ANGLIA RUSKIN UNIVERSITY

HOME-BASED NEUROLOGIC MUSIC THERAPY FOR UPPER LIMB REHABILITATION IN CHRONIC STROKE: A PILOT STUDY

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A thesis submitted in partial fulfilment of the requirements of Anglia Ruskin University for the degree of Doctor of Philosophy

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ANGLIA RUSKIN UNIVERSITY ABSTRACT
FACULTY OF ARTS, LAW AND SOCIAL SCIENCES
DOCTOR OF PHILOSOPHY

HOME-BASED NEUROLOGIC MUSIC THERAPY FOR UPPER LIMB REHABILITATION IN CHRONIC STROKE PATIENTS: A PILOT STUDY

BY ALEXANDER STREET
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1 ABSTRACT

Background
Upper limb hemiparesis following stroke is more common and resistant to treatment than in the lower limbs. Motivating, repetitious, task-driven interventions are needed for acute and community stage patients, with rehabilitation increasingly delivered in the home. Research has produced statistically significant gains following musical instrument playing and rhythmically cued exercises. This pilot study builds on previous research, investigating a musically synchronized, home-based exercise protocol called Therapeutic Instrumental Music Performance. The study examines three new aspects: 1) home-based, 2) facilitating music, 3) twice weekly dosage.

Methods
11 NHS stroke patients with hemiparesis who had completed their community rehabilitation were recruited within a crossover design. Participants all received treatment, randomized by the statistician via an envelope system into either treatment (n=6) or waitlist (n=5) groups. The intervention was delivered twice weekly over 6 weeks in each participant's home and data was collected using the Action Research Arm Test at five timepoints over 18 weeks. A blind assessor conducted pre and post treatment measures. Qualitative data informed on participant compliance, motivation and tolerance.

Results
10 participants completed the study. There was no statistical significance found between early and delayed intervention. Whilst statistical significance was found between timepoint means for all participants, there was no correlation between the groups and so no statistical significance in treatment effects. Raw data for each participant indicates improvement between treatment periods and qualitative data indicates that participants clearly perceived the facilitating musical structures as helping their movement synchronization, and that the intervention was motivating.

Discussion
The emphasis of this pilot study was on testing the TIMP protocol, the feasibility of home delivery at this dosage, and informing on motivation and tolerance. Statistical significance was not predicted, however data analysis indicates that time since stroke may not be a factor influencing response to this protocol for patients matching this study cohort. A replicated study with a larger sample size would help to substantiate this.

Key words: Therapeutic Instrumental Music Performance (TIMP), Neurologic Music Therapy (NMT), stroke, hemiparesis, chronic

Trial registration: NCT 02310438

TABLE OF CONTENTS

Acknowledgements **ii**

1 ABSTRACT **iv**

2 LIST OF FIGURES **xi**

3 LIST OF TABLES **xii**

4 NOTATION **xiii**

1 CHAPTER 1. INTRODUCTION **1**
1.1 Introduction *1*
1.2 Prologue *1*
1.3 Choice of intervention to investigate *2*
1.4 Introduction to the thesis *3*
1.5 Aims of the study *3*
1.6 Significance of the study *4*
1.7 Overview of the methodology *5*
1.8 Overview of the thesis *6*

2 **CHAPTER 2. STROKE AND UPPER LIMB FUNCTION** **8**
2.1 Introduction *8*
2.2 Literature search method *9*
2.3 Defining stroke and stroke care *10*
2.4 Types of stroke *11*
2.5 The effects of stroke, recovery and rehabilitation *11*
2.6 Acute stage *12*
2.7 Sub-acute stage *12*
2.8 Chronic stage *12*
2.9 Home based rehabilitation *13*
2.10 Hemiparesis and movement disorders *15*
2.11 Spasticity *17*
2.12 Subluxation *18*
2.13 Upper limb recovery and rehabilitation *18*
2.14 CIMT *25*
2.15 Other considerations for upper limb rehabilitation *26*
2.16 Other effects of stroke *27*
2.16.1 Psychological effects 27
2.16.2 Depression 27
2.16.3 Emotionalism 28
2.17 Speech *28*
2.17.1 Aphasia 28
2.17.2 Dysarthria 28
2.17.3 Apraxia 29
2.18 The somatosensory and motor systems *29*
2.18.1 Somatic sensory impairment 29
2.18.2 The somatic sensory system 30
2.18.3 Higher motor control 33
2.19 Summary *35*

3 CHAPTER 3. MUSIC THERAPY, NEUROSCIENCE AND UPPER LIMB REHABILITATION **37**
3.1 Introduction *37*
3.2 Music therapy and NMT *38*
3.3 Neurologic music therapy *39*

3.4 Therapeutic instrumental music performance 41
3.5 Music supported therapy (MST) 45
3.6 The Ronnie Gardiner Rhythm and Music Method 50
3.7 Music performance and audio-motor coupling 50
3.8 Audio-motor coupling linked to Gestalt theory 52
3.9 Neuroplasticity 54
3.10 Maladaptive plasticity 55
3.11 Rhythm perception and processing 56
3.12 Music and rhythm, emotion and cognition 60
3.13 The NMT's application of theoretical knowledge 60
3.14 Summary 62

4 CHAPTER 4. TIMP MUSIC SELECTION AND COMPOSITION 63
4.1 Introduction 63
4.2 Social, cultural and scientific background of music 63
4.3 Music, mood and motivation 65
4.4 The influence of music and shifting musical parameters on movement perception and performance 66
4.5 Sonification 67
4.6 Auditory feedback in robot assisted arm training 67
4.7 Natural versus artificially manipulated and computer generated music 68
4.8 Rhythm and tempo 69
4.9 Suitability of metronomes, musical structures and pre-composed music 71
4.10 Rhythm, attention and external temporal frameworks 73
4.11 Summary 74

5 CHAPTER 5. STUDY AIMS 76
5.1 Introduction 76
5.2 Meeting the need for upper limp hemiparesis interventions 76
5.3 Potentially improving proprioception via audio-motor coupling 76
5.4 Using music to support movement kinematics 77
5.5 Home-based rehabilitation as part of current NHS stroke care pathway 78
5.5.1 Exploring reduced Dosage 78
5.6 TIMP study aims 79
5.7 Research questions 80
5.8 Study design 80
5.9 Purpose statement 81
5.10 Hypothesis 81

6 CHAPTER 6. METHODOLOGY, MUSIC AND TABLE OF TIMP EXERCISES 82
6.1 Study design 82
6.1.1 Inclusion criteria 82
6.1.2 Exclusion criteria 82
6.1.3 Rationale for study design 83
6.2 Quantitative data collection 86
6.3 Qualitative data collection 87
6.4 Recruitment 88
6.4.1 Participant demographics 88
6.4.2 Additional demographic and clinical description 89
6.4.3 TREATMENT GROUP PARTICIPANTS 90
6.4.4 WAITLIST GROUP PARTICPANTS 92
6.5 Sample size 93
6.6 Randomization 94
6.6.1 Waitlist group activities 94
6.6.2 Outcome measures 94

6.6.3 ARAT scoring system 96
6.6.4 ARAT tasks 97
6.7 The 9HPT *99*
6.8 Semi-structured interviews *100*
6.9 Set up time *103*
6.10 EEG *103*
6.11 Statistical analysis *103*
6.11.1 Resampling 104
6.11.2 Intervention 104
6.11.3 Instrument choice 105
6.12 Equipment *106*
6.13 Spatial arrangement and transportation of the instruments *107*
6.14 The TIMP chart *108*
6.15 TIMP music patterns *108*
6.16 Summary *121*
6.17 TIMP table of exercises *122*
6.18 Notes on using the TIMP chart *137*
6.19 Metronome settings *137*
6.20 Use of live music *138*
6.21 Pre-recorded TIMP Music *138*
6.22 Recommended iPad settings *138*
6.23 Additional Music Software *139*
6.24 Monitoring tolerance *140*
6.25 Volunteer stroke participant *141*
6.26 Ethics *142*
6.26.1 Full list of forms submitted for ethics application 142
6.27 Summary *143*

7 CHAPTER 7. MAIN RESULTS **145**
7.1 Introduction *145*
7.2 Study design overview *145*
7.3 Attrition *146*
7.4 Descriptive data *147*
7.5 Analysis for the primary research question *149*
7.5.1 ARAT group mean results 149
7.6 Analysis for the secondary research question *154*
7.6.1 Summary 154
7.6.2 Analysis 154
7.6.3 Data 156
7.6.4 Descriptive statistics of the data prior to statistical analysis 156
7.6.5 Analysis of variance of ARAT overall 158
7.7 Raw data from individual ARAT scores *164*
7.7.1 Summary of raw data 168
7.8 Nine hole peg test (9HPT) analysis for the primary research question *169*
7.9 Analysis of variance on 9HPT for the secondary research question *170*
7.9.1 Summary 170
7.9.2 Analysis 170
7.9.3 Data 172
7.9.4 Descriptive statistics of the data prior to statistical analysis 172
7.9.5 Statistical analysis and interpretation of results 173
7.9.6 Analysis of variance of 9HTP pegs per minute 174
7.10 Raw data from individual 9HPT scores *180*
7.10.1 Summary of 9HPT results 181
7.11 EEG analysis *181*

7.12 Qualitative analysis *182*
7.12.1 Pre-treatment thematic analysis 183
7.12.2 Interview question design 183
7.12.3 Interview procedure 184
7.12.4 Summary and discussion 186
7.12.5 Post treatment thematic analysis 186
7.12.6 Summary and discussion 190
7.12.7 Using the musical structures 191
7.12.8 Relationship 191
7.12.9 Preference 192
7.12.10 Tolerance, purpose and positive change 192
7.12.11 Likert scale 192
7.12.12 Summary of Likert scale results 194
7.12.13 Discussion of qualitative results 195
7.13 Conclusion of TIMP study results *195*
7.14 Discussion *197*
7.15 Summary *198*

8 CHAPTER 8. CASE STUDIES **199**
8.1 Introduction *199*
8.2 Socioeconomic Status (SES) *199*
8.3 Subjects' medical information *200*
8.4 Case study subject A: treatment group, left handed, tremors on affected hand, doesn't like music and 'can't play it' *201*
8.4.1 Background 201
8.4.2 Mobility and transferring 202
8.4.3 Methods/Treatment 202
8.4.4 Descriptive detail of sessions 204
8.4.5 Results 208
8.4.6 Summary and conclusion 209
8.5 Case Study subject B: Waitlist group, 88 years old, moderate dysarthria, visual impairment and possibly experiencing 'emotionalism' *210*
8.5.1 Background 210
8.5.2 Methods/treatment 211
8.5.3 Descriptive detail of sessions 213
8.5.4 Results 215
8.5.5 Summary 216
8.6 Case study subject C: treatment group, highly accomplished musician, loss of sensation in fingers *216*
8.6.1 Methods/treatment 217
8.6.2 Descriptive detail of sessions 219
8.6.3 Results 220
8.6.4 Summary 222
8.7 Development of a new TIMP pattern variation *222*
8.8 Comparative discussion of Case studies *223*
8.8.1 Severity of stroke 223
8.8.2 Socioeconomic status 223
8.8.3 Musical training 224
8.8.4 Handedness 224
8.8.5 Mobility, mood and other medical complications 224
8.8.6 TIMP patterns 225
8.8.7 Tempo 225
8.8.8 Conclusion 226
8.8.9 Relevance of the research to the literature reviewed 226

9 CHAPTER 9. Discussion and future studies 228
9.1 Introduction 228
9.2 Positive outcomes 228
9.2.1 Publications and conference presentations resulting from the research 229
9.2.2 Music and instruments 229
9.3 Music therapy: social science and neuroscience models in research 230
9.4 Recruitment from the three NHS community stroke teams 232
9.5 Assessment tools 233
9.5.1 Alternative outcome measures 236
9.6 Reflections 237
9.6.1 Ethics 237
9.6.2 Blind assessor 238
9.6.3 The influence of previous, similar research on treatment delivery 239
9.6.4 The influence of session length on treatment delivery 239
9.6.5 Playing time in each session 240
9.6.6 Usefulness of the prerecorded music 240
9.7 The role of the music therapist in research of this type 241
9.8 Discussion of TIMP music composition and selection 241
9.9 TIMP and MST 243
9.10 Instrument selection for fine motor exercises 244
9.11 iPads and other devices for fine motor control and finger dexterity 245
9.12 Future TIMP research for fine motor movement 246
9.13 Additional participant information relevant to results 246
9.13.1 Treatment group 247
9.13.2 Wait list group 249
9.14 Outliers 250
9.15 Limitations 250
9.15.1 Sample size 250
9.15.2 Inclusion criteria 251
9.15.3 Qualitative analysis 252
9.16 Preliminary thoughts for a larger TIMP study 253
9.16.1 Introduction 253
9.16.2 Research design 253
9.16.3 Research team for recruitment, treatment, data collection, analysis 254
9.16.4 Quantitative measures 255
9.16.5 Control group interventions 255
9.16.6 Inclusion criteria 255
9.16.7 Outcome measures 256
9.16.8 Potential addition of EEG 256
9.16.9 EEG procedure 257
9.16.10 EEG recording procedure 258
9.17 EEG analysis 259
9.18 Epilogue 260

10 APPENDICES 263
10.1 Appendix 1. Ethics forms 263
10.1.1 Letter of favourable opinion 263
10.1.2 Protocol accepted by the ethics committee 264
10.1.3 Scientific report 313
10.2 Appendix 2. Research forms 314
10.2.1 Letter of invitation 314
10.2.2 Participant information sheet 316
10.2.3 Participant consent form 319
10.2.4 GP information sheet 321

10.2.5 Normal scoring averages for the 9HPT 325
10.2.6 ARAT normative data 326
10.3 Appendix 3. Participants' semi-structured interview responses transcribed 327
10.4 Appendix 4. Photographs of the researcher performing some TIMP patterns 347
10.4.1 TIMP 1c 347
10.4.2 TIMP 8 347
10.5 Appendix 5. Extra tables from the data analysis 348

11 Bibliography 351

2 LIST OF FIGURES

Figure 1. The NHS stroke care pathway, showing the desired model with ESD teams (Care Quality Commission, 2011, p.9). 13
Figure 2. fMRI scan of healthy subjects and subjects with left hemisphere stroke. 17
Figure 3. Basic model of ballistic movement (Carpenter and Reddi, 2012, p.190). 32
Figure 4. Parametric feedback (Carpenter and Reddi, 2012, p.191). 32
Figure 5. Direct feedback (Carpenter and Reddi, 2012, p.191). 32
Figure 6. Internal feedback (Carpenter and Reddi, 1012, p. 193). 33
Figure 7. Brain regions involved in deciding, reaching, grasping. 34
Figure 8. PET scans showing brain activity in three rhythm listening tasks. (Thaut, 2008, pp.118-119). 40
Figure 9. Graphs of stroke patients' wrist movement trajectories 40
Figure 10. A model of TIMP and audio-motor coupling supporting the three components of localizing, reaching and grasping an object 44
Figure 11. A comparison of three ARAT scores from MST studies (Rodriguez-Fornells et al., 2012, p.284. 46
Figure 12. fMRI scans showing a reduction in bilateral brain activity post MST treatment (Rojo et al., 2011, p.6). 52
Figure 13. TIMP study consort. 85
Figure 14. The Action Research Arm Test (ARAT) 99
Figure 15. Pre-treatment interview form 101
Figure 16. Post treatment interview form 102
Figure 17. Chord spacings for the Smartpiano on the touchscreen. 107
Figure 19. Overall ARAT means and 95% confidence limits. 152
Figure 20. ARAT means and 95% confidence limits. 153
Figure 21. ARAT overall for each period in sequence 1 and 2 158
Figure 22. Histogram of residuals with Normal density curve 160
Figure 23. Q-Q plot of residuals 161
Figure 24. Residuals against fitted values 162
Figure 25. Mean ARAT overall for each sequence and period 163
Figure 26. Line graph showing the pattern of change over five assessments for treatment group participants. 165
Figure 27. ARAT scores over the five assessments for waitlist participants. 166
Figure 28. Bar graph showing pre and post ARAT scores for all 10 participants. 167
Figure 29. 9HPT pegs per minute for each period in sequence 1 and 2 173
Figure 30. Histogram of residuals with Normal density curve 175
Figure 31. Q-Q plot of residuals for 9HPT 176
Figure 32. 9HPT residuals against fitted values 177
Figure 33. Mean 9HPT pegs per minute for each sequence and period 179
Figure 34. EEG cap in position on a subject's head. 258

3 LIST OF TABLES

Table 1. Nine different movement disorders resulting from stroke. (Handley et al., 2009, p.260). 15
Table 2. Principle advantages and disadvantages of upper limb interventions. (Adey-Wakeling and Crotty, 2013, pp.9-13) 21
Table 3. Summary of MST study data relevant to this TIMP study. 48
Table 4. Participant demographic data for both groups 88
Table 5. Participant age at time of joining the study 89
Table 6. Comparison of clinical and demographic data from both groups. 89
Table 7. TIMP exercises. 123
Table 8. Age at admission (years) for waitlist and treatment groups. 147
Table 9. Period post stroke recruited for both groups. 148
Table 10. Categorical variables for treatment and waitlist groups. 148
Table 11. The difference in ARAT overall score means between treatment and waitlist. 149
Table 12. Continuous variables by intervention type. 151
Table 13. Summary of linear mixed-effects model with response variable ARAT overall score by intervention type and time point. 154
Table 14. ARAT analysis of two treatment orders 155
Table 15. ARAT overall by sequence and period 157
Table 16. Analysis of Variance summary table of ARAT overall, taking carryover effects into account 159
Table 17. Analysis of Variance summary table of the ARAT overall, with no carry over effects 163
Table 18. ARAT scores for each participant at all five timepoints. 165
Table 19. Comparing pre and post treatment ARAT scores for treatment and waitlist participants. 166
Table 20. Comparing raw data group ARAT scores, means and differences. 167
Table 21. Simple mean differences between treatment and no treatment groups. 168
Table 22. Difference between overall 9HPT score means for waitlist and treatment groups 169
Table 23. Continuous variables for all participants in the 9HPT 169
Table 24. Sequence and periods for 9HPT 171
Table 25. 9HPT pegs per minute by sequence and period 172
Table 26. Analysis of Variance summary table of 9HPT pegs per minute, taking carryover into account 174
Table 27. Analysis of Variance summary table of 9HPT pegs per minute, with no carryover effects 178
Table 28. 9HPT raw scores for each participant. 180
Table 29. Pre and post intervention 9HPT scores for all participants. 181
Table 30. Pre-treatment themes from semi-structured interviews. 185
Table 31. Post treatment themes from semi-structured interviews. 187
Table 32. Pre and post Likert scale ratings shown against pre and post ARAT scores for each participant. 194
Table 33. Demographic and clinical data for the three case studies. 201
Table 34. Demographic data for Case study subject A. 202
Table 35. TIMP patterns used in each session. 203
Table 36. Tempo settings for subject A. 204
Table 37. ARAT scores at five timepoints for subject A. 208
Table 38. ARAT 'Grip' subscale task 7 score (pouring water). 208
Table 39. 9HPT scores. 209
Table 40. Case study subject B demographic and assessment data. 211
Table 41. TIMP patterns used by subject B. 212
Table 42. Tempo ranges for subject B. 213
Table 43. ARAT and 9HPT scores for subject B 215
Table 44. Demographic data for case study subject C. 217
Table 45. TIMP patterns used ny subject C in 11 sessions. 218

Table 46. Tempo ranges in each session for subject C. _____ 219
Table 47. ARAT and 9HPT scores for subject C _____ 220
Table 48. ARAT subscale scores for subject C. _____ 221
Table 49. Subject C time taken to complete Grip and Pinch subscales. _____ 222
Table 50. ARAT 'Pinch' subscale scores for participant three. _____ 248

4 NOTATION

Notation i. TIMP 1 110
Notation ii. TIMP 2 111
Notation iii. TIMP 3 & 4 112
Notation iv. TIMP 5 112
Notation v. TIMP 5 variation 114
Notation vi. TIMP 6 114
Notation vii. TIMP 6 variation 115
Notation viii. TIMP 7 115
Notation ix. TIMP 8 116
Notation x. TIMP 10 117
Notation xi. TIMP 10 variation 118
Notation xii. TIMP 11 119
Notation xiii. TIMP 12 120
Notation xiv. TIMP 12 variation 120

ENCLOSED MATERIALS

A compact disc containing recordings of the fascilitating music for each exercise is attached at the back of this thesis or available upon request from the researcher in the form of audiofiles. Note that the same music is used for TIMP exercises three and four (track 3 on the CD). The music is played by the researcher on a Ramirez classical guitar and was recorded directly onto Garageband music software on an iPad, using the built-in microphone. The recordings are the same as those used in sessions with participants. By each transcription of the music there are speaker symbols, which in the electronic version of the thesis can be clicked on to play the audio. Otherwise the CD/audiofiles can be used. There are no recordings of the alterantive patterns.

A video clip (see Figure 19) can also be viewed by clicking on the figure in the electronic version of the thesis, by playing the DVD in hard copies or by requesting a video file via e-mail from the researcher. This shows the volunteer stroke participant playing some of the TIMP patterns and is included with her full consent.

LIST OF ABBREVIATIONS AND DEFINITIONS OF TERMS

ADLs

Activities of Daily Living, such as personal care and food preparation

Abduction

Used to describe arm movements away from the body

Adduction

Used to describe arm movements towards and across the body

ARAT

Action Research Arm Test

Bpm

Beats per minute

CCS NHS Trust

Cambridgeshire Community Services National Health Trust

Contralateral

Used when referring to physical function on the opposite side of the body to the hemisphere where the stroke has occurred (the lesion site)

CVA

Cerebrovascular accident, or stroke

Distal

Smaller muscles and muscle groups such as those in the forearm, wrist and fingers that are further from the head and shoulders

ESD

Early supported discharge team, teams of therapists and professionals providing stroke rehabilitation services in the community

Extension

Straightening or extending at the joint, for example elbow reaching

Flexion

Bending of a joint, for example bending the elbow or knee

Haematoma

A localized build up of blood within the tissue but outside of the blood vessels, which, if it continues to collect and increase in size, requires surgical removal

HSP

Hemiplegic Shoulder Pain

Ipsilateral

A term used to describe physical function on the same side of the body as the brain hemisphere where the stroke has occurred.

MST

Music Supported Therapy

NHS

National Health Service

NMT

Neurologic Music Therapy

9HPT

Nine Hole Peg Test

Oedema

Fluid retention in the body causing swelling of the surrounding tissue

PEG

Percutaneous endoscopic gastronomy, tube inserted into the stomach (peg site) for intake of nutrition where the patient cannot take food orally

Pronation

Forearm rotation into the palm up position

Proximal

Joints and muscle groups closest to the upper body, in the case of the arm this would be those larger muscles in the shoulder and the biceps and triceps

RAS

Rhythmic Auditory Stimulation

Sensorimotor

Refers to the integration of the sensory and motor systems and the information gathered via the senses that is used to plan useful or functional motor actions

Subluxation

Partial dislocation of a joint, often the shoulder in people with stroke

Supination

Forearm rotation into the palm down position

TIMP

Therapeutic Instrumental Music Performance

Copyright declaration

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1 CHAPTER 1. INTRODUCTION

1.1 Introduction

This doctoral thesis presents a report on a randomized control trial, using a crossover design with repeated measures, comparing early and delayed intervention between two groups. The trial investigated the treatment effects of a Neurologic Music Therapy (NMT) intervention for upper limb hemiparesis with a projected 14 stroke patients recruited through the NHS, 10 of who completed the study, at the end of their statutory, community rehabilitation. Patients were recruited from Cambridgeshire Community Services (CCS) NHS Trust community stroke teams. They received all five assessments and six weeks of twice-weekly NMT in their home.

The following paragraphs in this chapter present the background, aims and significance of the study, an overview of the methodology, followed by an outline of the thesis.

1.2 Prologue

NMT training in 2009 presented research on and techniques for sensorimotor, communication and cognitive interventions with adults and paediatric populations. This training suited my thinking and approach to music therapy work, also bringing resolution to previous clinical experiences that had lacked supervisory support as very few clinicians had experience in applying neuroscience theoretical models and even fewer had any NMT training.

Upper limb rehabilitation became the focus of this study due to my clinical experience of using NMT sensorimotor techniques in neurodisability and special educational settings, seeing the positive results, but struggling to develop and fully establish effective assessments and protocols for people with stroke who have diverse needs. Studies were emerging that evidenced the efficacy for NMT techniques, more so for lower limb than upper, and I saw great potential if I could add to this evidence, particularly in the UK, where music therapy is more widely taught and practiced

within a social science framework as an intervention employing psychodynamic models for addressing emotional and psychological well-being.

1.3 Choice of intervention to investigate

A recent ochrane review of music therapy for acquired brain injury recommended further research into the effects of rhythm driven sensorimotor interventions for people with stroke based on the evidence from Rhythmic Auditory Stimulation (RAS) gait training studies that were included in the review. TIMP has not been widely researched and requires the additional element of music to which upper limb movements are synchronised. Another quite new technique for treating upper limb hemiparesis, MST, has been evidenced as effective through several studies in recent years and does not include facilitating music. For these reasons I chose to investigate TIMP as an intervention for stroke induced hemiparesis and to focus also on the selection and composition of the facilitating music.

During the planning of this research it became apparent that it could not be conducted at acute stage, with in-patients. This was due to the intense pressure that NHS stroke wards are under to deliver effective treatment as part of standard care and to discharge patients to their homes as quickly and safely as is possible in order to make available beds for new patients and in order that those discharged may be referred for community rehabilitation. Initially, following a meeting with the clinical lead of the stroke team, a large hospital in Cambridge had agreed to host the study, but then retracted the offer due to concerns regarding the extra pressure that it might put on the physio and occupational therapists.

Music therapy is not recognised by NHS trusts, other hospitals, or medical legal organisations, as a short-term intervention for hemiparesis, whereas those interventions offered by occupational and physical therapists as part of standard care are. Music therapy could not, therefore fit into the current stroke care pathway at the acute stage. The manager of CCS NHS trust, with whom I had been liaising with for a year or two prior to this research opportunity coming about, was extremely keen to accommodate the research on hearing about it. He and I immediately began discussing the prospect of recruiting people with stroke from the three stroke

rehabilitation teams that he managed, after they had completed standard community rehabilitation in their homes. In this way, the research evolved into a home-based pilot study.

1.4 Introduction to the thesis

There are limited interventions available for people with stroke, which effectively treat upper limb hemiparesis. Most rehabilitation is delivered in the home environment by community services comprising multidisciplinary health professionals. Interventions using rhythm, music and musical instrument playing have proved effective in improving upper limb function in hemiparesis in several studies, which will be presented and discussed in the literature review.

A music therapy intervention for upper limb hemiparesis has not been previously trialled in the home, at a frequency of twice weekly and with music as a facilitating framework to which movements are synchronised.

This thesis will guide the reader through the background to this research study, including the relevant literature, the aims and the methods used to achieve these aims and the results. Results will include primarily quantitative data, but with some qualitative data gathered in order to inform on participant experience. It is hoped that the reader will find the thesis structure clear and logical, the information and detail satisfactory, and the conclusions drawn from the results useful in informing future provision for the treatment of upper limb hemiparesis following stroke, particularly in the home environment.

1.5 Aims of the study

The aim of this study is to compare the efficacy of Therapeutic Instrumental Music Performance (TIMP) as a delayed or immediate short-term, home-based intervention for upper limb hemiparesis where statutory community rehabilitation has come to an end. It is hoped that the study will inform and improve future provision for this patient group and condition. The intervention was delivered in participants' homes, twice weekly and with facilitating music; aspects which have not been previously

studied. In addition to the quantitative measures used, qualitative data was also gathered as this is a novel intervention, not widely known or available within the UK, for which patient feedback will inform in terms of preference, tolerance and motivation to engage, all of which are crucial factors affecting outcomes for this patient group.

1.6 Significance of the study

Weakness on one side, or hemiparesis, is the most commonly encountered sensorimotor impairment resulting from stroke (Lawrence et al., 2001), with the upper limb reported as being more resistant to treatment than lower limb (Thaut et al., 2002). Effective upper limb treatments are lacking (Schneider et al., 2007; Altenmüller et al., 2009) and a review of current evidence for upper limb interventions reported a paucity of trained staff and treatment centres and a need for purpose-driven interventions that effectively target patient attention and motivation (Adey-Wakeling and Crotty, 2013). Evidence is emerging that indicates during the chronic stage of recovery, which is approximately defined as more than three months post onset, people with stroke have the capacity to continue making functional improvements (Barrett and Meschia, 2013). Community services, sometimes referred to as 'early supported discharge teams' (ESD) are reported to improve outcomes for (Donnelly et al., 2004), but an audit in 2010 recorded only 36% of hospitals in the UK were providing such services (Department of Health, 2010. p. 8).

Studies investigating the effects of instrumental playing on upper limb hemiparesis have produced positive results (Paul and Ramsey, 1998; Yoo, 2009) and statistically significant gains for participants' upper limb function (Schneider et al., 2007; Altenmüller et al., 2009; Schneider et al., 2010). Studies have also recorded neural reorganisation following MST and music listening exercises using electroencephalogram (EEG), functional magnetic resonance imaging (fMRI) and transcranial magnetic stimulation (TMS) (Altenmüller et al., 2009; Rojo et al., 2011; Rodriguez-fornells et al., 2012; Grau-Sánchez et al., 2013). A need has been highlighted for further research to support limited evidence for music therapy

interventions in the case of hemiparesis following stroke, particularly exploring the effects of rhythm and of dosage (Bradt et al., 2010).

The study reported here builds upon the existing evidence from the aforementioned studies and the emerging scientific evidence regarding music's effect on neuroplasticity (Magee et al., 2006; Craig, 2008; Malcolm, Massie and Thaut, 2009a; Hill et al., 2011; Altenmüller and Schlaug, 2013a; Altenmüller and Schlaug, 2013b), translates it into a home-based clinical protocol and examines the results. Thus, it adds to limited, existing research into the effects of musical instrument playing, rhythm and music on upper limb rehabilitation following stroke. Furthermore, this thesis contributes towards music therapy literature that focuses on the effects of clinical interventions, of which, it has been reported through literature review, there is surprisingly little (Gallagher, Mullan and Tolman, 2014). It addresses questions concerning timing of treatment delivery (delayed or immediately following completion of community rehabilitation), dosage and setting. Whereas most of the research to date on this topic has been in the form of 'pure research' and laboratory based, this study provides a novel intervention that was delivered one-to-one, in participants' homes. It therefore examines the feasibility as well as the effects of home treatment delivery at the end of standard NHS community care. Frequency of sessions was reduced compared to earlier studies, in order to determine effects at a lower dosage and to ensure that the sample size could be treated within the timeframes and resources available for this pilot study.

1.7 Overview of the methodology

This study is categorised as experimental applied research, which focuses directly on the effects of a clinical intervention, delivered as community rehabilitation, where there are many variables compared to more controllable laboratory research environments.

Quantitative behavioural data regarding changes in upper limb function was gathered using, primarily, the Action Research Arm Test (ARAT) (Lyle, 1981), within a crossover design with five repeated measures. Pre and post treatment measures were conducted by a NHS therapist who was blind to group allocation. Participants with

upper limb hemiparesis resulting from a stroke who met the inclusion criteria were randomized into either treatment (n = 6) or waitlist group (n = 4). The waitlist group received treatment nine weeks after completing community rehabilitation; the treatment group commenced immediately following randomization. Early and late intervention group results were analysed and compared using an analysis of variance and a linear mixed-effects linear model (see 7.3). All participants eventually received music therapy in their home, during which they played through musical patterns selected from a chart of 12 (see Table 7) designed specifically for this study and formulated through patient collaboration and consultation prior to recruitment. Qualitative data was collected by the researcher using a semi-structured interview at pre and post-treatment assessment points, just before and just after the six weeks of twice-weekly music therapy. The methodology is fully described in CHAPTER 6. METHODOLOGY, MUSIC AND TABLE OF TIMP EXERCISES.

1.8 Overview of the thesis

There are three literature review chapters to this thesis. The first is CHAPTER 2. STROKE AND UPPER LIMB FUNCTION which presents literature regarding the causes and effects of stroke and available interventions, as well as some explanation of the somatosensory and motor systems, which is pertinent to the intervention effects under examination. CHAPTER 3. MUSIC THERAPY, NEUROSCIENCE AND UPPER LIMB REHABILITATION then covers relevant research involving rhythm, music and instrumental playing applied for the purposes of upper limb rehabilitation. CHAPTER 4. TIMP MUSIC SELECTION AND COMPOSITION begins with a very brief summary of the therapeutic origins of music. It then presents research specific to music and rhythm perception and music and movement, which informed the researcher's composition and selection of music for each TIMP exercise. CHAPTER 5. STUDY AIMS links the literature reviewed in a more condensed form with the study aims, CHAPTER 6. METHODOLOGY, MUSIC AND TABLE OF TIMP EXERCISES, includes full details of the research design, the TIMP music transcriptions and descriptions, and the chart showing 12 TIMP exercise patterns and variations. CHAPTER 7. MAIN RESULTS begins with quantitative group data, discussion of results and conclusion, followed by the thematic analysis from the semi-structured interviews.

In CHAPTER 8. CASE STUDIES, describes the demographic data and details from sessions of three participants in order to inform on the process of delivery, participation, tolerance and motivation. CHAPTER 9. Discussion and future studies presents a discussion of the limitations of the study and reflections on the research process, including ethics application. Preliminary thoughts for a larger TIMP study outlines plans for a potential study encorporating more precise outcome measures across three georgraphically separate UK NHS sites.

The appendix contains all forms submitted to the NHS ethics committee in order to obtain full approval and some additional information regarding the setting up of equipment and photographs to illustrate how instruments and equipment were used. A CD at the back of the thesis contains recordings of the TIMP music patterns that were used in the study, the transcriptions for which are included in CHAPTER 6. METHODOLOGY, MUSIC AND TABLE OF TIMP EXERCISES.

2 CHAPTER 2. STROKE AND UPPER LIMB FUNCTION

2.1 Introduction

The following sections that comprise the first of three literature reviews for this doctoral thesis aim to guide the reader through the causes and effects of stroke, or cerebrovascular accident (CVA), and some of the ways in which the diagnosis and treatment of symptoms are managed. There will be some discussion of the brain regions and neural networks involved in the planning and execution of upper limb movements, including somatosensory systems. This is in order to demonstrate the wide range of systems potentially disrupted by stroke and the resulting heterogeneity of symptoms presented in the paretic upper limb. Review of this literature will help clarify why the research questions are being asked and why they are being addressed by employing this particular methodology and protocol design. CHAPTER 5. STUDY AIMS links the literature to the study aims in a more condensed form, which will hopefully aid the reader in following the methodology, results, conclusion and discussion.

In addition to discussing the causes and effects of and treatment for upper limb hemiparesis, there will also be some discussion of how cognitive, communication and psychological impairment from stroke can affect patient engagement, compliance and tolerance in upper limb rehabilitation and influence outcomes. Where possible the researcher has provided statistics on incidence of stroke, treatment and hospital length of stay from UK research and populations, as these are most relevant to this study, for which participants have been recruited from a community NHS trust.

CHAPTER 3. MUSIC THERAPY, NEUROSCIENCE AND UPPER LIMB REHABILITATION forms the second literature review, covering music therapy and NMT in relation to neuroscience and upper limb rehabilitation, with some focus on rhythm processing and music therapy research, which has aimed at rehabilitating upper limb hemiparesis. Some of this research has produced robust scientific evidence

for the effects of music and rhythm on driving neuroplasticity, improving movement kinematics and arm use for people with stroke in their activities of daily living (ADLs). Discussion of this research will help draw out both the rationale for this study, it's design and treatment protocol and the gap in knowledge that it informs.

CHAPTER 4. TIMP MUSIC SELECTION AND COMPOSITION presents research relevant to the composition process and selection of music by the researcher for the TIMP patterns. This element of the study is important to detail, as it is relatively new and not widely reported in research of this nature. Although the effects of rhythm and music on movement have been described in key literature regarding NMT and TIMP (Thaut, 2008), together with guidelines for music selection, this information was not referenced and linked to any specific research to support it. The researcher has provided a review of some of the literature regarding the influence of music on mood, motivation and attention, on rhythm perception, music and perceived motion and the use of metronomes, artificially generated music and natural music to support motor entrainment.

2.2 Literature search method

As well as academic data bases, the bibliographies of two core NMT text books (Thaut, 2008; Thaut and Hoemberg, 2014) were used to source further research and articles associated with sensory motor techniques used for upper extremity treatment. Search terms to find articles and literature specifically relevant to music, music therapy, stroke and upper limb hemiparesis, as well as music and movement were input using the Anglia Ruskin University library, PubMed and Google scholar as follows: 'NMT', 'music therapy', 'music', 'rhythm', and 'instrumental playing' combined with 'stroke', 'chronic', 'hemiparesis', 'upper limb', 'movement' and 'movement disorder', 'rehabilitation', 'community rehabilitation', 'recovery', 'statistics'. Some authors and review authors were also contacted either in-person or via ResearchGate, in order to obtain relevant publications.

Websites and databases accessed:

http://www.researchgate.net
Gale Cengage Academic One File

PubMed Central Journals

NESLi2 Wiley Online Journals

Cochrane Library

Oxford Journals 'Music Therapy Perspectives'

The Nordic Journal of Music Therapy http://www.tandfonline.com/toc/rnjm20/current

Science Direct

2.3 Defining stroke and stroke care

There are approximately 152,000 people affected by stroke in the UK every year (British Heart Foundation, 2012) causing more disability in adults than any other disease or condition. In more than 50% of cases severe disability is reported (Adamson, Beswick and Ebrahim, 2004b) and long-term dependency on others for support with activities of daily living (ADLs) in their home (Adamson, Beswick and Ebrahim, 2004a). The mean length of stay in hospital for stroke patients in the UK has fallen from thirty-two days in 2000 to twenty days in 2010 (British Heart Foundation, 2012). ESD and other community based rehabilitation teams are reported to improve outcomes, but an audit in 2010 recorded only 36% of hospitals in the UK were providing such services (Department of Health, 2010). A shortfall in spending on chronic stroke rehabilitation is also reported in the US (Miller et al., 2010), despite improvements in outcomes being evidenced in studies up to five years post stroke (Fens et al., 2013).

Published stroke registries (Barrett and Meschia, 2013) in the United States from the 1970s and 80s recorded a predominance for early to mid-morning strokes, which indicates that many people wake up with their symptoms. A substantial proportion also suffer their stroke whilst alone. This has implications for meeting the recommended neural imaging timescale in urgent cases, and for physicians in determining appropriateness of pharmacological treatment within their defined window of opportunity, as they need to know when the patient was 'last known well'; with no symptoms. Once the time when symptoms were absent has been established, a stroke scale may be used, such as the National Institutes of Health Stroke Scale (NIHSS) (Adams et al., 2007), which assesses and scores areas of function most commonly effected. Other factors such as blood sugar levels and blood pressure are

crucial in determining treatment suitability. For example, a blood pressure reading of more than 185/110mmHg, which cannot be corrected, would be a contraindication for treatment using intravenous medication, such as tissue plasminogen activator, which is usually given as soon after onset of ischaemic stroke as possible (Barrett and Meschia, 2013) and can significantly reduce cell damage.

2.4 Types of stroke

Clinical diagnosis through tests and the observation of signs and symptoms, in addition to tissue diagnosis or brain imaging is required following stroke (Barrett and Meschia, 2013). Brain imaging is recommended within 12 hours of hospital admission, or within one hour of onset where urgent treatment is required (Intercollegiate Stroke Working Party, 2012).

Of the two distinct types, Ischaemic strokes occur when blood vessels become blocked, causing starvation of oxygen and nutrients to surrounding parts of the brain and resulting in cell death in those parts. Approximately 85% of strokes are ischaemic (Intercollegiate Stroke Working Party, 2012).

Hemorrhagic strokes are the result of blood vessels in the brain bursting, bleeding and causing an increase in pressure on surrounding areas of the brain. About 15% of strokes are caused by bleeding in the brain due to aneurysms and arteriovenous malformation (AVM), and the symptoms tend to be more severe than in ischaemic stroke (Intercollegiate Stroke Working Party, 2012).

Transient ischaemic attacks (TIA), or ‘mini strokes’ are smaller, usually less severe strokes caused by temporary disruptions in the supply of blood and nutrients to a part of the brain. A TIA can cause disturbances in speech and vision, loss of sensation or weakness in the face, arms and legs. These effects will usually last for minutes or hours and resolve within 24 hours, but are taken as a warning sign for further vascular events (Bartlett, 2008).

2.5 The effects of stroke, recovery and rehabilitation

Each person who suffers a stroke will be affected differently, depending on the site or sites (location/s in the brain), side or hemisphere (sometimes lesions can occur in both hemispheres, known as bilateral strokes), and, more significantly, the severity of the

stroke (Coupar et al., 2012). A right hemisphere stroke may cause visuo-spatial, short-term memory, or judgement and behavioural problems, whereas a left hemisphere stroke usually causes problems with language and memory, with slow and cautious behaviour observed (Safranek, 2011). Other factors such as socioeconomic status, personal circumstances and individual personality traits might also influence level of recovery and should be considered when allocating treatments and services (Putman et al., 2007; Adey-Wakeling and Crotty, 2013).

2.6 Acute stage

In-patient acute rehabilitation, defined as being between 24 hours and 4 weeks post stroke onset (Barrett and Meschia, 2013), is usually provided only where patients continue to present with severe impairments, a procedure which is based on evidence that indicates this as being the phase where most recovery occurs (Fens et al., 2013).

2.7 Sub-acute stage

The majority of rehabilitation incorporating physical, occupational and speech therapies takes place at the sub-acute phase, defined as one to three months following onset. Treatment is delivered as part of outpatient services in rehabilitation centres (Barrett and Meschia, 2013).

2.8 Chronic stage

This stage is approximately defined as being more than three months post onset, and evidence is emerging that indicates during this stage of recovery people with stroke have the capacity to continue making functional improvements (Barrett and Meschia, 2013). EEG recordings have shown that electrical activity in the motor cortices continues to change and improve beyond the point at which good motor and ADL recovery is still being detected using standard assessment tools with those who have Barthel Index scores of >60 (Mahoney and Barthel, 1965) and who are up to 7 months post stroke (Giaquinto et al., 1994). This indicates further potential for recovery and, consequently, justification for continued rehabilitation provision. Below is a flow chart illustrating the changing care pathway for people with stroke.

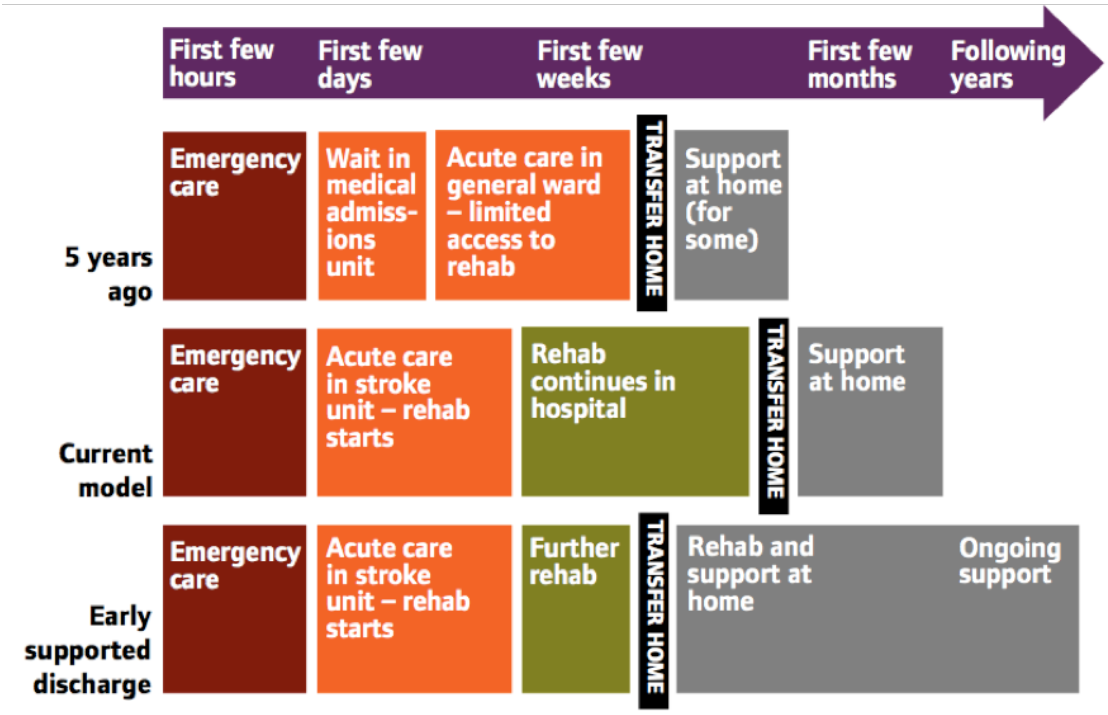


Figure 1. The NHS stroke care pathway, showing the desired model with ESD teams (Care Quality Commission, 2011, p.9).

2.9 Home based rehabilitation

Since the aim of NHS trusts and healthcare systems across the Western world (Schmid, 2010) is to increase the provision of home-based, out-patient rehabilitation services for people with stroke, it is important to briefly report on the current status, which will also clarify the significance of this pilot study as a home-based music therapy intervention. As stated earlier, only 36% of hospitals in the UK were reported as providing community rehabilitation via ESD teams (Department of Health, 2010). A systematic review of research into community based multidisciplinary care between 1980 and 2012 identified 14 RCTs for inclusion, seven of which were UK based trials (Fens et al., 2013). The authors found that 11 of the studies that assessed daily activities found no benefits for participants. They concluded that more accurate detail should be provided in future studies, in particular the trial design and treatment delivery. The UK trials included compared the MDT treatment with standard care. MDT treatment was of low dosage or not clearly specified, for example ‘three times in two months’, ‘one assessment visit and then as long as needed’, ‘until maximum

recovery'. One UK study included in the review compared intensive home-based therapy, which was six or more sessions per week, with less intensive, which was three or less sessions per week (Ryan, Enderby and Rigby, 2006). As well as people with stroke, elderly patients who had suffered hip fracture were also recruited for the study, but data was analysed separately. The outcome for those with stroke indicated that the more intensive dosage may have resulted in more short-term benefits in social participation and certain aspects of health-related quality of life. An identified weakness of the study, contributing to a lack of significance in the results, was the omission of detail regarding description of treatment in the extra sessions. There may, therefore, have been a qualitative difference between the treatment of the two groups.

