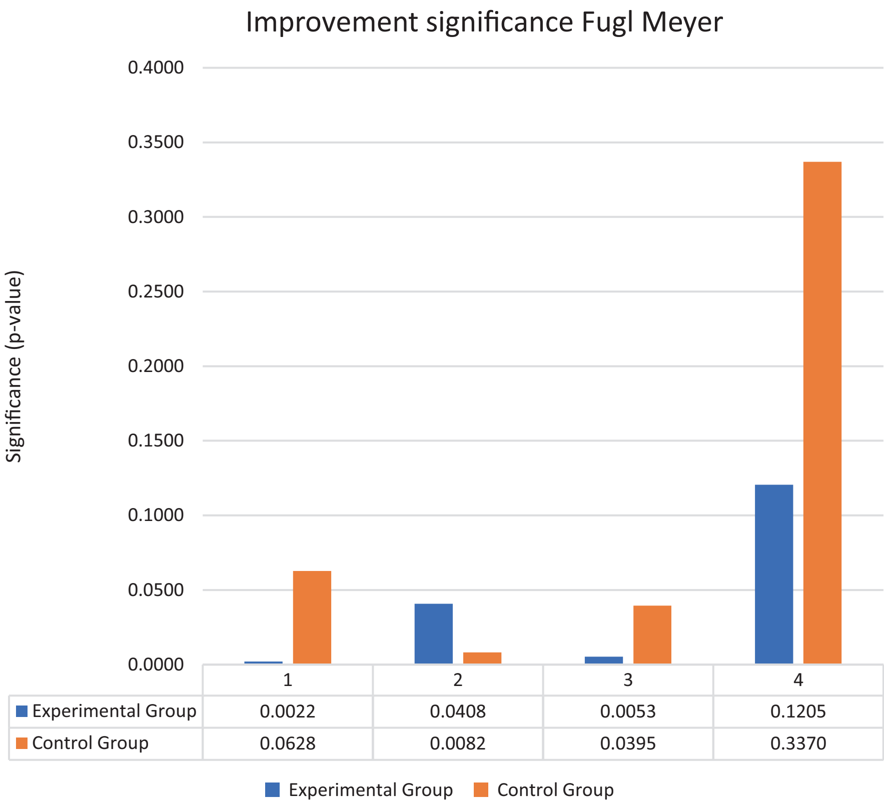

Fig. 4.5 Statistical significance of pre-post evaluation by the Fugl-Meyer assessment for the experimental group (blue) and control group (orange), for the following items: (1) shoulder/elbow/forearm, (2) wrist, (3) hand, and (4) coordination/speed

Delving deeper into the Fugl-Meyer assessment sections (refer to Fig. 4.5), the experimental group displayed a significant improvement in the shoulder, elbow, and forearm regions ($p = 0.002$). In contrast, the control group‘s progress was not statistically significant ($p = 0.062$). This observation aligns with the specific emphasis of the MyoMusic intervention on the shoulder, elbow, and forearm regions. As for wrist and hand rehabilitation, both groups registered significant progress. Specifically, the wrist exhibited significance levels of 0.04 and 0.008, and the hand at 0.005 and 0.039, for the experimental and control groups, respectively. In the domain of coordination and speed, neither group achieved significant progress. However, the experimental group exhibited a more pronounced improvement ($p = 0.12$) compared to the control group ($p = 0.33$).

Turning our attention to the Chedoke assessment (illustrated in Fig. 4.4), both groups made significant strides. Yet, while the control group‘s p value was borderline significant at $p = 0.046$, the experimental group showed a compelling level of significance at $p = 0.0002$.

The distinction between the experimental and control groups was the treatment regimen: The experimental group underwent 50 min of traditional physiotherapy combined with 10 min of MyoMusic intervention per session. In contrast, the control group solely received 60 min of traditional physiotherapy. Remarkably, the mere addition of 10 min with MyoMusic in each session resulted in noticeable improvements in the rehabilitation process for the experimental group. One direction of further research is to investigate the results of MyoMusic interventions with different lengths in order to assess the relative benefits of traditional physiotherapy and MyoMusic intervention.