Twenty studies were included in a review of home-based music therapy, none of which were UK based and none of which included people with stroke (Schmid, 2010). In contrast to the Ryan et al review of home-based MDT interventions previously discussed, the methodological quality of these publications was considered quite high, with the majority reporting a reduction in symptoms and improved quality of life for those participating.

These two review articles reveal a difference in the quality of the design and reporting between MDT and music therapy research, with the music therapy studies reporting more detail on the study design and treatment protocol than the MDT studies. The researcher speculates that one reason for this may be due to standard care therapies being much more established and accepted than music therapy and NMT, thus music therapy researchers exercise more rigor and care in research design and reporting in order to accurately investigate, gather valid data and gain integrity for their profession. It is also true to say that NHS health professionals cater for a much larger population of patients as part of an established nationwide stroke care pathway, where they cater, within their separate teams, to the needs of each individual. It is not, therefore, in the best interest of patients, nor feasibile, to deliver standardized treatments in universally prescribed doses and to assess each patient using the same tools. Added to this, there is no substantial scientific evidence to support interventions used in standard care (Pollock et al., 2014).

2.10 Hemiparesis and movement disorders

Weakness on one side, or hemiparesis, is the most commonly encountered sensorimotor impairment following ischaemic or haemorrhagic stroke (Lawrence et al., 2001), occurring in 80% of people with stroke (National Stroke Association, 2013) and with 40% having persistent lack of arm function (Intercollegiate Stroke Working Party, 2012). Hemiplegia is more severe than hemiparesis as there is usually complete, rather than partial, and permanent paralysis of one side of the body. This lack of use on one side has a profound effect on mobility and ADLs such as walking, dressing, washing, preparing food, eating and writing. Other movement disorders may occur at onset of the stroke, some time after (several years in some cases), or as a progressive condition (Handley et al., 2009)**.** Such disorders, briefly described in Table 1, can be caused by lesions in many areas of the motor circuitry, commonly in the basal ganglia or thalamus.

Table 1. Nine different movement disorders resulting from stroke. (Handley et al., 2009, p.260).

Hemichorea—unilateral, rapid involuntary motions of flexion and extension, rotation or crossing, which may involve all body parts, but predominantly distal parts
Hemiballismus (hemiballism)—severe, violent, arrhythmic and large amplitude excursion of a limb from a proximal joint with an element of rotation
Dystonia—a syndrome characterised by prolonged muscle contractions causing sustained twisting movements and abnormal postures of the affected body part(s)
Tremor—rapid rhythmic oscillation generally of the hands. In some cases wrist weights have been found to reduce symptoms
Myoclonus—sudden, involuntary jerking of a single muscle or a group of

muscles
Athetosis—slow, sinuous, writhing movements affecting mainly the hands and feet
Pseudoathetosis—abnormal writhing movements, usually of the fingers, caused by a failure of joint position sense (proprioception)
Asterixis—failure to sustain muscle contraction during postures with intermittent, generally arrhythmic lapses in muscle tone
Parkinsonism—triad of bradykinesia, increased tone and tremor

Not included in the table above, is upper limb apraxia, a disorder of higher motor cognition that is more commonly reported following left hemisphere CVA and requiring specific assessment and treatment (Stamenova, Black and Roy, 2012; Dovern, Fink and Weiss, 2012). The symptoms in the upper limbs are a loss of ability to imitate gestures, both symbolic and abstract, and to 'pantomime' (pretend to use by grasping the imagined objects) the use of objects and tools. Deficits are also observed in actual use of objects, particularly where a complex sequence of movements is required involving multiple objects. An example of the latter would be making a cup of tea, commonly requiring the use of tap, kettle, cup, milk and teaspoon, using grip, grasp, forearm rotation and reaching movements. Treatment and assessment tools for upper limb apraxia are still in the early stages of development, with only a handful of RCTs that have been conducted (Dovern, Fink and Weiss, 2012). The recommended treatment is 'gesture training', the effects of which have been shown to persist for at least two months. Tasks should be tailored towards each patient's individual ADLs and living environment, which would correspond with 'Repetitive task-specific training', summarised in Table 2.

The following fMRI images clearly show the differences between healthy subjects and those with left hemisphere lesions when moving their paretic right hand (Grefkes and Fink, 2011). fMRI detects changes in blood-flow, carrying glucose and oxygen to the brain regions that are activated due to the subject's efforts to perform the task.

Scan ‘A’ in , Figure 2 shows bilateral activity (activity in both hemispheres) in the stroke patient when moving the right hand, compared to the scan on the right, which shows activity that is expected in the left hemisphere when moving the right hand in normal subjects. Image ‘A’ shows right hand movement and image ‘B’ shows left hand movement (Grefkes and Fink, 2011, p.1265).

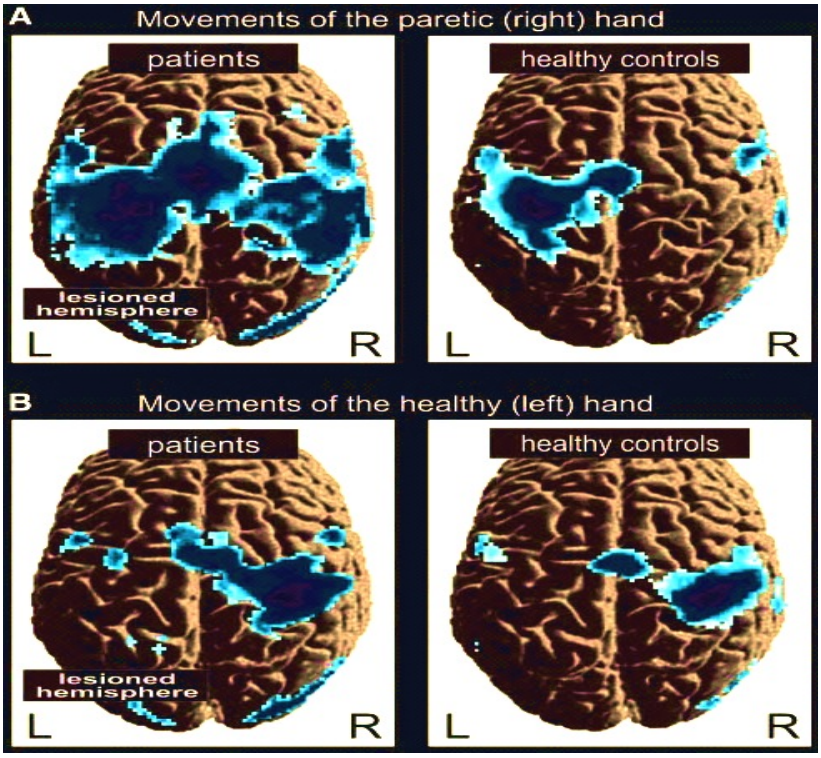


Figure 2. fMRI scan of healthy subjects and subjects with left hemisphere stroke.

2.11 Spasticity

Spasticity occurs in approximately 30% of stroke cases (Mayer and Esquenazi, 2003). Onset can be immediately following stroke, in the first days, or over the long-term following stroke. Whilst prevalence has been reported equally in upper and lower limbs, the more severe forms are reported in the upper. Thibaut et al., summarise research (Thibaut et al., 2013) showing that in the paretic upper limb the elbow and wrist are primarily effected (Wissel et al., 2010), and the most frequent pattern of spasticity is “internal rotation and adduction of the shoulder coupled with flexion at the elbow, the wrist and the fingers” (p. 1). Although great diversity of symptoms exists amongst people with stroke, the research offers the following definition

> Spasticity is part of the positive signs among other motor symptoms which occur after lesions in the descending corticospinal system such as spastic dystonia (muscle constriction in the absence of any voluntary movement), spastic co-contraction (contraction of both the agonist and antagonist muscles resulting from an abnormal pattern of commands in the descending supraspinal pathway), extensor or flexor spasms, clonus, exaggerated deep tendon reflexes and associated reaction (p. 1).

Lesion sites that may induce spasticity are "the brainstem, the cerebral cortex (in primary, secondary and supplementary motor area; SMA) and the spinal cord (pyramidal tract)" (Thibaut et al., 2013, p.2).

Spasticity is usually treated with physiotherapy and Baclofen, which is a gamma-Aminobutyric acid (GABA) agonist. This chemical crosses the blood–brain barrier and binds at the $GABA_b$ receptors of the spinal cord. Sedation, fatigue and drowsiness can present as side effects, which sometimes leads to oral drugs being considered as a second line of treatment, especially in the early stages post stroke. Although widely administered to patients with severe brain injuries, further evidence is required to establish its efficacy in combating spasticity (Thibaut et al., 2013).

2.12 Subluxation

This is a condition sometimes discussed along with other symptoms under a more general heading of hemiplegic shoulder pain (HSP), as in a review of evidence for a care pathway in such cases (Turner-Stokes and Jackson, 2002). The reviewers state that subluxation may be attributed to the over stretching of ligaments and muscles in the shoulder as a result of the flaccid and unsupported paretic arm and hand, which become heavier as the muscles do not support the weight of the bones. They add that clear definitions are still lacking, as is the link between subluxation and HSP. Detection by x-ray is only possible if conducted with the patient in an erect position.

2.13 Upper limb recovery and rehabilitation

In order to effectively perform ADLs we need the use of both arms, or as commonly referred to in rehabilitation, 'upper limbs'. Impairment of upper limbs following

stroke is extremely common (Adey-Wakeling and Crotty, 2013), significantly more resistant to rehabilitation treatment than gait (Thaut et al., 2002), and there is enormous variability in the extent of impairment between stroke patients (Langhorne, Bernhardt and Kwakkel, 2011) with no substantial scientific evidence to support interventions used in standard care (Pollock et al., 2014). The focus of this study is to address the question as to whether TIMP is an effective intervention for stroke upper limb hemiparesis.

Occupational and physical therapy treatments are available for patients at acute, post acute and community stage, with research supporting the key elements of intensity, specificity and repetition in any restorative, as opposed to compensatory, upper limb rehabilitation approach (Adey-Wakeling and Crotty, 2013). Recent research suggests that recovery for some people with stroke may continue over several months or longer, however it is also a commonly held principle that the most functional improvement is usually seen within the first three months, which also gives an indication of whether or not longer term recovery is likely (Medscape, 2013). Up to 70% of people with stroke who show some recovery of hand movement at four weeks post stroke have a high possibility of regaining full or good hand use, but if within the first three weeks post stroke no further movement is regained, then it is generally considered unlikely that full recovery will occur (Medscape, 2013). An observational study where upper limb capacity was measured at the start and end of rehabilitation found that hand recovery was predicted by the amount of proximal (using the larger muscle groups) arm control following stroke (Houwink et al., 2013), concluding that even in cases where there was minimal proximal elbow and shoulder control there was still a fair chance of regaining some movement in the hand long-term. Other research investigating the need for more sensitive assessment tools has found evidence that some kinematic outcomes from upper limb rehabilitation show further changes more than eight weeks post stroke, but that these are not detected using standard assessment tools (de Groot et al., 2012).

In a meta-analysis of literature reporting prognostic variables in upper limb recovery (Coupar et al., 2012), inconclusive evidence was found for time since stroke being a predictor, whilst other data suggested that younger people and males show better recovery. Comparisons between lesion site revealed no predictive value in upper limb

recovery and type of stroke (hemorrhagic or ischaemic) was not within the scope of the review. The most significant findings were that people with stroke recovered significantly more upper limb function if there was less impairment in their upper limb initially caused by the stroke. That is; less severe impairment at the time of stroke results in better recovery. Meta-analysis of the included studies also suggested that patients with left hemisphere lesions recovered upper limb function significantly more than those with right. Other research has also revealed that variability of arm movement trajectory, which is the accuracy of movements towards a target object and crucial to the effective performance of ADLs, is highly correlated with the level of impairment initially caused by the stroke (Freitas, Gera and Scholz, 2011).

Conventional treatments for hemiplegia, including upper and lower extremities, following stroke, include Brunnstrom (Brunnstrom, 1970), Bobath (Bobath, 1978) and neurodevelopmental approaches (Thaut et al., 2002; Belda-Lois et al., 2011). It has been reported (Malcolm, Massie and Thaut, 2009a) that such approaches have not demonstrated significant functional gains for patients due to their reliance on passive facilitation (Whitall et al., 2000) rather than applying the core principles of motor learning and motor control, requiring structured, specific and repetitive training protocols in order to drive sensorimotor neuroplasticity. These conventional therapeutic approaches are also thought to have under emphasized quality of movement, for example the timing and efficiency of movement and multijoint coordination.

A 2013 report (Adey-Wakeling and Crotty, 2013) investigating the evidence for efficacious upper limb rehabilitation treatments currently available for stroke patients summarized some of its findings in Table 2, including useful information on supporting evidence, referral/inclusion criteria, specialist training requirements for the clinician and advantages and disadvantages of the intervention.

Table 2. Principle advantages and disadvantages of upper limb interventions. (Adey-Wakeling and Crotty, 2013, pp.9-13)

Intervention	Origin	Principles	Application	Advantages	Disadvantages
Repetitive task-specific training	Origins in basic science and psychology research	Targets learning-dependent neuroplasticity	Repetitive part and whole task practice of meaningful tasks	Easy to apply, individualized, motivating	The number of repetitions recommended in evidence are frequently not achieved in the clinical setting
Bimanual training	Mudie and Matyas (1996)	Bilateral symmetrical movement activates bilateral motor cortices Bil transfer	Symmetrical or alternating use of bilateral upper limbs to complete task	Potentially more functional than unilateral training	Most evidence only in chronic phase. On specific for bilateral tasks
CIMT	Taub *et al.* (1994)	Aim to prevent learned nonuse of the affected upper limb and to prevent the associated reduction in cortical	Constraint of unaffected upper limb for 90% of waking hours, coupled with massed practice with	High-grade evidence for traditional CIMT. M protocols emerging for use in acute and subacute	Only a select group of patients meet inclusion criteria, Limited by adherence, fatigue and compliance, limited evidence

		representation	affected upper limb	stroke settings	in acute setting
Neuromuscular Electrical Stimulation (NMES)	Liberson *et al.* (1961)	Electrical stimulation to peripheral motor nerves to improve motor performance and cortical excitability	Applied by trained therapist; training provided to patient/family. Newer implantable options are more invasive, but may provide superior application	More effective if triggered by voluntary effort. C improve motor performance and reduce spasticity and shoulder pain. C home setting	Limited evidence of effect on function training. be uncomfortable; potential skin reaction. epilepsy, pregnancy and pacemakers. The time of application supported by evidence is frequently not matched in the clinical setting
Intervention	**Origin**	**Principles**	**Application**	**Advantages**	**Disadvantages**

Robotics	1990s to present	Move towards restorative approaches	Multiple applications; a assisted therapy with specificity of movement patterns, feedback and repetition	Method of increasing repetition/dose of therapy Provides feedback. Evide supports functional gains Appl acute, subacute and chronic phases of recovery. Good adherence and motivation	Equity of access to robotic technologies. N to standard therapy in equivalent dose. sLes effective for distal motor upper limb motor impairment
Virtual reality and gaming	1990s to present	Activation and engagement of bilateral neural motor areas occur as a result of motor execution and imagery of that task	Computer-based, interactive, immersive, multisensory simulation environment	Goal-directed; motivating with feedback. Carr over into ADLs.. Method for increasing therapy dose. Gene accepted and challenging	Potentially less acceptable to older patient group. Not superior to standard therapy in equivalent dose. E of access
Non-invasive	Recent	Changes in neural	TMS: rapidly	Cortical changes persist	Careful placement of

brain stimulation	clinical applications founded on decades of research	excitability (excitation/inhibition) secondary to stimulation	changing magnetic fields via coil over head, inducing small electrical currents over motor cortices. tDCS: application of constant low-current stimulation via electrodes	after stimulation. C safe if established protocols are followed	electrodes important for effective application. M cause skin irritation, dizziness, nausea and headache. M ay lo seizure threshold in susceptible patients

A review of upper limb rehabilitation interventions and their impact on stroke patients' quality of life (Pulman and Buckley, 2013) demonstrated a particular need for interventions in this area in addition to those addressing functional outcomes. The study reported similar interventions to Adey-Wakeling and Crotty (2013), those being; constraint induced movement therapy (CIMT), bilateral task training, neuromuscular stimulation, etc. Neither this review nor the previous report mentioned music supported therapy (MST) or NMT interventions, both of which have produced evidence for treatment efficacy in the domains of function and quality of life. A 2014 Cochrane review into upper limb interventions with stroke patients (Pollock et al., 2014) cited music therapy and rhythmic auditory stimulation, concluding that there is a lack of evidence for efficacy and recommending high quality trials. CIMT was reported as having low to moderate evidence, which contrasts with Adey-Wakeling and Crotty (2013), who report high-grade evidence.

2.14 CIMT

CIMT is not commonly available through the NHS and has been compared with MST (Schneider et al., 2010), which is another intervention for upper limb hemiparesis relevant to the study reported in this thesis, and which will be discussed in Chapter 3 (see Music supported therapy (MST). CIMT procedures require the patient's unaffected upper limb to be constrained, usually by placing a mitten over it, and the paretic arm forced into daily use and regular, daily exercises of high intensity in order to counteract what is termed 'learned disuse' (Dromerick, Edwards and Hahn, 2000; Page, Murray and Hermann, 2011). CIMT, also termed constraint induced therapy (CIT), has received criticism, with some studies resulting in limited improvements from highly intensive, forced use of the paretic upper limb, and without having any significant impact on quality of movement (Malcolm, Massie and Thaut, 2009a). But some argue that CIT research has also helped to develop rehabilitation techniques away from compensatory treatments and more towards a 'top down' approach, which aims at driving neuroplasticity (Belda-Lois et al., 2011), where undamaged areas of the brain become connected into neural circuitry, taking on the function of the damaged areas (see Neuroplasticity). Other studies have also reported this shift in

neurorehabilitation approaches towards motor learning and motor control theories (Jette et al., 2005). At acute stage with ischaemic stroke patients, one CIT study indicated that the treatment was effective in reducing arm impairment (Dromerick, Edwards and Hahn, 2000). A more recent CIT trial with chronic stroke patients suggests that functional improvements were due to effective compensatory movements, a common development in stroke patients with hemiplegia that indicates redundancy of motor control (de Groot et al., 2012), rather than decreased impairment and improved, normal motor control, this is also termed 'maladaptive plasticity' (Takeuchi and Izumi, 2012) (see Maladaptive plasticity). The study also recommended the use of more sensitive kinematic analysis rather than standard assessment tools such as the Action Research Arm Test (ARAT) (Kitago et al., 2013). Modified CIT (mCIT), found no significant difference in outcomes compared to the control group, with both groups improving equally well (Brunner, Skouen and Strand, 2012). This study reiterated the ambiguity of results from Randomized Control Trials (RCTs) that compare CIT with other treatments.

2.15 Other considerations for upper limb rehabilitation

As earlier described, the enduring focus of occupational therapy should be the incorporation of occupations with added purpose, or task relevance (Paul and Ramsey, 1998), which also prove more motivating for patients (Paul and Ramsey, 1998; Siekierka et al., 2007; Hochstenbach-Waelen and Seelen, 2012). A single case study (Earley, Herlache and Skelton, 2010) involving a musician with chronic hemiparesis highlights the importance of added purpose and high intensity of repetition, in this case positive results were due to a combination of fine motor exercises, required for violin playing, combined with a mCIT program.

Bilateral arm training has been reported as highly effective, more so than focusing predominantly on the paretic side, inducing neural reorganization and improving paretic arm function in ADLs (Mudie and Matyas, 2000). Other bilateral arm training studies found little evidence for increased functional gains, showing very slight improvements in the 'pinch' (fine motor) section of the ARAT and in the 9HPT (Morris et al., 2008).

2.16 Other effects of stroke

2.16.1 Psychological effects

The stroke association (Stroke Association, 2015) report the most common psychological effects of stroke as being depression, emotionalism, lack of confidence and fear of another stroke, whilst other research has reported chronic pain and anxiety in patients as key concerns (Whyte and Mulsant, 2002)

Studies report varying statistics for depression following stroke. In the UK incidence has been reported in up to 33% of cases (Stroke Association, 2015), whilst in the US in 2007 it was reported as being between 20% and 50% (Barker-Collo, 2007). Furthermore, many stroke patients go undiagnosed and untreated for depression and assessments in this area are not routinely conducted alongside those for physiological and communication impairments (Ruchinskas, 2002; Farner et al., 2010; Care Quality Commission, 2011; Kang et al., 2013). Despite the reported prevalence of depression, less than 40% of areas across the UK offer good access to counselling for stroke patients (Care Quality Commission, 2011)

2.16.2 Depression

Depression can occur at all stages post stroke, with major depression recorded at high levels at acute stage, and comparatively high levels one to three years post stroke (Whyte and Mulsant, 2002). Depression at community, or chronic, stage has also been linked to sustained impairment of ADLs (Farner et al., 2010). Depression after the acute period might also be explained in relation to an individual's process of coming to terms with the long-term effects on their daily lives, and realising how their future plans and aspirations will be transformed, both professionally and in their family and relationships (Stroke Association, 2012). Resources for psychological support at community stage in stroke recovery are scarce, and if recovery has allowed a return to independent living patients can experience isolation or the families supporting them can come under extreme pressure as they try to understand and support emotional and psychological needs (Farner et al., 2010; Care Quality Commission, 2011). Depression has also been linked to the physiological damage caused by the stroke,

which can damage neural pathways normally involved in mood regulation (Morris, Robinson and Raphael, 1993; Whyte and Mulsant, 2002).

2.16.3 Emotionalism

Emotionalism (House et al., 1989), also known as emotional lability (Allman, 1991) is a term given to describe heightened emotional responses, where the response is in keeping with the situation or stimulus, but more exaggerated than before suffering a stroke (Stroke Association, 2012).

2.17 Speech

Conditions resulting from stroke and affecting communication, speech and comprehension are aphasia, dysarthria and apraxia. Aphasia is the most common communication disorder (Warlow et al., 2008), usually present when the stroke has occurred in the left hemisphere of the brain. Impairment can be in speaking (expressive aphasia) or understanding speech (receptive aphasia) or in both areas, also including reading and writing (global aphasia).

2.17.1 Aphasia

Stroke patients with aphasia may say one word when they mean another, this can also include saying ‘yes’ when they mean ‘no’ or vice versa. A stroke patient with receptive aphasia may lose the sense of a conversation if long sentences are used, or be unable to understand instructions if there is too much competing auditory activity in the background. They may also be able to read a short headline or title but not the main text of a newspaper or other written document. This type of communication impairment has implications for the collection of qualitative data such as patient experience via semi-structured interviews.

2.17.2 Dysarthria

Dysarthria occurs when the stroke has affected those areas of the brain which activate the muscles of the mouth, lips and tongue, the vocal chords and the respiratory muscles required for speech production. This results in inarticulate and slurred speech due to reduced muscle strength, control and agility(Baker et al., 2006).

2.17.3 Apraxia

Apraxia affects the motor speech programming required for the coordination of mouth, lips and tongue, so that the patient is unable to select and sequence the required articulators volitionally in order to articulate phonemes or speech sound combinations. Unlike in dysarthric patients, there are not usually any signs of muscle weakness. There are two main types of apraxia: apraxia of speech is more often caused by lesions in Broca's area and leads to the substitution of target sounds for similar ones, or they are produced in a distorted manner; oral apraxia (buccofacial apraxia) results from a loss of ability to voluntarily move facial muscles, lips and tongue (Baker et al., 2006).

2.18 The somatosensory and motor systems

2.18.1 Somatic sensory impairment

In addition to the information that we gather through our vision and hearing in relation to physical movement, we interact with the external environment using other, essential information received through receptors in the skin that tell us about pressure, temperature and pain; a process known as exteroception. Proprioception provides information regarding body position and movement in space and time via receptors in the muscles and joints, as well as the skin. Our conscious perception of the position and movement of our limbs is referred to as kinaesthesia (Carpenter and Reddi, 2012).

Somatic sensory impairment, through damaged proprioception neural pathways, resulting from stroke has been reported as negatively influencing motor rehabilitation (DeSouza, 1983; Intercollegiate Stroke Working Party, 2012) and possibly causing abnormal movements such as tremors, which can occur once the initial motor deficit, for example the paresis, has improved (Handley et al., 2009). Therapeutic exercises which provide stroke patients with visual or auditory biofeedback from their movements during rehabilitation exercises have been reported as improving quality of movement, but with insufficient evidence from systematic reviews and clinical trials to make specific recommendations for a suitable type of biofeedback (Intercollegiate Stroke Working Party, 2012).

Impaired proprioception caused by stroke negatively influences actions such as

reaching, grasping and picking up objects, as patients may have less information about where their arm is spatially, and so judging the amount of movement required to reach an object becomes difficult. Information about the object, usually gathered through touching and getting a feel for it, as well as previous experience of performing such everyday actions, may also be impaired, and so planning the required muscle force for grasping, lifting and moving objects will be less efficient. Such everyday tasks may then become longer, slower and more laborious processes, where the patient reaches *approximately* towards the object, perhaps using visual and cognitive pathways, if intact, in order to compensate for the reduction in proprioceptive feedback (Carpenter and Reddi, 2012).

2.18.2 The somatic sensory system

"Feedback from the effects of motor responses is fundamentally important in the control of movement" (Carpenter and Reddi, 2012, p.189).

In everyday life the act of reaching and obtaining an object, and the neural processing required, occurs incredibly quickly, and is generally performed naturally and fluidly when the neural pathways between these regions are undamaged. Stroke impairs the flow of such motor tasks, as the connectivity between frontal cortex, basal ganglia, colliculus, cerebellum, reticular formation, supplementary motor area and primary motor cortex, as well as all other associated neural and corticospinal pathways, can be lost or badly disrupted due to the cell death caused in the stroke site or sites and damaged cells in the surrounding areas of the brain.

A basic understanding of how somatic sensory systems inform motor systems, in other words how our brain and body is connected and work together to continuously map our body position in relation to the external world, will help to clarify the way in which damage to these systems resulting from stroke disrupts motor planning. The discourse will also inform as to how interventions involving the playing of musical instruments, which provide auditory and tactile feedback as a result of upper limb movements, have been found to improve the quality (timing and accuracy) of such movements where hemiparesis has occurred. The interconnectivity between sensory

and motor systems holds particular relevance to the intervention under investigation in this study and those discussed in Chapter 3, the second literature review. 53% of people with stroke have been reported as having tactile impairment, 89% unable to effectively recognise objects through touch alone, without the need for visual or auditory information (stereognosis), and 63% experiencing impaired proprioception (Adey-Wakeling and Crotty, 2013).

Neural circuits controlling muscle length, for example how much the hand needs to open in order to reach around and grasp an object, use information from force-detectors in the skin and tendons that monitor the size, density (how solid the object is) and load (the weight) in order to make appropriate and effective adjustments for motor commands. Two different somatosensory models influencing motor planning are that of *parametric feedback* and *direct feedback* (Carpenter and Reddi, 2012, p.191). Rather than storing and accessing infinite movement programs for any possible action, *parametric feedback* (see Figure 4) enables us to perform motor tasks by trial and error, firstly using less complex all-purpose movement programs, then modifying them using 'error signals' from the previous failed or less efficient attempts. The *error signal* equates to a measure of how well the movement achieved the task. Whilst the motor planning remains inadequate, adjustments are made until it improves and the task is more effectively achieved. This is essentially how our motor systems learn to execute complex actions.

Direct feedback is a sensorimotor process that informs the precision of actions using the *error signal* as a *direct input* to the motor planning for the required action. This contrasts with *parametric feedback*, where the performance of the action is improved through trial and error. Carpenter and Reddi use the analogies of a ballistic missile and a guided missile when defining, respectively, *parametric* and *direct* feedback. The former will be aimed at its target using pre-programmed coordinates alone and it will not be possible to make adjustments to this trajectory once it is launched. In comparison, a guided missile will detect wind speed and direction after launch, and make adjustments to its coordinates in order to maintain course for its target.

The diagrams below (Carpenter and Reddi, 2012) compare different types of feedback, illustrating how the most efficient motor planning results from a combination of these types. The task being used as a model is the act of throwing a

scrunched-up piece of paper into a waste paper bin, with ‘controller’ referring to the person; ‘plant’ meaning the act of throwing and ‘noise’ referring to any unpredictable disturbances that influence the execution and result. Each diagram shows a sequence of what the person wants to achieve, or the ‘desired result’, the person planning the movements required and executing the movement to achieve the goal; the actual result.

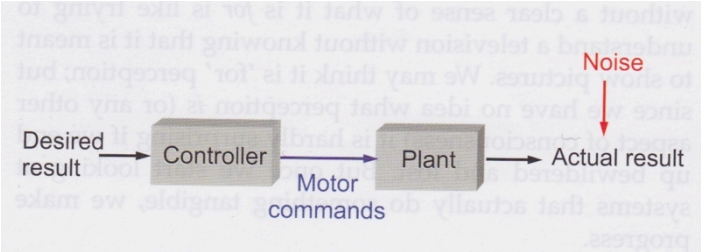


Figure 3. Basic model of ballistic movement (Carpenter and Reddi, 2012, p.190).

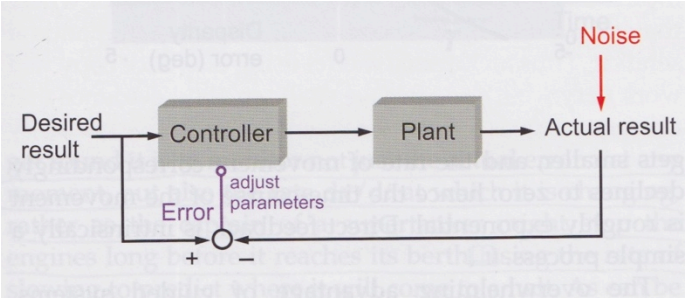


Figure 4. Parametric feedback (Carpenter and Reddi, 2012, p.191).

With *parametric feedback* the error signal from each attempt is not fed back directly into the system, but its parameters. The circle with arrows is referred to as the ‘comparator’ and represents a comparison between the actual result and the desired result

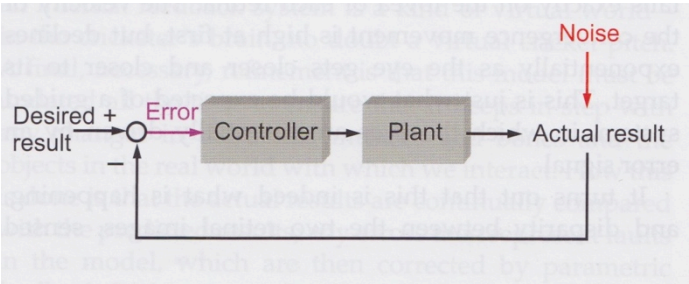


Figure 5. Direct feedback (Carpenter and Reddi, 2012, p.191).

Here, where there are errors in executing the motor task they immediately generate motor commands at every moment, known as ‘direct feedback’, in order to improve the action by altering the command as it occurs and better achieve the task.

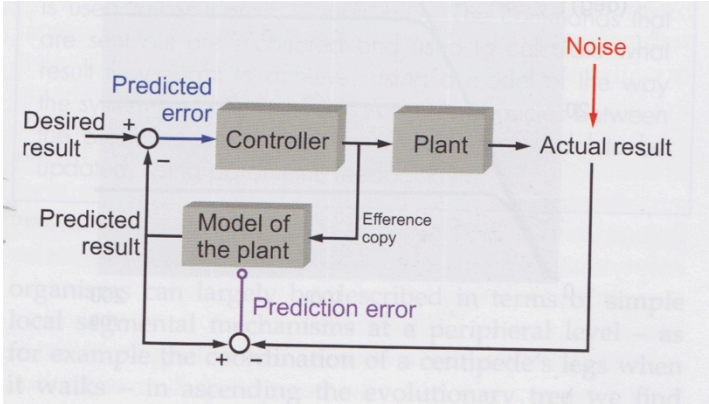


Figure 6. Internal feedback (Carpenter and Reddi, 1012, p. 193).

Previous experience, referred to as ‘internal feedback’, informs the performance before planning the movements and is an internal representation, or model of the plant, of what might be needed to achieve the action based on former knowledge of hand and arm mechanics and types of load. Adjustments to the model occur via ‘parametric feedback’.

2.18.3 Higher motor control

For the purposes of simplifying and studying the higher motor system exclusively, Carpenter and Reddi (2012) present a perspective of higher motor control by breaking down the everyday action of reaching and grasping an object into three components involving six brain regions. Figure 7, below (brain images taken from: http://commons.wikimedia.org/wiki/File:Brain_diagram_without_text.svg), illustrates this sequentially to further simplify the process and show the physical brain regions involved.

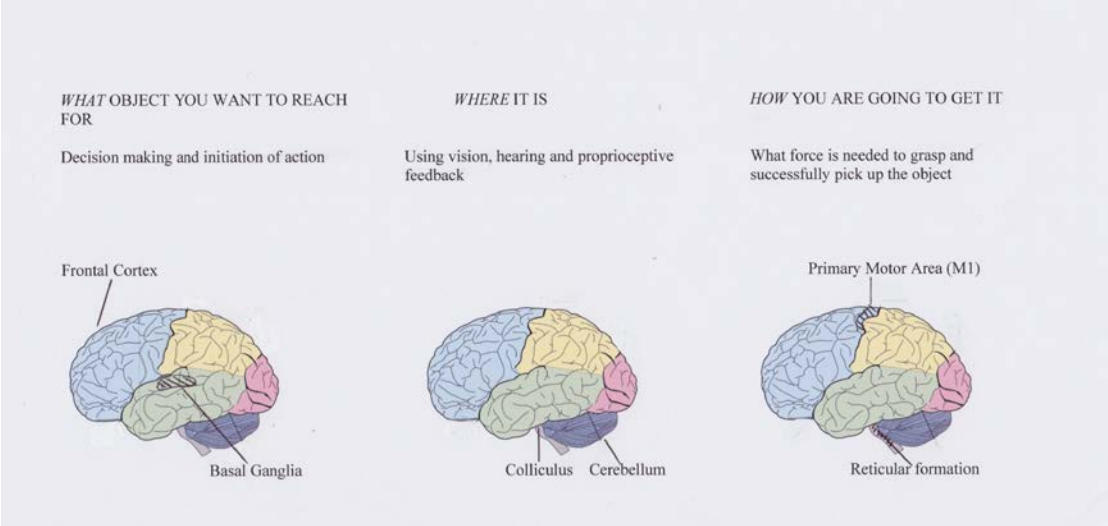


Figure 7. Brain regions involved in deciding, reaching, grasping.

Figure 7 shows the different brain regions identified in the process of deciding an action to reach and obtain an object, gathering information on its location and planning the required sequence of upper limb movements.

2.19 Summary

Upper limb hemiparesis is a complex condition that is often further impacted by cognitive and psychological symptoms, high muscle tone (spasticity) and other movement disorders such as tremors and dystonia. Existing interventions are not universally available across NHS trusts and are reported as lacking in evidence for efficacy, as invasive, having a narrow referral criteria, not delivering a high enough level of repetition of task-specific movements, or not accessible to older people with stroke (Adey-Wakeling and Crotty, 2013). There is evidence to support continued recovery of upper limb function at the chronic stage (Giaquinto et al., 1994; Barrett and Meschia, 2013), at which point NHS trusts aim to deliver treatment in patients' homes via ESD teams. 2010 figures report only 36% of NHS hospitals delivering ESD services.

Very little research has been conducted around home-based services, with insufficient detail regarding methodologies and treatment protocols (Fens et al., 2013).

Recommendations have been made to develop and implement interventions for hemiparesis that provide the patient with auditory and tactile biofeedback (Intercollegiate Stroke Working Party, 2012), which would support the mechanisms of damaged somatosensory and motor systems described in this chapter (Carpenter and Reddi, 2012) and improve proprioception, which is impaired in 63% of hemiparetic patients (Adey-Wakeling and Crotty, 2013).

Musical instruments offer great diversity with regard to how they are played (using finger movements or larger arm movements) and how they are arranged spatially. The selection and positioning of instruments can be adjusted to meet the player's existing repertoire and range of movements and then extended to increase them. Musical instrument playing requires a high number of task specific, repetitious movements and results in auditory and tactile feedback, thus potentially integrating the motor and somatosensory systems.

The following chapter reports on existing research into this activity and other music related research and its effects on motor as well as cognitive and emotional systems, involving stroke patients with hemiparesis. This review of literature will inform on the relevance, unique qualities and potential benefits of the intervention under investigation in this study, and the gap in knowledge that the study aims to address.

3 CHAPTER 3. MUSIC THERAPY, NEUROSCIENCE AND UPPER LIMB REHABILITATION

This chapter will focus on current definitions of music therapy models, terms and techniques, and published studies that have used NMT or related techniques, including TIMP, for the rehabilitation of upper limb hemiparesis. Some previously published brain scans have also been included in order to help illustrate the brain activation and neural reorganisation resulting from the interventions. Some of the studies have involved playing instruments without any rhythm or music to cue and support the movements required, others have used music or a metronome, and in some studies both musical instrument playing and facilitating music, together with other sensory cues have been employed. The chapter ends with the purpose statement, hypothesis and research questions before continuing into Chapter 4, which describes the methodology.

3.1 Introduction

Over more than twenty-five years scientific evidence for the therapeutic effects of music on health has begun to accumulate. Through advances in technology it has been possible to observe the behaviour of neural substrates and pathways on cortical, subcortical and reticulospinal levels during music based research (Thaut et al., 1993; Usher, 1998; Tecchio et al., 2000; Stephan et al., 2002; Molinari et al., 2005; Aldridge, 2005; Baker et al., 2006; Thaut, 2008; de L'Etoile et al., 2012; de l'Etoile and LaGasse, 2013; Thaut and Hoemberg, 2014). Music making has recently been discussed in the neuroscience arena as a tool for promoting neuroplasticity due to its function as a vehicle for transmitting visual, auditory, and motor information to the frontotemporoparietal regions (Wan and Schlaug, 2010), and adds some weight to support the rationale for instrumental playing to rehabilitate upper limb hemiparesis. A role for music therapy has been identified within neurorehabilitation programs for treating a range of psychological and physiological behaviours (Davis, Gfeller and Thaut, 2008), and this has been based on four primary theoretical principles: music supports and promotes 1) social interaction, 2) communication, 3) emotional expression, 4) neuronal connections in the brain (Baker and Magee, 2009).

3.2 Music therapy and NMT

In the UK all music therapists qualify through two years post graduate training and are registered with the Health and Care Professions Council (HCPC), along with all other health professionals such as occupational, speech and language and physical therapists, who are, unlike music therapists, generally found within what is termed 'standard care' in neurorehabilitation pathways. The psychological, emotional, cognitive and communication impairments of clients are often treated through the music therapist and client improvising music together, developing musical dialogues, songs and activities. This music therapy approach is not commonly found in UK neurorehabilitation settings, as it is not regarded as delivering the short-term, goal driven interventions offered by standard care. In addition, the benefits in emotional and psychological well-being that music therapy can bring to patients within neurorehabilitation settings are under acknowledged and it has been suggested that these areas are viewed as less important than the more visible, functional needs of patients (Magee, 1999). Even where music therapy has been found and reported to bring about short-term functional improvement (Bradt et al., 2010), resistance from healthcare providers finding the extra funding for music therapy may still be found when they argue that only the essential standard care professionals are required as they can provide treatments and measure outcomes that are specific to their modality (Magee, 1999).

Where music therapy interventions such as music improvisation, listening and songwriting have been available or researched in rehabilitation hospitals or centres for patients with traumatic or acquired brain injury, it has been found to improve patient mood and motivation, as well as participation in rehabilitation programs (Glassman, 1991; Nayak et al., 2000; Magee and Davidson, 2002; Magee, 2007; Sarkamo et al., 2008; Ansdell et al., 2010; Kim et al., 2011; Durham, 2013; Pool, 2013), which can and has improved functional outcomes for patients.

In the United States (US) music therapy finds its formal origins in work with World War I and II veterans, but its basic principles, still valid today, were reported much earlier, in the late 1800s (Davis, Gfeller and Thaut, 2008). It continues to be

advocated as a complementary treatment to medicine by such prestigious neurologists as Oliver Sacks (Sacks, 1985). It is more developed and supported to treat patients with neurological disease and injury in the US than in the UK, where a large body of research has contributed to the development of standardised techniques now brought together to form NMT (Thaut, 2008; Thaut and Hoemberg, 2014; Thaut and McIntosh, 2014).

3.3 Neurologic music therapy

One of the principal researchers and founding members of NMT is Professor Michael Thaut, professor of music and professor of neuroscience at Colorado State University. The techniques described (Thaut, 2008; Thaut and McIntosh, 2014; Thaut and Hoemberg, 2014) within this branch of music therapy are subdivided into three domains of rehabilitation: 1) sensorimotor rehabilitation, 2) speech and language rehabilitation, 3) cognitive rehabilitation. Five basic definitions of NMT are provided by Thaut, which make clear that techniques are evidence based, derived from scientific and clinical research, that treatments are standardized in terminology and application and adaptable to each patient's functional needs. All NMT techniques follow a design derived from a neuroscience model of music perception and production that is dependent on formal assessment and goal setting in collaboration with multidisciplinary team members. This model is referred to as the 'Transformational Design Model' (TDM) and is derived from another that is the central framework of NMT, the Rational-Scientific Mediating Model (R-SMM) (Thaut, 2008). The R-SMM is explained as "an epistemological model, that is, a model to show ways of generating knowledge concerning the linkage between music and therapy" (Thaut, 2008, p.118), which has also been separately reviewed as a tool for aiding NMTs in selecting the most effective interventions for patients (de L'Etoile et al., 2012). Thaut effectively presents this rationale and the link between music and potential therapeutic benefits using data gathered from scientific research, such as the positron emission tomography (PET) images in Figure 8. These show the activity of the midbrain during rhythmic pattern, meter and tempo listening and discrimination in normal subjects, illustrating the different regions of the brain that are simultaneously activated by these three elements of rhythm and, importantly, highlighting the

capacity common to humans to perceive and discriminate information on auditory rhythm. Figure 9 shows how listening and moving to a rhythmic pattern can influence motor task performance quality. The wrist movement trajectories taken from stroke patients with hemiparesis using movement and target sensors, illustrate how pulse as an auditory cue, can influence these trajectories and improve movement kinematics.

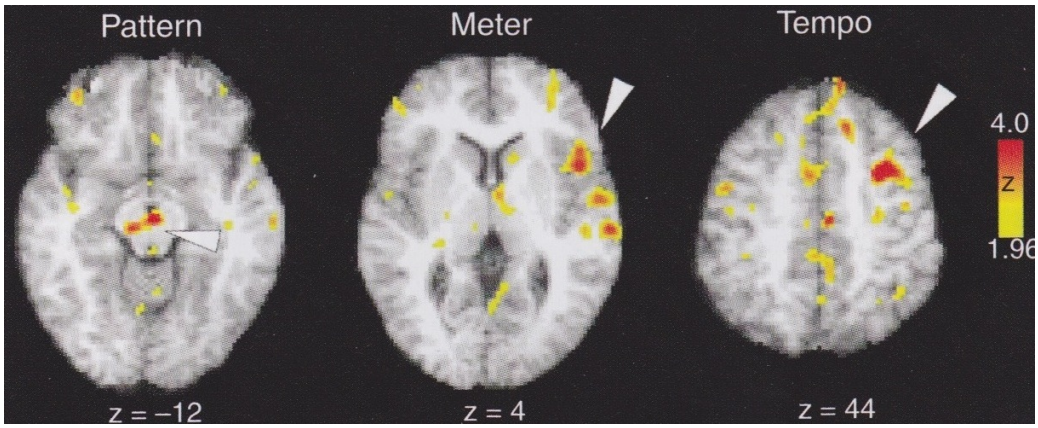


Figure 8. PET scans showing brain activity in three rhythm listening tasks. (Thaut, 2008, pp.118-119).

The Figure above shows PET image group means for three different listening tasks, which have been overlaid on anatomical MRI scans. The tasks involved normal controls who were non-musicians, discriminating differences between pairs of monotonic rhythmic patterns, meters and tempi.

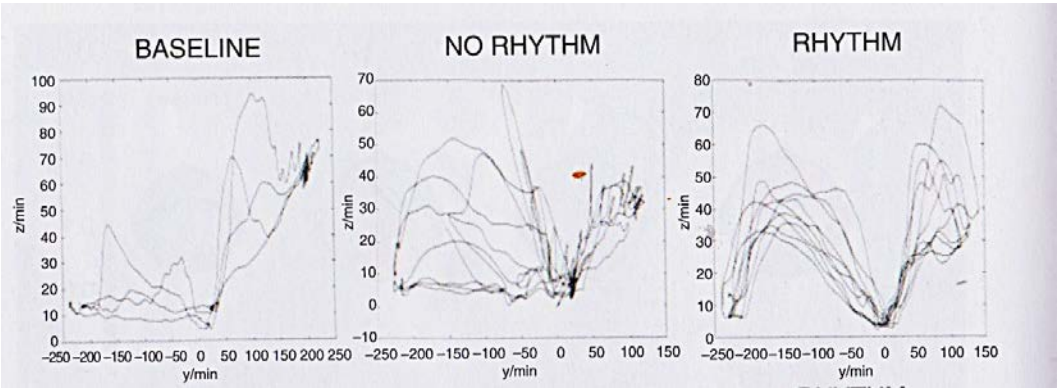


Figure 9. Graphs of stroke patients' wrist movement trajectories

Figure 9, above, shows the wrist movement trajectories of stroke patients' paretic upper limb as they move their arms across a table surface to three different touch sensors (Thaut, 2008, pp. 118-119). In the first graph participants performed the task to obtain a baseline measure, the second shows 30 seconds of movement and the third shows the same duration of repeating the movements but to a metronome beat. The third graph clearly provides a visual representation of how much smoother the movement trajectories become, due to the temporal structure within which to plan and execute movements that is provided by the metronome in this experiment.

The TDM is the model through which each NMT technique is applied and follows five steps:

1. diagnostic and functional assessment of the patient
2. development of therapeutic goals/objectives
3. design of functional, non-musical therapeutic exercises and stimuli
4. Translation of step 3 into functional therapeutic music experiences
5. Transfer of therapeutic learning to functional, non-musical real-world application (Thaut, 2008, p.131).

In summary, once goals have been set within the team following formal assessment, the neurologic music therapist creates musical exercises that facilitate them. When patients achieve their goals, the music is removed.

3.4 Therapeutic instrumental music performance

TIMP, a NMT technique which has not been widely researched, is a defined intervention suitable for upper limb rehabilitation, which comprises three essential elements: 1) Musical structure: clearly pulsed music, with melodic, harmonic and dynamic structures, which cue the organization of movements in time, space and force dynamics, 2) Choice of instruments and mode of playing, 3) Positioning or spatial arrangement of instrument/s to facilitate the target movement/s (Thaut, 2008). In addition to both ischemic and haemorrhagic stroke patients, other target

populations for TIMP application, where neurological injury or disease has caused damage to the motor areas are (Thaut and Hoemberg, 2014):

- traumatic brain injury (TBI)
- spinal chord injuries with paraplegia syndrome
- hypoxic brain damage
- spina bifida
- ataxiate-langiecstasia
- cerebral palsy
- poliomyelitis

TIMP guidelines do not specify that a metronome should be used, to which the facilitating music is played or recorded to. However ,using a metronome provides an external temporal framework, which can be matched to patients' existing movement frequency and which can be adjusted incrementally towards normal frequency without compromising movement quality (Thaut, 2008).

Whilst NMT techniques such as TIMP have become better defined in terms of supporting evidence, rationale and protocols over the last decade (Thaut and Hoemberg, 2014), other texts that were simultaneously published regarding music therapy in neurorehabilitation (Baker et al., 2006) have also defined instruments, adaptations of them and adaptive playing techniques for effectively treating physical, cognitive, emotional and communication impairments. A single case taken from a currently running stroke study presenting evidence for improved bilateral hand activity and control, involved the participant in playing Djembe and other drum patterns. The music therapist accompanied using drums or piano and the participant progressed through patterns of increasing difficulty. The study acknowledges both MST and TIMP related research, but does not precisely follow either protocols, rather devising an intervention derived from this research (Järvinen-Lepistö, P., Burger, B., Ala-Ruona. E., 2014). Non-NMT texts undoubtedly provide clinicians, whether NMT trained or not, with essential guidance on instrument selection and use, as well as ways of using music to achieve functional goals.

One small TIMP study, which included three participants who were all more than three years post stroke, examined the effects of acoustic instrument playing on upper limb function. Following the six sessions that took place over two weeks, the resulting data showed significant change in wrist and hand functional assessment outcomes using the Barthel Index, Fugl-Meyer Test and Modified Ashworth Scale. The primary conclusions of the study were that NMT could be beneficial in improving complex functional ability for stroke patients' ADLs and that further research be conducted (Yoo, 2009). This current study has developed a protocol including a table of 12 TIMP exercises. Other music therapy research exploring the effects of instrumental playing on upper limb paresis has contributed more significantly to the evidence base for efficacy, but followed a different protocol; with the omission of facilitating music and rhythmic attunement to which participants synchronise their movements. This omission is based upon facilitating music introducing another variable, depending on whether participants listen to the same music or if each one has their own, perhaps self-selected music, what that music is in terms of style or genre, and each participant's personal response to the music, which may be influenced by their own personal associations with it. These factors would arguably have varying influences on participants' level of motivation and capacity to maintain focus and not be distracted. However, a similar argument could be presented in that MST participants progress to play folk melodies, which might have varying effects on motivation and progress depending on each participant's familiarity with each melody. In this TIMP study the facilitating music for each TIMP pattern has been standardised as far as possible and described in detail in the Methodology and in Chapter 5 'TIMP music selection and composition'. Other TIMP research has been conducted with adults with cerebral palsy at a frequency of twice per week. Results indicated improved finger dexterity and velocity of movements (Chong et al., 2013).

Figure 10 below offers a summary of the effects of instrumental playing on the somatosensory and motor systems that were presented in Chapter 2 (Carpenter and Reddi, 2012), which the intervention under investigation, TIMP, might support.

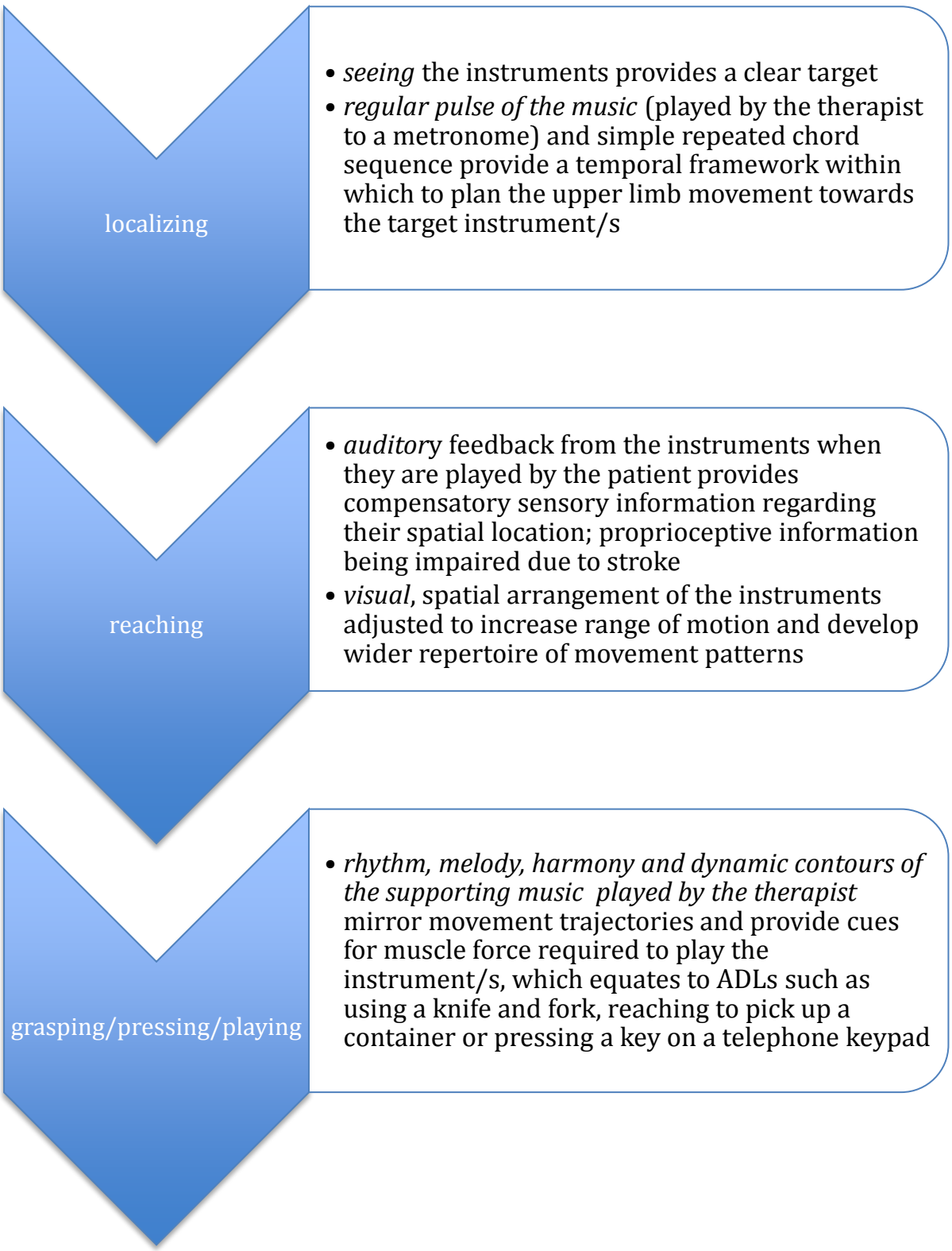


Figure 10. A model of TIMP and audio-motor coupling supporting the three components of localizing, reaching and grasping an object

3.5 Music supported therapy (MST)

MST is a technique that has produced scientific evidence to support its application as an intervention for upper limb hemiparesis (Schneider et al., 2007; Altenmüller et al., 2009), also showing greater efficacy when outcomes were compared with a matched group of stroke patients receiving CIMT (Schneider et al., 2010), which is a much more intensively delivered intervention (Taub et al., 1993). MST has also been trialled with groups of pairs, either playing in synchrony or taking turns to play through keyboard exercises (Floris Tijmen and Jens, 2014). The turn-taking pairs scored higher than the synchrony pairs in the 9HPT and the study indicated that the intervention could be effective and potentially more cost effective in this format, where participants modelled the exercises to one another. These studies, conducted in Germany and Canada, followed an exercise protocol using either an electronic keyboard only, or an electronic keyboard and electronic drum pads. In the 2007 and 2009 studies eight notes were available to be played using either a keyboard or drum pads. There were ten exercise patterns that gradually increased in complexity, with pattern 1 requiring the playing of a single note on the keyboard or a single drum pad, which triggered a note. The more complex of the ten patterns required participants to play a simple melody from a folk song containing 5-8 different notes. Computerized movement analysis was used to accurately monitor and measure for changes in participants' movement trajectories, alongside conventional measures including the Action Research Arm Test (ARAT) (Lyle, 1981) and Nine Hole Peg Test (9HPT) (Kellor et al., 1971). The results showed that upper limb function in the MST group, who also received standard treatment, improved significantly in speed, smoothness, precision and everyday use of the paretic upper limb compared to the control group who received conventional therapy only. A similar design, using keyboard only, was conducted with chronic stroke patients who received treatment three times per week for three weeks and in addition were required to practice at home (Villeneuve and Penhune, 2014). The study showed that this shorter term, lower dose design improved upper limb function in all participants, with some correlation indicated between more time spent on home practice and higher outcome scores. Table 3 summarises all MST studies, showing ARAT and 9HPT scores where available.

A comparison between ARAT scores (Rodriguez-fornells et al., 2012) from three MST studies (Schneider et al., 2007; Schneider et al., 2010; Rojo et al., 2011) is shown below in Figure 11, illustrating the significantly improved scores for acute patients in the experimental group compared to the controls who received conventional therapy (graph two), conventional therapy or constraint induced therapy (graph three). The first graph compares chronic stroke patient and healthy controls, showing the MST scores increasing towards normal.

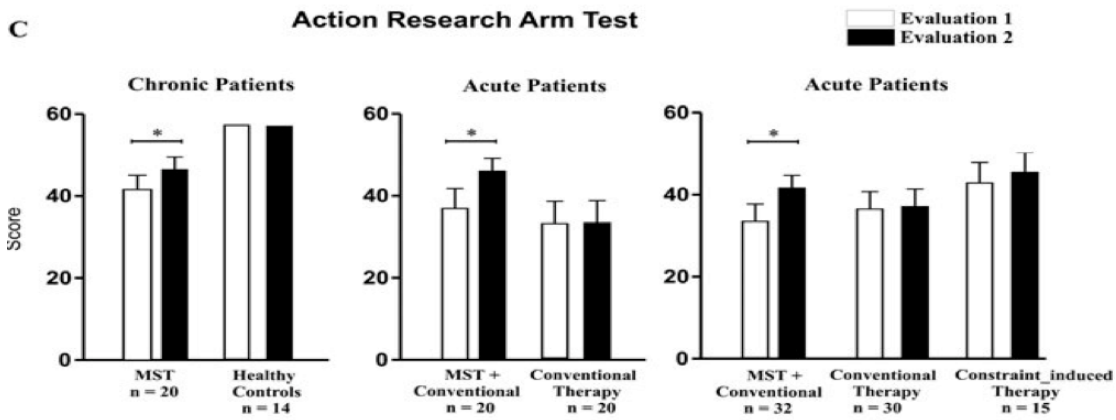


Figure 11. A comparison of three ARAT scores from MST studies (Rodriguez-Fornells et al., 2012, p.284.

Investigators	Total Sample	Site: L/R/ bilateral & Type: Ischaemic/Haemorrhagic	Period Post Stroke (months): experimental/Control	Period/Number of sessions	Facilitating Music	Equipment	ARAT (mean): pre/post, exp/control	9HPT (mean): pre-post; exp/control
Schneider. S., Schonle. P. W., Altenmuller. E., Munte. T. F. (2007)	40	20/20 & 34/6	2.1/1.9	3 weeks/15	No	Midi-piano & 8 electronic drum pads	36.9 – 45.9 32.8 – 33.3	4.9 – 6.1 4.15 – 4.3
Altenmuller. E., Marco-Pallares. J., Munte. T. F. and Schneider. S. (2009)	62	MG = 17/15; CG = 15/15 & 53/9	1.3/1.4 (mean)	3 weeks/15	No	Midi-piano & 8 electronic drum pads	33.3 – 41.4 36.4 – 36.9	4.1 – 5.4 4.9 – 4.9
Grau-Sanchez. J., Amengual. J. L., Rojo. N., Veciana de las Heras., M., Montero. J., Rubio. F., Altenmueller. E., Munte. FT. F., and Rodriguez-Fornells. A. (2013)	9	MG = 2/7 & 8/1 Control = no stroke	2.9 (mean)	4 weeks/20	No	Midi-piano & 8 electronic drum pads	37.7 – 45.5 57 – 57	4.7 – 4.7 9 – 9

Schneider. S., Munte. T., Sailer. M., Altenmueller. E. *(2010)*	*77*	3 groups: MG (32) = 15/17 & 26/6 CG = 15/15 & 27/3 TG11/4 & 12/3	MG = 1.9, CG = 1.9 TG = 1.7	3 weeks/15	No	Midi – piano & 8 electronic drum pads	MG: (2009) 33.3 – 41.4 CG: (2009) 36.4 – 36.9 TG: 42.7 – 45.4	MG: 4.1 – 5.4 CG: 4.9 – 4.9 TG: 4.9 – 5.1
Van Vugt. F. T., Ritter. J., Rollnik. J. D., Altenmüller. E. (2014)	28	17/11 & 24/4	40.6-45.6 days	3 to 4 weeks/10	No, but one group of pairs played together, in synchrony	Midi piano	Not used	Turn-taking group improved more than synchrony group
Villeneuve. M., Penhune. V., Lamontagne. A (2014)	13	6/6/1 & 9/4	42 months (mean)	3 weeks/9 + 2 X per week home practice	No	Midi piano	Not used	Individual scores improved

Table 3. Summary of MST study data relevant to this TIMP study.

Period post stroke, use of facilitating music (which was not used), ARAT and 9HPT scores are displayed in the table. For the bottom two studies there was no control group. The Van Vugt et al study compared groups of pairs either playing in synchrony or taking turns to play each exercise.

3.6 The Ronnie Gardiner Rhythm and Music Method

Another rhythm and music driven technique, currently undergoing clinical trials, has been used in Sweden within healthcare and neurodisability settings since 1993 and is known as The Ronnie Gardiner Rhythm and Music Method (RGRM) (Bunketorp Kall et al., 2012). This method is based on the principles of neuroplasticity, using rhythm, music, colour and the voice, as well as a unique notation system using text, shapes and movement to stimulate coordination, balance, endurance, attention, memory, body image and social interactions. Right and left sides of the body are simultaneously activated along with both brain hemispheres. Sound codes are derived from drum sounds and participants in the current study perform a total of 18 increasingly complex movement sequences at their own pace, as with MST, but playing body parts such as clapping and foot stamping rather than instruments. The current study is being compared to therapeutic riding (horse riding), also known as Equine-Assisted Therapy and Adaptive Riding and delayed intervention. Stroke patients between 1-5 years post stroke are still being recruited. Dosage is not clearly reported at this stage. The primarly outcome measure is the stroke impact scale version 2.0 (Duncan et al., 1999) and the secondary measure is the physical subscale of the fatigue impact scale (FIS) (Fisk et al., 1994).

3.7 Music performance and audio-motor coupling

Evidence has been found which explains the rapid acquisition of motor skills in musicians as being due to the sophisticated motor skills required throughout instrumental training, which is an important consideration in addressing the matter of understanding sensorimotor integration, as well as multisensory integration. Successful music performance is highly dependent on rapid auditory feedback from the instrument being played, which is continuously monitored by the performer and which links the instrumental sound to the motor programs that are being employed (Bangert et al., 2006). This corresponds with the descriptions of *Parametric, Direct* and *Internal Feedback* (The somatic sensory system, Carpenter and Reddi, 2012), whereby motor performance improves through previous experience modifying motor planning and the internal representation of previous, repeated attempts at specific tasks.

Musical motor performance involves the same brain regions as other motor tasks, those being the: motor, premotor, supplementary motor area (SMA), cerebellum and basal ganglia, as well as somatosensory, auditory, emotional, temporal, and memory loops (Altenmüller, 2001; Lotze et al., 2003; Meister et al., 2004). Musicians perform complex movement patterns, which are informed by continuous auditory feedback from their playing (Altenmueller, et al., 2009), and feedback from movements is fundamentally important in order to inform and control them (Carpenter and Reddi, 2012). The MST studies, which have involved non-musicians, have reported on *audio-motor coupling* in participants, where auditory pathways become more integrated with the movement planning neural circuits. Other studies have illustrated the potential for neural reorganisation due to instrumental training, including one showing the involuntary activation of motor systems in pianists when listening to music (Haueisen and Knosche, 2001), and another recording activity in the primary auditory regions of violinists as they silently tapped out a song. *Audio-motor coupling* has also been observed within minutes of novice piano players beginning to practice (Classen et al., 1998).

Preliminary evidence has indicated that technology such as magnetoencephalography (MEG) and EEG, which have high temporal resolution, could offer new insights into the mechanisms of movement-organization and execution in the brain (de Vico Fallani et al., 2009). EEG data from one of the MST studies showed treatment related changes in electrical activity, which the researchers suggest is related to increased motor region activity. The effects of MST on the brain were measured using functional Magnetic Resonance Imaging (fMRI) in a single case study with a right handed, left hemisphere lesion female participant, who received four weeks of daily MST (20 sessions), following the same protocol as in the two earlier studies (Rojo, et al., 2011). When the participant used her affected upper limb the pre-treatment scans showed widespread and excessive activity in the primary sensorimotor-pre-motor network in the left (contralateral) side and activation on the right (ipsilateral) side. Following MST treatment, the scans showed a reduction in excessive contralateral brain activity, with some reduction also in the ipsilateral hemisphere (see Figure ___ below). In other words, the fMRI scans show that the treatment resulted in more efficient neural firing, leading to more focused motor planning. In movements using the participant's unaffected upper limb, no neurological changes occurred. Scans also

showed changes in brain activity when just listening to the music performed during the study, revealing that prior to treatment only the temporal cortex was active, whereas post-treatment scans showed bilateral activation of the motor areas, with more activity in the left hemisphere. These outcomes from the treatment led to further discussion of the *audio-motor coupling* effect.

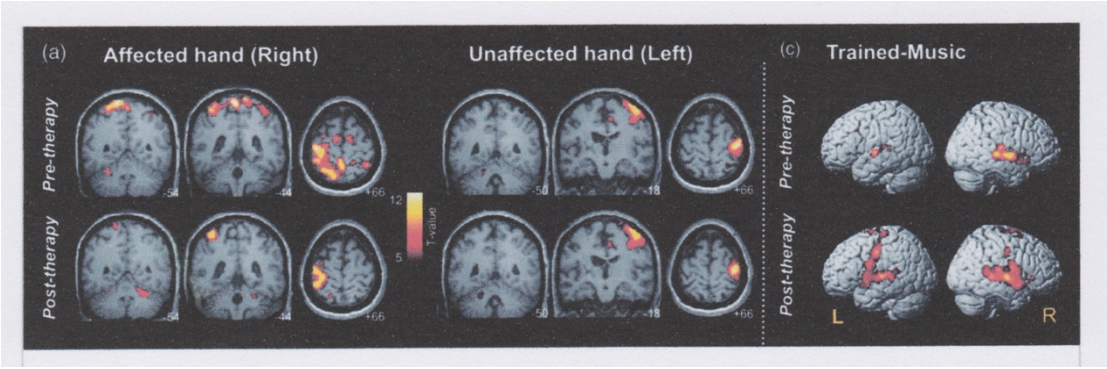


Figure 12. fMRI scans showing a reduction in bilateral brain activity post MST treatment (Rojo et al., 2011, p.6).

The above fMRI scans show a reduction in bilateral activity post MST treatment (a) and more focused activity in the contralateral motor areas. The right hand scans (c) show an increase in motor region activity during the listening task post treatment.

3.8 Audio-motor coupling linked to Gestalt theory

As mentioned in the introduction to this thesis, the earlier work of Susan Greenfield, specifically Gestalt theory, was assimilated into the clinical thinking of music therapist Julia Usher in the late 1990s (Greenfield, 1995; Usher, 1998), before terms such as neuroplasticity and neural reorganisation became so widely used. The model describes neuronal recruitment and discusses possible links between neuronal assembly formation and the development of musical gestalts, alluding to neuronal reorganisation and audio-motor coupling. The basic premise of this assimilation was to recognise how central arousal levels in clients are, and that optimising (not over or under stimulating) them can lead to greater potential for the therapist to then use

music to support the repetition of an action. Through repetition more neural connections can develop and the client is able to engage for longer periods, repeating more controlled and purposeful movements and interactions. Whilst there may be similarities in this model of learning with the processes of instrumental learning, the focus here is on the movement being purposeful, highly repetitious and motivating, rather than developing the skills required to learn and reproduce a repertoire of pre-composed pieces. The theory can also be linked to the different types of feedback (ballistic and internal) from motor responses (Carpenter and Reddi, 2012) (see The somatic sensory system) and how this can lead to improved motor performance through error-correction and repetition. Usher's introducing of this neuroscientific theoretical model into her clinical work indicated great potentials for music therapists and was quite pioneering at the time, particularly from a UK, predominantly psychodynamic perspective. Research continues to be published that supports the use of music in order to assess, monitor and provide interventions using a model of optimal arousal, leading to improved awareness and improved attention in patients with neurological injury, in-particular those with catastrophic injury who are termed as having disorders of consciousness (O'Kelly and Magee, 2013; O'Kelly et al., 2013; Magee et al., 2014).

The crossover and partnership that has been slowly emerging between music, music therapy and neuroscience and the clinical application of neuroscience models and rationales has led to the emergence of music therapy assessment tools and interventions such as MATADOC, MST and TIMP. These protocolised interventions are based on scientific evidence that they induce neural reorganisation, exploiting the brain's potential for neuroplastic change under the research conditions described in the literature so far discussed and which has been examined under the conditions of this study. As such, music therapy clinicians working within neurodisability settings would also benefit from some understanding of what induces this process and why.

3.9 Neuroplasticity

The Oxford concise medical dictionary definition of neuroplasticity is:

> "the ability of the brain to develop new neurons and/or new synapses in response to stimulation and learning. Recent research shows that the brain retains its plasticity throughout life, more or less, depending on the person's state of health, etc. Following injury to the brain, neuroplasticity may allow uninjured areas to take over the processes previously carried out by the injured areas" (Martin, 2010; Neuroplasticity, 2010)

From a popular science narrative, Daniel Levitin provides a simplified description of neuronal recruitment potential, explaining that for 2 neurones the possible connections are 2, for 3 there are 8, with 4 there are 64, with 5 neurones the potential then increases to 1,024, and so on (Levitin, 2008).

The changes in cortical organization that occur following stroke have been proposed as being due to two related factors. Firstly the degeneration of neurons at the lesion site and secondly the disruption of neural networks in the areas of the brain that are undamaged but connected to the damaged areas. These can be areas that are adjacent to or remote from the damaged site (5 mm or more in distance from the lesion), located in the contralateral motor cortices or subcortical motor structures (Levin, 2000). In hemiparesis, use of the affected side during rehabilitation has been described as an interaction between cortical injury and skilled movement, which can profoundly affect reorganisation in spared neuronal networks (Nudo. R. J., Barbay. S., Kleim. J. A., 2000).

Multiplexing is another term relevant to the processes of neuroplasticity and describes the multiple use of neurons and fibres that enables their participation in various functions (Bach-Y-Rita, 2010). This phenomenon is defined in a musical context by Wan and Schlaug, who state "music making places unique demands on the nervous system and leads to a strong coupling of perception and action mediated by sensory, motor, and multimodal integrative regions distributed throughout the brain" (2010 cited in Wan and Schlaug, 2010, p.566). They further explain that the audio, sensory,

visual and motor information is transmitted across frontotemperoparietal regions that "overlap with a "hearing-doing" or "seeing-doing" action-observation network that is commonly known as the mirror neuron system" (2010b & 2007 cited in Wan and Schlaug, 2010, p.567). In addition to these neural networks and regions, they continue, subcortical, limbic areas are involved because music making can be a pleasurable experience. This presents a robust rationale for employing music and rhythm based sensorimotor interventions, because they not only facilitate neural reorganization, but they have been found to maintain patient motivation and adherence.

3.10 Maladaptive plasticity

Whilst the term 'neuroplasticity' is becoming more widely used, there is a risk that this phenomenon will always be associated with positive results for patients when rehabilitation interventions are applied, which is not necessarily the case. Maladaptive plasticity describes hindered functional recovery or the development of unwanted symptoms during the process of recovery, such as compensatory movements in the process of motor rehabilitation (Jang, 2013). A review article aiming to provide an overview of maladaptive plasticity following stroke in order to clarify the most appropriate rehabilitation approaches for optimum cortical reorganisation focused on four factors influencing outcomes: 1) compensatory movement, 2) ipsilateral motor projections (activity of the motor cortices in the brain hemisphere where the lesions are), 3) competitive interaction, 4) rehabilitation and non-invasive brain stimulation (Takeuchi and Izumi, 2012). The paper highlights levels of arm function, proximal and distal, as indicators for any one of these four factors and suggests consideration of the 'competitive interaction hypothesis' in order to prevent maladaptive plasticity during rehabilitation. This hypothesis describes the unaffected hemisphere as inhibiting the affected hemisphere through abnormal interhemispheric inhibition that restricts motor function, possibly resulting from unbalanced changes in both hemispheres. The paper cites research indicating that there is more activation of the unaffected hemisphere in patients with poor motor function, which can be seen in Figure 2. It also describes the ipsilesional (side where the stroke lesion is) premotor cortex (PMC) as usually having an inhibitory function on the contralateral hemisphere, which is disturbed by the stroke, particularly in patients whose hand function is poorer than their proximal arm function, again, clearly visible in the PET

images in Figure 2. This loss of inhibitory function could cause hand and proximal arm regions to compete for areas within the motor cortex, in-turn leading to competitive use of the hand and proximal arm. In other words, this is learned mis-use, where there is an increase in cortical representation for an abnormal movement because this is the movement that has been practiced. For example, excessively raising the shoulder and using the trunk in order to reach up for an object will reinforce the motor networks in the brain for this movement, rather than re-learning, or rehabilitating, shoulder and elbow extension. Approaches suggested by Grefkes and Fink (2011) in cases where patients have good motor function, include the avoidance of intense training of proximal movements as these become compensatory, no evidence is cited to support rehabilitation programs that address this problem. The authors hypothesise that regional anaesthesia of the proximal arm in order to inhibit movement might partly ameliorate this competitive interaction during hand exercise performance. However, there is currently no supporting evidence for this type of intervention. Other approaches cited in the paper are CIMT, which may improve hemispheric imbalance, and bilateral arm training, which improves the balance of excitability in both hemispheres but may be more suited to proximal rather than distal arm function.

Current information regarding plasticity and maladaptive plasticity clearly needs to be accessed and understood by relevant health professionals, including music and neurologic music therapists, in order to inform appropriate and optimum interventions.

3.11 Rhythm perception and processing

Research identifying the cortical and subcortical circuits of the brain involved in the processing of music is on-going. Some has focused on specific musical elements such as rhythm and the components of rhythm such as pulse, meter and tempo. Rhythmic Auditory Stimulation (RAS) research has clearly identified the impact that rhythm can have on gait rehabilitation in a number of patient groups (Thaut et al., 1993; Prassas et al., 1997; Thaut, McIntosh and Rice, 1997a; Hurt et al., 1998a) and if auditory rhythm can promote neural reorganisation and lead to improved movement when applied as a

neurorehabilitation treatment, then understanding which regions of the brain are involved in rhythm perception and processing would be useful and perhaps help clarify which patients would benefit the most from music therapy or other therapeutic treatments that are dependent on rhythm, or beat-based techniques. The necessity for such clinical knowledge informing practice is supported by existing research, for example increased variability in the performance of tasks requiring synchronisation to rhythmic cues has been shown where the basal ganglia is affected, either by Parkinson's disease or focal lesions (Sowinski and Dalla Bella, 2013). This knowledge informs the clinician about suitability of rhythm driven interventions, particularly in the upper limbs where movement is less intrinsically rhythmic compared to gait.

Based on the compelling evidence for efficacy reported for RAS in gait training for brain injured patients recommendations have been made for further research into rhythm based techniques to treat hemiparesis in stroke patients (Bradt et al., 2010). In exploring the physiological brain mechanisms underlying rhythmic synchronization behaviour using magnetoencephalography (MEG), (Thaut, 2008) it was established that the amplitude of a specific brainwave was generated in response to changes in beat interval. Changes in beat interval equate to the speeding up and slowing down of a metronome beat, thus creating variations in the time between one beat and the next and disrupting beat predictability. This was observed whether the changes in speed were consciously perceived by the participants or not. That is to say, the rhythm to which participants were listening was either increased or decreased by less than 5 per cent, which is below conscious perception, or, in the second experiment, by between 5 and 20 per cent, which is perceivable. This experiment showed that beat interval processing occurs below conscious perception. The amplitude of this identified brainwave, the M100, increased in synchrony with increases in time between one beat of a rhythm and the next, and likewise with decreases in beat intervals. Further analysis revealed that the M100 brainwave was generated in the primary auditory cortex. The change in magnitude of this brainwave could only be possible if it were a part of a larger neural circuit, involving other brain regions and subcortical circuits, as it is well established that neurons cannot fire with greater or lesser power, they simply fire. The M100 being part of a larger neural network, which was collectively responding to the changes in beat interval, would explain the changes in amplitude

(Thaut, 2008). Neuronal circuits, including reticulospinal pathways in the brain stem and spinal cord involved in rhythmic motor performance, have long been identified as engaging in auditory beat perception (Paltsev and Elner, 1967; Rossignol and Jones, 1976).

An investigation to find whether specific motor regions were engaged in the processing of beat or pulse within different rhythms, by asking normal participants to reproduce different types of rhythmic sequences, showed that rhythms with regular beats and accents (duration-based rhythms) were better reproduced by participants, and fMRI scans indicated that the basal ganglia and supplementary motor areas may mediate beat perception (Grahn and Brett, 2007). Research with Parkinson's patients (Grahn, 2009), a condition where the motor system including the basal ganglia is affected, supports the role of the basal ganglia in beat perception, showing that this patient group does not perform as well as normal controls in rhythm discrimination tasks. This research also showed how listening to rhythms with a clearly discernable beat (beat-based rhythms) improved the functional connectivity between basal ganglia, primary motor cortex, secondary motor cortex, and the auditory cortex. Understanding how different 'partially distinct' brain mechanisms such as the basal ganglia (beat-based) and cerebellum (duration based), are engaged in the processing of different rhythmic material is important as these different rhythms can be used to support exercises that compensate damaged mechanisms (Grahn and Watson, 2013). Other research has highlighted the potential for auditory rhythmic stimuli to support motor control, reporting that patients with cerebellar damage present with errors in muscle contraction and increased variability when performing repetitive finger tapping exercises (Molinari et al., 2003). The authors cite research indicating that the cerebellum performs the task of extracting temporal information from sensory inputs and channelling it to the motor system. Patients tested in detecting changes in frequency of auditory rhythm who had cerebellar atrophy, which, although being a degenerative condition, produces symptoms comparable with stroke (Spinocerebellar Ataxia, 2015), performed significantly less accurately compared to patients with focal damage and normal controls. Interestingly, healthy subjects and participants with focal damage and atrophy were all able to synchronise tapping with an auditory stimulus. The coupling between stimulus and motor response for all three groups shared similar variations in timing errors when the stimulus was altered in frequency

at both perceived and non-perceived levels. In summary, patients with cerebellar damage, whether focal or atrophic, present with impaired conscious detection of rhythmic variation but not impairment of movement timing when entraining movement to rhythm. This indicates the use of rhythm as effective in supporting motor rehabilitation. The report concludes that either the basal ganglia or the cerebellum are active during temporal discrimination tasks, possibly at different stages of processing. Timing is a function distributed amongst several neural circuits that can each process time information, and the degree to which each circuit is activated depends on the specific task and its timing requirements. This has clear implications for goal setting during rehabilitation and, in the case of this TIMP study, assigning the correct exercise at the optimum tempo for each participant with consideration for type of stroke, site of lesion/s and their individual movement pathology.

Other research has indicated that more complex rhythms, such as syncopated rhythms, require more repeated listens in order for the basal ganglia to become activated, revealing that attention is key to processing this more complex auditory information, and that attention also serves to integrate brain regions for performing motor tasks in general (Chapin et al., 2010). The need for attention, highlighted by Chapin et al, in order to achieve the kinds of motor tasks included in previous music therapy studies and this TIMP study is also a key component of the simplified reaching and grasping model previously described (see 'Higher motor control', Figure 7, p.31) with the first stage engaging the frontal cortex in order to attend to the object that is to be reached, grasped and lifted (Carpenter and Reddi, 2012).

As has been so far discussed, music therapy research findings investigating the neural processing of rhythm and music, and the effects of rhythm on movement, which first began emerging in the early 1990s, suggest that music can stimulate complex cognitive, affective and sensorimotor processes in the brain, and that these processes lead to enduring changes in the way the brain is connected or organised. This resulting neural reorganisation improves functionality in cognitive, affective and sensorimotor activities of daily life, in other words "the brain that engages in music is changed by this engagement" (Thaut, 2008, p.62).

3.12 Music and rhythm, emotion and cognition

Sarkoma (Sarkamo et al., 2008) found statistically significant gains following a self-selected music listening study involving sixty stroke patients. These gains were in the domains of verbal memory, short-term and working memory, language, visuospatial cognition, focused attention, sustained attention, music cognition and executive function. This study presented clear evidence that, for stroke patients, regularly listening to their music of choice in the earlier stages post stroke significantly improved their cognitive recovery and helped prevent negative mood; often experienced following stroke.

Some key attributes of music and music therapy have been offered (Nayak et al., 2000) as an explanation of how music can influence mood. The structure of a music therapy session in a non-threatening environment nurtures successful and meaningful interactions between therapist and patient/s. The memories and personal associations that people have with personally meaningful music can evoke emotional responses in the listener, and the rhythm of the music can induce physiological responses, regulating heart rate, respiration, blood pressure and muscle tone. Studies including composition and improvisation activities that were selected based on participant preferences were shown to enhance mood and positively effect, social interactions and behaviour amongst participants.

One paper (Craig, 2008), reporting on the therapeutic use of music in occupational therapy (OT) found that 54 per cent of OTs use music and up to 100 per cent report positive effects for their patients in enhancing participation and engagement. The paper specifically outlines the emotional and cognitive effects of using music, citing studies that have found music to be used in music therapy to help elicit more positive mood and other studies where music has been found to positively regulate arousal in order to improve attention and memory and to reduce anxiety.

3.13 The NMT's application of theoretical knowledge

When assessing stroke patients and applying interventions for sensorimotor rehabilitation it is essential for health professionals to understand the causes and

effects of stroke, as well as brain anatomy and its relation to lesion site and pharmacological treatment in order to manage spasticity and other stroke induced movement disorders such as dystonia and tremors. The NMT training, accompanying manuals and published texts clearly state that NMTs are required to build a working knowledge in these areas. Whilst this may appear to be a daunting undertaking in terms of assimilating knowledge, without it the setting of achievable functional exercises would be more of a challenge, if not impossible in the researcher's opinion.

Understanding the benefits of receiving auditory feedback in order to compensate for loss of sensation and proprioceptive feedback, for example, should lead music therapists to the selection and positioning of the most appropriate instrument or equipment, including adaptive beaters and playing devices, and appropriate hand-over-hand support at the optimum frequency and with appropriate facilitating music. Insight into compensatory movements and their implications for maladaptive plasticity should lead to interdisciplinary discussion and planning, in order to optimize pharmacological intervention and the potential use of bilateral exercises, which can avoid proximal and distal competition for representation in associated cortical regions and help balance interhemispheric excitability. This too has implications for type of instruments and equipment, and their positioning. For NMT application, interdisciplinary assessment is required and this does or should provide detailed, specific information regarding the type of movement impairment for each patient, its cause and recommended treatment. But the NMT clinician will still be required to understand what potential effects facilitating music will have in terms of rhythmic attunement and in relation to areas of the brain affected that might impair sensorimotor integration and render certain music or over-complex rhythms ineffective or even adverse to therapeutic objectives. They will also need to select instruments and position them effectively, monitoring these key factors throughout sessions in order to optimally meet and expand goals. Then, of course, before considering any of the above, each NMT must first be a musician of high attainment and great experience in order to make informed clinical judgements and devise effective musical exercises within the TDM.

3.14 Summary

There is mounting scientific data, much of which has been presented in this chapter of the literature review, showing the way in which music and musical elements are processed in the brain (Grahn and Brett, 2007; Grahn, 2009; Grahn and Rowe, 2009; Grahn, 2012; Grahn and Watson, 2013), how music and rhythm can affect movement (RW.ERROR - Unable to find reference:52; Malcolm, Massie and Thaut, 2009a), and how playing musical instruments can drive neural reorganization to improve upper limb function (Altenmüller et al., 2009; Rojo et al., 2011; Grau-Sánchez et al., 2013). Scientific models have been formulated linking the effects of music on therapeutic outcomes (the Rational-Scientific Mediating Model, or R-SMM), leading to structured approaches to functional goal setting by NMTs using interventions from within this particular branch of music therapy (the Transformational Design Model, or TDM) (Thaut, 2008). A gap in knowledge exists to support some NMT techniques, with only two TIMP studies reported (Yoo, 2009; Chong et al., 2013), and to support rhythm driven music therapy interventions that effectively improve upper limb hemiparesis following stroke (Bradt et al., 2010). Whilst rhythm and strongly rhythmic music has been found to be effective for RAS gait training, which is an intrinsically rhythmic physical action, research has also found that other elements of music support more complex movements, such as those of the upper limbs. This research is presented in the following chapter, comprising the third and final section of the literature review.

4 CHAPTER 4. TIMP MUSIC SELECTION AND COMPOSITION

4.1 Introduction

A central consideration for this study was composing and selecting appropriate music to provide a temporal framework for participants to synchronise their movements to and which mirrored movement trajectories such as elbow flexion and extension and wrist pronation and supination. These upper limb movements are much more complex than in the lower limbs, requiring reaching and grasping movements as well as extremely fine finger dexterity.

The researcher's first instrument is the classical guitar, which is a versatile and portable instrument, and was used to develop and deliver the TIMP music. This was done initially in collaboration with the volunteer stroke patient, prior to beginning recruitment of CCS patients. The following chapter presents the rationale for the music used, based on: 1) the clinical experience and training of the researcher, 2) NMT training and published guidelines for the use of music in the application of sensorimotor techniques (Thaut, 2008; Thaut and Hoemberg, 2014), 3) suitability for this patient population and the research design, 4) current scientific evidence regarding the relationship between music and movement and music processing in the brain.

4.2 Social, cultural and scientific background of music

Evidence for the presence of music has been found in every human society so far discovered (Storr, 1993; Titon, 2009; Abrams et al., 2013). The origins and evolution of music in its various cultural and functional contexts continues to be discussed and debated, but historical records and archeological evidence identify its existence and functional use in activities, rituals, ceremonies and dance, over 10s of thousands of years (Blacking, 1995; Wallin, Merker and Brown, 2001; Thaut, 2008). Records also identify its use in communication, to regulate emotions and to facilitate self-

expression (Zatorre and Salimpoor, 2013). Music and movement experienced in infancy through the singing of lullabies and activity songs whilst being rocked and moved to the underlying pulse, marks the beginning of a musical relationship that is arguably universal to all human cultures (Phillips-silver, 2009) and which continues the innate human practice of improvising, composing and applying music for bonding, social and functional purposes (Wang, 2015). In the case of infant and mother interaction, at three weeks the infant can be effectively soothed by the mother's rocking and rhythmic singing because it already has the neural circuitry to perceive tactile and auditory stimuli as corresponding (Antonietti, 2009). The cardio-respiratory rate of a baby synchronises with lullabies due to the rhythmic and emotional quality of the music (Juslin and Sloboda, 2001).

In addition to the social and cultural study of music and with the development and wider availability of brain scanning technology, it is now possible to see the direct effects that music has on the brain and somatosensory systems. Various brain scanning technologies have been used to examine the neural processing of rhythm (Grahn, 2009; Grahn and Rowe, 2009; Grahn, 2012; Grahn and Watson, 2013), as well as pitch (Zatorre, Evans and Meyer, 1994; Griffiths and Hall, 2012), harmony (Passynkova, Sander and Scheich, 2005) and timbre (Menon et al., 2002). Data on the more holistic effects of music on the brain and sensorimotor systems is also being gathered, with some researchers (Abrams et al., 2013) arguing for music to be played to subjects in its complete and 'natural' form, rather than being broken down into its individual components such as melody or rhythm via synthetic means in a search for the corresponding neural substrates. It is argued that this will provide a truer image of the gestalt neural processing of music and its regulatory effects on perceptual-motor functions (Thaut, 2008; Abrams et al., 2013). However, there is a rationale, based on the aforementioned research into rhythm, pitch and harmony processing, that a componential enquiry in addition to the gestalt view has helped inform clinical music therapy practice, in particular formulating protocols for sensorimotor rehabilitation following brain injury or onset of neurological disease that is specifically and effectively rhythm driven, such as Rhythmic Auditory Stimulation (RAS) for gait training (Thaut et al., 1993; McIntosh et al., 1997; Thaut, McIntosh and Rice, 1997b; Hurt et al., 1998a; Thaut et al., 2007; Kim et al., 2012; Grahn and Watson, 2013; Nombela et al., 2013).

4.3 Music, mood and motivation

Particularly within neurorehabilitation settings and throughout the process of rehabilitation, which increasingly takes place in the community, patient motivation is a major factor that, when lacking, can hinder engagement in and adherence to treatment. A number of music therapy studies illustrate the use of music and the inclusion of music therapy within multidisciplinary rehabilitation, with in-patients and out-patients, in order to improve patient mood and enhance motivation (Nayak et al., 2000; Jochims, 2004; Magee et al., 2006; Craig, 2008; Sarkamo et al., 2008; Street, 2012). Music is not used exclusively by music therapists for these purposes and research (Craig, 2008) reporting on its therapeutic use in occupational therapy (OT), the discipline whose role it is to rehabilitate the skills required to perform ADLs using the upper limbs or to provide adaptive training and technological support, found that 54 per cent of OTs use music and up to 100 per cent report positive effects for their patients in enhancing participation and adherence. Craig's paper specifically outlines the emotional and cognitive effects of using music, citing other studies where it has elicited more positive mood, positively regulated arousal in order to improve attention and memory, and reduced anxiety. Other research into music listening has reported widespread neurological activation on both cortical and subcortical levels (Abrams et al., 2013), and it was also found to increase blood flow velocity in the middle cerebral artery, required to supply oxygen and nutrients to the brain in the required high quantities, in a significant number of patients with acute ischaemic stroke (Antic et al., 2008). Listening to preferred music elicits increased activity in frontal and temporal areas of the brain, as revealed in EEG recordings, in patients with disorders of consciousness (O'Kelly et al., 2013). Self-selected music listening amongst stroke patients (Sarkamo et al., 2008), as previously stated, has resulted in improved cognitive recovery as well as enhanced mood and a reduction in depression.

4.4 The influence of music and shifting musical parameters on movement perception and performance

Research into music and movement perception (Eitan and Granot, 2006) has revealed associations between changes in musical parameters, such as tempo, pitch interval, melodic contour, attack and dynamics, and bodily motion in physical space. This research goes some way to support the rationale for using music to help cue and mirror movement. Increases in the intensity of music, for example the combined effect of increased tempo, dynamics and attack, have been found to correlate with spatial ascents, whereas the opposite (musical abatements) correlate with descents; movements such as lowering a limb. Research into sensory substitution devices for the blind that aid the reaching and grasping of objects (Proulx et al., 2008) has developed technology that converts visual images detected through small video cameras mounted on spectacles into auditory patterns (Meijer, 1992), with lower frequency sounds representing downward movements and higher frequencies representing upwards movements. The brightness, size and shape of the target objects were also represented, respectively, by loudness, duration and frequency spectrum, and frequency modulations.

Pitch changes have also been found to correlate with lateral position; increases with right-side position and decreases with the left. There is a rationale for an evolutionary link to the way humans perceive sounds in this way, as it is crucial for us to know if an approaching object will present danger, or something pleasurable or interesting. An ability to perceive the direction from which objects are approaching and their speed of approach informs fight or flight mechanisms (Neukom, Oechslin andBennet, 2008). In a contemporary environment this is exemplified in the Doppler effect, where the sound of an approaching car is perceived as rising in pitch, and falling in pitch as it moves away, thus informing the subject of its proximity and the potential risk of impact. Research into illusory or imagined motion (Eitan and Granot, 2006) reports that changes in pitch contour prompt participants to imagine movement along vertical, horizontal and diagonal spatial axes. It has been hypothesized that, should changes in such musical parameters be made, listeners would associate them with corresponding changes in dimensions of motion, i.e. spatial verticality, distance or speed. Other research investigating pitch-space correspondence found that the effects on

modulating or driving visual motion perception were not as strong as previously assumed, but that correspondence could become stronger if subjects were trained to associate changes in pitch with changes in visual motion (Hidaka et al., 2013).

4.5 Sonification

Further evidence has been found regarding pitch-space perception, following a small study investigating the potential for sonification as a tool for upper limb rehabilitation (Scholz et al., 2014). Sonification is defined as using a sound stimulus to represent otherwise inaudible information, in this instance sound representing movement trajectory (Scholz et al., 2015). The study concluded that pitch prompted faster, more effective learning when mapped onto a vertical movement axes during training, where the upper limb ascending movement corresponded to an ascending scale, and brightness of tone (the second sound parameter under investigation) was only effective when mapped onto the horizontal axis for corresponding arm movements.

4.6 Auditory feedback in robot assisted arm training

A review of literature regarding auditory feedback when using robot assisted upper limb training with stroke patients presents various studies highlighting the underuse of auditory stimuli to drive plasticity, citing music and music therapy studies and robot training systems that use auditory feedback. The paper describes two functions for auditory feedback with such devices: 1) for knowledge of results; 2) for knowledge of performance. The paper concludes that auditory feedback can increase motivation and speed up the learning process through auditory representation of temporal and spatial information that is pertinent to the required movement kinematics for specific task performance (Rosati et al., 2013). The improved rate of motor learning through such feedback fits the somatic sensory model described earlier (Carpenter and Reddi, 2012), involving feedback that informs and improves each attempt at performing a motor task.