The results reported in this chapter are based on a 25-session intervention with a post-evaluation right after the last session. Further research is needed to assess the long-term benefits of the intervention by evaluating both groups after a period of time as well as to assess the benefits of longer interventions. This will allow us to optimize the music-based intervention in terms of its duration per session and the number of sessions.

One of the advantages of using a digital music interface in stroke rehabilitation is that as all the motion data are processed by the computer, it is easy to monitor and track the patients' progress in a very precise manner. With MyoMusic, the data about limb position, orientation, velocity, reach, and muscle activity can be recorded and later analysed. Figure 4.6 shows the patients' average progress over the course of 25 sessions in terms of performed tempo (in beats per minute), the score computed by MyoMusic according to the number of correctly performed notes by the patients, and the arm reach, expressed as a percentage of the initial reach of each patient. As can be seen, there is a clear improvement in all three aspects. Although they played the pieces at a faster tempo every time, they kept improving their accuracy (i.e. MyoMusic score), and they had a wider arm movement.

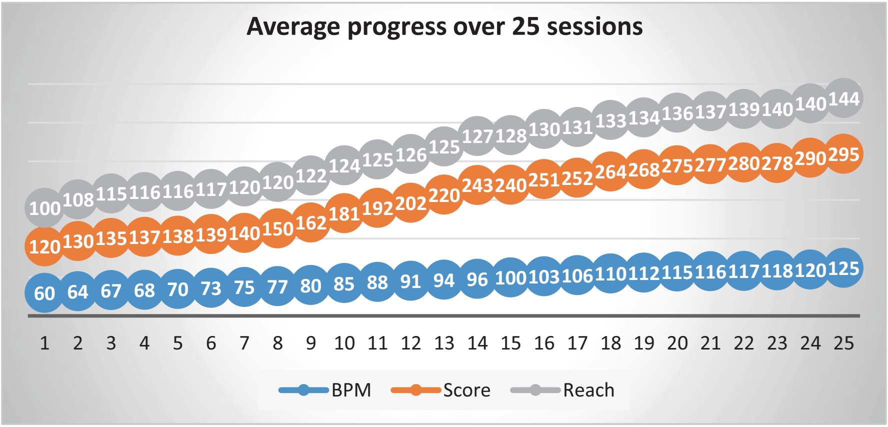

Fig. 4.6 Patients' average progress over the course of 25 sessions: performed tempo (in beats per minute) in blue, note accuracy MyoMusic score in orange, and arm reach (in %) relative to the initial reach in grey

4.4 Protocol: Music-Based Intervention for Stroke Rehabilitation

Objective: The overall objective of the intervention protocol is to improve motor recovery in chronic stroke patients through the use of music-based motor therapy. Specifically, the protocol aims to:

1. Enhance the effectiveness of a music-based motor therapy intervention compared to only traditional physiotherapy in improving motor recovery in chronic stroke patients.
2. Personalize the music-based motor therapy sessions to improve motor individual recovery in chronic stroke patients.
3. Maximize the extent to which the benefits of music-based motor therapy intervention generalize to other aspects of motor function, beyond the specific upper extremity movements targeted by the intervention.
4. Explore the potential mechanisms underlying the beneficial effects of music-based motor therapy on motor recovery in chronic stroke patients.
5. Assess the feasibility and acceptability of the music-based motor therapy intervention among chronic stroke patients and their caregivers.

By achieving these objectives, the intervention protocol aims to provide evidence-based guidelines for the use of music in stroke rehabilitation and to improve the quality of life of chronic stroke patients.