4.7 Natural versus artificially manipulated and computer generated music

As stated in the introduction, technology has allowed access to much greater detail concerning the neural processing of music and its component parts. In a study investigating synchronized brain responses when participants listened to 9-minute 'natural' musical excerpts in their complete form (Abrams et al., 2013) the lesser known late-baroque symphonies of William Boyce were used in order to avoid memory related and familiarity effects, whilst maintaining clearly identifiable western musical and, in particular, temporal characteristics that subjects were assumed able to process easily. Participants were monitored for neurological responses using fMRI whilst listening to the excerpts in their natural form and compared to an artificially manipulated form, where frequencies were scrambled and silences between movements in the music removed. The artificial excerpts elicited less activation of the motor and associated sensory-motor integration and motor imagery regions than did the natural music. In summary, the study identifies widespread brain activation through natural music listening where listeners were specifically engaged in the tracking of structural musical elements over extended time periods. Furthermore, the research shows that motor regions are time-locked to structural components of the music (rhythm, for example) in its complete, organic form, and not only by low-level acoustic cues such as those provided by a metronome or by separated musical components such as pulse. It is then suggested that this is partly due to the use of music through the course of human evolution in conjunction with dance and synchronized movement. This has implications for using such musical accompaniment, not necessarily 'known' music or songs and with the possibility of patients entraining movement to different musical patterns to support and improve sensorimotor function where there has been neurological damage such as in the case of stroke.

The neural processing of metrical structures in music was studied by comparing participants' finger tapping performance onto an electronic drum pad along with: 1) expressive forms of music, 2) mechanical music, 3) mechanical music with accented beats ('mechanical' meaning computer generated or electronically sequenced) (Drake, Penel and Bigand, 2000). The expressive forms contained microstructures, such as

subtle variations in tempo, rhythm and timbre, which are a natural part of music performance and also occur due to each performer's interpretation of the score. The mechanical forms provided only the information included in the score. Accuracy of tapping was found to be better with the mechanical music compared to the expressive music. The mechanical music with accented beats did not prompt any significant improvement in synchrony. This research suggests that the subtle variations in timbre, timing and melodic contour, for example, created through live performance of music would not support accuracy of upper limb movement trajectories as well as music generated electronically by computer.

The difference between this research and the TIMP research under discussion, is that in the latter participants played music live and in synchrony with the researcher. They used more complex movement sequences than those required to tap on a single electronic trigger that produced a single sound. There was, therefore, a live interaction between the therapist and each participant, within the framework of each facilitating musical structure. The music contained subtle rreal-time changes in timbre, melody and timing. There were also visual cues accenting the pulse of the music that came from the movements of the researcher as he played, for example swaying to the music, foot/leg moving and tapping to the pulse, and the hand and finger movements required to play the music on the guitar. Participants also received auditory feedback from the range of instruments that they played and the ways in which they played them, which is more acoustically varied and produces a wider dynamic range than is the case from tapping an electronic trigger.

4.8 Rhythm and tempo

Stimulating music has been found to correlate with increased muscle activity, but sedative music less correlated with decreases in muscle activity (Safranek, Koshland and Raymond, 1982). Variations in EMG (Electromyogram, used to measure the electrical activity of muscles when active or resting) activity increase where uneven rhythms are used to support movements, whereas regular rhythms lead to a decrease, which might suggest that the latter is better suited to supporting more controlled muscle activation. Slower movements have been found to produce continuous EMG patterns whilst faster movements show activity in bursts. Some research has found

that preferred tempo of performing motor tasks results in more consistent EMG patterns for all subjects (Safranek, Koshland and Raymond, 1982), which suggests that facilitating music for upper limb exercises should be played at the patient's preferred tempo in order to elicit optimum movement timing and control. A review of rhythm and movement research with Parkinson's patients states that rhythms lose their therapeutic effect when too cognitively challenging for patients and when not attuned to their existing pace (Nombela et al., 2013). NMT texts on sensorimotor protocols stipulate that the music and metronome tempo should initially be set to patients' existing movement frequency (Thaut, 2008; Thaut and Hoemberg, 2014) and gradually adjusted towards normal without compromising movement quality. Further research into the significance of task parameters such as tempo during intensive motor training was recommended following a study investigating upper limb reaching with stroke patients (Massie and Malcolm, 2012). Participants were instructed to perform a reaching task in a single session at either a self-paced or fast as possible frequency. The task required elbow and shoulder flexion-extension, key movements for performing ADLs. Results showed that reaching was significantly faster and smoother, with maintained target accuracy where speed of movement was emphasised in the instructions. Less anterior trunk displacement was also observed.

In this TIMP study, participants were not passively listening to music, but performing specific movement sequences to achieve instrumental playing within a musical framework that aimed at helping them to focus on the movement timing and accuracy and not detract from this. Due to the high muscle tone and spasticity that accompanies some upper limb hemiparesis, music with an even rhythm would also be more appropriate, but, based on research discussed here, not necessarily sedative or relaxing music as this does not correlate with decreases in muscle activity and may also be less effective in optimising arousal, focusing and sustaining attention than stimulating music would be.

4.9 Suitability of metronomes, musical structures and pre-composed music

Walking is the most intrinsically rhythmic movement that humans perform. This would indicate that music and songs in their complete form with a clear or reinforced pulse would aid entrainment, motivate patients and not detract from these objectives when compared to using a metronome only, which would also be potentially less motivating. A review of NMT in neurorehabilitation literature (Altenmüller and Schlaug, 2013a) reports that clarity is still required as to whether and when metronome only or rhythmically accentuated music in RAS is more effective in improving temporal synchronization of a sensorimotor task. An RAS gait training study with Parkinson's patients (Thaut et al., 1996) used four different instrumental pieces in four different styles: folk, country, jazz and classical, which participants could choose for themselves. To emphasize the beat a metronome click was embedded into the music. The music was in 2/4 and 4/4 and 32 bars in length. A digital sequencer was used to record the music in order that the tempo could be adjusted without compromising the music quality and pitch. More current and portable technology, such as the iPads used in this TIMP study, does not allow tempo adjustment without compromising the pitch and quality of the recording. To overcome this problem the music for each TIMP exercise was recorded twice using a microphone onto one iPad to two different metronome settings, played by the researcher. This was in order to facilitate rehearsal by participants, with hand-over-hand guidance to improve movement quality and synchronization with the music. Several other RAS studies also used specially prepared music in two or three different styles, with a metronome beat embedded in order to emphasize the beat and recorded using a sequencer or midi equipment that enabled tempo adjustment (McIntosh et al., 1997; Hurt et al., 1998b; Kwak, 2007). Metronome stimulation has also been compared to music stimulation in the delivery of RAS with Parkinson's patients, with findings indicating the former as being more effective (Nombela et al., 2013).

Upper limb movements are more complex than lower limb, requiring the integration of more complex cortical, subcortical and reticulospinal networks in order to achieve much finer dexterity when performing an infinite range of reaching, grasping and manipulating movements with great accuracy and precision. Depending on the type of

upper limb impairment and its neurological cause, a metronome beat alone can serve very well to accompany a tapping exercise, whereby the patient aims to touch two or more visual targets (Malcolm, Massie and Thaut, 2009a). When performing complex wrist rotation, reaching, finger and thumb movements in order to play musical instruments, which share movement kinematics and sequences with those required for ADLs, musical frameworks may be more effective as they can be composed to mirror these movements spatially and give temporal and muscle force cues. This area is one that requires further investigation and it is still not clearly understood whether predictability and timing regularity play a crucial role in supporting MST exercises (Altenmüller and Schlaug, 2013a), which require the playing of instruments in a similar way to in this TIMP study. A pilot study examining the feasibility of combining metronome cueing with occupational therapy standard care for upper limb rehabilitation (Hill et al., 2011) found greater functional gains in the control group. Although this combined treatment approach brought other benefits for experimental group participants, such as in motivation and improved quality of life scores, it did not produce the results that previous studies using metronome based upper limb entrainment techniques have reported (Whitall et al., 2000; Thaut et al., 2002; Malcolm, Massie and Thaut, 2009a).

RAS was applied to upper limb hemiparesis in stroke patients with auditory cues provided by a metronome in order to reduce compensatory movements and improve arm flexion and extension (Malcolm, Massie and Thaut, 2009a), resulting in decreased trunk compensation, increases in shoulder flexion and slight increases in elbow extension. These outcomes are similar to those found in the study investigating the impact of speed of performance on reaching and in reducing compensatory trunk movement (Massie and Malcolm, 2012), however the exercises were more complex, the training period longer and more intensive, and participants moved to a metronome beat set to their existing movement frequency. Bearing these factors in mind it would appear that further research into the impact of speed on movement in stroke patients would, as previously stated, be beneficial, possibly helping to identify specific cases where increased movement frequency would bring about better results.

A study with stroke patients combining music and movement at acute rehabilitation stage (Jun, Roh and Kim, 2013) used songs selected by the researcher and a music

therapist that were meditative and popular during the patients' youth. Whilst listening to and singing along with these songs patients performed a standardized stretching exercise protocol comprising 22 different exercises and including shoulder, arm, wrist and finger stretches. Following this were instrumental playing exercises using un-tuned hand percussion, with patients playing along to eight different songs and encouraged to express themselves in their playing. Upper limb range of movement results were significantly better for the experimental group compared to the control group receiving standard care.

4.10 Rhythm, attention and external temporal frameworks

The facilitating music for TIMP exercises must cue both motor and attention functions (Thaut, 2008). Within neurorehabilitation models, attention is recognized as the foundation for learning, with some researchers identifying several different types, such as focused, sustained and alternating (Mateer and Sira, 2006). Research has found that different rhythmic material and music elicits different levels of attention. Attention also serves to integrate brain regions for performing motor tasks in general (Chapin et al., 2010). Research has shown that rhythms with regular beats and accents (duration-based rhythms) are more easily reproduced (played) by participants (Grahn and Brett, 2007). The explanation for this is that attention is key to processing more complex auditory information and the basal ganglia (concerned with voluntary movements, regulating motor and pre-motor activity) needs to become more activated through repeated listens in order that attention becomes more focused on the rhythmic stimuli (Grahn and Brett, 2007). Findings from this research would indicate that carefully considering the complexity of the music for TIMP, particularly rhythmic complexity, is important when the music is intended to provide clear temporal cues to support movement timings with a stroke patient's paretic upper limb, especially where it is known that there is damage to the basal ganglia. The neural processing requirements for more complex rhythmic material would also impact on stroke patients' capacity to synchronise their movements assuming that their cognitive function has been affected, causing difficulty for them in focusing and sustaining attention on each exercise. The point in the music at which participants play should also be on the regular, accented beats of the underlying pulse.

Some cognitive impairment is quite common following stroke and this influenced decisions regarding complexity of the music for this study. For example, a participant who appears to struggle with TIMP 1 (see Table 7. TIMP exercises.) a single hit of the cymbal achieved with an elbow extension, may be struggling to focus on the temporal framework provided by the music and synchronise with it, thus not fully benefitting from the cues in the music. It could even be argued, with reference to research so far discussed (Eitan and Granot, 2006; Malcolm, Massie and Thaut, 2009a), that in such cases a metronome only or simple, digitally generated musical structures could be more appropriate.

4.11 Summary

In summary, the TIMP music must be perceived as organized and meaningful in order to effectively regulate perceptual-motor functions. Music that is too complex would not suit a patient with greater cognitive impairment who struggles to focus and sustain attention and attend selectively to stimuli.

Based on the literature presented there appears to be a human predisposition to correlate certain musical patterns with movement direction, such as ascending scales with ascending or extension movements of the limbs. Rhythm appears to support intrinsically rhythmic movements such as walking and arm reaching movements requiring elbow and shoulder extension and flexion. Tempo set to hemiparetic stroke patients' existing frequency of upper limb reaching movement using a metronome improves movement quality and reduces compensatory trunk movements. There is some evidence that, in some cases, these extension movements can improve where instructions are given to perform them as fast as possible. Taking into account these factors, it appears more of a challenge to protocolise music to support such complex upper limb movements in order that it can be applied across a heterogeneous cohort in terms of cognitive and physiological function, cultural background and musical preference.

This study, as well as informing where there is a lack of research regarding dosage and home-based efficacy and feasibility, will also explore the effects of specifically composed and selected musical patterns in supporting and improving hemiparetic

upper limb function. These patterns have come about through collaborative work with a volunteer stroke patient. Participant feedback regarding their experience of the intervention and collected via semi-structured interviews will also provide data on the role of the music (see CHAPTER 7. MAIN RESULTS).

The following Chapter will briefly describe the aims of this study and link them with the literature so far discussed.

5 CHAPTER 5. STUDY AIMS

5.1 Introduction

The literature reviewed in the previous three chapters reveals a gap in knowledge regarding:

1. effective interventions for upper limb hemiparesis
2. the effects of TIMP, which includes facilitating music, on upper limb movement kinematics
3. feasibility and efficacy of home-based delivery
4. treatment dosage, with a frequency of twice weekly treatment as opposed to a higher frequency

In the following sections the aims of the study are reiterated, clarifying the link between the literature reviewed and the research aims and study design.

5.2 Meeting the need for upper limp hemiparesis interventions

80% of stroke cases result in hemiparesis (National Stroke Association, 2013; Adey-Wakeling and Crotty, 2013) and in half of those lack of arm function is persistant (Intercollegiate Stroke Working Party, 2012). Hemiparesis is significantly more resistant to rehabilitation treatment than gait (Thaut et al., 2002; Adey-Wakeling and Crotty, 2013), there is enormous variability in the extent and type of impairment between stroke patients (Langhorne, Bernhardt and Kwakkel, 2011) and no substantial scientific evidence to support interventions used in standard care (Pollock et al., 2014). This study offers some evidence for the effects of a new and innovative intervention for upper limb hemiparesis, which could potentially be of benefit to some stroke patients as part of standard care.

5.3 Potentially improving proprioception via audio-motor coupling

Feedback from movements via the somatosensory system is essential for effective planning, control and execution of movement (Carpenter and Reddi, 2012). Where these pathways have been damaged due to stroke, motor rehabilitation is greatly

impaired (DeSouza, 1983; Intercollegiate Stroke Working Party, 2012). There is insufficient evidence from systematic reviews and clinical trials to make specific recommendations for a suitable type of biofeedback to accompany upper limb treatment, which is recommended for patients (Intercollegiate Stroke Working Party, 2012), to compensate for somatosensory damage, occurring in 63% of hemiparetic patients (Adey-Wakeling and Crotty, 2013).

Auditory feedback, as a result of hemiparetic stroke patients' playing of musical instruments, has been shown to result in 'audio-motor coupling' where the auditory systems take on a more integrated role in motor circuits, known as neural reorganisation due to the plasticity of the brain (Schneider et al., 2007; Altenmüller et al., 2009; Schneider et al., 2010). This compensates for damaged somatosensory pathways. The auditory circuits increased role in supporting upper limb movement has resulted in significantly improved upper limb function for the stroke patients. However, effects are not clear and require further research in order to explore dosage, for example reduced to twice weekly. In addition, effects are not widely studied as a stand-alone therapy (rather than combined with standard care) and in the home environment, where more variables are present. This study explores both dosage and home delivery, thus adding to this area of knowledge.

5.4 Using music to support movement kinematics

Research into music and movement perception (Eitan and Granot, 2006) has revealed associations between changes in musical parameters, such as tempo, pitch interval, melodic contour, attack and dynamics, and bodily motion in physical space. This research goes some way to support the rationale for using music to help cue and mirror movements of the upper limbs. MST studies, whilst evidencing instrumental playing as effective in the treatment of upper limb hemiparesis, did not investigate the effects of music as part of the treatment. RAS was applied to upper limb hemiparesis in stroke patients with auditory cues provided by a metronome in order to reduce compensatory movements and improve arm flexion and extension (Malcolm, Massie and Thaut, 2009a), resulting in decreased trunk compensation, increases in shoulder flexion and slight increases in elbow extension. A gap in knowledge exists to support some NMT techniques, with only one TIMP study targeting stroke hemiparesis reported (Yoo, 2009). There is a further lack of evidence regarding rhythm driven

music therapy interventions that effectively improve upper limb hemiparesis following stroke (Bradt et al., 2010). It has also been stated that little music therapy research has been conducted that specifically focuses on the effects of clinical interventions (Gallagher, Mullan and Tolman, 2014).

5.5 Home-based rehabilitation as part of current NHS stroke care pathway

All NHS trusts aim to provide home-based out-patient rehabilitation services in the form of early supported discharge teams (Schmid, 2010), which were provided by just 36% of hospitals in 2010 (Department of Health, 2010). Very little research has been conducted around home-based services, with insufficient detail regarding methodologies and treatment protocols (Fens et al., 2013). Similar music therapy interventions to the one under investigation in this study have not been widely conducted in the home environment (Malcolm, Massie and Thaut, 2009a; Villeneuve and Penhune, 2014). Home-based music therapy in general has been practiced to a small extent predominantly in Germany and the US, but not in the UK, mainly with elderly clients and not for treating the effects of stroke (Schmid, 2010).

5.5.1 Exploring reduced Dosage

MST research has been delivered at a frequency of between three and five times per week, summarised in Table 3 (Schneider et al., 2007; Schneider et al., 2010; Grau-Sánchez et al., 2013; Floris Tijmen and Jens, 2014; Villeneuve and Penhune, 2014). One of the two published TIMP studies delivered treatment three times per week (Yoo, 2009), the other, with cerebral palsy, was twice weekly (Chong et al., 2013). The Ronnie Gardiner Rhythm and Music (RGRM) method has not clearly reported on dosage (Bunketorp Kall et al., 2012) and an ongoing study, sharing characteristics with TIMP, is delivering treatment twice weekly combined with standard care (Järvinen-Lepistö, P., Burger, B., Ala-Ruona. E., 2014). Dosage is a key area of upper limb hemiparesis treatment recommended for further research following review of music therapy interventions for acquired brain injury (Bradt et al., 2010).

5.6 TIMP study aims

More numerous and effective interventions are required to treat the heterogeneous effects of upper limb hemiparesis and this TIMP study aims at determining the effects of TIMP on a small cohort of patients in the form of a pilot study. The study was designed based on the recommended protocol for TIMP, taken from the literature (Thaut, 2008; Yoo, 2009; Thaut and Hoemberg, 2014), and informed by the researcher's NMT training, follow-up (fellowship) training, and clinical experience using TIMP and other NMT sensorimotor techniques. In addition the researcher collaborated with a volunteer stroke patient in order to trial playing patterns and facilitating music for this study. The methodologies and results of similar studies where stroke patients played musical instruments and where rhythm and music have been used to support priming, timing and movement trajectories of upper limb movements have also been referred to during the course of designing this study.

The TIMP music has been composed based on published recommendations (Thaut, 2008; Thaut and Hoemberg, 2014) and research that has reported on the effects of rhythm and music on movement (see CHAPTER 4. TIMP MUSIC SELECTION AND COMPOSITION). Instrument and equipment selection, including stands and iPads, is intended to present targets and auditory feedback to facilitate increased movement range of proximal and distal joints, finger dexterity and quality of movement, with the aim of improving the performance of ADLs. In particular, the auditory and tactile feedback is intended to compensate for loss of sensation in the fingers due to somatosensory damage. Such auditory feedback might induce neuronal reorganisation, which would be detected using EEG recordings of participants whilst listening to the facilitating music at pre and post treatment stages (see 6.13 EEG analysis).

Instruments and equipment have also been selected in order to allow their easy transportation into each participant's home. The aim of NHS trusts across the UK is to provide rehabilitation in patients' homes and little research has been done in this setting, either of standard care interventions or those specific to music therapy.

5.7 Research questions

1. Is TIMP more effective when delivered immediately after statutory rehabilitation has ended compared to nine weeks later?

2. Does Therapeutic Instrumental Music Performance (TIMP) improve upper limb function after statutory rehabilitation has ceased to be effective and consequently ended?

3. How do participants experience TIMP?

5.8 Study design

The study design is fully described in CHAPTER 6. METHODOLOGY, MUSIC AND TABLE OF TIMP EXERCISES. The aim of using a crossover design in this pilot study was to measure the effects of TIMP on upper limb movement kinematics with two groups of stroke patients with hemiparesis, comparing early and delayed intervention. ARAT and 9HPT (standard assessment tools) were used to do this, with pre and post intervention assessments conducted by a therapist who was blind to participant allocation. All participants were randomised into two different groups, with one group receiving treatment immediately following completion of statutory community rehabilitation, compared to another who received treatment after a delay of nine weeks following randomization. With measures taken at five different timepoints the aim was to establish baseline stability and sustained effects of treatment. In addition, the individual results for each participant were also examined within the context of their own pathology (within participant analysis). Participant feedback regarding their experience of the intervention, playing the instruments and synchronising movements to music, will help indicate adherence, tolerance and motivation levels. Semi-structured interviews have been used to achieve this, with data analysed using thematic analysis.

Data was analysed to compare the two group outcomes using repeated measures analysis of variance within a linear mixed-effects linear model. In order to account for the small sample size, a statistical approach was adopted to generate a larger number

of permutations using the data collected, from which the probability (*p* values) of the observed results has been calculated (see 6.12.1Resampling).

5.9 Purpose statement

This research study explored three new aspects compared to similar research: 1) reduction in dosage, 2) home-based treatment delivery, 3) facilitating music for each participant to synchronise their movements to. All results are discussed in CHAPTER 7. MAIN RESULTS.

5.10 Hypothesis

The hypothesis was that there would be no difference between early and delayed intervention group outcomes (Primary ResQ1), but that TIMP would improve upper limb function post treatment in both groups beyond the outcomes achieved by the end of statutory NHS community rehabilitation (Secondary ResQ2). It was also expected that participants would experience the instrumental playing and music as supportive. It is pariculary expected that they would perceive the instruments as clear visual targets for movements and that the music would provide clear temporal frameworks for planning moveents and improving trajectories (Tertiary ResQ 3). Previous music therapy and music based studies in the form of pure, lab based research, have produced statistically and clinically significant results for patients. However, they have been predominantly delivered at a frequency and duration of three to five times per week for three to four weeks (see Table 3). Studies have not been conducted which explore the effects with a reduced dosage, in this case twice per week.

6 CHAPTER 6. METHODOLOGY, MUSIC AND TABLE OF TIMP EXERCISES

The methodology for this study, including the table of 12 TIMP exercises, has been published in Frontiers of Human Neuroscience (Street et al., 2015).

6.1 Study design

A crossover design with five repeated measures was used in this study.

6.1.1 Inclusion criteria

1. Age 18 + (no upper age limit)
2. 3 – 60 months post stroke
3. Any type and site of stroke
4. Has hemiparesis and is able to lift the affected hand up, unassisted, onto a table top whilst seated
5. Movement in at least one finger
6. Has completed statutory community rehabilitation
7. Is not receiving any other treatment for upper limb during the course of participation in the study
8. Can consent to treatment

6.1.2 Exclusion criteria

1. Below the age of 18
2. Less than three months post stroke
3. More than 60 months post stroke
4. Cannot lift their affected arm onto a table top whilst seated without assistance
5. Has no movement in any of their fingers on the affected side
6. Cannot consent to treatment
7. Cannot follow instructions to perform exercises
8. Is still receiving upper limb treatment, either from CCS or another organization or therapist
9. Is not deamed medically fit to participate by their GP, CCS team members or any other medical professional (all GPs were informed of patients who consented to participate)

Participants were randomized into either treatment (n =6) or waitlist (n =4) groups by the statistician using an envelope system. Pre and post-treatment measures were conducted by a therapist blind to participant allocation and all other measures, including semi-structured interviews, were conducted by the researcher. All participants received assessments at the same time-points following randomization. The primary objective was to measure whether or not the treatment had an effect on grasp, grip, pinch and gross movement in the affected upper limb following TIMP. The second objective was to measure for changes in finger dexterity.

6.1.3 Rationale for study design

A crossover design with pre-test, post-test and follow-up measures was used as this enabled the researcher to observe how stable baseline measures were, i.e. was spontaneous recovery or deterioration taking place before treatment with waitlist participants, or were fluctuations in arm function occurring due to other factors such as antidepressants affecting energy levels, Baclofen or Botox levels changing? Cross-over designs have been used effectively in previous stroke and neurorehabilitation research (Corr, Phillips and Walker, 2004; Tyson, Sadeghi-Demneh and Nester, 2013). The design has been recommended where intervention effects on chronic conditions within heterogeneous populations are being measured, as the power of the repeated measures element of the design is effectively utilized whereby particpants act as their own controls (Cowell et al., 2010). In other words, the study design allows comparison of outcomes for immediate and delayed treatment, as well as within participant analysis. This research design is currently employed as part of another, ongoing music therapy study investigating motor recovery with stroke patients, from which a case study was recently published (Järvinen-Lepistö, P., Burger, B., Ala-Ruona. E., 2014). A randomized control design comparing music therapy treatment with standard care was not feasible to conduct for this study, as music therapy is not recognized in the UK as a treatment for sensorimotor impairment such as upper limb hemiparesis and, therefore, is not included in the UK provision of standard care for neurodisability through primary care trusts. One music therapy study with stroke patients conducted in the UK in collaboration with a NHS trust was found that used an RCT, comparing music therapy with music therapy plus standard care. One of the

aims of the RCT was to explore the appropriateness of such a design in measuring the benefits of music therapy treatment on stroke (Purdie, Hamilton and Baldwin, 1997). For this TIMP study a design comparing standard care with music therapy plus standard care was not deemed feasible by the host to the study due to previously experienced problems with coordinating community based rehabilitation and applied research in this way. It was not expected that the earlier intervention group would benefit more than the delayed intervention, but that there was a fair chance of both groups benefitting to a similar level. The design enabled an ethically sound confirmatory investigation as to whether this hypothesis was true or not.

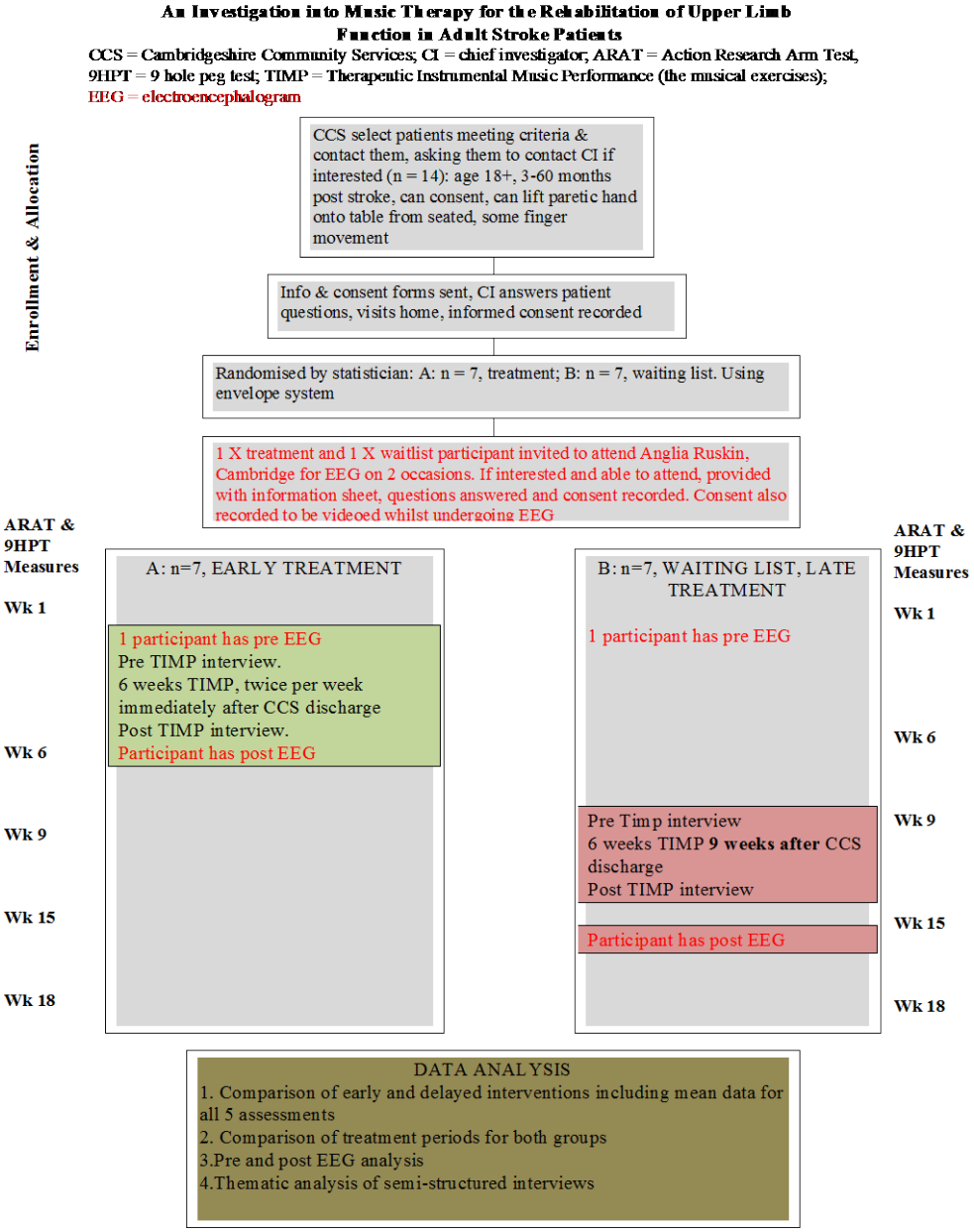


Figure 13. TIMP study consort.

The study consort in Figure 13 shows the crossover design with repeated measures, intended to include seven participants in each group. One participant from each group was also intended to attend EEG recording twice: 1) immediately after randomization, 2) immediately following treatment. 10 participants completed the study and an eleventh dropped out before beginning treatment. In the treatment group assessments

were conducted by the blind assessor at week one and six, and in the waitlist group at week nine and 15.

The study reported here will build upon the existing knowledge of music's effect on neuroplasticity and existing, but underexplored, NMT sensorimotor interventions, and translate this into a clinical protocol that may improve outcomes for upper limb function. Thus, it will add to limited, existing research into musical instrument playing and rhythm on upper limb rehabilitation following stroke. It will also address questions concerning dosage, setting and the timing of treatment delivery. Whereas most of the research to date on this topic has been laboratory based, this study provides a novel intervention that was delivered one-to-one, in participants' homes. Therefore, it examined the feasibility of home treatment delivery at the end of standard care.

In addition to quantitative data collection, participant experience of TIMP recorded via semi-structured interviews provides data regarding tolerance, motivation, access and compliance to treatment. Maintaining effective levels of motivation are key to sustaining engagement in treatment and, when too low, can impair treatment responses and reduce compliance and tolerance.

6.2 Quantitative data collection

Each participant received a total of 12, one hour individual music therapy sessions in their home, delivered twice weekly over the course of six weeks. They were not required to practice or perform any exercises set by the researcher between sessions. Each participant also received the Action Research Arm Test (ARAT) (Lyle, 1981) and Nine Hole Peg Test (9HPT) (Kellor et al., 1971) assessments at the same five time points after baseline measure; Timepoint 1: Week 1 after randomization, and Timepoints 2-5: at weeks 6, 9, 15 and 18 over the course of the study. The design allowed for analysis of treatment and no treatment by comparing treatment group with wait list group data. It was also possible to compare early versus late intervention following discharge from the community rehabilitation treatment, as the wait list participants had a delay of nine weeks between community discharge and beginning TIMP. Data collected from wait list group participants prior to TIMP treatment was

analyzed to determine whether there was any spontaneous change in upper limb function, which can occur as an independent covariate (Kwakkel, Kollen and Twisk, 2006).

6.3 Qualitative data collection

Although unusual in a randomized crossover design study, qualitative data was collected from each participant in order to explore patient preference with regard to using music to support exercises, and factors that might provide insights into patient motivation, tolerance and compliance. These aspects are important given the innovative treatment being used, the dosage and the setting, i.e. within the home environment. Another study (Thornberg, 2013) investigating how stroke patients understood participation in rhythm and music activities used semi-structured interviews conducted by the researcher, with material analyzed using a phenomenographic approach. The results indicated increased body awareness and competence in task performance, providing valuable data that could have implications for informing the ways in which health professionals can more effectively prepare to meet the needs of individual patients.

Qualitative data was collected by the researcher immediately before and after the 6 weeks of TIMP, by using a semi-structured interview that was devised for this study and comprises three questions regarding the participant's experience of playing the instruments and playing to the music (see Figure 15 and Figure 16). This data provides an overall impression of the patient experience of and feasibility for this treatment protocol.

There was also a five point Likert scale (Likert, 1932) for recording how much participants felt the treatment would help them and, at the end of the six weeks of TIMP, how much they felt it actually had helped them in their ADLs. The researcher recorded, in written form, participant's responses during the interview for later thematic analysis. Open questions were asked to give participants the opportunity to express their preconceptions and communicate their experience, with the possibility of other themes arising. The quantitative data gained with the Likert response scale

has been used to record a time series of treatment responses and not to control for auto-correlation.

6.4 Recruitment

Participants were recruited from three geographically separate community stroke rehabilitation teams operating in the south of England within the same NHS trust. Patients discharged from community rehabilitation who met the inclusion criteria were invited to participate in this study by the stroke teams. The length of time in receipt of community rehabilitation and the frequency of treatment were not controlled for due to enormous variability in this regard between community stroke therapists and stroke teams within the host organization. Unfortunately no pre and post community rehabilitation outcomes score data was available from the three community stroke teams as they did not share the same assessment tools nor necessarily conduct assessments to measure outcomes. Potential participants who expressed an interest and contacted the researcher were visited by him in their homes, in order to demonstrate the treatment methods, including some playing patterns, and to answer any questions. All participants were required to give informed consent, which was recorded.

6.4.1 Participant demographics

Variable	Category	Number of values	Percent of overall total	Intervention type		P-value
				Waitlist n = 5	Treatment n = 6	
Gender	Overall	11	100.0	5 (100.0%)	6 (100.0%)	0.567
	Female	6	54.5	2/5 (40.0%)	4/6 (66.7%)	
	Male	5	45.5	3/5 (60.0%)	2/6 (33.3%)	
Stroke type	Overall	11	100.0	5 (100.0%)	6 (100.0%)	0.545
	Haemorrhage	3	27.3	2/5 (40.0%)	1/6 (16.7%)	
	Ischaemic	8	72.7	3/5 (60.0%)	5/6 (83.3%)	
Stroke site	Overall	11	100.0	5 (100.0%)	6 (100.0%)	1.000
	Bilateral	1	9.1	1/5 (20.0%)		
	Left	3	27.3	1/5 (20.0%)	2/6 (33.3%)	
	Right	7	63.6	3/5 (60.0%)	4/6 (66.7%)	
Dominant hand	Overall	11	100.0	5 (100.0%)	6 (100.0%)	0.455
	Left	2	18.2		2/6 (33.3%)	
	Right	9	81.8	5/5 (100.0%)	4/6 (66.7%)	

Table 4. Participant demographic data for both groups

P values in Table 4 indicate no statistically significant difference between groups with regards to gender, stroke type and site, and gender.

Intervention type	Mean age	Standard deviation	Percentiles					Number of values	Number of missing values
			Smallest 0%	25%	Median 50%	75%	Largest 100%		
Waitlist	67.6	18.30	46.0	51.3	66.0	85.3	88.0	5	0
Treatment	53.2	21.86	23.0	27.6	63.0	69.3	73.0	6	0
Overall	59.7	20.73	23.0	47.3	65.0	72.3	88.0	11	0

Table 5. Participant age at time of joining the study

	Treatment	Waitlist
Age: mean	53.2	67.6
Gender: M/F	2/4	2/2
Months after onset: mean	19	12.5
Stroke type: ischemic/hemorrhagic	5/1	2/2
Affected upper limb: R/L/bilateral	2/4	1/2/1
Handedness: R/L	4/2	4/0
Dominant hand affected	2	2

Table 6. Comparison of clinical and demographic data from both groups.

6.4.2 Additional demographic and clinical description

Below is some additional clinical and socio-economic information gathered through the researcher's observations and conversational information recorded in his research journal. The socio-conomic status of patients has been highlighted as an important consideration in some cases when allocating treatment and services, as this can affect an individuals capacity to afford transportation costs, fully comprehend the importance of attending out-patient rehabilitation, make appropriate lifestyle choices or adaptations and maintain motivation (Putman et al., 2007; Adey-Wakeling and Crotty, 2013). No questionnaires were used by the researcher to gather socio-economic data, but it is estimated, based on properties and locations visited, professions, cultural and educational backgrounds disclosed. Based on this information the participants from this study would be representative of five out of seven currently identified social classes, ranging from 'traditional working class' to

‘elite’ (Savage et al., 2013). This being a novel treatment requiring the synchronized playing of musical instruments to music, participants all volunteered information regarding their levels of musical ability and experience, in one case a participant (treatment group 6) joined the study following her own enquiry as to whether music therapy was available as an intervention via the NHS.

6.4.3 TREATMENT GROUP PARTICIPANTS

Participant 1

This participant would be categorised within the ‘elite’ class, well educated and with a high level of economic and social capital. He was 65 years-of-age, lived with his wife, was right handed and suffered a right hemisphere ischemic stroke, experiencing a high degree of spasticity in his affected upper limb, with very little finger extension and slight flexion. His overall range of movement was very limited and he was unable to extend his arm and rest his affected hand on the table whilst seated the measured 15cm away in order to perform the ARAT. The participant was unable to lift any object in any of the five assessments. He had studied classical piano as a child and loved music, particularly classical piano, also having a keyboard set up in his home.

Participant 2

Participant two, who is also a case study subject in CHAPTER 8, suffered a right hemisphere CVA following aortic dissection (a tear in the aorta) and heart surgery, causing multi-focal infarcts in the frontal, parietal and occipital lobes. He would be given the socio-economic classification of ‘traditional working class’ and lived with his wife. The participant presented with left side hemiparesis and tremors in the left lower limb and hand, particularly when trying to extend his arm in order to reach, grasp or release an object. He had no previous musical experience and made a point of stating when consenting that he did not like and could not play music, whether it be carrying a melody or playing a beat.

Participant 3

Categorised approximately within the 'established middle class', participant three lived alone and suffered a right intracerebral haemorrhage. She also suffered from arthritis in her middle and ring fingers of the affected hand and presented with some dystonic movements but had good finger dexterity. This participant had also been an accomplished musician, performing with other musicians for many years. The details of any formal musical training are not known.

Participant 4

The second youngest participant in the study would be approximately categorized as 'established middle class' based on family economic and cultural wealth. This participant suffered a left cerebral middle embolism (blockage) and central retinal artery occlusion, causing very high spasticity and hemiparesis in her right, dominant hand. She had never received any pharmacological treatment for spasticity such as Baclofen or Botox, which are commonly administered for such conditions; the reasons for this are not known. The participant had very slight finger flexion and limited extension. She used compensatory trunk and shoulder movements in order to extend her arm and reach objects. She lived with her parents and exercised every day by swimming and using a gym. Her stroke brought an end to university studies. She had some musical tuition whilst at school.

Participant 5

This participant was the youngest in the study, of unclear social class, but possibly between 'new affluent worker' and 'established middle class'. She suffered an occlusion of the left carotid and middle cerebral arteries, causing paresis and spasticity in her right, dominant upper limb. The participant used some compensatory trunk and shoulder movements, with quite good elbow extension and finger dexterity. She was formerly an undergraduate student, lived with her boyfriend and had some instrumental tuition at school.

Participant 6

This participant would be categorised between the ‘established middle class’ and ‘elite’ class, with a high level of economic and social capital and very ‘high highbrow’ cultural capital. She is also a subject in the case studies CHAPTER 8 and suffered a right hemisphere frontoparietal stroke following an embolism post heart surgery. She was right handed and presented with loss of sensation in her fingers as well as some cognitive impairment, particularly evident when she played her recorder as she struggled to identify finger positioning to achieve notes, to move the correct finger and position it accurately. Prior to her CVA she was an extremely proficient player and arranger of music, who had received a high level of musical training over many years. She lived with her husband.

6.4.4 WAITLIST GROUP PARTICPANTS

Participant 1

This participant (subject B in the CASE STUDIES chapter) was the most senior in the study, aged 88, and estimated to be within ‘traditional working class’ category. She lived with her husband and had no musical background. There was little clinical information available regarding her CVA, other than it was left side ischaemic. She did not present with any other associated movement disorders such as tremors or spasticity, but she did have a visual impairment affecting her hand-eye coordination and presented with ‘emotionalism’ (see Other effects of strokePsychological effects). Her ROM was largely unaffected, with some problems evident in motor planning in her fingers.

Participant 2

Participant two presented with the most complex impairments resulting from CVA, which in this case was bilateral. He would be categorized in the ‘elite’ socioeconomic status, lived with his wife, had no musical training but was familiar with classical repertoire. The neuroradiology reports indicate evidence of multiple lesions consistent with septic emboli, stating ‘new small cortical focus of restricted diffusion in

posterior inferior part of left parietal lobe in keeping with recent infarct'. Old bilateral and right occipital infarcts and multiple cerebral microbleeds in both hemispheres were also noted. In addition, after joining the study he experienced a transient ischaemic attack (TIA) between the first and second ARAT. He consistently presented with left side visual neglect, which impaired his locating of objects on that side. He was generally disorientated and struggled to follow instructions, for example confusing left with right or placing an object in the wrong place; this also indicated working memory deficits.

Participant 3

Also lacking in clinical information from his records, this participant would be estimated as 'technical middle class' and lived with his wife and son. He suffered a right hemisphere ischaemic CVA, causing hemiparesis and high spasticity, the latter was being treated with Botox. The participant had very slight finger flexion and extension and elbow extension and flexion, using compensatory trunk and shoulder movements to reach objects and having limited grip and grasp. He had no musical training but enjoyed listening to music.

Participant 4

Participant four was the second most senior, aged 84. She would be estimated as being between the 'technical middle class' and 'established middle class, and she lived alone. She suffered an intracerebral, internal capsule bleed, causing mild hemiparesis including loss of sensation in her fingers and dystonia. She also had severe arthritis in her affected index and middle fingers. The participant experienced 'emotionalism' and possibly depression, for which she was prescribed an antidepressant. Unfortunately she struggled to adhere to this medication due to its side-effects and she frequently complained of feeling sick, fatigued and of low mood.

6.5 Sample size

The sample size was carefully calculated in consultation with the academic supervisory team and host to the research. It was based on what would be feasible for

the researcher to deliver within the available time and resources of this full-time PhD and what would generate a sample size representative of the heterogeneity of impairment in order to adequately examine management of the research. Risks, benefits and the logistics of delivering treatment in the home, given that it is labour intensive, and participant compliance in this environment were all observed. The home environment introduced variables that could not be controlled for, such as space available to set up equipment, management of seating equipment to optimize positioning for the intervention and assessments, distractions in sessions such as the activities of family members or other residents present in the home. The instruments were not permanently set-up, as would be the case in a research lab, where instrument height and distance from participant can be maintained and standardized. In this study TIMP was delivered at a frequency much lower than has been the case in existing research of this nature, so effects at this dosage were not known. All of these logistical factors warranted detailed examination in a smaller pilot study, which could inform a larger study, determined through power calculation.

6.6 Randomization

Each time a participant signed a consent form to join the study the researcher contacted the statistician by e-mail at Anglia Ruskin University, Chelmsford and requested him to randomly allocate the new participant into one of the groups. The statistician did this by opening a sealed envelope with a group name (waitlist or treatment) inside and informed the researcher via e-mail of the allocation.

6.6.1 Waitlist group activities

Participants randomised into the waitlist group did not engage in any upper limb rehabilitation interventions whilst waiting to begin treatment. They had been discharged from community rehabilitation and did not employ any private or other practitioners over the period of waiting.

6.6.2 Outcome measures

A wide range of assessment tools and technology have been used to record outcomes in upper limb post-stroke rehabilitation. A literature review on the role of music therapy in physical rehabilitation recommended that assessment tools should be

selected that can be adjusted for use across different populations, such as computerized systems and goniometer (Weller and Baker, 2011). Within the NHS trust from where participants were recruited for this study, no single assessment tool was used by physiotherapists (PT) or occupational therapists (OT) and so it was not possible to use any end of community rehabilitation upper limb assessment outcomes taken by stroke team clinicians or continue using the same tools in this study. This is probably explained by the heterogeneity of the patient population, presenting hugely varying general and specific sensorimotor symptoms, as well as the time required to administer assessments, where therapists' clinical judgment (in clinical rather than research situations) is adequate in determining the most effective interventions for each individual patient. It was necessary to find outcome measures that were reliable, with a clear and repeatable protocol and without the need for extensive training or delivery by a qualified PT or OT. The problem of finding appropriate assessment tools for music therapy research has been highlighted by previous, experienced researchers (Magee, 1999). In the initial application for ethics approval a goniometer was included as the primary outcome measure, but the committee would not approve its use, describing it as unreliable and too difficult to use accurately without adequate training. The goniometer would have required the researcher and blind assessor to undergo specialist training in its use as well as a high degree of practice on stroke patients. Also in the initial study proposal was the use of motion capture and EEG, both of which were rejected by the ethics committee as they felt that this would be asking too much of patients, and that EEG was old-fashioned. EEG and motion capture would also have incurred significant costs to the research budget, required to cover the travel costs for each participant to attend the Anglia Ruskin facilities in Cambridge.

The ARAT, was the primary outcome measure of upper limb function for this study, with the 9HPT specifically measuring for changes in finger dexterity. The ARAT and 9HPT have been used in four different studies investigating the effects of musical instrument playing on upper limb hemiparesis (Schneider et al., 2007; Altenmüller et al., 2009; Rojo et al., 2011; Amengual et al., 2013). The ARAT has also been used for constraint-induced movement therapy studies (Kitago et al., 2013), and a study investigating the Ronnie Gardiner Rhythm and Music Method (RGRM) using a unique note system, rhythm and movement with stroke patients (Bunketorp Kall et al.,

2012). It has excellent inter-rater reliability(Hsieh et al., 1998; van der Lee et al., 2002), excellent intra-rater reliability (van der Lee et al., 2002) and excellent convergent validity against the Fugl-Meyer (De Weerdt, 1985). The ARAT is a timed, nineteen item measure that is divided into four categories: grasp, grip, pinch and gross movement. Each item, or action, is performed by the participant while seated with their back against the chair, a measured distance from the table (15cm), where all of the assessment items are individually placed for each task (see Figure 14). The test recreates the movements or sequences of movements required to perform many ADLs, such as reaching up onto a shelf to obtain a food ingredient or pouring liquid from one container to another. A table map for the ARAT is laid out flat on the tabletop and this has markers on it to indicate the start and end position for each object used in the test, thus optimizing consistency between patients and settings. The assessment can take up to 30 minutes if the patient needs to complete all items in every subcategory, otherwise the time required is approximately 10 minutes.

6.6.3 ARAT scoring system

The performance of each task is timed using a stopwatch, and scored according to the following scale:

0. unable to perform any part of the task within 60 seconds
1. poor quality movements (for example compensatory movements from the trunk or shoulder instead of flexing and extending the elbow) and inability to complete the task within 60 seconds
2. task completed, but with difficulty; i.e. it took much longer than indicated in average scores for the same age group as the patient, and the arm, hand or finger movements that the patient performed in order to complete the task indicated difficulty in coordination
3. normal performance, where the task was completed in less than 5 seconds, with good body posture and normal hand, arm and finger movements.
‘Normal’ body posture means that there were no or minimal compensatory movements made in order to achieve the task, for example using trunk movements in order to help raise the arm high enough to reach an object on a shelf.

This scoring has been refined (Yozbatiran, Der-Yeghiaian and Cramer, 2008) since Lyle's initial system, in order to help improve inter and intra-rater reliability. 'Normal movements' are more specifically defined in this version. In the grasp, grip and pinch subscales, the participant cannot score a 1 unless they are able to grip and lift the item using any type of grip. If the subject is only able to move the object around with their hand on the table surface, this does not count as completing any part of the task and so scores 0. In the pinch subscale, the subject must be able to pick up the ball bearing or marble using the correct finger and thumb combinations, otherwise they score 0. For the gross subscale, if the subject scores 0 for the first task, then they score zero for the other two. If the score is 3, then the total score is 9, without the need to complete the other two tasks. If the score is 1 or 2 for the first task, then the other two require assessment. The palm of the hand must make contact with the three targets; behind the head, top of the head and then mouth, which forearm rotation, in order to be scored 2 or above. The instructions are more specific for the sitting position, asking the subject to sit with their head still and in a neutral, upright position, and to touch the back of their head with their palm without compromising this position.

The ARAT protocol for each category begins with the most difficult task, if the patient can complete the task, scoring 3, then there is no need to continue with the other items in that category. If the patient fails to complete the first and most difficult task, they then continue with the easiest and progress through increasingly more difficult tasks until completing that category and moving on to the next. If the patient fails the second, easiest task, then they score zero in that task and the remaining ones in that category, without the need to complete them all.

6.6.4 ARAT tasks

The tasks in the ARAT are as follows:

GRASP
Task 1-4 10cm/2.5cm/5cm/7.5cm block of wood moved from target on table map to shelf above the table using any kind of grasp involving the thumb and fingers in opposition.

Task 5 cricket ball moved from table to shelf. Spherical grip.

Task 6 sharpening stone moved from table to shelf. Lateral grasp.

Arm movements identified for GRASP subcategory: elbow flexion and extension, shoulder flexion and stabilisation, thumb and finger extension to release each object.

GRIP

Task 7 using two cups, one filled with water to a mark on its side, cups positioned on a tray, over the markers on the table map. Patients lift the cup with water in and pour it into the empty cup. In addition to the tray, which is not part of the standard ARAT equipment. the assessor also brings absorbent kitchen towels. These measures help protect the participant as well as table and floor surfaces, which might be damaged should water spill onto them. Cylindrical grip.

Task 8-9 move two different metal tubes (2.25cm and 1cm diameter) from starting plinth to target plinth. Any type of grip can be used.

Task 10 pick up a washer from inside a tin lid and place it over a target plinth. Pincer or 3 jaw chuck grip.

Arm movements for GRIP subcategory: forearm between mid position and pronation, elbow flexion and extension, wrist pronation and supination.

PINCH

Task 11-16 pick up a ball bearing and then a marble from a tin lid positioned on the table and place in a tin on the shelf. This is done using ring finger, index and middle finger, separately opposing the thumb.

Arm movements for PINCH subcategory: forearm is between mid position and pronation, elbow flexion and extension, shoulder flexion to reach the shelf and shoulder stabilisation to maintain the position and release the object.

GROSS

Task 17 raise hand from lap to behind head

Task 18 hand from lap to top of head
Task 19 hand from lap to mouth

The score is out of a possible 57.

Figure 14. The Action Research Arm Test (ARAT)

Figure 14 shows the ARAT materials including the map indicating the start and target position for each object to be reached, grasped and moved.

6.7 The 9HPT

The 9HPT, more specifically measures finger dexterity and is widely used in stroke rehabilitation and related research (Schneider et al., 2007; Altenmüller et al., 2009; Grau-Sánchez et al., 2013; Floris Tijmen and Jens, 2014; Villeneuve and Penhune, 2014), with a 'good' rating in test-retest and inter-observer reliability. (Heller et al., 1987). It is a timed test, using standardized equipment comprising a rectangular plastic board (wooden board versions are also available) with a rounded, concave tray at one end containing nine small white pegs and at the other end nine holes into which the participant must (one at a time) place the nine pegs from the tray and then remove them, placing them back into the tray as quickly as possible. Each participant practiced with their unaffected hand first, then the affected side. Participants were seated while performing the test, which takes no more than two minutes to administer,

depending on the age of the patient and their existing degree of finger dexterity. The stopwatch was stopped after one minute if the task had not been completed by then. If the participant had managed to place some pegs in holes, these were counted and the number recorded in order to measure for any improvement in task performance. Participants were able to pick up each peg using any type of grip, but forearm rotation is also required in order to place pegs into the holes and to remove them.

6.8 Semi-structured interviews

Using the principles and processes described in Interpretative Phenomenological Analysis (IPA) (Smith and Osborn, 2008) material from the semi-structured interviews was analyzed into themes. Open questions were used in order to encourage participants to offer descriptions of their experience of playing the instruments and playing to the supporting music. In keeping with IPA principles, the underlying aim of the questions was to offer participants a chance to explain how they felt the treatment would affect them and describe how they were experiencing, feeling and thinking about the processes involved. The researcher noted participant responses in written form, directly onto their questionnaire sheets as they responded to each question. The pre and post treatment questionnaires are shown below. The full written responses of participants are typed (for legibility) onto questionnaire sheets and included in the Appendix.

Pre-treatment Semi-Structured Interview

1. What do you think the treatment will be like?

2. How will it feel playing the instruments?

3. How will it feel playing to the music?

4. Please score how much you feel music therapy will change your arm and hand use in daily living.

1 = not at all, 5 = very much

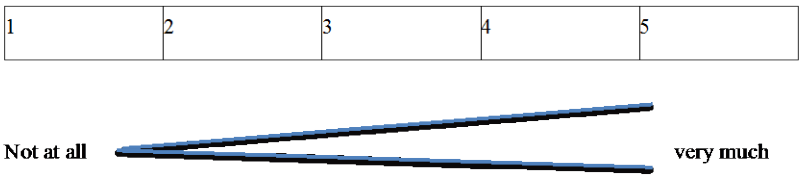


Figure 15. Pre-treatment interview form

Post Treatment Semi-Structured Interview

1. What do you think about the treatment?
2. How does it feel playing the instruments?
3. How does it feel playing to the music?
4. Please score how much you feel music therapy has changed your arm and hand use in daily living.

1 = not at all, 5 = very much

1	2	3	4	5

Not at all very much

Figure 16. Post treatment interview form

6.9 Set up time

Setting up of all TIMP equipment required 10 minutes at the start and end of each session. For participants who required more finger dexterity exercises, the set-up time was less as only the iPads and speaker were required, which were either mounted on the stand or positioned on a table surface.

6.10 EEG

Two participants, one from each group (treatment and wait list), were intended to visit Anglia Ruskin University, Cambridge on two occasions for EEG recording. Full ethical approval was given for this via IRAS. The first measure was for a baseline recording immediately following randomisation and the second immediately post six weeks TIMP treatment.

Participants invited for EEG would follow all other procedures described in the initial protocol for the duration of the study. At each stage of preparation and recording in the EEG lab, the researcher would explain what was going to happen and ask each participant if they were comfortable and happy to continue. The procedure was tested on a volunteer and all preparations completed for recruitment.

6.11 Statistical analysis

For the primary outcome measures, for the appropriate analysis of the crossover design with repeated measures, a linear mixed-effects linear model approach was used. Analyses of data gathered at the five timepoints from the ARAT and 9HPT were performed using the computer program R (R Core Team, 2015). R is a highly flexible program for statistical analysis and graphics, containing a core set of tools for classical data manipulation that is continuously updated with new modules for performing ever more specialized procedures (Logan, 2010).

The fitting of the linear mixed-effects model was achieved using the function lmer from the R package lme4 (Bates et al., 2014; Bates, D., Maechler, M., Bolker, B.,

Walker, S, 2015). The percentile bootstrap confidence limits of the components of variance were obtained using function confint from R package lme4. The bootstrap P-values for testing model effects were obtained using the function mixed from the R package afex (Singmann, H., Bolker, B., Westfall, J, 2015). The estimates, the means and the difference between the means and their standard errors and confidence limits were obtained using the function lsmeans from the R package lsmeans (Lenth, 2015) The plots of means were produced using function effect from the R package effects (Fox, 2003). This method of analysis avoids the need to make strong assumptions about the distribution of the data, namely that fitted model residuals are Normally distributed.

6.11.1 Resampling

The term 'Bootstrapping', as described in meetings with the statistician, refers to a statistical method of resampling whereby random samples are taken from the original data set (the data gathered in this study from the ARAT and 9HPT comprising 50 samples of data) and randomly put back into the data set, thus generating a larger sample, in this case 9999. This method provides an estimate of the shape of the distribution of the mean. By doing so it is possible to observe how much the mean might vary with a much larger sample size. It has been used in the analysis for this study, as the sample size is too small to make inferences regarding statistical significance of the results, variance and confidence intervals.

6.11.2 Intervention

TIMP involves playing musical instruments, electronic or digital music equipment in a way that demands specific movements and movement sequences. Training in the theoretical underpinnings and application of TIMP can be obtained as part of a three-day NMT training course. It is also possible to find instructions in the application of NMT techniques in the Handbook of Neurologic Music Therapy (Thaut and Hoemberg, 2014). Musical equipment used for this study was spatially arranged for each participant in each session in order to facilitate and practice movements that were impaired. For example elbow flexion and extension was facilitated by reaching forwards and playing the cymbal and/or bongos on a stand positioned in front of

them, or the iPads on a stand; shoulder abduction by playing bongos or cymbal positioned to the side. Specific aspects of movement such as priming, timing, range, force, trajectory and quality were supported and mirrored in the facilitating music, which was predominantly performed live by the therapist, but could also be played in identical, pre-recorded format from an iPad. All music was played to a metronome beat, set to each participant's existing frequency of movement, and each musical pattern that accompanied each exercise was comprised of strongly pulsed, simple, repeated patterns, which provided a predictable temporal framework for participants to synchronise their movements to and achieve a high number of repetitions.

6.11.3 Instrument choice

The instruments played by participants in this study were selected for their portability, flexibility in offering various spatial arrangements, and the quality and range of audio feedback that they could offer through a wide variety of playing techniques. These were important considerations for a treatment being delivered in the home environment, where access and space might have prevented the use of many conventional acoustic instruments. Percussion instruments are accessible to non-musicians and require a wide range of movements and movement sequences, potentially employing all muscle groups (Thaut, 2008). They can also be positioned for unilateral and bilateral playing, and played using hands, fingers and other finger joints such as the knuckles, or with beaters, drumsticks and plectrums. There was also a playing pattern that facilitated grip and release finger movements (see pattern 11 in the TIMP chart, using hand held percussion). iPad touch screen instruments are also accessible to non-musicians and offer the appeal of more contemporary soundworlds, with which some participants might have identified more closely with and been more motivated by than with the acoustic instruments. Audio feedback and quality from the iPad touch screen instruments was enhanced through the use of a 'Jawbone Jambox' Bluetooth, wireless speaker, mounted on the microphone stand that held the iPads; also saving space and eliminating the need for cables (with the exception of TIMP 8, which requires two iPads and two short leads to connect them via a headphone splitter). The effort required to trigger sounds using touchscreen instruments can also be reduced or increased by adjusting the touch sensitivity. Playing techniques for iPads did not require technique acquired through musical training and were easily

accessible using finger tips, finger and thumb joints and movements not commonly associated with the sounds that they produced; such as that of the ‘smartpiano’, which required vertically ascending or descending finger movements across bars on the screen that represented and produced piano chords (see Figure 18), with the bass notes in the lower portion of each bar. Playing these touch screen instruments also required more shoulder stability and controlled upper limb abduction, adduction, flexion and extension movement patterns than was the case with the larger acoustic instruments which provided much larger target areas.

6.12 Equipment

The instruments used in this study were: bongos on an adjustable stand, 14” cymbal on a boom stand, two iPads, which mounted on a single microphone boom stand using two iPad holders that could present various angles for playing, a small Bluetooth speaker (see Appendix 1. 31. Researcher playing TIMP 8.) showing the two iPads and speaker mounted together on single stand), which mounted on the boom stand with the iPads, Garageband music software, ThumbJam music software, three cabasas (small, medium and large), a selection of standard and adapted drum sticks and beaters, a pair of drum sticks made for playing iPad touch screen drums, a set of finger picks, a plectrum made for playing iPad touch screen guitars.

Adjustments to the iPad settings (see Appendix) were made in order to ensure that when participants played the touch screen instruments, the screen display and settings did not change or move, but the instrumental sounds were triggered, thus alleviating any frustration that may have been caused by technical issues with the iPad on top of participants’ existing motor control problems.

Smartpiano chords offered opportunities for participants to practice finger flexion and extension and other fine motor movements using a wide range of finger combinations, including thumb only (see patterns 6-10 in the TIMP chart). Smartbass and Smartguitar were used to practice these movements, in addition to a pinch grip by holding the iPad plectrum in order to play individual strings or chords. The 'sustain' switch for Smartpiano was set to 'on' in order to provide participants with more sustained harmony and auditory feedback before they went on to play the next chord.

Chords for the touchscreen instruments (selected from the Garageband instrument menu) were set for some patterns so that each one was separated by a blank chord space in order to minimize error in participants' playing (see Figure 18).

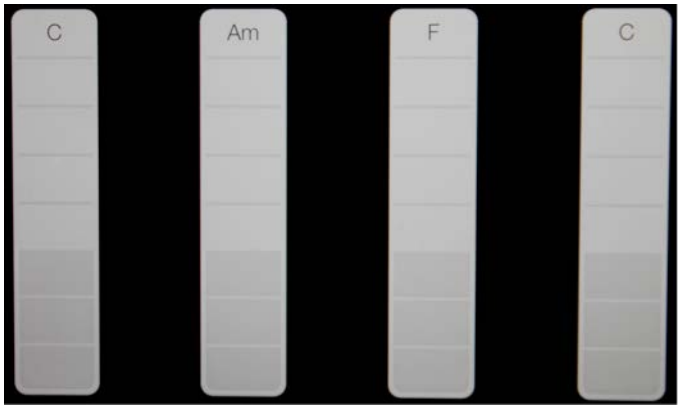


Figure 17. Chord spacings for the Smartpiano on the touchscreen.

When playing the Smartpiano illustrated above participants aim to touch the white strips at the bottom of the screen. As they move their finger up, the notes of the chord are sounded from low to high register. In addition, the 'sustain' switch on the screen is set to on, so that the gradual addition of notes as the finger moves up each chord accumulates to make a sustained chord, rather than staccato notes.

6.13 Spatial arrangement and transportation of the instruments

A total minimum area of two metres squared was required to set up the cymbal on boom stand and bongos on stand, including space for the participant to sit. The area increased depending on how far the instruments were moved away from the participant in order to facilitate increased range of movements.

It was important to ensure that all equipment was transported with minimum risk of damage when carried in and out of the car and in to the various properties visited. A travel bag with extending handle and wheels was used to transport the bongos, cymbal and all hardware, hand percussion, beaters and drum sticks. All together this weighed 16.7kg. A shoulder bag was used to transport the two iPads, metronome and all paperwork. The microphone stand with iPad brackets attached was carried separately without cases and the classical guitar transported in a robust, hard case.

6.14 The TIMP chart

The protocol for TIMP in this study was compiled to form a chart of 12 exercises with variations (See Table Table 7). The extensive detail was developed and refined through the course of delivering treatment to a volunteer stroke participant. It therefore represents an intervention that was refined through patient collaboration, prior to recruiting participants via the host NHS trust database, in order to maximize patient compliance.

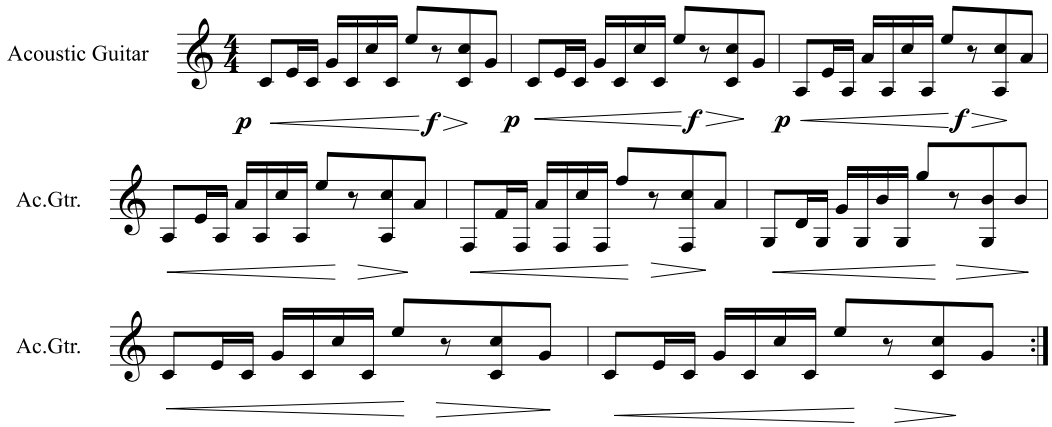
6.15 TIMP music patterns

The facilitating music for the 12 exercises and variations presented in Table 7 is intended to provide a temporal framework of auditory cues to support the priming and timing of participants' movements, and to mirror movement trajectories and cue muscle force using appropriate combinations of musical parameters such as pulse, rhythm, tempo, dynamics, harmony and melody. These frameworks have been composed and selected within a harmonic and rhythmic language that is commonly found in the western popular and classical music repertoire. The decision was made not to use complete, familiar pre-composed songs, with the exception of TIMP 7, for several reasons. In his clinical experience the researcher has observed this to be a distraction for some patients who may try to sing along whilst playing instruments but are unable to attend to these tasks simultaneously. Such division of oral and sensorimotor coordination can be taxing even for novice musicians and in the case of stroke patients with hemiparesis, motor planning often requires greater conscious effort. This point has been raised previously (Thaut and Hoemberg, 2014) in relation to patients with attention impairment. However, it has also been reported that singing the words to familiar songs can provide a memory aid for movement patterns, aid breathing and provide an additional, internal pacesetter (Thaut, 2008).

Considerations for patients' musical preference and cultural background have been recommended when selecting facilitating music for TIMP (Thaut, 2008). Since this is a labour intensive intervention delivered to twelve different stroke patients in their homes within the model of community rehabilitation, it was not considered a feasible

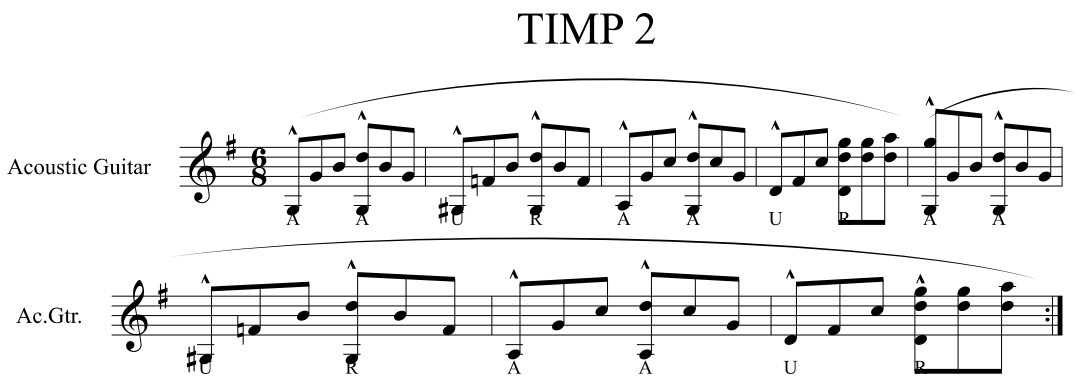
undertaking to add to the complexity of recruitment, assessment and treatment by researching each participant's preferred music before scheduling and delivering each block of 12 sessions. A metronome beat, whilst providing a temporal framework for the priming and timing of each exercise, would not provide any mirroring of movement trajectories nor cues for muscle force, which changes in melodic and harmonic patterns and intensity can. A metronome beat could also become monotonous and not serve to motivate participants as effectively (which the researcher has experienced in clinical work), nor would there be any interaction between therapist and participant, which emerged as a motivating theme in the analysis of qualitative data (see Chapter 6: 'Main results'). The music patterns composed for each exercise can be delivered in a flexible manner, allowing for variations in intensity and form that have proven engaging, effective and enjoyable for patients in previous clinical work. Below are transcriptions and descriptions for each musical structure and variations used for each of the 12 TIMP exercises.

In the electronic version of the thesis double click on the speaker symbol. In hard copies play tracks as listed on the CD enclosed at the back.

TIMP 1

Notation i. TIMP 1

For TIMP 1, each participant plays a single beat of the cymbal on beat three of each bar. The cymbal can be struck using hand, drumstick, adaptive beater or finger picks, depending on the target movement/s and existing level of upper limb function.

The arpeggio for TIMP 1 provides an ascending step pattern over one octave (‘e’, ‘g’, ‘c’ for the C major chord)) before arriving at the participant’s cymbal strike; the note ‘e’ for the C and Am chords, and notes ‘f’ and then ‘g’ for the F and G chords. This mirrors, or provides an illusory representation of, the arm extending forward, or extending to the left or right, depending on whether the target movement is elbow extension or shoulder abduction/adduction. This scale pattern occurs on each chord of a standard western four chord progression: C, Am, F, G. The dynamic increases and there can also be a slight accelerando leading to the note falling on the cymbal strike, all of which is intended to help mirror the movement trajectory and cue the muscle force by building the musical intensity.

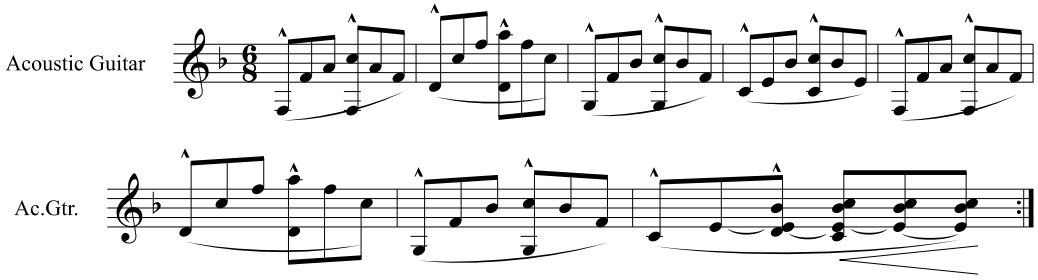


Notation ii. TIMP 2

TIMP 2 is in 6/8 time and participants play with the affected hand (A) on beats one and four of bar one, then the unaffected (U) side plays beat one of the second bar. Beat four of bar two is a rest (R) and playing continues using this pattern in each bar. This progression can also be strummed in cases where more rhythmic emphasis is required.

The music for TIMP patterns 2, 3 and 4, requiring the corresponding number of consecutive beats with the participant's affected side, is simple and predictable, and in an idiomatic western popular form. The purpose of the music is to enable participants to focus on the pulse, accented beats and the priming and timing of each movement. Due to the increased frequency of movement required for two or more consecutive beats, it became more challenging to compose a musical pattern that mirrored the movement trajectories as the arm moved from one percussion instrument to the next, and the emphasis in the music shifted to the rhythmic and harmonic properties. However, there is some cueing in the arpeggios used, which can be enhanced with dynamic contours (increasing and decreasing the dynamics).

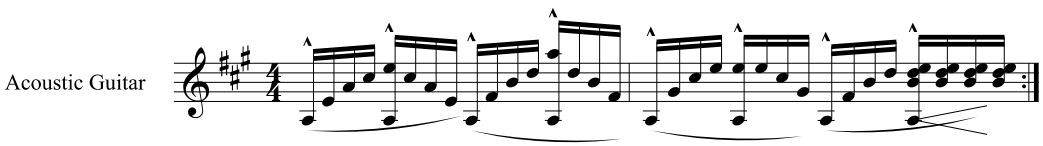
TIMP 3 & 4



Notation iii. TIMP 3 & 4

For TIMP 3, in 6/8 time, participants use their affected hand to play on beats one and four of bar one, then beat one of the second bar, with the unaffected hand playing beat four of the second bar. For TIMP 4, the affected hand plays all accented beats. A variation requires the participant to play the four accented beats with the affected hand, then the same pattern played in reverse using the unaffected side. This variation serves to reduce fatigue in the affected upper limb, which rests while the unaffected side plays, as well as exploiting any positive effects from bilateral playing, as has been indicated in some research previously discussed (Mudie and Matyas, 2000).

TIMP 5



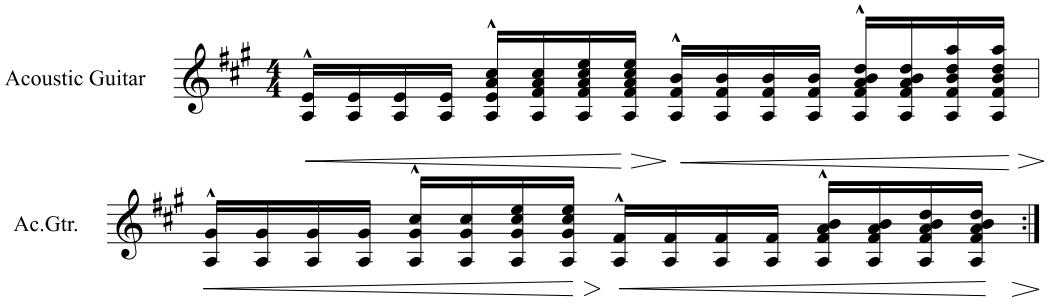
Notation iv. TIMP 5

TIMP 5 is the only specifically bilateral playing pattern where participants alternate left and right hands, crossing midline to play the cymbal or bongos. TIMP 1c is a bilateral variation with music that mirrors each, alternating arm extension, whereas for TIMP 2, 3 and 4 the music does not mirror the trajectory as effectively, but helps cue the priming and timing. For TIMP 5 participants play on each accented beat of the bar.

Having practiced this movement, crossing midline in a kind of 'swimming' motion, and having used a similar musical pattern quite extensively in clinical work, the researcher found that strumming each chord into a crescendo really helped to cue the muscle force and prime the movement. In some sessions this became a very energising movement pattern for patients. It came about through work with a client some years ago, who spontaneously began to play a horizontal rack of cowbells as if swimming front-crawl, crossing his mid-line. The accompanying musical pattern and harmonic progression could be associated with optimism or freedom, and this can be a very liberating movement when participants get into the swing of the rhythmic chord changes with the anchoring 'A' bass pedal. This musical pattern exploits the resonance of open guitar chords, with each arpeggiated note of the preceding chord being sustained into the next, thus sustaining harmonic intensity.

This musical pattern has also been delivered simultaneously with the music playing from the iPad whilst the researcher played the same chords live on the guitar with crescendos leading up to the slide from one chord to the next, cueing the point at which participants should play.

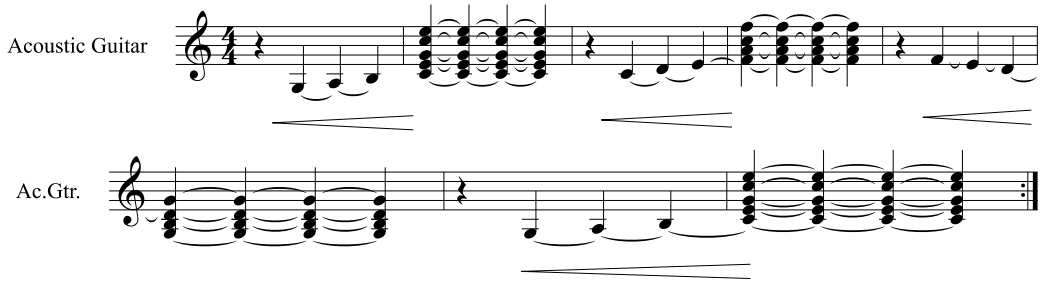
TIMP 5



Notation v. TIMP 5 variation

Version two of TIMP 5 requires participants to play at a reduced frequency, on beats 1 and 3 of each bar. Chords are strummed with gradually accumulating intensity to mirror the forward reaching movement trajectory across midline to play the cymbal and then one bongo. Each beat of the bar is accented in order to provide a strong sense of pulse.

TIMP 6



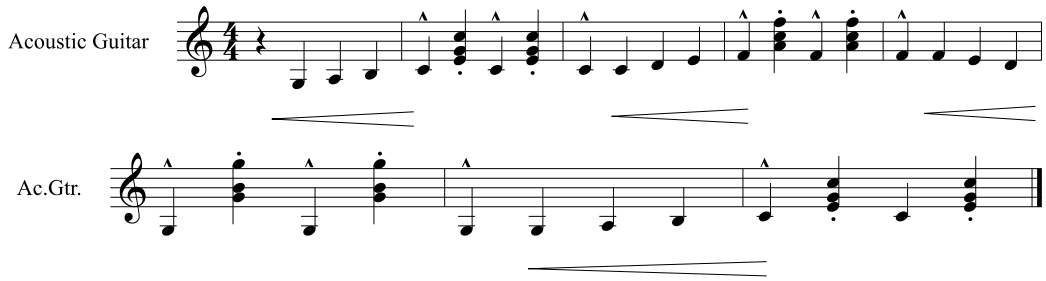
Notation vi. TIMP 6

For TIMP 6 participants are required to play a single thumb movement across the iPad screen on the first chord after the three bass notes (every other bar).

The TIMP 6 pattern can be effectively used with the participant playing along to the recording on the iPad and the words ‘get ready and play’ sung by the researcher in-

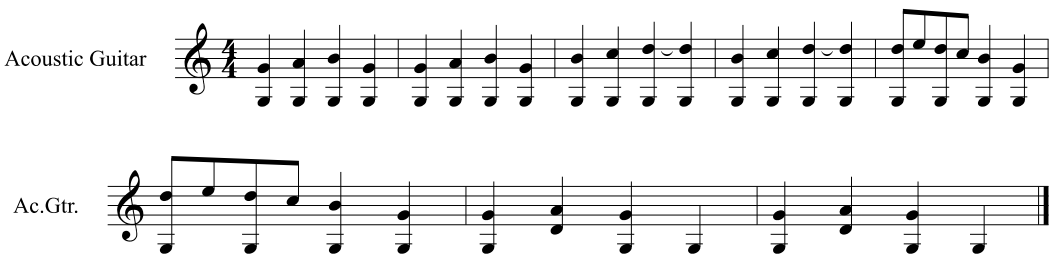
time to the ascending (descending in bar five) bass note lead-in, which mirrors the extension of the thumb across the screen, spanning as many of the guitar strings on the iPad screen as possible. In order to make the pulse clear it is helpful sometimes, after each bass note lead-in, to play each repetition of the chord alternating bass note, chord, bass note, chord, bass note, rather than a single strum of the chord (see Notation vii. TIMP 6 variation).

TIMP 6



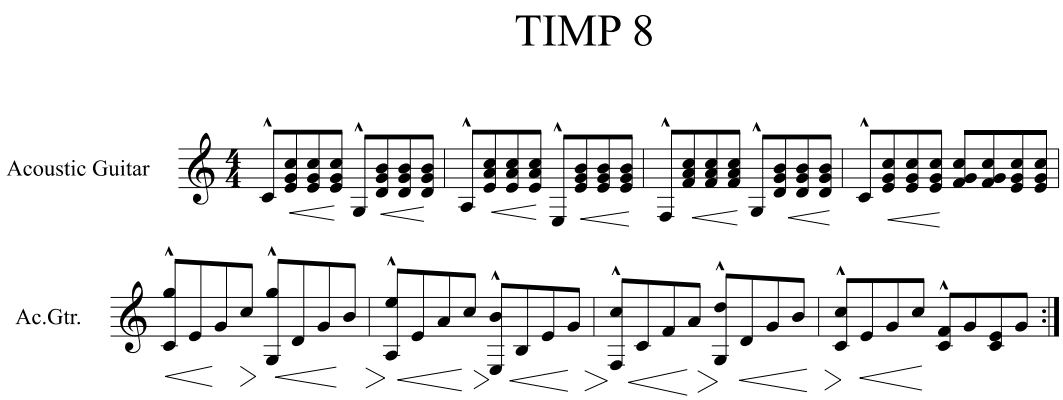
Notation vii. TIMP 6 variation

For this variation of TIMP 6 alternating bass note and chord playing is used in order to emphasise the pulse after each bass note lead-in.

TIMP 7

Notation viii. TIMP 7

TIMP 7 uses the Frere Jacques melody, which facilitates a single finger extension or alternating finger extensions on beat one of each bar. This is the only pattern that uses a familiar pre-composed melody; ‘Frere Jaques’ played in G major.

The music was selected as it aims to facilitate a movement requiring finer motor control that can be performed on a single chord in accompaniment to a predictable melodic pattern. The participant plays the Smartkeyboard touch screen instrument in Garageband on the iPad, strumming a single G major chord using finger extensions along to the melody on beat one of each four-beat phrase of the song. The playing pattern advances to include the G, D5 G chords over the ‘ding dang dong’ refrain of the song, which requires faster finger movements in order to play them on 1st, 2nd, and 3rd beats of the final two bars. The support for movements from the music in this exercise comes from the priming and timing cues in the pulse and melodic phrasing.

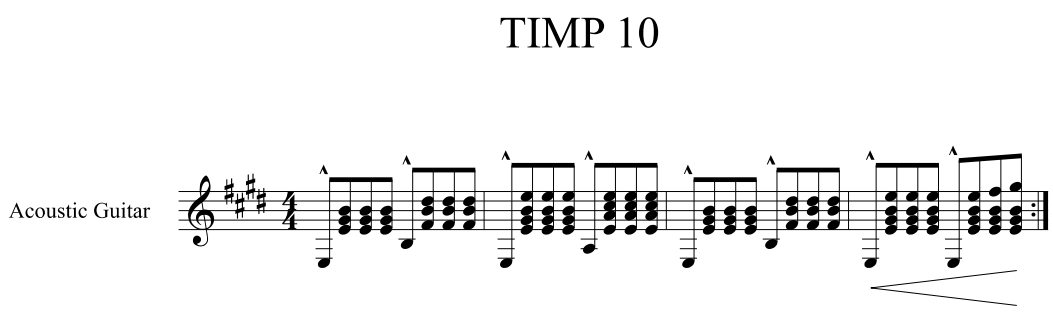


Notation ix. TIMP 8

For TIMP 8, participants are required to play patterns utilizing up to four fingers or using the plectrum held with thumb and any individual opposing finger combination; index, middle or ring finger.

The first five chords of TIMP 8 follow the same sequence as Pachelbel's Canon and there is a Baroque flavour to the progression that is intended to be both relaxing and compelling for participants. In this key on the classical guitar and played with good technique, it is possible to add variations on a melodic line (see transcription Figure 7, second stanza). Two iPads are used by participants in order to facilitate bilateral playing with gross movements as well as fine movements using the fingers, and to enable adequate spacing between each chord on the Smartpiano iPad screen, which requires less accuracy for those with dystonia (See Figure 18).

TIMP 9 (not notated) uses Garageband Smartbass or Smartguitar, following the same harmonic progression as TIMP 8, but using one iPad. The spacing of the seven chords on a single iPad screen is closer together, requiring more accurate finger dexterity and sustained shoulder stability. Alternatively, this exercise can facilitate pinch grip, using the plectrum, with the participant either picking individual bass strings with the Smartbass, or strumming ascending or descending across the strings of the Smartguitar.

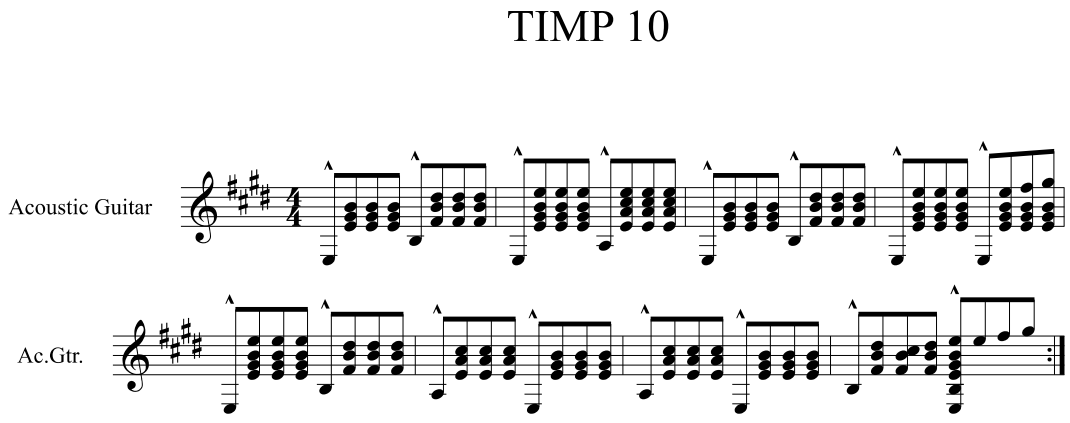


Notation x. TIMP 10

The audio file for TIMP 10 is a recording of the strummed chords, not arpeggiated as in the transcription. A recording was not provided for participants as the researcher always played the pattern, as shown in the transcription.

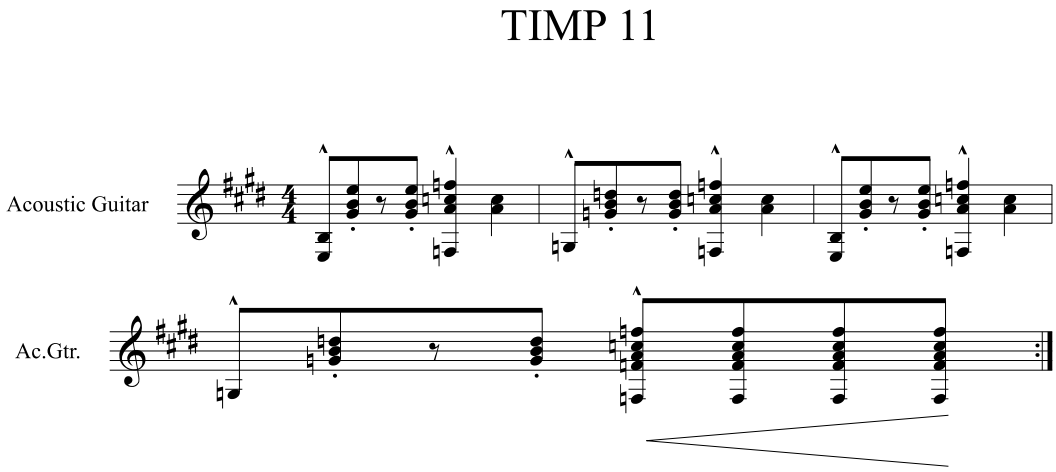
TIMP 10 for accompanying an E major scale ascending only. This pattern requires one or two finger combinations, with participants playing each note on beats one and three of the bar, corresponding with the accented beats.

This pattern uses Thumbjam music software, whereas the other patterns all use Garageband. This software offers a variation in how the bars on the screen representing each note are arranged, which are not designed as virtual instruments. It also offers a cello sound, which the researcher selected for this exercise based on its potentially motivating qualities; being of high audio quality, offering participants a new and different instrumental sound to play. The music accompanies participants playing an ascending scale in E major, or ascending and then immediately descending scale using a single finger held onto the screen and slid up or down to each consecutive note (see Notation xi). E major was selected to widen the harmonic range offered by each different TIMP exercise. The scale range selected was E2 to E3, as this resonated well through the Bluetooth speaker, giving participants high quality auditory and tactile (through the speaker resonating on the stand or table surface) feedback.



Notation xi. TIMP 10 variation

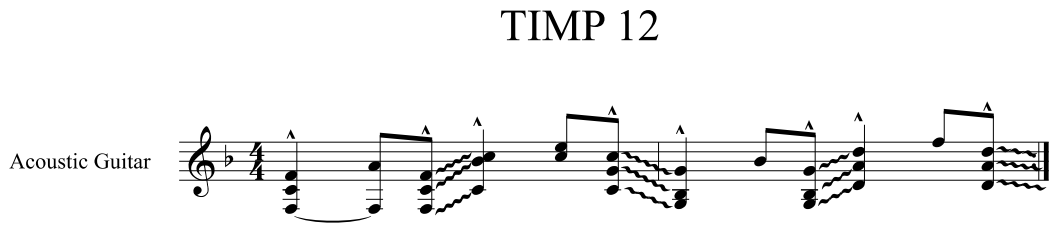
The accompanying chords for participants to play both ascending and descending E major scale patterns, requiring more shoulder stabilisation.



Notation xii. TIMP 11

The music for TIMP 11 is harmonically and rhythmically structured in a Spanish idiom.

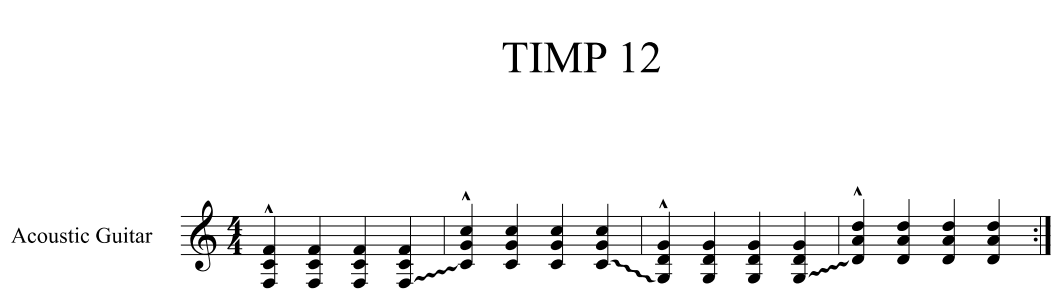
Participants play the cabasa, holding the handle of the instrument in their unaffected hand and, if possible, placing their affected fingers over the top in order to grip the beads whilst the unaffected hand twists to produce a sound. The affected hand then releases the beads, reaches forward and hits the cymbal using the fingers. The twist of the cabasa occurs on beat one and the cymbal hit on beat three of each bar. The music is in a Spanish idiom, with a strong, driving pulse intended to compliment the sound of the cabasa and help maintain participant focus on this complex sequence of movements.



Notation xiii. TIMP 12

The music for TIMP 12 supports a movement that is very resistant to treatment and very limiting in terms of performing ADLs for stroke patients.

The exercise is wrist and forearm pronation and supination (rotation). Participants hold a drumstick or a cabasa horizontally in front of them using their affected hand, with the bongos and cymbal positioned to the left and right, at either end of the drumstick/cabasa. They then rotate their wrist and forearm in order to play first one, then the other percussion instrument in time to the music, on beats one and three of the bar or, at half speed, beat one of each bar. The glissando between each chord change is intended to mirror the rotation movement in the wrist and forearm.



Notation xiv. TIMP 12 variation

Alternatively, this harmonic sequence can be played by strumming the chords and gradually building the intensity towards each chord change, where the participant plays. This increase in intensity aims at cueing the muscle force required to rotate the forearm and wrist.

6.16 Summary

This chapter has provided information regarding how music is processed across diverse brain regions, including those areas concerned with attention, with emotions and the motor cortices, which plan and control movement. Literature has been presented from studies evidencing the influence of melody on movement direction and of rhythm on movement timing and trajectory. This information supports the rationale for composing and using music as an external auditory timekeeper to which it is possible for participants to synchronise their movements in order to improve upper limb coordination, range of movement and finger dexterity.

Along with NMT training, including in the use of TIMP and RAS, and clinical experience, this literature informed the researcher as to what type of music to assign to specific TIMP exercises. As previously described, the TIMP music and exercises were also trialed and refined through collaborative work with a volunteer stroke patient prior to recruitment for this pilot study. The transcriptions of TIMP music are provided to illustrate the essential structures employed to mirror and support each upper limb movement, which the participants then synchronized their movements to, those being pulse, melodic and dynamic contour, harmony and intensity. The transcriptions are accompanied by brief descriptions of the function of specific musical parameters and structures, the exercises or required movements, as well as the equipment and instruments used for certain exercises and the sounds that they produced, which the music sought to compliment. The same music was used for each TIMP exercise, as described in the table of TIMP exercises (Table 7. TIMP exercises.), with each participant, but with some room for variation of musical patterns as illustrated in the transcribed variations. Variations always maintained focus on reinforcing the structures in the music that facilitated the participants' required sequence of movements.

6.17 TIMP table of exercises

In table patterns gradually increase in complexity. 1-5 show gross motor exercises, 6-10 are for fine motor, exercises 11 and 12 target grip and release, wrist/forearm pronation/supination/deviation.

Table 7. TIMP exercises.