Population: Chronic stroke patients who have suffered from ischemic or haemorrhagic stroke within the previous 3 months, with normal hearing, affected by emiparesia or monoparesia, with no cognitive impairment.
Duration: 25 therapy sessions over the course of 6–10 weeks.
Outcome measure: Fugl-Meyer assessment for the upper extremities (FMA-UEs) as a primary outcome measure of motor recovery.
Protocol:

1. Patient evaluation: All patients will undergo an initial evaluation using the Fugl-Meyer assessment for the upper extremities (FMA-UEs) to determine baseline motor function.
2. The music preferences of each patient are identified in an interview. These preferences are then used to select music pieces that are integrated into the music therapy sessions, ensuring a personalized and engaging experience for each patient.
3. Treatment: Patients will receive 30 min of music-based motor therapy using either traditional music instruments or a motion-sensing-based adaptive music interface. Sessions should be individual and conducted by a professional and qualified music therapist. During the session, clients would perform familiar and simple melodies with clear rhythmical patterns using the affected limb, while the music therapist accompanies them with a traditional musical instrument. Arm movement span and melody tempo would be

adjusted at the beginning of each session according to the state and progress of each patient. If a motion-sensing-based adaptive music interface is used, motion data will be recorded in digital format (typically the same music interface will record the motion data).

4. Motor assessment: At the end of the treatment period, all patients will be evaluated using the Fugl-Meyer assessment for the upper extremities (FMA-UEs) to determine motor recovery. If motor data were acquired during the intervention, the data will be organized temporally and analyzed to assess progress within sessions.
5. Statistical analysis: The motor gains of both groups, as assessed by the Fugl-Meyer evaluation, will be analyzed to determine the effectiveness of the music-based motor therapy. The results will be compared and significance will be computed to determine the level of improvement. If data from a control group is available, the differences between the music therapy and control groups should be assessed.
6. Data interpretation: Results will be interpreted to determine the effectiveness of music-based motor therapy for improving motor recovery in chronic stroke patients.

Conclusion: The results of the intervention will be used to establish the effectiveness of music-based motor therapy in stroke rehabilitation.

4.5 Chapter Summary

This chapter discusses the potential benefits of integrating music and technology into stroke rehabilitation. Specifically, we present the findings of a randomized, double-blind, controlled, longitudinal clinical study that involved 30 chronic stroke patients. The control group (N = 15) received 60 min of traditional physiotherapy, while the experimental group (N = 15) received a music-based motor therapy using a motion-sensing-based adaptive music interface for 10 min in addition to the 60 min of traditional physiotherapy. Both groups underwent 25 therapy sessions over a period of 6 weeks. To measure motor recovery as the primary outcome, patients were blindly evaluated at the beginning and end of treatment using the Fugl-Meyer assessment for the upper extremities (FMA-UEs). At 25 sessions post-treatment, both groups demonstrated significant motor gains in wrist and hand movement. However, only the experimental group showed significant improvement ($p = 0.002$) in shoulder, elbow, and forearm movement as assessed by the Fugl-Meyer assessment. It is noteworthy that our music-based intervention specifically targeted these areas. These findings suggest that combining music and technology can be beneficial for improving motor recovery in chronic stroke patients. Based on these results, we proposed a music-based 25-session intervention protocol for stroke rehabilitation.

References

Altenmüller E, Schlaug G (2013) Neurologic music therapy: the beneficial effects of music making on neurorehabilitation. Acoust Sci Technol 34:5–12. https://doi.org/10.1250/ast.34.5

Altenmüller E, Marco-Pallares J, Münte TF, Schneider S (2009) Neural reorganization underlies improvement in stroke-induced motor dysfunction by music-supported therapy. Ann N Y Acad Sci 1169:395–405. https://doi.org/10.1111/j.1749-6632.2009.04580.x

Black M, Wang W, Wang W (2015) Ischemic stroke: from next generation sequencing and GWAS to community genomics? OMICS 19:451–460. https://doi.org/10.1089/omi.2015.0083