	TARGET MOVEMENT (bold) ASSOCIATED MUSCLE GROUPS	INSTRUMENT/S & EQUIPMENT	POSITIONING	PARTICIPANT INSTRUCTIONS	PLAYING PATTERN	FACILITATING MUSIC	VARIATIONS
1	Single beat with affected side: **Elbow and shoulder flexion & extension, shoulder abduction and adduction.** Some wrist extension or deviation, finger extension, wrist between pronation and supination, core muscles	**14" Cymbal on boom stand**, adaptive beater and wooden drum stick, or finger picks slotted over thumb and/or finger/s	Cymbal positioned at a distance and height that the participant can reach to play Gradually raise height/increase distance and angle to facilitate increased movement range	Relax shoulders, feet flat on the floor Extend arm and fingers to cymbal. Relax & rest hand on lap or by side after playing Prompt can be sung to music: 'reach & reach & play, relax'	Affected side always play on beat 3 of each bar Each cycle of the sequence requires **8 beats** of the cymbal	C, C, Am, Am, F, G, C, C 8 bar chord sequence in 4/4 Arpeggiating & building the intensity of each chord towards beat 3	**A**: using hand/fingers/ finger picks **B**: adaptive beater or drum stick **C**: alternating affected & unaffected side (bell of cymbal on one beat)

2	2 successive beats with affected side: **Elbow flexion & extension**, slight shoulder extension and adduction, wrist between pronation and supination, grip, core muscles	**Cymbal on boom & bongos on stand,** adaptive beater and 2 X wooden drum sticks, finger picks	Bongos on affected side, at achievable height & angled so that larger one is further from participant, cymbal for unaffected side. Gradually reposition for increased range of movement	Try to focus on elbow bending & stretching Relax shoulders, feet flat on the floor, reach arm (and fingers). Relax arm & rest hand on lap after playing Sung prompt: Left (affected) & left & right, relax	Affected hand plays beat 1 & 2, unaffected plays 3. Beat 4 is a rest.	Rhythmic, energetic, jazz idiom: G7, G♯Dim, Am7, D7, played in 4/4 over two bars. Arpeggiated and/or strummed with strongly accented beats Each cycle of chords requires **6 beats on the percussion (4 on affected side**)	**A:** using hand/fingers/ finger picks **B:** adaptive beater (affected) drum stick (unaffected)**C:** drum stick both hands

3	3 successive beats with affected side: **Shoulder and elbow flexion, & extension**, **shoulder abduction**, slight shoulder adduction, wrist between pronation and supination, grip, core muscles	**Cymbal on boom and bongos on stand,** adaptive beater and wooden drum sticks, finger picks	Bongos on affected side (as above), adjusting the height and positioning of instruments to facilitate greater shoulder & elbow extension or shoulder abduction	Try to focus on elbow bending & stretching Sung prompt: Left (affected) & left & left and right	On each beat of the bar: affected side plays bongo 1, then 2, then cymbal, then unaffected side plays cymbal bell (hitting the centre of the cymbal)	Any 1, 6, 2, 5 chord sequence played over two bars. Strongly pulsed arpeggios or strummed rhythm in 4/4 Each cycle of chords requires **8 beats on the percussion (6 on affected side)**	**A:** using hand/fingers/ finger picks **B:** adaptive beater (affected side) and drum stick (unaffected) **C:** two drum sticks
	TARGET MOVEMENT (bold) & ASSOCIATED MUSCLE GROUPS	INSTRUMENT/S & EQUIPMENT	POSITIONING	PARTICIPANT INSTRUCTIONS	PLAYING PATTERN	FACILITATING MUSIC	VARIATIONS

4	4 successive beats with affected side: **Shoulder & elbow flexion & extension**, **shoulder abduction**, slight shoulder adduction, wrist between pronation and supination, grip, core muscles	**Cymbal on boom and bongos on stand,** adaptive beater and wooden drum sticks, finger picks	Bongos on affected side (as above), adjusting the height and positioning of instruments to facilitate greater shoulder & elbow extension or shoulder abduction	Try to focus on elbow bending & stretching Sung prompts as TIMP 2 & 3	On each beat of the bar: affected side plays bongo 1, then 2, then cymbal, then cymbal bell, unaffected side then plays the pattern in reverse order	Any 1, 6, 2, 5 arpeggiated or strummed chord sequence played over two bars, strongly pulsed rhythm in 4/4 Each cycle of chords requires **8 beats from the affected side**	**A:** using hand/fingers/ finger picks **B:** two drum sticks, affected side plays the pattern, then unaffected side plays pattern in reverse while affected side rests
	TARGET MOVEMENT (bold) & ASSOCIATED MUSCLE GROUPS	INSTRUMENT/S & EQUIPMENT	POSITIONING	PARTICIPANT INSTRUCTIONS	PLAYING PATTERN	FACILITATING MUSIC	VARIATIONS

5	Bilateral playing, crossing midline: **Shoulder adduction, extension and flexion**, **elbow flexion & extension**, grip, wrist between pronation & supination, core muscles	**Cymbal on boom and bongos on stand,** adaptive beater and wooden drum sticks, finger picks	Bongos on affected side, cymbal on unaffected side Distance of instruments from participant and width apart of instruments varies, to facilitate increases in shoulder adduction and extension	Feet flat on ground, try to relax shoulders and achieve smooth twisting action at shoulders and torso to play left and right	Both hands crossing midline alternating affected and unaffected side on beat 3 of each bar, progressing to beats 1 (L) & 3 (R)	Open 'A' bass note played over arpeggiated or strummed chords: A, Bm, C♯m, Bm, Played with clear pulse, 4/4 time over two bars	**A:** using hand/fingers/ finger picks B: adaptive beater (affected) and drum stick (unaffected) **C:** two drum sticks

6	Fine motor: thumb only or thumb and index, middle or ring finger gripping a plectrum **Thumb extension and flexion**	**iPad & Garageband** music software using 'Smartguitar', iPad touch screen plectrum, speaker connected	On lap on affected side, on stand at appropriate height, or on table top	Fingers rest on the side of the iPad, the thumb extends side to side across the screen strings Participants aim to strum across as many strings as possible with each thumb stroke, in time to the beat	Chord strummed using thumb only on beat 1 and 3 until final bar (C), which is beat 1 only	C, F, G, C sequence in 4/4. Each played with bass 'lead in' as follows: g, a, b, **C** (*chord*), c, d, e, **F** (*chord*), f, e, d, **G** (*chord*), g, a, b, C (*chord***)**	**A:** up and down stroke with thumb, twice on each chord, including final chord strummed 4 times **B:** holding the iPad plectrum using the thumb and index, middle or ring finger and strumming across the strings

7	Fine motor control of fingers or arm: single or two finger combinations using various fingers, or pinch grip **Shoulder stabilisation, finger extension (any/all finger/s or part of finger), wrist deviation,** elbow extension, wrist extension	**iPad & Garageband** with 'Smartpiano', sustain switch on, chords set to G (Left side of screen) and G, D5, G in centre of screen, speaker connected. Alternatively, Smartguitar using the plectrum	In line with affected side. At a height approximate to a standard keyboard height, or that does not demand participant to extend arm excessively to reach the keys. In some instances placing the iPad on the participant's lap or a table (affected side) may offer the most accessibility and focus on finger extension	Relax shoulders, reach with your finger/s, feet flat on floor Participants may initially trigger the sounds using knuckle or other part of finger The therapist should encourage and support use of finger tips where possible	iPad: playing a single 'G' chord by sliding finger tip/s, knuckle, etc, vertically upwards over the chord and/or slightly away from body Alternating affected and unaffected side, 1st beat of each bar	Frere Jacques in G major with strong pulse	**A**: unaffected fingers play the G, D5, G, chords on 'ding, dang, dong' lyric section of song **B:** affected side plays G, D5, G section **C:** affected hand uses index, then middle finger to play 'G' unaffected hand plays G, D5, G section D: using the iPad plectrum and Smartguitar

8	Fine motor control: single to 4 finger combinations **Finger movements or finger extensions**, shoulder stabilizing, elbow flexion and extension, shoulder extension, abduction and adduction. Core muscles	**2 X iPads**: both mounted on a single microphone stand Garageband music software using 'Smartpiano'. iPads connected to speaker using two mini jack leads and a splitter input	iPads one above the other or next to each other, mounted on two iPad clamps which are both on the same microphone stand	Initially, therapist instructs participants whilst playing the chords by singing the chord names or 'play' each time the participant is required to play the next chord.	Any finger or finger combination playing each chord individually in time to the music. Finger can extend to play ascending chord or flex to play descending chord (down the screen)	8 chord sequence played to accompany the alternating chords on iPad 1 and iPad 2 as follows: C, G, Am, Em, F, G, C, C. with each chord arpeggiated. Clear accents on bass note of each chord to emphasize pulse	**A:** single finger extension alternating left and right hands **B:** single finger extensions, affected hand only **C:** 2 fingers alternating left and right hands (index L, index R, middle L, middle R, etc) **D:** alternating left and right hands using 3 fingers (as above) **E:** alternating left and right hands using 4 fingers (as above)
	TARGET MOVEMENT (bold) & ASSOCIATED MUSCLE GROUPS	INSTRUMENT/S & EQUIPMENT	POSITIONING	PARTICIPANT INSTRUCTIONS	PLAYING PATTERN	FACILITATING MUSIC	VARIATIONS

9	Fine motor control: single to 4 finger combinations or thumb and finger pinch grip using iPad plectrum **Finger movements or finger extensions,** Thumb, Index, middle and ring finger extension and flexion, shoulder stabilization, elbow flexion, core muscles	**iPad:** Garageband music software, 'Smartbass' or 'Smartguitar' and speaker, mounted on stand or resting on lap or table top, iPad plectrum	iPad positioned in portrait rather than landscape in order to facilitate 'keyboard' style finger patterns on the strings. iPad on stand, or on participant's lap	Relax shoulders, feet flat on floor Initially, sing each chord name	Playing on the first beat, then 1 & 3, then 1, 2, 3.	Chord sequence: C. G. Am, Em, F, G, C:‖ 4/4, (one chord per bar)	**A:** index **B:** index and middle **C:** index, middle ring **D:** index, middle, ring, little finger **E:** thumb, index and other fingers **F:** using iPad plectrum held using thumb and index, middle or ring finger and used to play individual notes on each string or chords
	TARGET MOVEMENT (bold) & ASSOCIATED MUSCLE GROUPS	INSTRUMENT/S & EQUIPMENT	POSITIONING	PARTICIPANT INSTRUCTIONS	PLAYING PATTERN	FACILITATING MUSIC	VARIATIONS

10	Fine motor control: single to 2 finger combinations **Finger movements or finger extensions,** finger, wrist, elbow or shoulder extensions, some shoulder abduction or adduction depending on positioning	**iPad:** mounted on the boom stand, speaker connected. ThumbJam Cello, E3 to E4, major scale setting	Mounted on stand in portrait position, so that as the fingers move up the screen, the scale ascends	Keep finger in contact with screen for the full duration of the music, moving it up/changing finger in time with the music Sing 'play' to participants each time they are required to move to the next note	Playing up the screen: E, F♯, G♯, A, B, C♯, D♯, E	Ascending scale: E, B, E, A, E, A, B, E. Descending scale: E, B, A, E, A, E, B, E . Arpeggiating the chords and with a 'turn around' phrase at the end to indicate 'back to the start note (E)' For example the notes: b, c♯, d♯ on the 'B" string	**A:** hold position sustaining the top 'E' note of the scale at the top of the screen, then following the music to descend back down the screen to bottom note 'E'

11	[1](Baker et al., 2006)**Grip, wrist ulnar and radial deviation**, elbow flexion	**Cabasa**: small, medium and large sizes **Bongos or cymbal** on stand	Cabasa held in unaffected hand, affected hand aims to grip the beads over the top/round the side with any finger/thumb combination and twist to produce sound	Relax shoulders, 'twist, release, reach, play' (spoken or sung to participants in-time with music)	Playing on 1st (cabasa twist) and 3rd (bongo/cymbal) beat of each bar	Strongly pulsed, rhythmic and staccato music, for example Spanish idiom using E, F/E bass, 4/4 time	**A:** grip and twist cabasa with affected hand on beat 1, then release it and hit the cymbal on beat 3 using the affected hand (no stick or beater)
	TARGET MOVEMENT (bold) & ASSOCIATED MUSCLE GROUPS	INSTRUMENT/S & EQUIPMENT	POSITIONING	PARTICIPANT INSTRUCTIONS	PLAYING PATTERN	FACILITATING MUSIC	VARIATIONS

[1] This exercise is described and illustrated in Baker and Tamplin , 2006, p79 and adapted for this exercise.

12	**Wrist and forearm pronation & supination,** shoulder adduction, elbow extension, core muscles	**Cymbal on boom and bongos on stand,** two drum sticks or beaters taped together so there is a tip at either end or single stick/beater rotated so that tip plays cymbal then bongo	Cymbal and bongos slightly less than a beater's distance apart focusing efforts on wrist and forearm rotation Alternatively, play bongos, rotating wrist/forearm to play bongo 1 then bongo 2	Sung prompt: turn &turn & play	Affected hand only plays bongo with one end of the stick, then cymbal or bongo 2 with the other end on beat 3 only (slow rotation) or 1 & 3	Octaves or chords: F slide to C, slide to Gm, slide to Dm 4/4 time over 2 bars, with strong accent on beats 1 & 3 & crescendo between each chord	**A:** holding just the adaptive beater and making full forearm pronation and supination movement to play cymbal then bongo or bongo 1, bongo 2 **B:** using a cabasa instead of stick/beater

Figure 18. Video excerpt of volunteer stroke participant playing TIMP patterns

The video clip shows the volunteer stroke participant playing some of the patterns shown in Table 7 and is included with her full consent. The P number between some of the exercise clips does not refer consistently to each of the TIMP exercises in the table as it was still in a stage of development, but it can be observed how upper limb movements are targeted, the degree of repetition facilitated and how the music served to mirror movement trajectories.

Patterns were recorded onto the iPads at metronome settings of 50 and 60 beats per minute (bpm) respectively, using the 'audio recorder' selected from the Garageband instrument menu and input via the iPad built-in microphone. This offered two tempo settings for participants to synchronise to in order to try each exercise whilst the researcher physically guided their arm movements in cases where hand-over-hand support was required. Following this, the researcher and participant played together, with the researcher playing the supporting music live, in-time to a metronome listened to via an ear-piece.

Most of the TIMP patterns have variations, where participants could follow alternative finger patterns, or be given various beaters, drum sticks, plectrums and finger picks to use with the instruments as required. This equipment served one of two functions: they either facilitated improved access to the instruments and improved sound quality and auditory feedback from their movements and playing, or they required from the participant more complex finger movements, bilateral playing patterns and additional grip or pinch movements. Some participants may have struggled to grip beaters initially and have been more able to access instruments using

hands and fingers only, with the focus more on gross motor movement. In this way, the musical tasks demanded maximum physical performance.

6.18 Notes on using the TIMP chart

For all participants, regardless of how much gross motor control and range they had, the cymbal was selected and positioned for their affected upper limb to play when using TIMP 1 and all variations of this pattern, as it provides the most auditory feedback with the least amount of force required. For TIMP 2, 3 and 4 the affected side played the bongos, leading to the cymbal.

Positioning of iPad/s when targeting finger dexterity and fine motor control was determined by the presence of any additional movement disorders such as tremors, dystonia or spasticity. If such symptoms were present then positioning the iPads at a table with the participant's arm resting on the table surface allowed greater stability. In some cases it was possible to work towards mounting the iPads on the stand in order to extend the exercise to target shoulder stability as well as fine motor movement.

6.19 Metronome settings

Pacing of movements can be problematic in hemiparetic movement disorders. Tapping exercises to external precisely paced auditory cues provide opportunities for rehearsal of movement timings. Using a metronome with a 'tap' facility, each participant's natural playing tempo could be calculated by tapping into the metronome in-time with their playing. The literature recommends beginning treatment at the existing movement frequency and increasing towards normal once movement quality has been improved (Thaut et al., 2002). Following this, the researcher played the music in a manner that strongly accented each beat. If the movements involved a high level of compensatory movements, for example from the trunk or shoulder, then the metronome speed was reduced until the participant could be observed as having more time to plan movements between each beat, and synchronise their playing with the music using more controlled and better quality movements. Following this, increases of approximately 10 bpm could be made provided that the movement quality was not

compromised. The correlation between tempo and motor learning has been discussed in recent publications (Massie and Malcolm, 2012; Furuya, Nakamura and Nagata, 2013), and was a consideration sessions with each participant.

6.20 Use of live music

The music needed to be performed live for a number of reasons, among which were: 1) the need to be able to play in a range of tempi in order to support different frequencies of movement, which also varied depending on the difficulty level of the exercise; 2) to facilitate a musical interaction that would serve to motivate and support participants as they performed the exercises in the moment. It was, therefore, necessary to use a portable instrument capable of producing melody and harmony with good projection, dynamic and rhythmic range.

6.21 Pre-recorded TIMP Music

Some participants were required to play each pattern initially without musical accompaniment in order that they understood the instruction and could get a feel for the movement. Following this they could try the movement with the music. In order to facilitate hand-over-hand support for participants who had receptive dysphasia and struggled to follow verbal instructions as to how and when to play, or simply struggled to follow the pulse and cues in the music, two separate recordings of each TIMP pattern were made; one at 50 and the other at 60 beats per minute (BPM). In this way participants could begin playing and be physically supported by the therapist, playing at a slower frequency before the music was played live and the musical interaction between therapist and participant established. In Garageband I used the audio recorder selected from the iPad instrument menu, using the built-in microphone rather than an external one. I listened to the metronome beat through headphones in order to avoid the microphone picking it up, this then allowed me to play the recorded guitar music to participants with or without the metronome beat.

6.22 Recommended iPad settings

Before setting up iPads for participants to play, settings need to be adjusted under ‘SETTINGS’ from the main screen menu as follows:

1. 'auto-lock’ set to 'never'
2. 'lock rotation' whilst holding the iPad in landscape position
3. 'multitasking gestures' off

Also within SETTINGS, in the ‘control center’, ‘Access Within Apps’ needs to be disabled. This will then prevent the ‘control center’ menu from popping up when participants play the smart keyboard beginning with upwards finger movements on the chord bars from the bottom of the screen.

6.23 Additional Music Software

Thumbjam music software was added at a late stage in the TIMP pattern design and is used for TIMP 10. The software should be set so that the tool bar is hidden by selecting ‘Pref’ (bottom right corner of screen) and sliding ‘show tol bar’ switch to off. Compared with Garageband, it is less a multi-track recording program, instead offering an extremely diverse range of scales and high quality instrument sound samples that are well suited to real-time music performance, both solo and ensemble. Another feature is the vibrato, tremolo and note-bend setting, allowing the player to perform these effects either by shaking the screen or moving the finger from side to side on each note. For TIMP 10, if the player moved their finger from side to side, then they created a tremolo effect and this was used to monitor arm and finger stability; if they played the note without any tremor or side-to-side motion, then the note was steady. The researcher selected the cello sound for its warmth and sound quality and novelty, in the key of ‘E’ major, spanning one octave and beginning on ‘E2’. On-screen, using just one octave, the software offers large enough spaces in the form of horizontal bars across the full screen width for the fingers to make screen contact and seemed particularly useful for ascending scale patterns with the finger gradually rising up the screen in portrait position on the stand, requiring shoulder stabilization, elbow extension and finger flexion and extension. The researcher felt that this pattern had particular aesthetic appeal for participants, with the sound quality

resonating well through the Bluetooth speaker, and the combination of classical guitar and cello sounds.

6.24 Monitoring tolerance

Session duration was determined based on the researcher's clinical experience delivering TIMP and with reference to existing literature. A review that included 15 studies of music therapy in physical rehabilitation (Weller and Baker, 2011) found session length ranged from three 50-minute sessions, to one or two 60-minute weekly sessions for 12 months. In the MST studies, each participant was instructed to play exercises for as long as they could (Schneider et al., 2007; Altenmüller et al., 2009), in 30 minute sessions, five days per week and in addition to conventional therapy.

The researcher used a timer in all sessions, which was initially set to two minutes, after which the exercise would either be repeated or the spatial arrangement of instruments was altered to extend movement range, or another variation or exercise was introduced. Episodes of playing would then proceed through the session in two minute blocks and, depending on tolerance levels, could extend to five minutes. This also created a target playing period and enabled the researcher to stop and ask each participant if they would like to continue or have a rest. The researcher also asked more specific questions to determine if participants were experiencing any discomfort or pain possibly related to each exercise, for example in the back, neck, shoulder, elbow, wrist, fingers, not normally present. If the participant felt that the participant was experiencing pain or discomfort related to the musical exercises then treatment was paused and these symptoms discussed, before either continuing or considering any potential need for a GP or physiotherapy consultation, which was never the case.

For all exercises participants were encouraged to keep their feet flat on the ground in order to provide support for their back and core muscles and optimize movement control when playing the instruments. This instruction to participants became a part of the TIMP protocol for the study following review of video footage with members of the host NHS trust team and academic supervisors, which was taken during sessions with a volunteer stroke participant prior to recruitment for this study.

6.25 Volunteer stroke participant

As earlier reported, prior to recruitment for the pilot study, a volunteer stroke participant was recruited from a local community organisation (non-NHS), where people with stroke met once a week. The volunteer began the six weeks of treatment on 20/08/2013. This was in order to 1) check the feasibility of home delivery of treatment, 2) trial and refine the exercises and facilitating music, 3) check tolerance and patient experience of the intervention and assessments.

The volunteer was female, in her late 50s, 54 months post stroke, with left side hemiparesis resulting in a high degree of spasticity, mainly proximal movement with compensatory trunk and shoulder movements and some finger extension. She suffered a right intracranial haemorrhage resulting in an acute haematoma centred on the right external capsule, some oedema surrounding and damage to the right lateral ventricle. She completed the six weeks of twice weekly music therapy, pre and post treatment assessments and provided feedback regarding the exercises and music that enabled further refinement for the main pilot study. Consent was recorded to participate and to have sessions videoed for analysis, which was invaluable.

Post intervention responses to semi-structured interview questions indicated that the volunteer found the experience relaxing, it enabled her to monitor her performance and progress, and she found the music provided a cue for when to play. ARAT scores indicated no improvement and 9HPT was beyond the volunteer's ability throughout participation.

The volunteer's contribution enabled the researcher to more specifically modify the TIMP exercises and music, as well as try some different instruments such as autoharp in order to explore how they might facilitate improved finger, wrist and forearm movement. During sessions we explored bilateral playing patterns, seating and instrument positioning using the stands, as well as chairs and tables in her home. During these sessions the researcher also began to monitor tolerance and time the duration for which the volunteer played. Video excerpts of her playing the patterns were taken to one of the physiotherapist managers at one of the NHS community stroke teams, who commented on the researcher's verbal commands to the volunteer,

as well as instrument spatial arrangement and seating position. Following this collaborative work with the volunteer, TIMP patterns were reprganised into categories and numbered as follows: gross movement exercises TIMP 1-5, fine motor TIMP 6-10, and wrist/forearm rotation/deviation TIMP 11-12.

6.26 Ethics

This music therapy research study investigates an intervention aimed at promoting physiological change and as such it is categorized as biomedical research. Music therapy research of this nature has not been widely conducted in the UK, particularly within NHS trusts. For these reasons the application for ethical approval via the Integrated Research Application System (IRAS) required a detailed protocol, describing in full detail every aspect of the research and all that would be required of both the participants and the researcher. The detail of the protocol for this application is an important and central aspect to be acknowledged and adhered to by all future researchers investigating music therapy interventions that fall within biomedical research. This requirement also highlights how such research differs from that which is usually conducted in the UK, which more closely follows a client led intervention or investigates psychological and emotional outcomes following a music therapy intervention rather than requiring participants, stroke patients in this instance, to perform specific physical exercises that require focus, stamina and high repetition.
It must also be acknowledged that there is an enormous heterogeneity within this patient group, which accounts for some extremely physically and emotionally vulnerable patients.
Further to the protocol document, completed IRAS application and all relevant forms for the study, a scientific review of the study was also requested by the regional ethics committee (REC), which was provided by Professor Michael Thaut and approved by the committee.

6.26.1 Full list of forms submitted for ethics application

- IRAS application
- Detailed study protocol (14,000 words)
- Letter of invitation to participate in the TIMP study
- Participant information sheet for TIMP study
- GP information sheet for TIMP study
- TIMP Consent form
- Pre and post semi structured interview questionnaires
- Letter of invitation to participate in the EEG study
- Participant information sheet for the EEG part of the study
- GP information sheet for the EEG part of the study
- EEG participant questionnaire
- EEG consent form
- EEG permission to video form for participants
- Consort diagram
- Scientific report from Professor Michael Thaut, evaluating the design and relevance of the study

All forms submitted for ethical review and approved by the committee can be found in the appendix.

6.27 Summary

In this chapter the study design and the rational for its use in answering the research questions has been described. The process of recruitment, randomization and assessment of participants, as well as demographics has been explained in order to understand the flow of the study. Literature has been presented to help illustrate the lack of research investigating home-based music therapy interventions for hemiparesis and the frequency of twice weekly treatment. Some detail regarding the process of obtaining ethical approval in order to recruit NHS patients further informs the reasoning for selecting ARAT and 9HPT as assessment tools and for the research design. The table of TIMP exercises is presented, as this is the protocol for the intervention, designed in collaboration with the volunteer stroke patient. Some

additional photographs illustrating TIMP playing patterns as well as information regarding iPad music and configuring iPad settings can be found in the appendix.

7 CHAPTER 7. MAIN RESULTS

7.1 Introduction

This chapter begins with a brief overview of the study design, followed by a short section on attrition and then the descriptive data for the cohort. Analysis of quantitative data, raw ARAT and 9HPT scores for each participant, and qualitative data analysed from the interviews are presented in separate sections in this chapter. Analysis of data for the ARAT and 9HPT are given for each research question separately. The chapter ends with a conclusion and discussion.

7.2 Study design overview

In order to clarify the rationale for statistical analysis of data this section begins with a brief overview of the study design. The primary RCT research question for this confirmatory study asks 'Is TIMP more effective when delivered immediately after statutory rehabilitation has ended compared to nine weeks later?' In order to measure treatment effects on participants a standard occupational therapy assessment tool was used as the primary outcome measure, the Action Research Arm Test. A single statistical significance test was employed to calculate the group effect and difference between the group means, that being a repeated measures analysis of variance. Due to the small sample size, a larger number of random permutations of the data gathered was generated, from which the *p*-values were obtained, which indicate the statistical significance of the results. For the statistical analysis the probability was calculated at the 5% significance level ($p = 0.05$), meaning that if the result falls below this threshold then the null hypothesis, that there would be no difference between group mean outcomes, is rejected. In the case of this study, if one of the groups achieved group mean scores that led to a calculation of 0.01 difference between that of the other, then this would be statistically significant.

A cross-over design was used in this study, in which participants were randomly allocated into two groups, both receiving the same treatment and with the assumption that the intervention would have the same effect on both groups at different times; immediately following completion of standard community rehabilitation, compared to nine weeks after completion of standard community rehabilitation. The design enables

a fair comparison between these two conditions. In such a design repeated measures are required as the condition of those in the waitlist may spontaneously change following their baseline assessment at recruitment stage; in other words baseline stability must be recorded so as not to confound the data for treatment effects (pre and post treatment period). The washout period of two weeks checks for carry-over effects, i.e. does the washout assessment detect the same score as at post treatment or a sudden decrease?

This type of standard design enables the effect of the intervention to be estimated and assessed. It requires all the values for the response variable (ARAT and 9HPT measures at all five timepoints) to be involved in that estimation. The statistical model used for analysis of data is a linear mixed-effects model and contains both fixed effects, such as age, gender and handedness, and random effects, such as those of the intervention.

7.3 Attrition

One participant dropped out of the study, completing only the first assessment. The participant had been randomly allocated into the waitlist group, but was clearly very keen to begin treatment. Some frustration may have been caused by this and contributed to his withdrawal. The participant was also living in a very precarious and conflicted home environment with his mother, and community services had been unable to provide interventions in his home, the participant communicated his frustration with regard to this situation. In order to recruit this participant, it was necessary to work closely with the community stroke team and arrange for attendance at the music therapy centre rather than the home. Prior to this I had also arranged, in consultation with community services, another venue for him to attend, which was within walking distance of his home, but it was then decided to be unsuitable. These factors are very likely to have contributed to his withdrawal from the study. A final factor may have been the participant's short-term memory impairment, however, this would have been a more minor influence in the researcher's opinion, as he regularly called to check when the next assessment would be and the researcher regularly communicated, as agreed with the participant, how many weeks until the next appointment.

Considering these factors for this participant, and how for waitlist participants in particular similar influences on sustained participation might apply, attrition was low, with data collected from 10 participants at all five time points over 18 weeks.

7.4 Descriptive data

The tables below contain descriptive data for the study cohort, including mean ages (years), time post-stroke (months) at recruitment stage, gender, type and site of stroke and handedness, as well as standard deviations. It can be seen that there is data for 11 participants, with one of these completing only the first assessment and no treatment before dropping out of the study. Since no data was collected, this participant will not appear in the main study analysis.

Intervention type	Mean age	Standard deviation	Percentiles					Number of values	Number of missing values
			Smallest 0%	25%	Median 50%	75%	Largest 100%		
Waitlist	67.6	18.30	46.0	51.3	66.0	85.3	88.0	5	0
Treatment	53.2	21.86	23.0	27.6	63.0	69.3	73.0	6	0
Overall	59.7	20.73	23.0	47.3	65.0	72.3	88.0	11	0

Table 8. Age at admission (years) for waitlist and treatment groups.

The mean age for both groups is lower than the average representative of the stroke patient population in the UK, reported between 1999 and 2008 as 71 years in men and 77 in women (Lee, Shafe and Cowie, 2011). Table 8 shows that there were significant differences in age between groups. Percentile confidence limits show that the oldest in the waitlist group was 88 years compared to 73 in the treatment group, and the youngest in the waitlist was 46 compared to 23 in the treatment group. This demographic information may be relevant to recovery rates of upper limbs according to some research, which suggests that younger people with stroke and males show better recovery (Coupar et al., 2012).

Intervention type	Mean (months)	Standard deviation	Percentiles			Number of values	Number of missing values
			Smallest 0%	Median 50%	Largest 100%		
Waitlist	13.80	5.357	7.0	14.00	19.0	5	0
Treatment	19.00	17.332	3.0	15.00	52.0	6	0
Overall	16.64	13.002	3.0	15.00	52.0	11	0

Table 9. Period post stroke recruited for both groups.

The difference in mean interval (months) at the time post stroke of joining the study between the groups is 5.20, with a large standard deviation in the treatment group from the mean of 17.332 months, showing that the groups were not symmetrical in terms of time post stroke. This is due to the longer period post stroke of one treatment group participant, 52 months, as indicated in the largest, 100% percentile column, compared to 19 months in the waitlist. According to some data (Medscape, 2013) both groups fall outside of the three-month window where most motor recovery and response to treatment is expected.

Variable	Category	Number of values	Percent of overall total	Intervention type		P-value
				Waitlist n = 5	Treatment n = 6	
Sex	Overall	11	100.0	5 (100.0%)	6 (100.0%)	0.567
	Female	6	54.5	2/5 (40.0%)	4/6 (66.7%)	
	Male	5	45.5	3/5 (60.0%)	2/6 (33.3%)	
Type of condition	Overall	11	100.0	5 (100.0%)	6 (100.0%)	0.545
	Haemorrhage	3	27.3	2/5 (40.0%)	1/6 (16.7%)	
	Ischaemic	8	72.7	3/5 (60.0%)	5/6 (83.3%)	
Site	Overall	11	100.0	5 (100.0%)	6 (100.0%)	1.000
	Bilateral	1	9.1	1/5 (20.0%)		
	Left	3	27.3	1/5 (20.0%)	2/6 (33.3%)	
	Right	7	63.6	3/5 (60.0%)	4/6 (66.7%)	
Dominant hand	Overall	11	100.0	5 (100.0%)	6 (100.0%)	0.455
	Left	2	18.2		2/6 (33.3%)	
	Right	9	81.8	5/5 (100.0%)	4/6 (66.7%)	

Table 10. Categorical variables for treatment and waitlist groups.

The *P*-values for Table 10 have been calculated using Fisher's exact test (Fisher, 1958). The *p* values indicate that there are no statistically significant differences between the groups in terms of gender, stroke type, site of stroke and handedness.

In terms of gender, the groups were quite evenly matched, 54.5% female, 45.5% male and representative of the stroke population with some data reporting higher incidence in women (1 in five compared to 1 in 6 for men) (Stroke Association, 2015).

72.2% of the cohort had suffered an ischaemic stroke, which concurs with data indicating this as the predominant type of stroke occurring in 85% of cases (Intercollegiate Stroke Working Party, 2012). There were more right hemisphere stroke participants than left (63.6%) but only 6.7% more in treatment than in waitlist groups (3/5 compared to 4/6). Some evidence indicates that right hemisphere stroke is more resistant to upper limb rehabilitation treatment than left side (Coupar et al., 2012). With the groups quite evenly matched in this regard this may not have been an influential factor on mean outcomes, whereas severity of stroke, which is not indicated in the demographic data as there were no assessment scores (for example Glasgow coma, Barthel index) for participants available from their time of admission into acute care, would be more likely to have had an influence on treatment outcomes (Coupar et al., 2012).

7.5 Analysis for the primary research question

The main purpose of the statistical analysis for this randomized controlled trial was to calculate the difference between early (treatment) and late (waitlist) intervention. The comparison of the group means is presented as a repeated measures analysis of variance by way of a linear mixed-effects model.

7.5.1 ARAT group mean results

The difference between the group means gathered from participants' overall ARAT mean scores (mean of 20 in waitlist, which is made up of 4 participants who received 5 assessments, and 30 in treatment, which is made up of 6 participants who received 5 assessments) has been calculated as -12.83 (95% Confidence Interval [CI]: -38.46 to 12.80), giving a value of $P = 0.28$, which is not statistically significant. The 95% CI indicates that there is a 95% chance that these two values (-38.46 and 12.80) contain the true value.

Intervention type difference	Difference between means	Standard error	95% confidence limits	
			Lower	Upper
Treatment - Waitlist	-12.83	11.11	-38.46	12.80

Table 11. The difference in ARAT overall score means between treatment and waitlist.

Again, this implies that there would be no statistically significant treatment effects between delayed and immediate intervention groups. The wide confidence limits are due to the small sample size, where it is more difficult to accurately calculate a range within which the true population mean lies. The range may also have been confounded by the scores of certain outliers in the study, one of which did not score anything in the ARAT at any of the five timepoints (see Figure 27).

Variable	Intervention type				Difference T - W			
	W = Waitlist n = 5		T = Treatment n = 6		Difference between the means (Standard error)	95 % confidence limits		P-value
	Mean <Median>	Standard Deviation (IQR) [Range]	Mean <Median>	Standard deviation (IQR) [Range]		Lower	Upper	
Age at admission (years)	67.6 <66.0> n = 5	18.30 (51.3 to 85.3) [46.0 to 88.0]	53.2 <63.0> n = 6	21.86 (27.6 to 69.3) [23.0 to 73.0]	-14.43 (11.55)	-37.69	7.43	0.280
Time of music therapy post-stroke (months)	13.80 <14.00> n = 5	5.360 (9.0 to 19.0) [7.0 to 19.0]	19.00 <15.00> n = 6	17.330 (7.6 to 23.6) [3.0 to 52.0]	5.20 (7.162)	-6.72	20.61	0.704
ARAT overall score at time point 1	38.00 <43.00> n = 5	12.630 (31.3 to 46.0) [16.0 to 46.0]	21.17 <20.00> n = 6	17.120 (7.3 to 35.8) [0.0 to 44.0]	-16.83 (8.674)	-32.57	1.29	0.102
ARAT overall score at time point 2	33.00 <37.50> n = 4	10.100 (25.5 to 39.0) [18.0 to 39.0]	23.50 <22.50> n = 6	20.640 (3.7 to 45.2) [0.0 to 47.0]	-9.50 (9.368)	-27.43	9.43	0.419
ARAT overall score at time point 3	36.25 <41.50> n = 4	12.280 (27.2 to 43.6) [18.0 to 44.0]	25.50 <24.50> n = 6	20.420 (7.3 to 47.2) [0.0 to 49.0]	-10.75 (9.877)	-29.02	9.67	0.367
ARAT overall score at time point 4	39.25 <42.50> n = 4	12.090 (29.9 to 47.5) [22.0 to 50.0]	24.50 <21.00> n = 6	20.100 (8.2 to 48.0) [0.0 to 48.0]	-14.75 (9.769)	-33.12	5.23	0.251
ARAT overall score at time point 5	39.00 <41.00> n = 4	14.090 (28.3 to 49.0) [20.0 to 54.0]	24.67 <21.50> n = 6	20.530 (7.3 to 47.2) [0.0 to 50.0]	-14.33 (10.331)	-34.00	6.62	0.276

Table 12. Continuous variables by intervention type.

In Table 12, above, the standard deviations are based on within-group data and not pooled estimates. The standard errors of differences between means and confidence limits have been obtained using 9999 bootstrap samples (see 6.13.1 for definition). *P*-values have been obtained using 1000 permutation samples and show no statistical significance. The means for both groups are plotted in Figure 20 in order to illustrate the differences between the group means and their confidence limits. The treatment group mean is lower than for waitlist and confidence limits are similarly wide for both groups (illustrated in Figure 19 below), reflecting the low to high ARAT score range present in each.

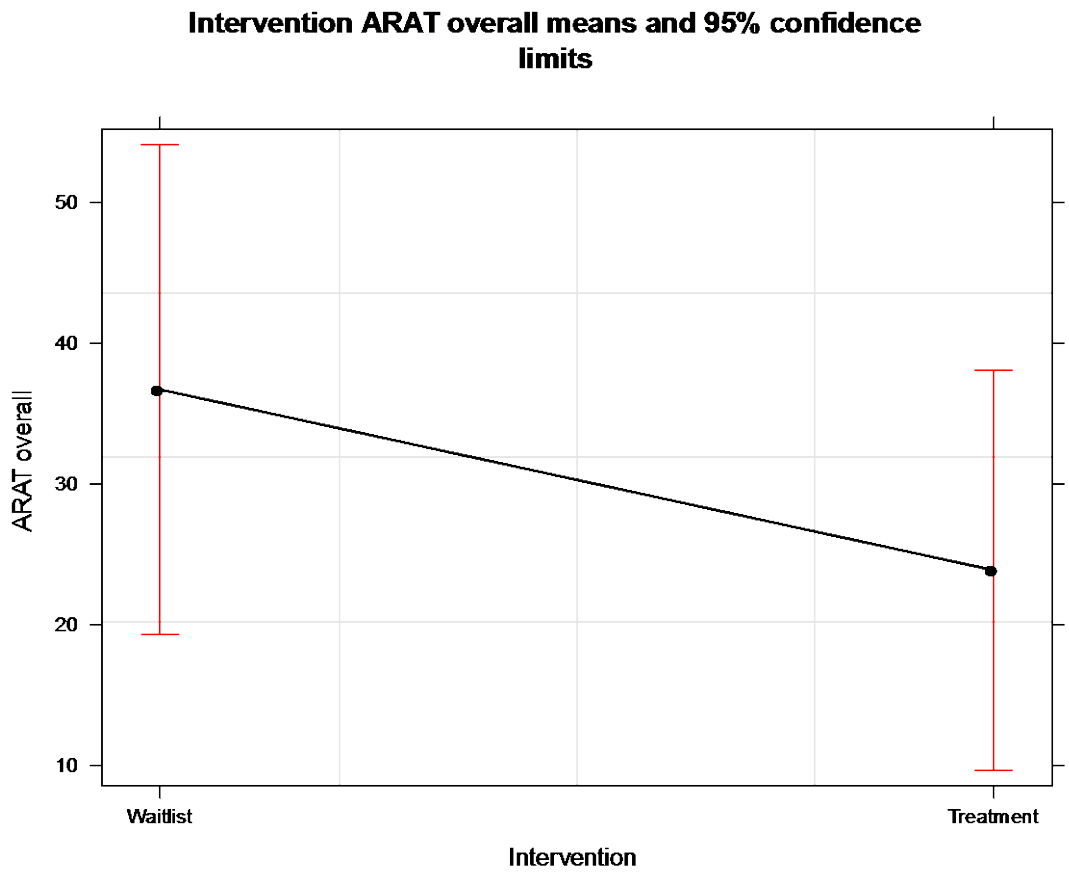


Figure 19. Overall ARAT means and 95% confidence limits.

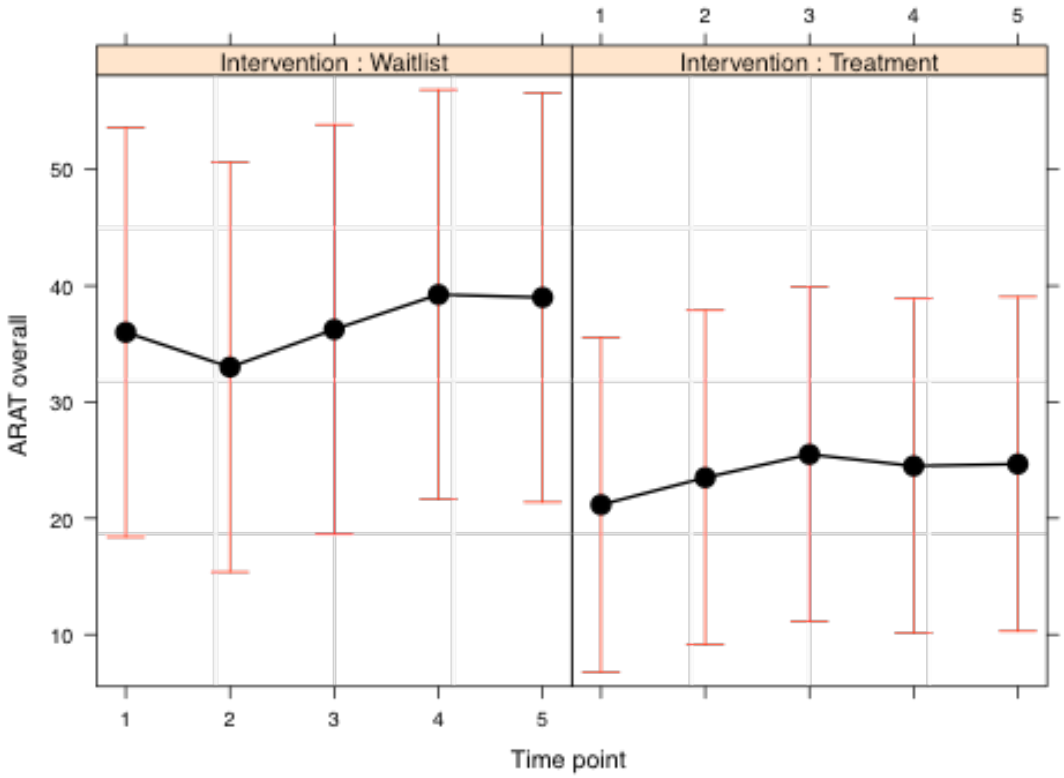


Figure 20. ARAT means and 95% confidence limits.

The vertical axis in Figure 20 shows the ARAT score range, between 0 and 57. The horizontal axis indicates the five timepoints. There is no interaction between groups visible in the graphs, both show increases when comparing timepoint 1 and 5. The intervention period for the treatment group was between timepoint 1 and 2, where an increase is visible and continues through the washout period (timepoint 2 and 3), then falls. This might suggest that effects of treatment were sustained through the washout period, but then reduced due to withdrawal of treatment. For the waitlist group the treatment period is shown between timepoints 3 and 4, where an increase is visible but which also appears to be a continuation of spontaneous improvement from timpeoint 2. Between timepoints 4 and 5, the washout period, there is a slight decrease is scores. Patterns of change in relation to treatment effects are best understood by examining the raw data and individual circumstances during participation for this small cohort, and this would have implications for inclusion criteria for a larger study. This is done in 7.7 and shown in Figure 29, a bar graph of pre and post ARAT scores for each participant. Of particular relevance to the pattern of change in the waitlist group, dropping significantly between timepoints 1 and 2, is participant 2 (participant number 8 in the study) suffering a TIA during this period, resulting in a dramatic fall in score from 46 to 36 out of 57.

Source of variation	Degrees of freedom	Sum of squares	Mean square	F ratio	Bootstrap probability
Intervention type	1	12.436	12.436	1.33	0.28
Time point	4	118.180	29.545	3.17	0.03
Interaction	4	60.900	15.225	1.63	0.21
Residual	36	335.81	9.328		

Table 13. Summary of linear mixed-effects model with response variable ARAT overall score by intervention type and time point.

Table 13 summarises the ARAT analysis, showing the *p* values (bootstrap probability) for intervention type and time point.

7.6 Analysis for the secondary research question

This section presents the analysis of variance (ANOVA) of the crossover design in order to calculate treatment effects.

7.6.1 Summary

The difference between the treatment means was not statistically significant, 1.313 with standard error 0.674, and no carryover effects were detected. The difference between the sequences was not statistically significant, but statistical significance was found in the variation among the time points.

7.6.2 Analysis

ARAT overall results were measured using a crossover design with a random allocation of subjects to one of two sequences of treatment orders. A baseline observation (labelled as “Run-in” in Table 14) of ARAT overall was made prior to the first treatment. A second baseline observation was taken at the start of the second treatment period, which is termed “Washout”. There was also a follow-up observation made after a washout period following the second treatment period (sequence 2, refer to study consort, Figure 13), but the use of this in the analysis is not recommended

(Ding et al., 2015). The analysis undertaken here has two sequences and four periods for the comparison of two treatments. This is shown schematically in Table 14 below.

		Period			
		1	2	3	4
Sequence	1	Run-in	Intervention (Music therapy)	Washout	Control
	2	Run-in	Control	Washout	Intervention (Music therapy)

Table 14. ARAT analysis of two treatment orders

This statistical model (Ratkowsky, Alldredge and Evans, 1992) requires predictors to be generated to represent treatment, first-order carryover, and second-order carryover. The first-order carryover effect would arise in Period 3 from a treatment administered in Period 2. The second-order carryover effect would arise in Period 4 from a treatment administered in Period 2. The analysis firstly assesses any treatment effect along with any carryover effects. If no carryover effects are detected it is possible to modify the statistical model to exclude them, and hence assess any treatment effect using the simpler statistical model. This two-stage approach has been the subject of some controversy in the literature (Armitage, 1991) and caution has been expressed against employing it because of its effect on significance levels and potentially misleading and unsatisfactory results (Ratkowsky, Alldredge and Evans, 1992; Ding et al., 2015). This implies that the recommended approach to the analysis of this type of crossover design is to omit any assessment of carryover effects and to proceed with a statistical model that excludes the carryover parameters. The current thinking is that an essential assumption in the analysis of crossover designs of the type used in this study is that the treatment produces no carryover effects. For a crossover study of this design to be planned it must be known in advance that the treatment produces no carryover effects. This highlights a conflict with the analysis of data from this study design, as the research questions require a response to comparison of early and late intervention and to treatment effects. This is why for the primary research question, comparing early and late intervention, a parallel design is used for analysis, and for the secondary question, determining treatment effects, a crossover design is used.

An essential assumption in the analysis of crossover designs is that there are no carryover effects. If there were to be carryover effects then the analysis would not

provide an unbiased estimate of the difference between the interventions (the two sequences shown in Table 14. Although the presence of carryover effects can be tested, the tests have been described as ineffective, as has the facility to adjust the difference in treatments for carryover effects (Ding et al., 2015)

Analyses have been performed using the computer program R (R Core Team, 2015). The analysis is by the general linear model (analysis of variance/multiple regression) with Type II sums of squares being obtained using function Anova from R package car (Fox, 2011). This approach to analysing the data also applies to the 9HPT for the secondary research question (see 7.9).

7.6.3 Data

A data set for 11 participants was used in the analysis by the statistician, one of the participants withdrew following the first assessment and so the missing values will mean that this participant will not appear in the main analysis by default.

7.6.4 Descriptive statistics of the data prior to statistical analysis

The purpose of this introductory section is to display the main features of the data so that clinicians working in the field can determine whether the participants are typical and that the values are within what would be expected. This section does not involve any statistical inference.

Sequence/Period	Mean	Standard deviation	Percentiles					Number of values	Number of missing values
			Smallest 0%	25%	Median 50%	75%	Largest 100%		
Sequence 1/Period 1	21.17	17.12	0	9.0	20.0	33.3	44	6	0
Sequence 1/Period 2	23.50	20.64	0	6.3	22.5	41.8	47	6	0
Sequence 1/Period 3	25.50	20.42	0	10.3	24.5	43.3	49	6	0
Sequence 1/Period 4	24.50	20.10	0	10.8	21.0	42.5	48	6	0
Sequence 2/Period 1	36.00	13.64	16	33.3	41.0	43.8	46	4	0
Sequence 2/Period 2	33.00	10.10	18	31.5	37.5	39.0	39	4	0
Sequence 2/Period 3	36.25	12.28	18	34.5	41.5	43.3	44	4	0
Sequence 2/Period 4	39.25	12.09	22	36.3	42.5	45.5	50	4	0
Overall	28.65	16.86	0	15.3	33.5	44.0	50	40	0

Table 15. ARAT overall by sequence and period

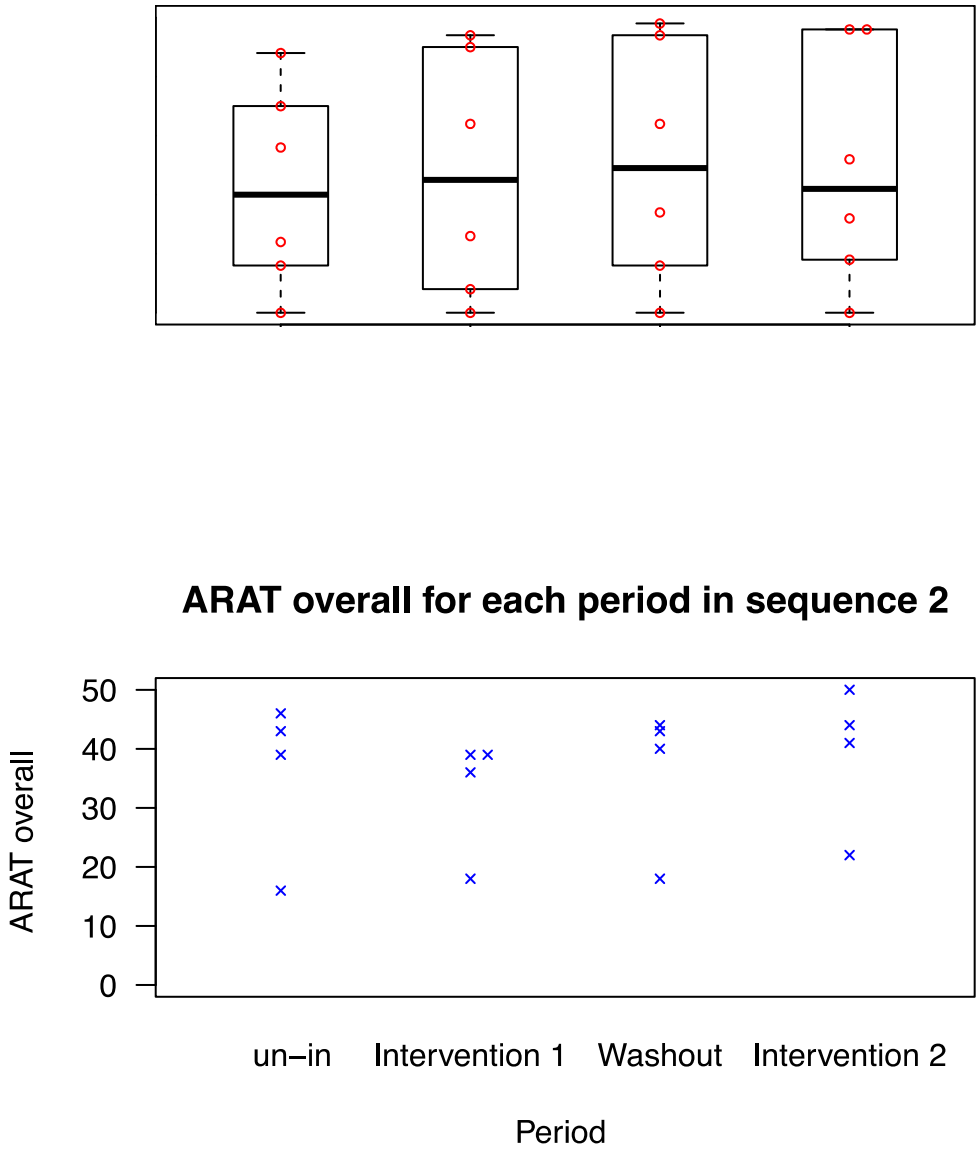


Figure 21. ARAT overall for each period in sequence 1 and 2

7.6.5 Analysis of variance of ARAT overall

The first analysis in this section compares the mean ARAT overall between treatments using the approach of Ratkowsky et al (Ratkowsky, Alldredge and Evans, 1992), when possible carryover effects are taken into account.

Source of variation	Degrees of freedom	Type I sum of squares	Mean Square	Variance ratio	P-value
Between-subjects					
Sequence	1	1490.017	1490.017	1.29	0.289
Residual	8	9249.083	1156.135		
Within-subjects					
Period	3	86.100			
Treatment	1	33.075			
Carryover1	1	9.339			
Carryover2	1	11.736			
Residual	24	205.750	8.573		
Source of variation	Degrees of freedom	Type II sum of squares	Mean square	Variance ratio	P-value
Treatment	1	34.133	34.133	3.98	0.057
Carryover1	1	20.008	20.008	2.33	0.140
Carryover2	1	11.736	11.736	1.37	0.253
Residual	24	205.750	8.573		
Total	39	11085.100			

Table 16. Analysis of Variance summary table of ARAT overall, taking carryover effects into account

The assessment of the treatment and carryover effects is achieved using the Type II sum of squares, and neither the treatment effect nor the carryover effects are statistically significant. The estimate of the difference between the treatment means is 1.313 with standard error 0.674. The statistical inference requires the assumptions that the analysis of variance residuals are Normally distributed with constant variance. These are checked using the graphics shown in Figure 22 below.

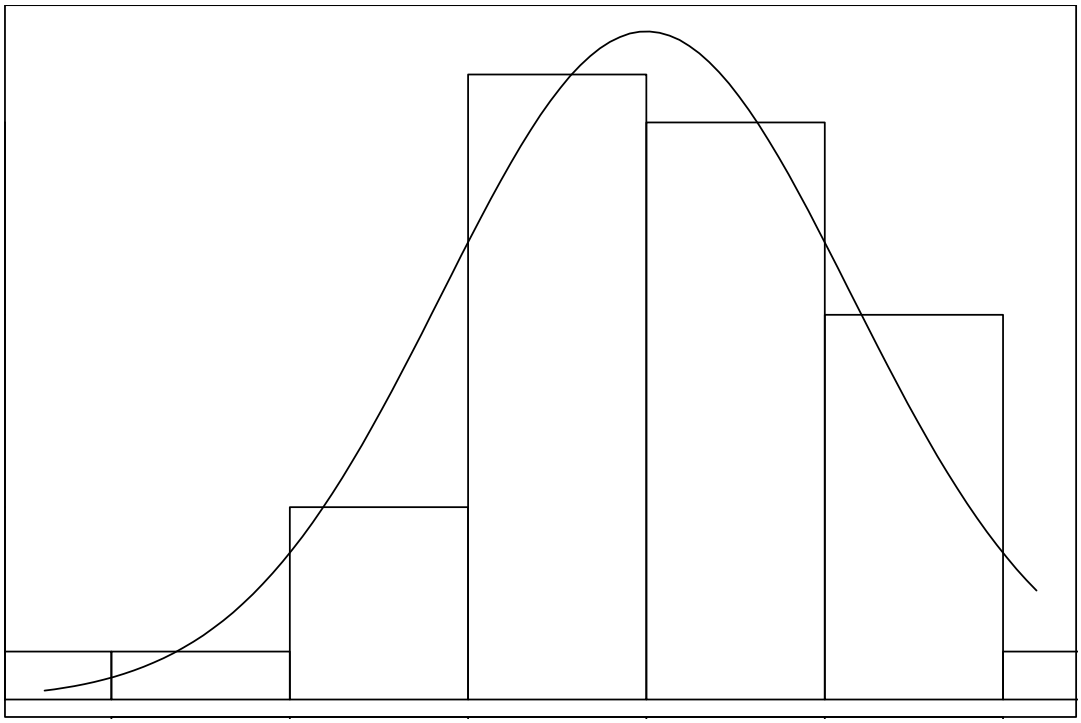


Figure 22. Histogram of residuals with Normal density curve

The histogram of the residuals looks as if the distribution of the residuals is approximately Normal, but it is difficult to judge. An easier way is by using a Normal probability plot, which is designed to produce a straight line if the residuals are Normally distributed.

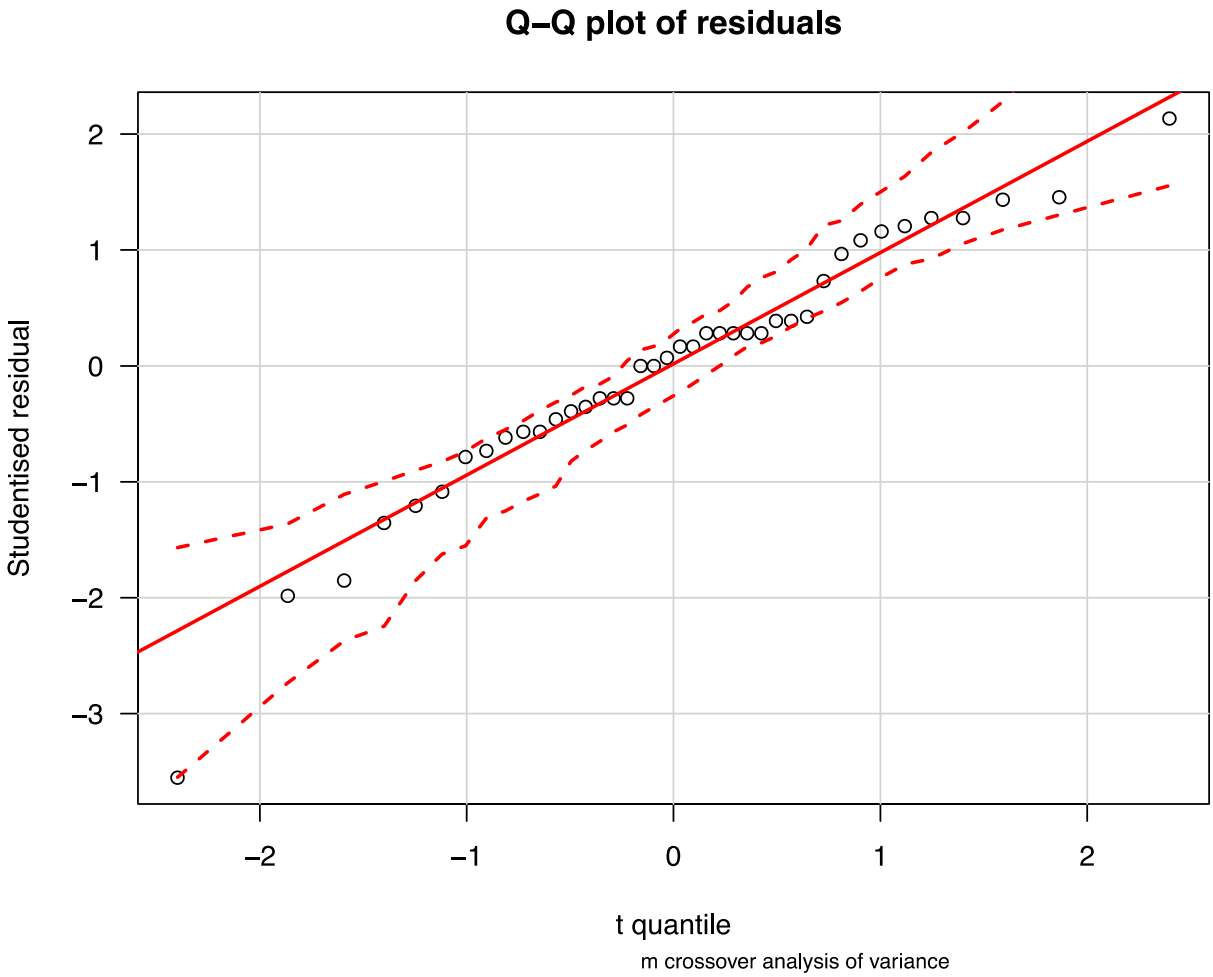


Figure 23. Q-Q plot of residuals

The Normal probability plot shows that the residuals do not produce a line that is exactly straight, and so they are not exactly Normally distributed. However, the classical methods of statistical inference are robust against moderate departures from Normality, and so these do not confound the results.

A plot of the residuals against the fitted values can reveal non-constant variance as shown in Figure 24 below.

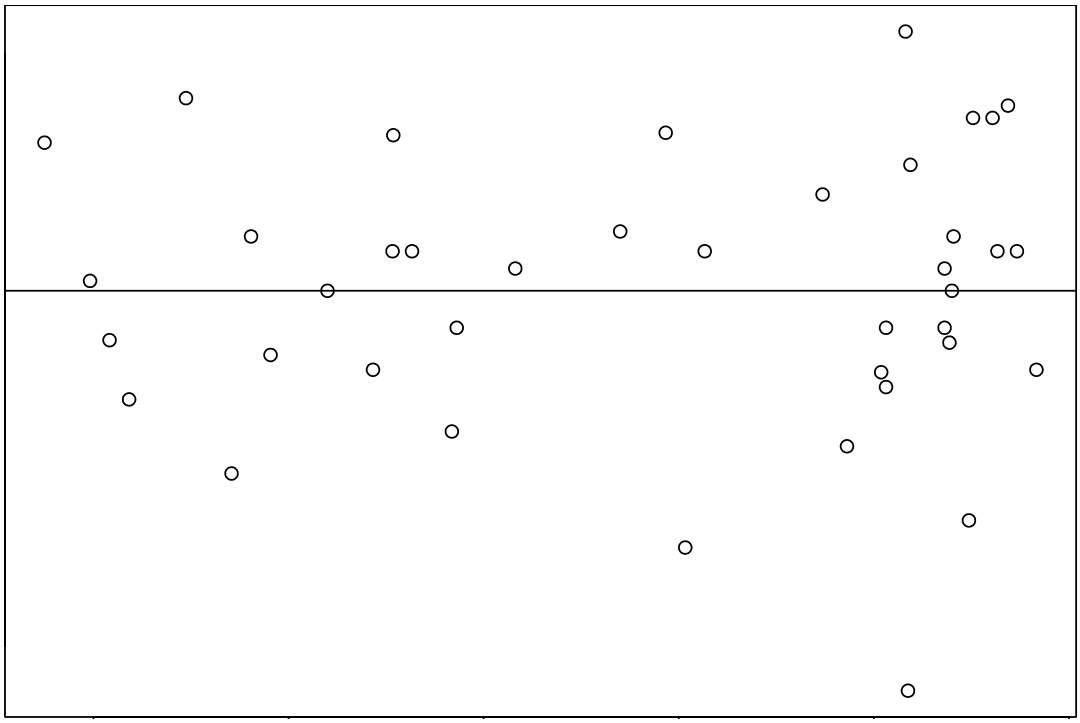


Figure 24. Residuals against fitted values

The horizontal band of points on the plot with a more-or-less constant vertical spread shows that there is not a serious problem with non-constant variance, furthermore the statistical procedures are robust against moderate departures from the assumptions.

The two-stage approach to the analysis of the crossover design is shown in Table 17 below, which shows that there is still not a statistically significant difference between the treatments means. From this second stage revised analysis the estimate of the difference is 1.313 with standard error 0.674. This analysis allows for the assessment of both Sequence and Period. The difference between Sequences is not statistically significant, but there is statistically significant variation among the Periods. The means for the ARAT overall for each sequence and period are plotted in Figure 26 (below), giving a visual representation of change.

Source of variation	Degrees of freedom	Type I sum of squares	Mean Square	Variance ratio	P-value
Between-subjects					
Sequence	1	1490.017	1490.017	1.29	0.289
Residual	8	9249.083	1156.135		
Within-subjects					
Period	3	86.100	28.700	3.290	0.036
Treatment	1	33.075	33.075	3.791	0.062
Residual	26	226.825	8.724		
Total	39	11085.100			

Table 17. Analysis of Variance summary table of the ARAT overall, with no carry over effects

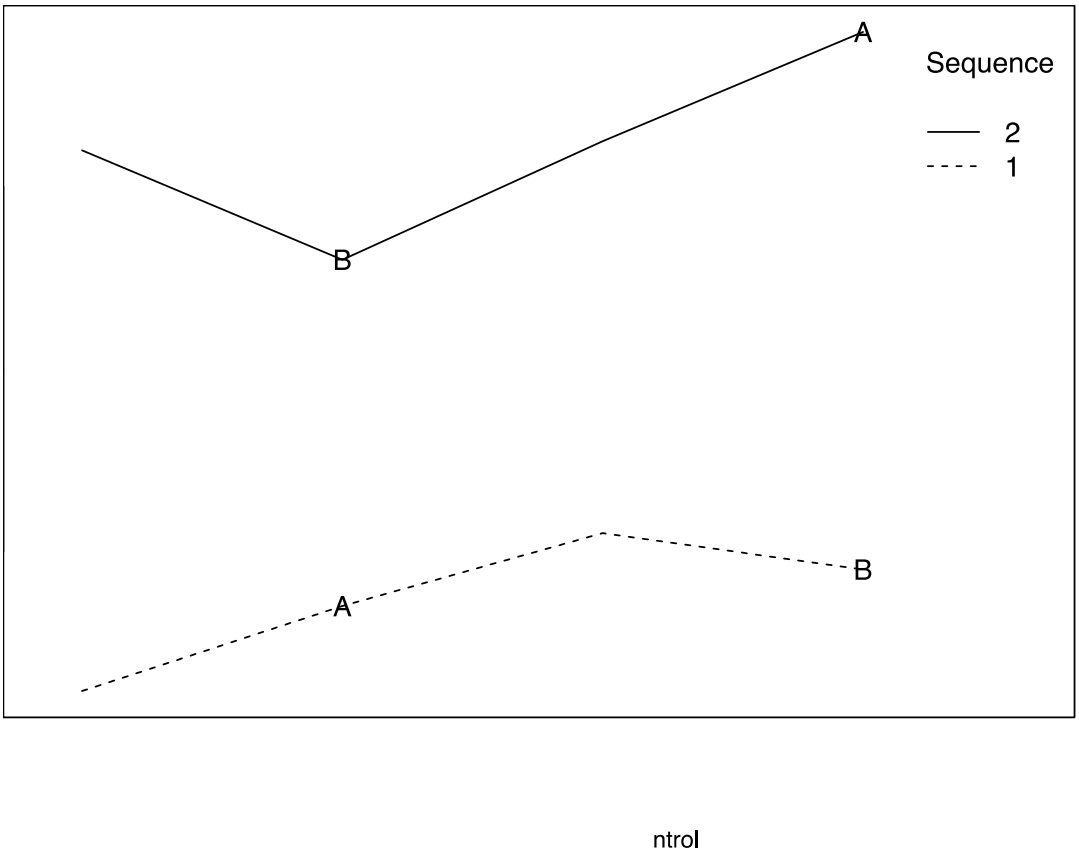


Figure 25. Mean ARAT overall for each sequence and period

The vertical axis in the graph (Figure 25) generated from the R program shows the ARAT score ranges up to 35, but the maximum possible scores were 57.

7.7 Raw data from individual ARAT scores

Below are tables presenting the raw ARAT scores from each assessment and for each participant. For the treatment group participants the pre and post treatment measures are at timepoints 1 and 2, for the waitlist group they are at timepoints 3 and 4.

"Participant number"	Group	"Time point 1"	"Time point 2"	"Time point 3"	"Time point 4"	"Time point 5"
1	Treatment	0	0	0	0	0
2	Treatment	12	13	17	16	16
3	Treatment	44	47	47	48	47
4	Treatment	8	4	8	9	8
5	Treatment	28	32	32	26	27
6	Treatment	35	45	49	48	50
7	Waitlist	43	39	43	50	54
8	Waitlist	46	36	46	36	40
9	Waitlist	16	18	18	22	20
10	Waitlist	39	39	40	44	42
11	Waitlist	46	NA	NA	NA	NA

Table 18. ARAT scores for each participant at all five timepoints.

For the treatment group time points 1 and 2 (green) represent pre and post treatment assessment scores. For the waitlist, time points 3 and 4 (red) represent pre and post treatment scores. The scores of participants 4 and 8, one from each group, both decreased at the end treatment assessment.

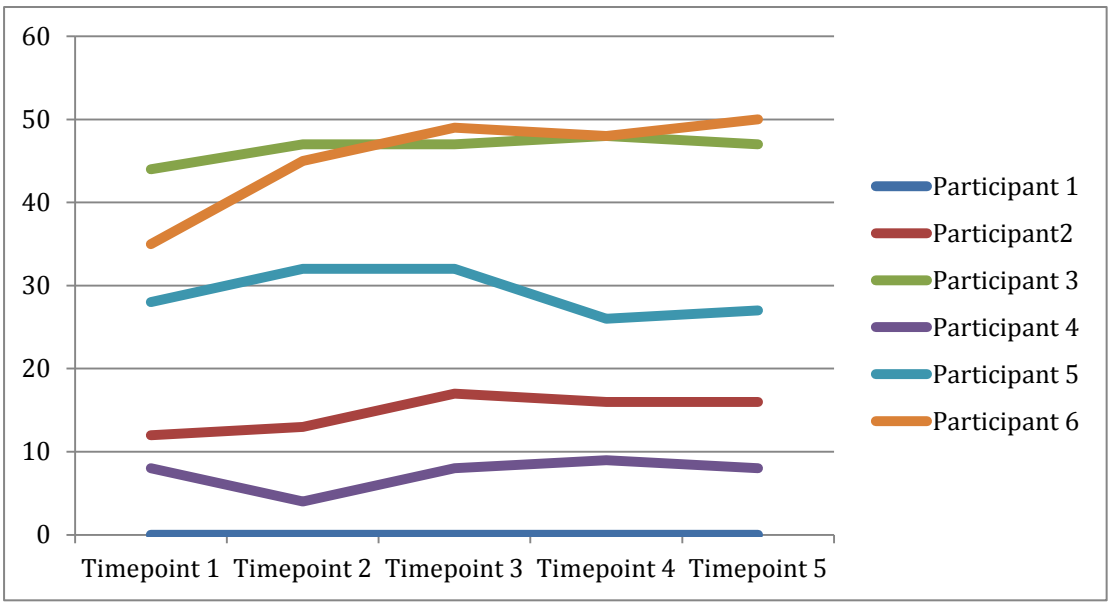


Figure 26. Line graph showing the pattern of change over five assessments for treatment group participants.

In Figure 27 participant 1 is represented along the x axis in blue, showing no score at any point in the ARAT. Participant 6 shows the steepest curve of improvement following treatment and is discussed in CHAPTER 8. CASE STUDIES.

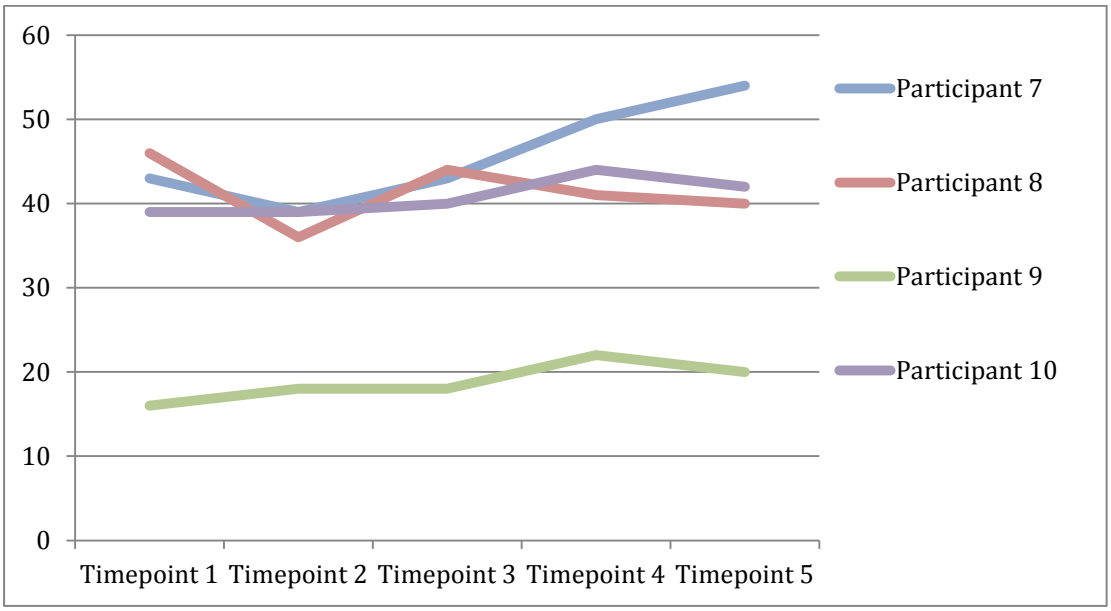


Figure 27. ARAT scores over the five assessments for waitlist participants.

Participant 8 in Figure 28 shows a steep drop in score at time point 2, probably due to a TIA that he suffered between assessments. He had also originally suffered a bilateral stroke, with lesions in both hemisphers.

Treatment participant number	Pre ARAT	Post ARAT	Waitlist participant number	Pre ARAT	Post ARAT
1	0	0	1	43	50
2	12	13	2	46	36
3	44	47	3	18	22
4	8	4	4	40	44
5	28	32			
6	35	45			

Table 19. Comparing pre and post treatment ARAT scores for treatment and waitlist participants.

Table 19 shows the actual ARAT scores out of 57 for each participant pre and post treatment in order to clarify how much change occurred. Reference to the ARAT scoring system in 6.8.1 will further clarify this.

	ARAT pre (mean)	ARAT post (mean)	Difference (mean)
Treatment group	127 (21.17)	141 (23.50)	+ 14 (+ 2.33)
Waitlist group	145 (36.25)	157 (39.25)	+ 12 (+ 3.00)

Table 20. Comparing raw data group ARAT scores, means and differences.

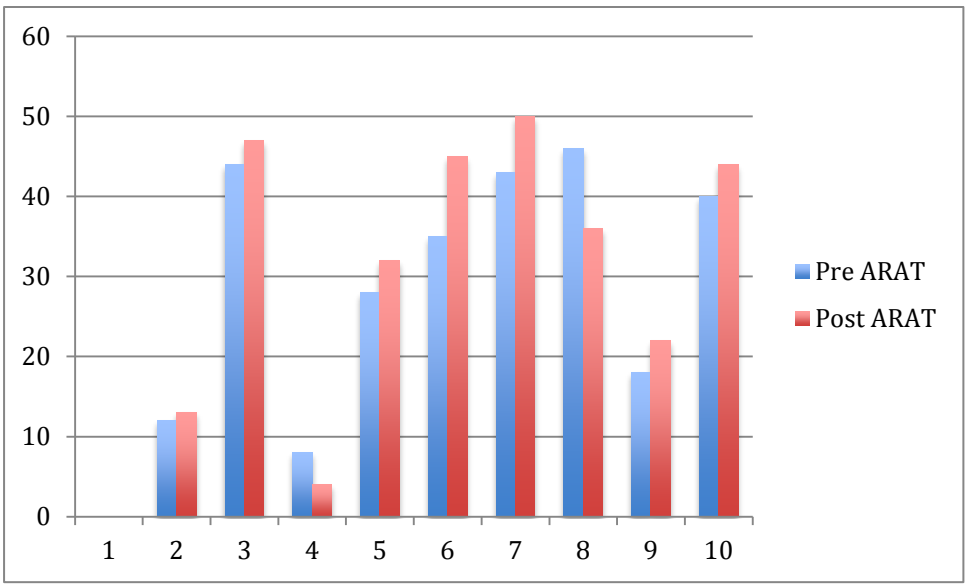


Figure 28. Bar graph showing pre and post ARAT scores for all 10 participants.

Figure 29 (above) illustrates that 7/10 participants increased their scores following TIMP treatment. However, in the table showing participants' individual pre and post ARAT scores it can be seen that participant two improved by a single point, which could have been due to a scoring error in the assessments or a minor fluctuation in arm function. This also brings into question the sensitivity of the ARAT, where changes in quality of movement are not detected or are only reflected in the timings of task performance, such as that of subject A in CHAPTER 8. CASE STUDIES.

(Waitlist) NO TREATMENT mean difference week 1 to 6	(Waitlist) TREATMENT mean difference week 9 to 15	(Treatment) NO TREATMENT mean difference week 9 to 15	(Treatment) TREATMENT mean difference week 1 to 6
-12	+ 3	+1	+ 2.34

Table 21. Simple mean differences between treatment and no treatment groups.

Table 21, above, shows how the ARAT mean scores for both groups differed during no treatment and treatment periods. Whilst receiving no treatment, i.e. in the waiting period for waitlist or post treatment period for treatment group, ARAT scores were lower than when receiving treatment. However for the waitlist group one participant with bilateral lesions (participant 8) influenced the mean score, as he suffered a TIA between assessment timepoints 3 and 4. The data comparing differences between group means when not receiving treatment has not undergone analysis of variance, so it is not known whether results are of statistical significance. However, the researcher feels that these results are relevant in defining the potential effects of the intervention under investigation and such analysis of data might be relevant to a larger study where the primary research question is on how effective the intervention is compared to standard care using the same crossover design.

7.7.1 Summary of raw data

Seven participants showed improved upper limb function on their affected (most affected) side as reflected by their pre and post treatment ARAT scores. Four in the treatment group showed improvement and three in the waitlist. As presented in 7.6, the analysis of variance of group means that these individual scores comprise found statistical significance between timepoints.

7.8 Nine hole peg test (9HPT) analysis for the primary research question

No statistical significance in 9HPT means was found between early and delayed intervention. The difference was -2.326 (95% CI: -11.32 to 6.66), producing a *p* value of 0.564. Table 22 shows the results with standard error.

Intervention type difference	Difference between means	Standard error	95% confidence limits	
			Lower	Upper
Treatment - Waitlist	-2.326	3.902	-11.32	6.66

Table 22. Difference between overall 9HPT score means for waitlist and treatment groups

Variable	Intervention type				Difference T - W			
	W = Waitlist n = 5		T = Treatment n = 6		Difference between the means (Standard error)	95 % confidence limits		P-value
	Mean <Median>	Standard Deviation (IQR) [Range]	Mean <Median>	Standard deviation (IQR) [Range]		Lower	Upper	
Age at admission (years)	67.6 <66.0> n = 5	18.30 (51.3 to 85.3) [46.0 to 88.0]	53.2 <63.0> n = 6	21.86 (27.6 to 69.3) [23.0 to 73.0]	-14.43 (11.55)	-37.69	7.43	0.280
Time of music therapy post-stroke (months)	13.80 <14.00> n = 5	5.360 (9.0 to 19.0) [7.0 to 19.0]	19.00 <15.00> n = 6	17.330 (7.6 to 23.6) [3.0 to 52.0]	5.20 (7.162)	-6.72	20.61	0.704
9HPT pegs per minute at time point 1	3.98 <0.25> n = 4	7.630 (0.0 to 9.2) [0.0 to 15.4]	2.31 <0.50> n = 6	4.060 (0.0 to 3.2) [0.0 to 10.4]	-1.67 (3.934)	-10.32	4.46	0.774
9HPT pegs per minute at time point 2	1.50 <0.50> n = 3	2.180 (0.1 to 3.4) [0.0 to 4.0]	3.27 <0.25> n = 6	6.840 (0.0 to 3.3) [0.0 to 17.1]	1.77 (2.923)	-2.83	8.29	1.000
9HPT pegs per minute at time point 3	6.99 <7.18> n = 4	7.240 (0.6 to 13.3) [0.0 to 13.6]	3.32 <0.75> n = 6	5.630 (0.0 to 4.9) [0.0 to 14.4]	-3.67 (4.077)	-11.24	4.54	0.528
9HPT pegs per minute at time point 4	5.33 <5.25> n = 4	5.370 (0.6 to 10.1) [0.0 to 10.8]	4.51 <0.25> n = 6	6.820 (0.0 to 12.7) [0.0 to 14.0]	-0.81 (3.671)	-7.67	6.46	0.997
9HPT pegs per minute at time point 5	7.65 <5.99> n = 4	8.660 (0.6 to 15.2) [0.0 to 18.6]	5.86 <1.75> n = 6	7.960 (0.0 to 14.0) [0.0 to 18.0]	-1.79 (5.155)	-12.27	7.81	0.793

Table 23. Continuous variables for all participants in the 9HPT

The figures in the 'mean' columns for waitlist and treatment indicate mean number of pegs inserted into and removed from a board with nine holes in it (9 in and 9 out again) within a maximum time limit of two minutes. The *p* values in Table 23 show no statistical significance when comparing the group means. The 'difference between the means (standard error)' column shows some fluctuation, increasing from – 1.67 at timepoint 1, to 1.77 at timepoint 2, which coincides with the treatment period assessments for the treatment group. This increase in difference between group means

is explained by the increase in mean score (2.31 to 3.27) of the treatment group between timepoints 1 and 2 and the decrease in scores for the waitlist group (3.98 to 1.50). This increase in standard error could be linked to participant 2 in the waitlist, who suffered the TIA in this period, resulting in a lower score at timepoint 2. The confidence limits shown in the table indicate an increase in the difference between upper limit mean scores, from 4.46 at timepont 1 to 7.81 at timepoint 5. The difference between groups in lower confidence limits between groups fluctuates much more. The pattern and range of change in confidence limits reflects the changes in mean scores for both groups, with treatment and waitlist both increasing across the 5 timepoints, but greater fluctuation in the waitlist. Interestingly, the waitlist group show the biggest increase in mean, but it was a treatment group participant who made the most significant increase in 9HPT scores, increasing from 5 pegs in 120 seconds to 18 pegs in 60 seconds see 8.6 in Case Studies. This can be explained by the inclusion of data from particpant 5 in the waitlist group.

7.9 Analysis of variance on 9HPT for the secondary research question

7.9.1 Summary

The following analysis compares the 9HPT pegs per minute for two intervention types using a crossover design. The difference between the treatments is not statistically significant. No carryover effects have been detected. The variation among the periods is not statistically significant.

7.9.2 Analysis

9HPT pegs per minute has been measured using a crossover design with a random allocation of participants to one of two sequences of treatment orders. In addition, as with the ARAT analysis for the secondary research question, a baseline observation (Run-in) observation of 9HTP pegs per minute was made prior to the first treatment. A second baseline observation was taken at the start of the second treatment period (washout), and a follow-up observation made after a washout period after the second

treatment period. The same recommendations regarding this method of analysis applies as previously stated in Analysis (7.5.2).

		Period			
		1	2	3	4
Sequence	1	Run-in	Intervention (Music therapy)	Washout	Control
	2	Run-in	Control	Washout	Intervention (Music therapy)

Table 24. Sequence and periods for 9HPT

Although research into the statistical methodology underpinning this type of crossover design has led researchers increasingly to the view that it does not allow for the reliable assessment of carryover effects, there is nevertheless a continuing tradition of including carryover parameters in the statistical model, and for the available software to present evaluations of these effects. This statistical model (Ratkowsky, Alldredge and Evans, 1992) requires predictors to be generated to represent treatment, first-order carryover, and second-order carryover. The first-order carryover effect would arise in Period 3 from a treatment administered in Period 2. The second-order carryover effect would arise in Period 4 from a treatment administered in Period 2. In the first instance the analysis here assesses any treatment effect along with any carryover effects. If no carryover effects are detected it is possible to modify the statistical model to exclude the carryover parameters, and hence to assess any treatment effect using the simpler statistical model. This has already been presented as the two-stage approach in the ARAT analysis for the secondary research question, and the debate around this method stated.

Analyses have been performed using the computer program R (reference 3). The analysis is by the general linear model (analysis of variance/multiple regression) with Type II sums of squares being obtained using function Anova from R package car (reference 4).

7.9.3 Data

A data set for 11 participants was submitted for analysis. One of the volunteers withdrew following the first assessment and so the missing values will mean that this volunteer will not appear in the main analysis by default.

7.9.4 Descriptive statistics of the data prior to statistical analysis

The purpose of this introductory section is to display of the main features of the data so that clinicians working in the field can determine whether the participants are typical for this patient group and that the values are within what would be expected. This section does not involve any statistical inference.

Sequence/Period	Mean	Standard deviation	Percentiles					Number of values	Number of missing values
			Smallest 0%	25%	Median 50%	75%	Largest 100%		
Sequence 1/Period 1	2.314	4.061	0	0.13	0.50	2.00	10.38	6	0
Sequence 1/Period 2	3.274	6.838	0	0.00	0.25	1.63	17.14	6	0
Sequence 1/Period 3	3.317	5.632	0	0.13	0.75	3.25	14.40	6	0
Sequence 1/Period 4	4.514	6.818	0	0.00	0.25	9.54	14.02	6	0
Sequence 2/Period 1	5.310	8.767	0	0.25	0.50	7.96	15.43	3	1
Sequence 2/Period 2	1.500	2.179	0	0.25	0.50	2.25	4.00	3	1
Sequence 2/Period 3	6.989	7.237	0	1.13	7.18	13.04	13.60	4	0
Sequence 2/Period 4	5.325	5.369	0	1.13	5.25	9.45	10.80	4	0
Overall	3.953	5.708	0	0.00	0.50	7.75	17.14	38	2

Table 25. 9HPT pegs per minute by sequence and period

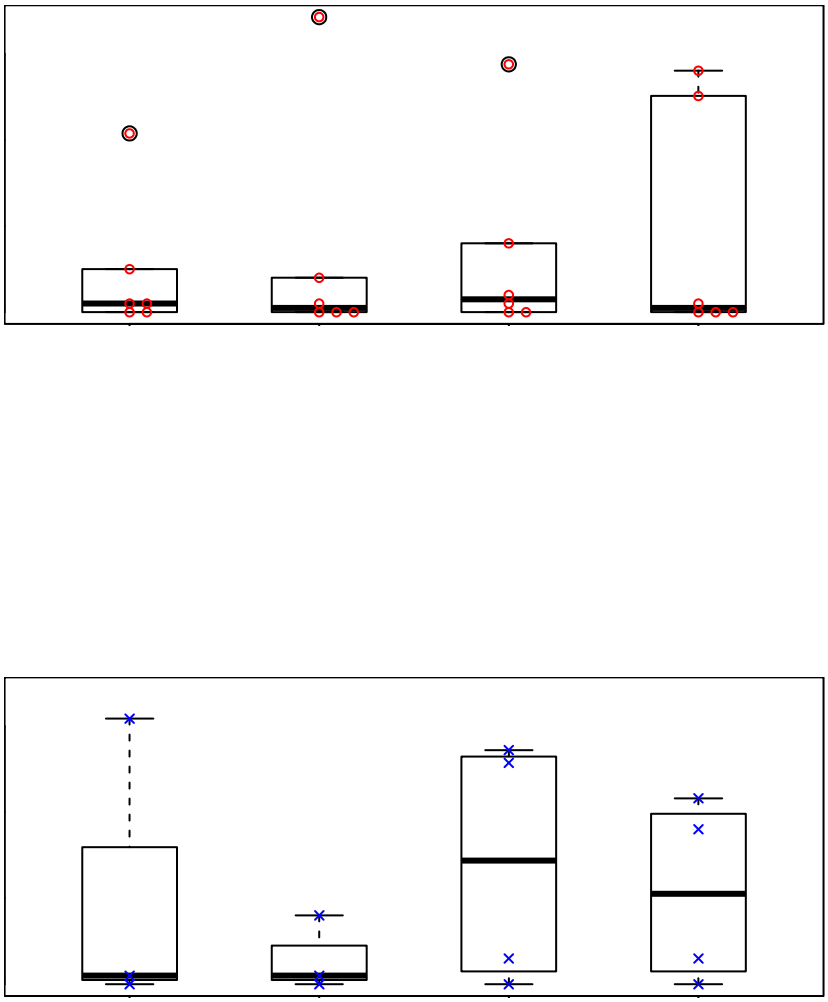


Figure 29. 9HPT pegs per minute for each period in sequence 1 and 2

The top figure shows sequence 1 participant means and the bottom shows sequence 2. Number of pegs is indicated on the vertical axis and time point or period along the horizontal. Circles and crosses represent the confidence limits (percentiles).

7.9.5 Statistical analysis and interpretation of results

This investigation is a randomised experimental design and the main purpose of the statistical analysis is to estimate the “treatment effect”. That is the difference between the means for the groups receiving the interventions.

7.9.6 Analysis of variance of 9HTP pegs per minute

The first analysis in this section compares the mean 9HPT pegs per minute between treatments using the approach of Ratkowsky et al, when possible carryover effects are taken into account.

Source of variation	Degrees of freedom	Type I sum of squares	Mean Square	Variance ratio	P-value
Between-subjects					
Sequence	1	23.288	23.288	0.20	0.668
Period	1	82.634	82.634	0.712	0.427
Residual	7	812.403	116.058		
Within-subjects					
Period	3	13.392			
Treatment	1	0.478			
Carryover1	1	7.421			
Carryover2	1	24.677			
Residual	22	241.002	10.955		
Source of variation	Degrees of freedom	Type II sum of squares	Mean square	Variance ratio	P-value
Treatment	1	22.746	22.746	2.08	0.164
Carryover1	1	0.870	0.870	0.08	0.781
Carryover2	1	24.677	24.677	2.25	0.148
Residual	24	241.002	10.955		
Total	37	1205.296			

Table 26. Analysis of Variance summary table of 9HPT pegs per minute, taking carryover into account

The assessment of the treatment and carryover effects is achieved using the Type II sum of squares, and neither the treatment effect nor the carryover effects are statistically significant. The estimate of the difference between the treatment means is 2.385 with standard error 1.655 (95% CI: -1.047 to 5.817). The statistical inference requires the assumptions that the analysis of variance residuals are Normally distributed with constant variance. These are checked using graphics and displayed in Figure 30, 31 and 32.

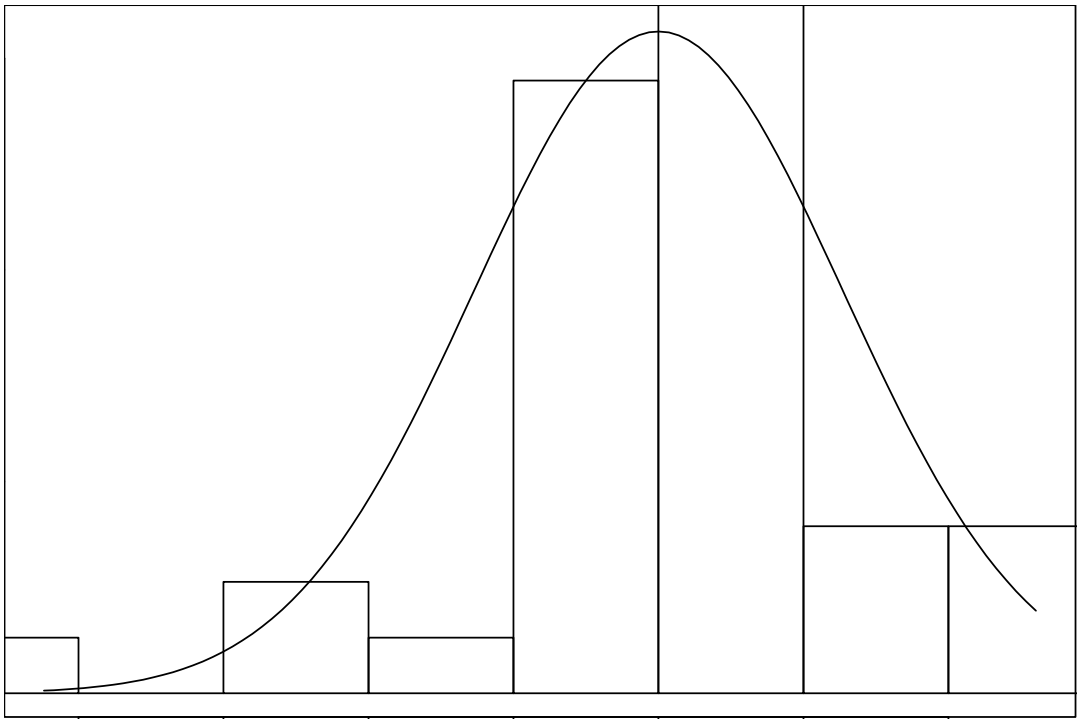


Figure 30. Histogram of residuals with Normal density curve

The histogram of the residuals looks as if the distribution of the residuals is approximately Normal, but it is difficult to judge. An easier way is by a Normal probability plot, which is designed to produce a straight line if the residuals are Normally distributed.