Ellis RJ, Thayer JF (2010) Music and autonomic nervous system (dys)function. Music Percept 27(4):317–326. https://doi.org/10.1525/mp.2010.27.4.317

Forsblom A, Laitinen S, Särkämö T, Tervaniemi M (2009) Therapeutic role of music listening in stroke rehabilitation. Ann N Y Acad Sci 1169:426–430

Fugl-Meyer AR, Jaasko L, Leyman I, Olsson S, Steglind S. (1975). The post-stroke hemiplegic patient. Scand J Rehabil Med 7:13–31

Gladstone D, Danells CJ, Black SE (2002) The Fugl-Meyer assessment of motor recovery after stroke: a critical review of its measurement properties Neurorehabil Neural Repair 16(3):232–240. https://doi.org/10.1177/154596802401105171

Hakkennes S, Keating JL (2005) Constraint-induced movement therapy following stroke: a systematic review of randomised controlled trials. Aust J Physiother 51:221–231. https://doi.org/10.1016/S0004-9514(05)70003-9

Koelsch, S. et al. (2010) Functional neuroimaging. In Music and Emotion (Juslin, P. and Sloboda, J.A., eds), p. 975, Oxford University Press

Morris D, Taub E, Mark VW (2006) Constraint-induced movement therapy: characterizing the intervention protocol. Europa Medicophysica 42(3):257–268

Peurala SH, Kantanen MP, Sjögren T, Paltamaa J, Karhula M, Heinonen A (2012) Effectiveness of constraint-induced movement therapy on activity and participation after stroke: a systematic review and meta-analysis of randomized controlled trials. Clin Rehabil 26:209–223. https://doi.org/10.1177/0269215511420306

Pulman J, Buckley E, Clark-Carter D (2013) A meta-analysis evaluating the effectiveness of two different upper limb hemiparesis interventions on improving health-related quality of life following stroke. Top Stroke Rehabil 20:189–196. https://doi.org/10.1310/tsr2002-189

Särkämö T, Tervaniemi M, Laitinen S, Forsblom A, Soinila S, Mikkonen M et al (2008) Music listening enhances cognitive recovery and mood after middle cerebral artery stroke. Brain 131:866–876. https://doi.org/10.1093/brain/awn013

Sauzet O, Kleine M, Menzel-Begemann A, Exner A-K (2015) Longitudinal randomised controlled trials in rehabilitation post-stroke: a systematic review on the quality of reporting and use of baseline outcome values. BMC Neurol 15:99. https://doi.org/10.1186/s12883-015-0344-y

Schlaug G (2009) Part VI introduction: listening to and making music facilitates brain recovery processes. Ann N Y Acad Sci 1169:372–373. https://doi.org/10.1111/j.1749-6632.2009.04869.x

Schlaug G, Norton A, Marchina S, Zipse L, Wan CY (2010) From singing to speaking: facilitating recovery from non-fluent aphasia. Future Neurol 5:657–665. https://doi.org/10.2217/fnl.10.44

Schneider S, Schönle PW, Altenmüller E, Münte TF (2007) Using musical instruments to improve motor skill recovery following a stroke. J Neurol 254:1339–1346. https://doi.org/10.1007/s00415-006-0523-2

Stevenson T, Thalman L, Christie H, Poluha W (2012) Constraint-induced movement therapy compared to dose-matched interventions for upper-limb dysfunction in adult survivors of stroke: a systematic review with meta-analysis. Physiother Can 64:397–413. https://doi.org/10.3138/ptc.2011-24

Thaut MH, Abiru M (2010) Rhythmic auditory stimulation in rehabilitation of movement disorders: a review of current research. Music Percept 27:263–269. https://doi.org/10.1525/mp.2010.27.4.263

Vamvakousis Z, Ramirez R (2016) The eyeharp: a gaze-controlled digital musical instrument. Frontiers Psychol 7(906):1–14. https://doi.org/10.3389/fpsyg.2016.00906