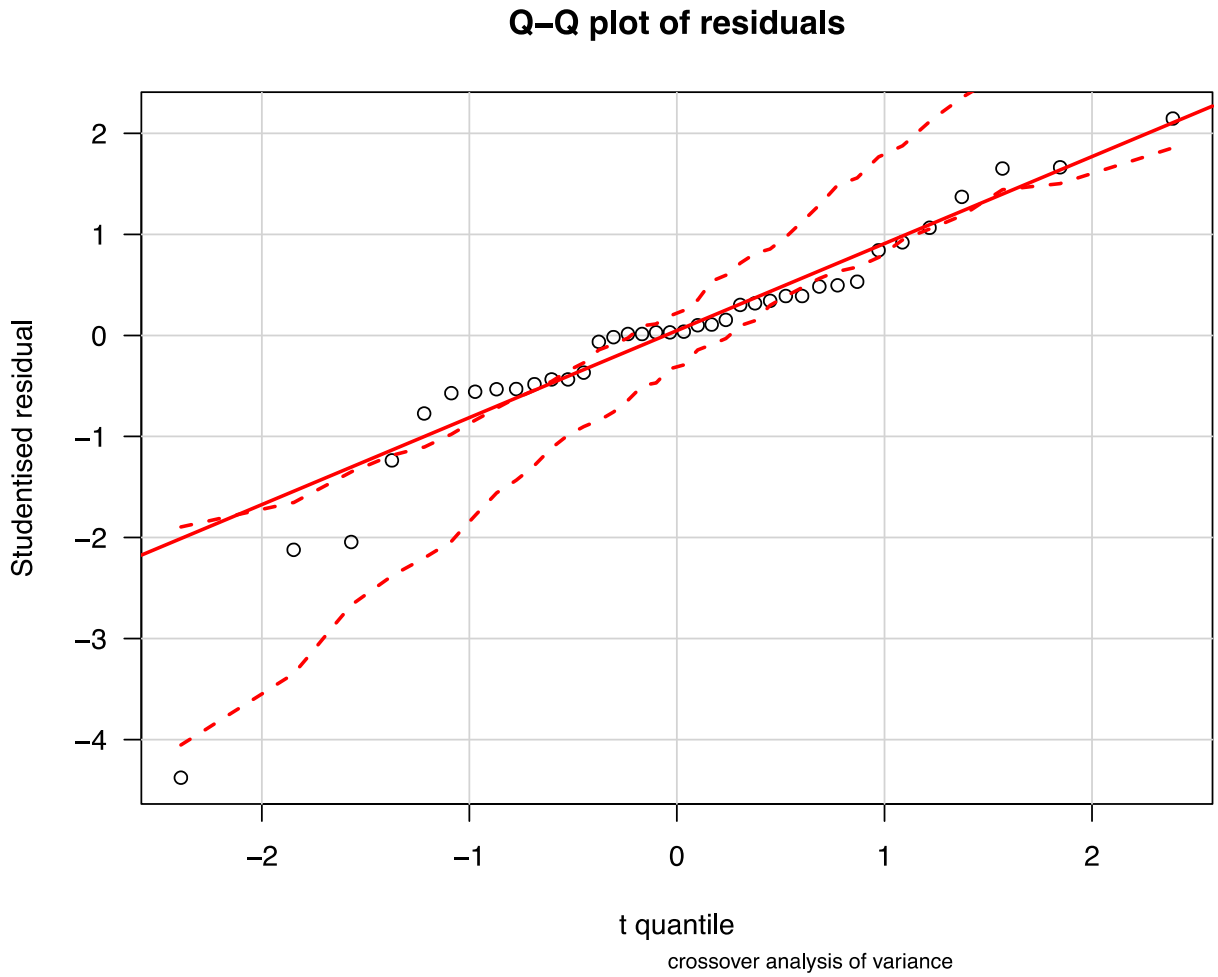


Figure 31. Q-Q plot of residuals for 9HPT

The Normal probability plot shows that the residuals do not produce a line that is exactly straight, and so they are not exactly Normally distributed. However, the classical methods of statistical inference are robust against moderate departures from Normality, and so there is no serious problem here.

A plot of the residuals against the fitted values can reveal non-constant variance.

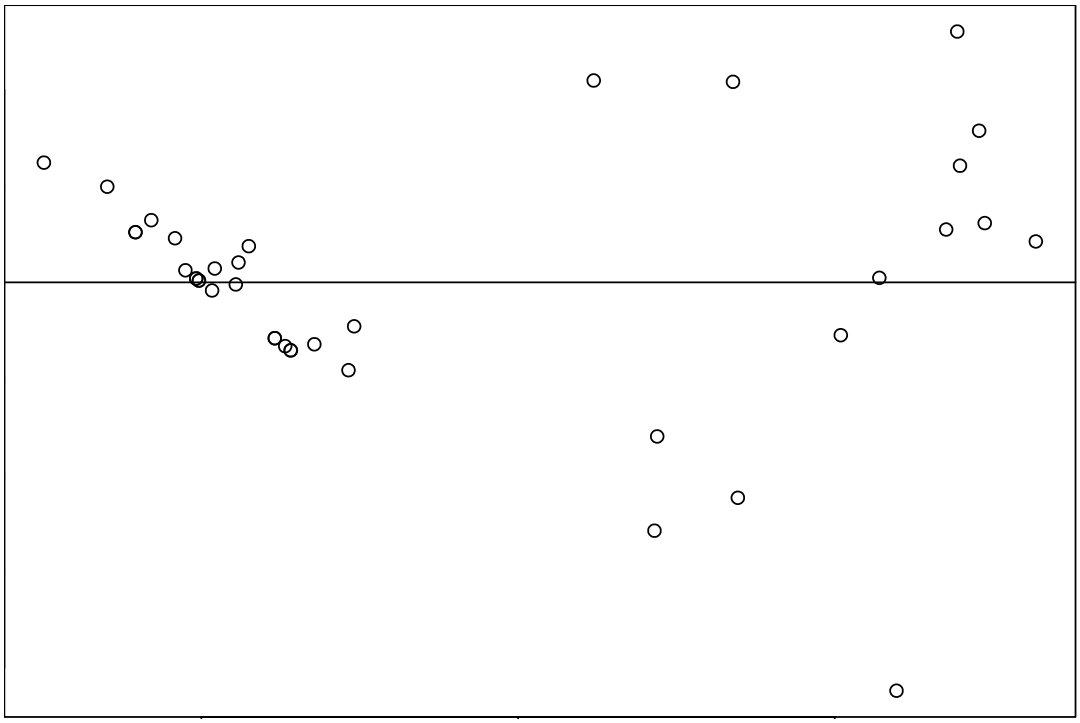


Figure 32. 9HPT residuals against fitted values

The plot does not show a simple horizontal band of points and so there is a suggestion that there might be some non-constancy of the variance. Further inspection of the data leads to the suggestion that the reciprocal of the observations provides values that are nearly Normally distributed with constant variance. This transformed variable could be called “Seconds per 9HTP peg”. Unfortunately some patients did not always place a peg, and hence the transformed value could not be calculated. The analysis therefore continues with the original values and can be expected to give reasonable results as the statistical methods are robust against moderate departures from these assumptions. The following analysis excludes carryover parameters from the statistical analysis. This analysis could either be regarded as the second stage of a “two-stage” analysis, or it could be the analysis adopted when carryover effects are not considered.

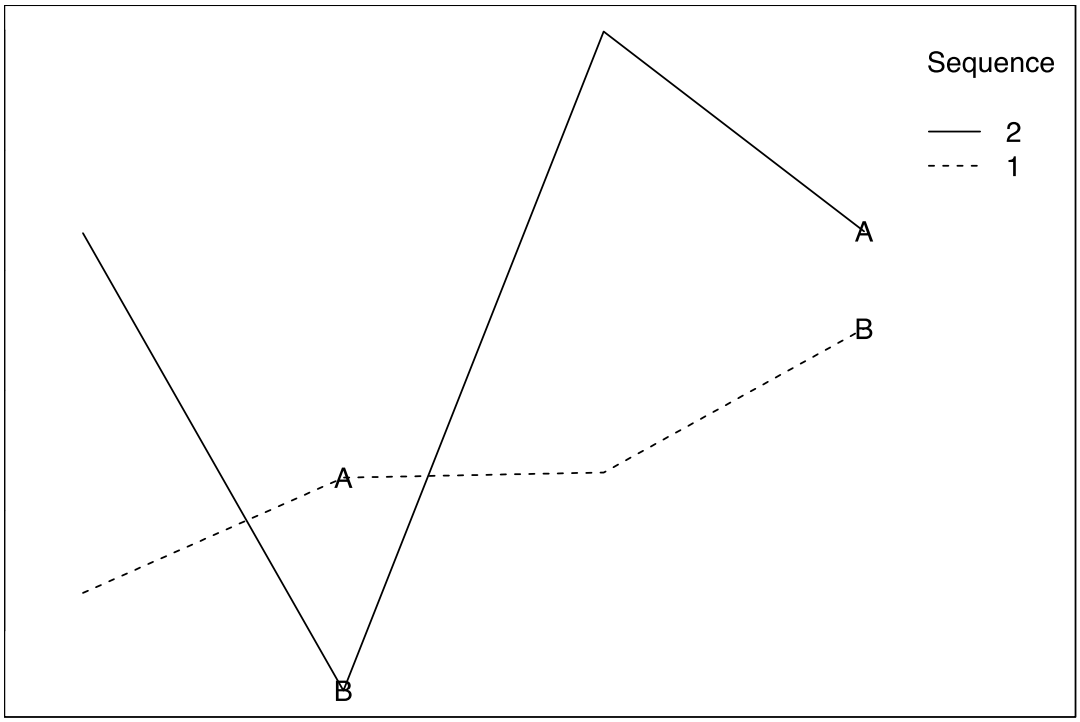
Table 3.1.2: Analysis of variance summary table of 9HTP pegs per minute, with no carryover effects

Source of variation	Degrees of freedom	Type I sum of squares	Mean Square	Variance ratio	P-value
Between-subjects					
Sequence	1	23.288	23.288	0.20	0.668
Period_4	1	82.634	82.634		
Residual	7	812.403	116.058		
Within-subjects					
Period	3	13.392	4.464	0.392	0.760
Treatment	1	0.478	0.478	0.042	0.839
Residual	24	273.100	11.379		
Total	37	1205.296			

Table 27. Analysis of Variance summary table of 9HPT pegs per minute, with no carryover effects

The table above shows that there is still not a statistically significant difference between the treatments means. From this analysis the estimate of the difference is 0.169 with standard error 0.823 (95% CI: -1.530 to 1.867).

This analysis allows for the assessment of both Sequence and Period. However, the patients were randomly allocated to the sequences, and it is therefore illogical to test for a difference as it is known in advance that any difference must have arisen through chance. (It might also seem unnecessary to include a parameter for sequence in the statistical model, as they are supposed to be experiencing the same interventions, but this is done to ensure that the other effects are all estimated as within-subjects contrasts.) It can be seen that the variation among the Periods is not statistically significant.



A = Music therapy, B = Control

Figure 33. Mean 9HPT pegs per minute for each sequence and period

7.10 Raw data from individual 9HPT scores

"Participant number"	Group	"Time point 1"	"Time point 2"	"Time point 3"	"Time point 4"	"Time point 5"
1	Treatment	0/120	0/120	0/120	0/120	0/120
2	Treatment	1/120	1/120	2/120	1/120	7/120
3	Treatment	18/104	4/120	8/120	18/86	18/79
4	Treatment	0/120	0/120	0/120	0/120	0/120
5	Treatment	1/120	0/120	1/120	0/120	0/120
6	Treatment	5/120	18/63	18/75	18/77	18/60
7	Waitlist	NA	NA	18/84	18/120	18/58
8	Waitlist	18/70	8/120	17/75	18/100	18/103
9	Waitlist	0/120	0/120	0/120	0/120	0/120
10	Waitlist	1/120	1/120	3/120	3/120	3/120
11	Waitlist	0/120	NA	NA	NA	NA

Table 28. 9HPT raw scores for each participant.

Participant 5 in the waitlist is included in Table 28 above, in order to clarify mean results and standard error as expressed in Table 23. Numbers 1-5 across the top of the table represent each of the five assessment time points. Numbers to the left of / represent number of pegs, numbers to the right represent time taken in seconds (120 seconds was the maximum time allocated); 18/104 = 9 pegs inserted and then extracted one at a time in 104 seconds). NA = missing data.

Treatment participant number	Pre 9HPT no of pegs/seconds	Post 9HPT no of pegs/seconds	Waitlist participant number	Pre 9HPT/no of pegs/seconds	Post 9HPT/no of pegs/seconds
1	0	0	1	All/84	All/120
2	1/120	1/120	2	All/75	All/100
3	6/120	4/120	3	0	0
4	0	0	4	3/120	3/120
5	1/120	0			

6	5/120	All/63			

Table 29. Pre and post intervention 9HPT scores for all participants.

Participant two in the waitlist suffered a bilateral stroke and the pre and post scores here are for his left, more affected side.

7.10.1 Summary of 9HPT results

The group means showed no statistical significance between early and delayed intervention, nor across timepoints. Only three participants in total managed to complete the 9HPT, inserting and removing all pegs one at a time. Three participants did not insert any pegs in the board over the five assessments. Two participants improved in task performance post treatment, one from each group. Four participants achieved lower scores post treatment than pre. Three participants achieved higher scores at the end of the study (assessment point 5) compared to their first assessment. Participant 6 in the treatment group, who was a highly accomplished musician, made the most improvement. She was three months post stroke and her main impairment was loss of sensation and reduced coordination in the affected fingers (see Chapter 7 'Case studies').

The challenges presented to participants by this standardised task are that the pegs lie in a smooth, concave dish attached to the bottom of the pegboard and the pegs slide around in the dish each time an attempt is made to grip and lift one out. For participants with a forearm position that was not between pronation and supination due to high spasticity and a lack of forearm and wrist rotation, there was an additional problem presented as they were often unable to turn the peg in their fingers in order to get it into a hole.

7.11 EEG analysis

Two participants consented to attend Anglia Ruskin University EEG lab for pre and post EEG recording. One participant then withdrew from the study for reasons unrelated to it. The other participant withdrew only from the EEG as it was felt that the travel to and from Anglia Ruskin might place an extra burden on the spouse, who was already providing a high level of support. This participant

completed all other aspects of the study and benefitted greatly from TIMP, as reflected in her ARAT and 9HPT scores.

The hypothesis for EEG recording and analysis was, that there would be a different pattern of activity after treatment in parietal lobes, motor cortices and auditory cortices.

We intended to compare:

1. stroke related regions of interest (ROIs) (Stroke areas reported in the patient data)

2. pre-defined ROI (Central; sensory/motor areas) against a normative EEG / LORETA database in order to detect intra-individual changes (in- or decrease of z-scores) over time points of measurements within the delayed intervention frame. Topography and coherence data would inform about in- and/or decrease of connectivity (with focus on central data). Pre/post paired t-test would indicate the probabilities and directions of change. We expected the post-intervention measures to show a lowering of z-scores (i.e. normalisation) and an increase of connectivity to/within central areas.

Pre/post music listening data of TIMP patterns to be employed in the intervention; 1) LORETA ROI analysis on central areas based on PSA and values projected into LORETA space; 2) Analysing topographical shifts of pre/post power and frequency changes. We expected the post-intervention data to show increased connectivity in centro-parietal areas.

7.12 Qualitative analysis

Responses to the semi-structured interview questions were analysed by the researcher using the principles of interpretative phenomenological analysis (IPA), and following the methods described by Storey (Lyons, 2007). Commonalities between participants' responses were first identified by carefully reading (several times) through their responses. Close attention was paid to the language that was used to describe their preconceptions before treatment and their experience after treatment. The researcher then chose themes to become headings for the tables that he felt participants'

responses could fit into. Superordinate themes were thus established, from which subthemes were then extracted. For example, if several different participants' responses to question one, pre-treatment, described how they imagined they would cope and progress, then the researcher interpreted this as falling under the general theme of 'presenting a challenge', within which 'self-monitoring' could also be suggested, which is an extremely pertinent aspect of the recovery and rehabilitation process for people with stroke, as well as families and professionals involved. Sub-themes relevant to this theme were 'hope' and 'uncertainty', also themes often arising from conversation during sessions with participants as they expressed their varying levels of uncertainty, anxiety and hope. This being a new and relatively unknown intervention, participants' responses also reflected their uncertaintly as to whether it would be effective or even manageable for them, especially for those who might feel anxious towards playing music and using the equipment involved. Further discussion of the post-treatment themes begins under 7.12.6. The superordinate and sub-themes, together with illustrative quotes from the pre and post treatment questions (see appendices for full transcriptions) are presented in two separate tables below and discussed in relation to the third research question:

How do participants experience TIMP?

7.12.1 Pre-treatment thematic analysis

Before treatment each participant responded to the following questions:

1. What do you think the treatment will be like?

2. How will it feel playing the instruments?

3. How will it feel playing to the music?

7.12.2 Interview question design

The purpose of including semi-structured interviews in this quantitative research study was to capture an impression of how participants experienced the treatment.

This information is important in determining how receptive stroke patients might be to a little known and innovative intervention not commonly encountered within the UK, NHS stroke rehabilitation pathway. In this way information could also be gathered regarding tolerance, motivation, self-monitoring and preference. The structure and procedure of interviews was not intended to generate a high volume of data, but capture the initial responses of participants to the three questions (the fourth question required a Likert scale rating from the participants). The questions aimed to focus each participant on their preconceptions about and experience of TIMP and this experience in relation to their upper limb hemiparesis. All interview forms with participants' responses can be found in Appendix 3.

Questions were formulated in consultation with academic supervisors, the manager of the NHS trust hosting the study and a public research group called INsPIRE (patIeNt and Public Involvement in Research), linked to the NHS study host. The public research group is comprised of members of the public and patients who volunteer to review and comment on research ideas and related documents. Whilst there was some doubt expressed regarding the openness of questions at pre-treatment stage, participants were all given the opportunity to try some of the TIMP exercises as part of the researcher's home visit. Thus, all participants had an experience of TIMP prior to consenting and randomization, which could potentially inform their pre-treatment interview responses. This was in addition to the participant information sheet, also reviewed by the same three parties.

7.12.3 Interview procedure

The researcher conducted all interviews and wrote responses next to each question on each participant's question sheet. Interviews were not recorded, nor was a request made to do so in the ethics application. If a participant struggled to offer a response, then the researcher prompted by asking a less broad question, for example in question one pre-treatment, the question 'do you think it will be hard work, fun, tiring or rewarding?' would be asked to help elicit a response if required. More specific questions were rarely required to elicit responses, particularly post treatment. For participants who had a speech impairment due to their stroke (two in total), or cognitive impairment (one participant), responding to the questions was more

challenging. One participant, with bilateral lesions, was unable to respond coherently and did not appear to fully comprehend the questions due to cognitive impairment.

Table 30. Pre-treatment themes from semi-structured interviews.

Superordinate themes	Sub-themes	Examples of illustrative quotations
Presenting a challenge	Self-monitoring, hope, uncertainty	'it will be testing, to see if I can do it'; 'depends if I can do it'; 'open to trying, left side I can feel, right is weaker'; 'helpful, not about learning music'; 'difficult, cos of lack of grip and twist. Should become easier to reach and touch with skin'; 'hopefully enjoyable, depends if I can do it'; 'I'm not musically minded, I've never played instruments'; 'I don't know'; 'I'm pleased it's come along out of the blue in my life'; 'I'm not really sure what you're asking me to play'; 'frustrated'; 'the arm is fine, but the hand, it's been quite a while, maybe not enough to…, maybe slight improvement'
Having purpose and meaning	ADLs, motivation	'hugely different from being asked for no apparent reason to hit the table'; 'it may help with playing the recorder, everything, holding knives and forks'; 'good to have things to do with my hand'; 'good, using the arm for anything practical'; 'fun, nice, alright'; 'keep me on track'
Perceiving structure	Helping movement and attention	'very stimulating to keep to a beat, help focus the mind on it'; 'it'll give me set times to play'; 'using music to get my hands and arms moving'

7.12.4 Summary and discussion

The majority of themes that emerged from the pre-treatment questions were linked to the challenge that the intervention might present, uncertainty as to what may result and each participant's hope that the intervention would be beneficial. Some participants appeared more optimistic and insightful than others, which is possibly due to their having had previous musical experience and understanding the commonality in movements between instrumental playing and everyday arm and hand use in order to perform ADLs. Some may have also spent more time reading, considering and discussing the participant information sheet with others, or engaged on a more intellectual level and visualized the process for themselves more clearly, thus linking the exercises with ADLs. Some participants showed more awareness pre-treatment of their specific difficulties and were compelled to talk about them, perhaps indicating an urgency and a willingness to find a way of improving their upper limb use. This is apparent in the quotations 'open to trying, left side I can feel, right is weaker', and 'difficult, cos of lack of grip and twist…'. Other comments made by participants during sessions, which were not recorded as they were outside of the interviews, indicated anxiety regarding rate and degree of recovery.

7.12.5 Post treatment thematic analysis

For post treatment interviews participants responded to the following questions:

1. What do you think about the treatment?

2. How does it feel playing the instruments?

3. How does it feel playing to the music?

Table 31. Post treatment themes from semi-structured interviews.

Superordinate themes	Sub-themes	Examples of illustrative quotations
Using the musical structures	Rhythm, tempo, anticipation,	‘keeping to the beat, the same with no music wouldn’t work’; ‘I liked the beat, helped me know when to play’; ‘when I missed a note I was able to know when the next note was coming’; ‘the addition of harmony was good’; ‘it helps you get into a sort of rhythm, things go more smoothly if you get into a rhythm’; ‘I knew the chord that was coming next’; ‘the repeated patterns are important’
Relationship	Musical interaction, support	‘it was nice having one-to-one attention’; ‘it was nice, as we played I could pick up the music’; ‘it’s also important to play with someone else, someone who can pressure you into doing it right’; ‘nice playing with other people rather than alone’

Preference	Opinion on instruments/equipment and ways of playing/using them, music selection	'I enjoyed the tablets, I feel bongos should be played with hands not sticks'; 'I liked the bongos especially because they're real as oppose to iPads'; 'the repeated patterns are important, with songs they're already in your head, for example the Beatles are playing it and you've got to play along. Something to do with the anonymity of a pattern, doesn't make any difference if you play to the pattern right or wrong'
Tolerance	Fatigue, effort, challenge	'it was hard work at times'; 'it takes a lot of concentration'; 'it didn't make me tired'; 'the plectrum was hard to use'; 'I was able to move my arm without having to think about it'

Purpose	ADLs, motivation	'it was compelling, worthwhile… the music makes it, you can participate, there is aesthetic pleasure'; 'good, helpful movement'; 'enjoyed it'; 'very good, helped a lot'; 'encourages the goal of holding a fork'; 'I can put my arm into a position which aids getting dressed'; 'never played any instruments before, they are a goal, hitting the cymbal became a target'; 'hitting something, you realize you've done something'; 'it's quite fun and cheers you up'; 'it gives me a more positive attitude'
Positive change	Self-monitoring, outcomes	'I've got more reach, I was learning to get in-time'; 'I got used to the rhythm, I went faster and slower than the beat sometimes'; 'I think more about using my left hand'; 'beginning it was harder to get my arm to move, now it's less so'; 'it helped a lot, I couldn't move my fingers at all before'; 'I feel like my fingers have become more active, especially my thumb, opening and closing has definitely improved';

7.12.6 Summary and discussion

What is immediately apparent and not surprising is the increase in the amount that participants had to say and the number of superordinate themes for post treatment

responses. At this point the participants had received all of their treatment sessions, monitored their own progress in many cases, and received feedback each session from the researcher on such things as changes in their range and quality of movement and movement timing. They had also had time to reflect on their experience, in some cases discussing aspects of the treatment with their spouse. In a sense, by the end of the treatment period most of the participants had gained and communicated some expertise in TIMP as active research participants.

7.12.7 Using the musical structures

As with the pre-treatment themes, structure and purpose emerged, illustrating the link between these themes and their central focus in this intervention; music providing a clear, predictable framework within which purposeful movements can be rehearsed and repeated. The quote: ‘ the addition of harmony was good’ was confirmed as meaning that the harmonic accompaniment that the researcher provided and the participant playing harmonic sequences using the iPads was good (for example in TIMP 9 and 10). Further clarification was required and not obtained regarding what the participant meant by ‘good’, i.e. this was supportive in facilitating movement or motivating, or both.

7.12.8 Relationship

Some responses drew attention to the interactive nature of the intervention, for which the researcher chose the superordinate theme of ‘Relationship’. This title reflects the basic principles of the researcher’s core music therapy training, which were grounded in psychodynamic theory. The illustrative quotes do reflect a sense of relationship in the music making, with reference to ‘we’, ‘one-to-one attention’, ‘playing with someone else/other people’. This theme is discernable from other quotes that are more clearly commenting on the music such as ‘I liked the beat, helped me know when to play’, under the theme of ‘Using the musical structures’. The quote ‘keeping to the beat, the same without music wouldn’t work’ clearly refers to the musical structure, but alludes to the musical relationship as the music was predominantly played together with the researcher and not with prerecorded music from the iPad. A

comment noted in the research diary reads ‘it’s enjoyable, like being in a band’, reflecting that for this participant the interaction was compelling and collaborative.

7.12.9 Preference

Preference emerged with regard to instruments, equipment and music selection. This is particularly useful as, again, this is a novel intervention that is not found within stroke rehabilitation pathways, therefore establishing whether the instruments, music and equipment both serve their intended function and are compelling or enjoyable to play is crucial. Seating and positioning were not commented on in the context of preference but in that of purpose; ‘hitting the cymbal became a target’. It is useful to know that the participant making this comment positioned the cymbal in sessions in order that he could aim for the embossed manufacturers logo. Rather than being categorized as a preference, the researcher regards this as the participant exercising autonomy and using the instrument in a more functionally refined manner for a specific purpose, which was to improve accuracy of movement or trajectory.

7.12.10Tolerance, purpose and positive change

Fatigue and pain were monitored by the researcher with each participant in every session by asking at the start of the session if any pain or discomfort was experienced since the previous session. Responses in interviews from some participants indicated that some exercises were particularly challenging; ‘holding the plectrum’, others indicate that the intervention enabled easier movement ‘without thinking about it’. Thus, some information regarding tolerance was obtained.

Participants commented on the purposefulness of exercises and outcomes due to the intervention, some of which focused on functional change ‘I feel like my fingers have become more active, especially my thumb, opening and closing has definitely improved’, and some on changes in performance to the music using the instruments ‘I got used to the rhythm, I went faster and slower than the beat sometimes’.

7.12.11Likert scale

In a similar study to this (Schneider et al., 2007) a five-point scale was used, asking participants to rate how much they felt they had benefitted in order to assess the subjective experience of treatment. The scale used here was intended to give a time series of scores or ratings pre and then post treatment, in response to the prompt: (pre) 'please score how much you feel music therapy will change your hand and arm use in daily living'; (post) 'please score how much you feel music therapy has changed your arm and hand use in daily living'.

The scale was included in order to provide further feedback in relation to participant experience and give them an opportunity to monitor how use of their affected side changed due to the TIMP exercises. Throughout treatment periods the researcher asked participants about how they used their affected side each day, which, combined with the question scored using the Likert scale, helped maintain focus on the aim of treatment. The ratings selected by participants help give an indication of how participants perceived the treatment in relation to ADLs and any change or benefits that it brought about.

The ordinal scale is ordered so that 1 = not at all and 5 = very much Table 32 has each participant's rating aligned with their ARAT pre and post scores as it is interesting to see how their perception of change in upper limb use correlates with these scores, although the inclusion of the scale was not intended for this purpose. It is important to maintain focus on the question put to each participant, which was to score how much they felt the intervention had benefitted them in their ADLs. Even though for some participants, as in the case of participant 1, they did not show any improvement with the ARAT, they reported in sessions that they had started to use their affected upper limb more.

Participant	Pt 1	Pt 2	Pt 3	Pt 4	Pt 5	Pt 6	Pt 7	Pt 8	Pt 9	Pt 10
Likert Pre score	3	3	3	2	3	3	3	3	3	3

Likert Post score	5	3	2	1	4	3	4	4	4	4
Pre ARAT	0	12	44	8	28	35	43	44	18	40
Post ARAT	0	13	47	4	32	45	50	41	22	44

Table 32. Pre and post Likert scale ratings shown against pre and post ARAT scores for each participant.

7.12.12 Summary of Likert scale results

The Likert scale ratings were not included with the intention of seeking any correlation with quantitative outcome measures, but have been presented in the table above for brief discussion as they may have implications for future research in this area. Pre-treatment, nine out of the ten participants selected three on the Likert scale. Given that most participants were unfamiliar with music therapy, but were given an opportunity to read the participant information sheet and to try some of the exercises before consenting, it would be reasonable to assume that they would choose the middle score pre-treatment, hopeful but uncertain, as reflected in pre treatment interview responses, about treatment effects. Participant 1 rated treatment effects as 5 despite not achieving any score in ARAT or 9HPT, but reporting that he was using his affected side more in daily activities, describing how he was able to use it when putting on his seat belt in the car, which he drove to and from work using adaptive technology. He was particularly engaged throughout sessions, communicating how much he enjoyed playing the instruments and creating music with the researcher. The researcher observed that his range of movement increased as he played the cymbal and bongos on stands, which would not have been detected using the ARAT or 9HPT. Also recorded in this participant's pre-treatment interview was his comment that he felt he might benefit if he continued for two years, which, in the researcher's observations and clinical experience, may well have been the case. Five participants rated treatment effects as 4, increasing from pre-treatment rating of 3. Four of these participants did show an increase in ARAT score, possibly indicating that they had quite accurately monitored their response to the TIMP exercises and seen an increase in use of their affected upper limb in ADLs.

7.12.13 Discussion of qualitative results

The emerging themes indicate that most participants comprehended the aim of the intervention, found it to be motivating and used it to try and achieve improved upper limb function, monitoring their performance and progress. Importantly, participants found the musical structures to be supportive in facilitating movement synchronisation and the instruments effective as tools to target improved gross and fine movement. The principle research question in this study is a quantitative one, however, due to the importance of motivation, adherence and tolerance during every stage of rehabilitation amongst people with stroke, and the novelty of this intervention, this qualitative data will serve to inform future clinical application of TIMP and further research.

7.13 Conclusion of TIMP study results

TIMP delivered in the home and at a frequency of twice weekly is feasible and improved upper limb function for some participants. The intervention was motivating for the majority of participants, who were able to tolerate a high degree of repetition of upper limb movements to help improve movement range and quality, grip and activities of daily living.

The group means for both groups show an increase between the treatment time points, as illustrated in Figure 21, those being timepoints 1 and 2 for early intervention and 3 and 4 for delayed intervention. Statistical significance ($p = 0.03$) was found between timepoint means but no correlation between the groups was found in the analysis. Statistical significance was not found between early and delayed intervention means for ARAT or 9HPT. The Analysis of Variance for TIMP effects did not find any statistical significance. The results are attributed to the small sample size, reflected in the confidence limits of the data analysis.

For this cohort, the facilitating music was recognized as an effective organizing structure to support upper limb exercises and participants were, on the whole, able to synchronise their movements to the musical patterns.

iPads and acoustic instruments were accessible to all participants, spanning an age range between 23 and 84 years. Some preference was expressed for playing instruments using conventional means, such as hands rather than sticks on bongos. One participant expressed a preference for acoustic instruments over tablets, due to the difference in acoustic feedback.

For participants with higher spasticity a longer period of treatment and/or higher frequency of weekly sessions may facilitate improvement in range of movement, which would require more sensitive assessment tools to measure. A study investigating TIMP with more severe hemiparesis would be of value, for example higher spasticity as was the case for some participants in this study, in order to test dosage and duration of treatment for this specific TIMP protocol.

7.14 Discussion

At the centre of this study was the aim of piloting 12 TIMP playing patterns as a home-based intervention for upper limb hemiparesis, comparing early and delayed treatment delivery. The results suggest that participants with what would be classified as mild to moderate upper limb impairment who do not suffer from any particular cognitive difficulties benefitted the most from TIMP, regardless of time since stroke or age. It has been suggested in other research that patients with this level of impairment benefit the most from early supported discharge (ESD) team services (Langhorne, Bernhardt and Kwakkel, 2011). Participants who did not show improvement of function in their assessment scores had more severe impairment and were not suited to this intervention protocol, at least not at the dosage administered and in the six weeks allocated. This highlights the importance of appropriate selection of participants for such a study and the referral of patients to interventions most suited to their current level of impairment, as previously reported (Houwink et al., 2013).

The TIMP protocol, whilst sharing some attributes with MST and stemming from scientific research into the effects of rhythm on movement kinematics, has not been clinically or scientifically researched to a great extent. Whilst MST applies a protocol of musical instrument playing exercises, it has not explored any additional effects of using facilitating rhythm and music, which would be derived from existing scientific evidence for its role in supporting the priming, timing, trajectory and muscle force required for the upper limb movements within each exercise pattern. This study achieved an investigation into the effects of music on participant experience and projected to measure the physiological effects using EEG. Using such measures would help to establish an such effects, contributing to the findings of previous studies reporting on audio-motor coupling.

Research into the effects of musical instrument playing and rhythm supporting movements has been based on a model of daily treatment, five days per week, which has produced statistically significant results (Schneider et al., 2007; Altenmüller et al., 2009; Malcolm, Massie and Thaut, 2009b; Rojo et al., 2011; Amengual et al., 2013). Studies with a lower frequency of treatment have not been widely conducted and with such a reduction in frequency it is not known what the treatment effect will be. This

study has shown a tendency for improvement between treatment periods at a dosage of twice weekly, which could be confirmed with a larger study.

There is great heterogeneity of upper limb impairment within this patient group and the ARAT has been developed as a tool that can capture change within these parameters by recreating a protocol combining tasks commonly performed within ADLs. The table of TIMP exercise patterns (see Table 1) developed for this study describes the target arm movements for each instrumental exercise in the first column, then the instrument/s and equipment to be used, the positioning of each instrument and how it should be played. It can be seen that the musical exercises require arm, hand and finger movements that are the same or similar to those required in order to perform tasks in the ARAT and 9HPT. .

7.15 Summary

Although in this trial, with a small sample size, we did not predict significant differences between the two group outcomes, we still expected to report on feasibility of the delivery and efficacy of intervention. MST and trials investigating the effects of rhythm and music on upper limb kinematics have taken place in research laboratories and included, predominantly, inpatients two months post stroke. This TIMP study included participants up to five years post stroke, where community rehabilitation in their home had been completed. The majority of rehabilitation for stroke patients in the UK takes place in patients' homes and does not target upper limb hemiparesis alone, but mobility and independent living skills in a more holistic model. To date there have been no reports of feasibility of this type of intervention in participants' homes. As such the study will make a contribution to new knowledge in the field that could influence future service design.

8 CHAPTER 8. CASE STUDIES

8.1 Introduction

Following on directly from the main results in Chapter 7, in this chapter three case study subjects have been selected for discussion because of their particular engagement in and responses to the intervention in relation to their post-stroke effects and pathology, their age, medical, musical background or socioeconomic status (SES). The case studies provide greater detail relevant to TIMP application not previously given in this thesis, including: 1) session details such as TIMP patterns used and tempo, engagement, motivation, self-monitoring and how the instruments and equipment were used, 2) how the researcher responded musically to subjects' playing, 3) the potential influence of SES on anxiety levels, treatment conditions such as space and distractions in subjects' homes, and how these factors might affect treatment outcomes. A chart is provided for each case study showing which TIMP patterns and pattern variations were used and how many times over the six weeks of treatment (please refer to Table 7 in Chapter 6 under Methodology). Selection of subjects was not conducted following a process of purposive sampling, although it would conform to certain types such as maximum variation, including both the more extreme and typical participants from this pilot study (Palys, 2008). Qualitative data from the semi-structured interviews is not included in the discussion of case studies, as it has already been analysed and discussed in the results section. Notes from the research diary and observations by the researcher, which contain more qualitative detail and scope than the semi-structured interviews set out to provide, have been used in order to build a fuller picture of each subject and their individual pathology and treatment responses. This detail should serve to inform on patient suitability, management of treatment delivery, and help to predict outcome potentials.

8.2 Socioeconomic Status (SES)

The SES of each subject has been briefly discussed in order to help clarify the circumstances in which treatment of stroke and recovery was taking place. Information was not sought from participants as part of the study specifically for

discussion in this respect, but is based on the researcher's observations of and conversations with each of the subjects in sessions. Some research has highlighted SES as affecting motor recovery at inpatient stage and six months post stroke (Putman et al., 2007). Only one of the case study subjects participated within this timeframe, however the researcher feels that some discussion of the potential influence of SES within the context of this research would inform on engagement, tolerance and management of symptoms such as anxiety and pacing treatment delivery within sessions. The Putman study states that Barthel index (Mahoney and Barthel, 1965) and Rivermead Motor Assessment scores for those who had attained higher educational achievement and income were significantly higher than for those of lower SES. A hypothesis offered by the authors was that those of higher SES were more proactive in seeking coping strategies and problem solving, and thus counteracting their experience of uncertainty with regard to recovery.

8.3 Subjects' medical information

Obtaining accurate medical information that details precise lesion sites and any assessment scores such as Glasgow Coma Scale (Teasdale and Jennett, 1974), Hemispheric Stroke Scale (Adams et al., 1987) or the Barthel Index has not been possible for all case study subjects. This is due to inconsistencies in the detail of patient reports and documentation between different hospitals and acute services. This lack of information may limit a more in-depth discussion of subject suitability for TIMP or the most appropriate duration and frequency of TIMP treatment based on brain regions known to be damaged due to CVA.

	Gender/ Age	SES	Type	Side affected	Months post stroke	ARAT Pre	ARAT Post
Subject A	M/61	Traditional working	Ischaemic	Left (dominant)	14 months	12/57	+ 1
Subject B	F/88	Traditional working	Hemorrhagic	Right (dominant)	10 months	43/57	+ 7

Subject C	F/74	Established middle/elite	Embolic	Left (non-dominant)	3 months	35/57	+ 10

Table 33. Demographic and clinical data for the three case studies.

8.4 Case study subject A: treatment group, left handed, tremors on affected hand, doesn't like music and 'can't play it'

8.4.1 Background

The first subject is a 61-year-old British male, estimated to be within the third of seven identified social class categories, that being 'traditional working class' (Savage et al., 2013). He suffered a right hemisphere Cerebral Vascular Accident (CVA) following aortic dissection (a tear in the aorta) and heart surgery, causing multi-focal infarcts in the frontal, parietal and occipital lobes. His stroke occurred 14 months prior to joining the study. The subject presented with left side hemiparesis and tremors in the left lower and upper limb, particularly when trying to extend his arm in order to reach, grasp or release an object. Tremors cause rapid oscillations, usually in the hand, whilst performing an action, and have been associated with lesions in the caudate nucleus, thalamus, striatum, cerebellum and brain stem and sub-thalamic, frontal or parietal infarcts. Tremors render the performance of self-care and food preparation tasks such as shaving and pouring liquids extremely challenging, if not impossible. The subject's dominant hand was his paretic, left hand. Following his stroke he was still able to lift his affected arm and move his fingers and thumb very slightly. In addition to his stroke and heart problems, the subject also had a serious lung infection, was nil-by-mouth, taking nutrients through a percutaneous endoscopic gastronomy tube (PEG) directly into his stomach.

The subject presented as a very serious person and understandably concerned about his current state of health. He appeared keen to try the treatment, contacting the researcher immediately following receipt of the invitation to participate letter. Before beginning treatment the subject commented that he did not like nor listen to music and that he could not play music in any form, be it singing a melody or tapping along to music in time.

8.4.2 Mobility and transferring

The subject was unstable when walking, using a walking aid, and his Berg balance scale score at acute stage was 12/56 and then in December 2014 (four months before beginning music therapy) had increased to 28/56. Due to this participant's medical complications and balance problems when walking, extra care was required when he transferred from his armchair to a more upright dining chair, which was required to maintain best posture in order to perform TIMP exercises with greatest efficiency. The PEG bag needed to be carried each time the subject transferred at the beginning and end of each session and assessment, either by the researcher, the assessor or his wife if she was present, ensuring that the tube connecting it to his PEG site (on his stomach) was not pulled and that the subject was not at risk of falling. The subject's remarks and demeanour throughout the treatment period indicated his feelings of vulnerability, uncertainty and pain, as well as his desire to receive effective interventions, his hope and determination to recover.

Gender	Age	Stroke type	Site	Post stroke	Dominant hand	ARAT		9HPT	
M	61	Ischaemic	Right hemisphere, multi-focal infarcts in frontal, parietal, occipital lobes	14 months	Left	12/57	13/57	1/120	1/120

Table 34. Demographic data for Case study subject A.

8.4.3 Methods/Treatment

The subject's pre-treatment ARAT score was 12, with scores of 1/3, indicating partial completion of task, against the majority of the 19 tasks. He was able to grasp and lift most objects and use the correct finger combinations to pick up the ball bearing and

marble, showing good finger dexterity, but he was unable to combine these pinch grip movements with elbow and shoulder extension and shoulder stability in order to place objects onto the necessary targets (the shelf and the back of the table). Completion of assessment tasks was further impaired by frequent onset of hand tremors. Looking at his ARAT score sheet clearly indicates that these extensor movements were impairing his performance of ADLs and should, therefore, be the focus of TIMP exercises. The subject completed all 12 sessions within the six-week period. The tables below show the TIMP patterns and metronome settings used in sessions over the six-week period of treatment.

TIMP pattern number	Number of sessions in which pattern was used
TIMP pattern number	
1. Elbow flex/ext. Shoulder abd/add	(also 1b, 1c) All
2. Elbow flex/ext.	(also 2a) 6
3. Shoulder flex/ext. Shoulder abd.	3
4. Shoulder flex/ext. Shoulder abd	2
5. Shoulder add/abd. Elbow flex/ext	7
6. Thumb ext/flex	6
7. Finger ext/flex, wrist deviation	1
8. Finger flex/ext	2
9. All finger flex/ext, pinch	(also 9a) 5
10. Finger flex/ext	6
11. Wrist deviation, grip	0
12. Pron/sup of wrist/forearm	0

Table 35. TIMP patterns used in each session.

Flex = flexion, Ext = extension, abd = abduction, add = adduction, pron = pronation, sup = supination.

Session number/metronome tempo setting range (bpm)
(S1)/48 - 56
(S2)/50 - 70
(S3)/50 - 100
(S4)/50 - 100
(S5)/50 - 60
(S6)/50 - 55
(S7)/55 - 60
(S8)/50
(S9)/55
(S10)/53 - 58
(S11)/50 - 65
(S12)/50 - 55

Table 36. Tempo settings for subject A.

8.4.4 Descriptive detail of sessions

8.4.4.1 Hand over hand and verbal support

In the first session pre-recorded music from the iPad was used in order that the researcher could provide hand-over-hand guidance and aid faster synchronisation to the music, which the subject was struggling to achieve. Sometimes verbal cueing was required from the researcher in order to assist with synchronisation, such as ‘get ready, and play, relax your arm’, chanted rhythmically in time to the music. Subject A commented in session two that he couldn’t do it because he had no sense of rhythm and didn’t know when to play. In following sessions he commented on his performance regularly, communicating with the researcher that he was ‘getting into the swing’, or ‘getting warmed up’, which he felt took about ten minutes, and that if he could hit the cymbal it gave him more confidence.

8.4.4.2 Instrument positioning and playing method

Initially subject A played the cymbal set at its lowest point on the stand using an adaptive beater, which is heavier than a drum stick, with a thicker handle and a large, round, rubber end approximately the size of a table-tennis ball. The main objective of TIMP 1 was to improve elbow extension and we continued to use this pattern in all sessions, gradually extending the distance of the cymbal from A and using TIMP 1b and 1c. We also used this pattern to improve shoulder adduction and flexion, and elbow flexion by positioning the cymbal on his right side above head height. In the fourth session during TIMP 1 the subject relaxed his arm, fully extended, down by his side following each cymbal hit, making it part of the movement pattern. This was a spontaneous modification of the playing pattern by the subject. He commented that it gave more momentum to his playing, producing more volume and improving performance. The researcher observed that this larger arm movement facilitated more repeated flexion movements of greater range.

8.4.4.3 Tolerance

All patterns were played in two-minute blocks, monitored using a timer, which allowed the researcher to frequently assess whether the subject was experiencing shoulder pain or any other discomfort, and to adjust the spatial arrangement of equipment. Vigilance towards pain and fatigue was particularly important with this participant, who was still in a vulnerable state of health and very driven and determined to recover even in the face of pain during and due to treatment. In session five, during TIMP 5 (playing bilaterally) the subject's left arm extended well to hit the cymbal, whereas initially he was only just clipping the edge of it. The researcher noted that there were fewer tremors than in the previous session and that they reduced in general the further into each session we progressed. This observation corresponded with subject A's own observation that he felt warmed-up ten minutes into each session.

8.4.4.4 Tempo

The majority of TIMP was delivered using live music played by the researcher to a metronome, which was listened to through an earpiece. Metronome settings usually began at 50bpm, which required more shoulder stability than at a faster tempo when extending the elbow, and increased in order to facilitate more elbow extension repetitions with less strain on the shoulder. Metronome settings for finger exercises, as can be seen in Table 36, did not increase as much as for the more proximal arm exercises and maintained a setting between 50 and 60bpm. These metronome settings for fine motor exercises were calculated based on the subject's existing frequency of movement and the researchers clinical experience which indicates that where finger movement is impaired and requires re-training, doing so at a lower frequency allows the subject to focus on isolated finger movements, whilst avoiding the build up of tension in the larger, proximal muscles. Finer motor movement retraining, if undertaken at a frequency that is too high and beyond the subject's current ability, can cause secondary neuromuscular problems, such as dystonia; also reported as a secondary movement disorder in stroke cases (Handley et al., 2009).

8.4.4.5 Tempo for TIMP 6, thumb exercises

In Table 36 showing tempo settings for subject A, it can be seen that in sessions three and four the tempo reached 100bpm. This was whilst the subject performed TIMP 6, requiring thumb movements across the touchscreen guitar. This TIMP pattern was used in six sessions in total, with particular focus in these two sessions where we gradually increased the tempo and observed the movement quality, which was compromised at a higher frequency and so not repeated in following sessions.

8.4.4.6 Isolating movements from within sequences

More focused observation of and exercises for thumb movement using TIMP 6 was required with this subject as he was able to grip and lift, but not combine these movements with extension. In other sessions, as already reported, the focus was on arm extension and flexion using the cymbal. TIMP treatment over a more extended period would have led to exercises combining grip, grip release with extension exercises, as explained in this subject's summary and conclusion.

8.4.4.7 Variations in musical structure to support performance

The researcher adjusted the way that he played the music for TIMP 5 (used in 7/12 sessions), adding much more crescendo, or intensity, to the strumming of each chord. It was noted that this improved the subject's synchronisation. This additional musical intensity, particularly for TIMP 5, was also used in sessions with other participants.

8.4.4.8 Self-monitoring

During TIMP 1 the subject was interested in more precisely understanding the progress he was making, prompting the researcher to measure the distance of the cymbal from him using a tape measure. The centre of the cymbal stand was 71cm from the chair leg closest (on his left side) and the approximate height, measured from the floor to the low edge of the cymbal was 72cm. In following sessions the distance was increased to 78cm and then 85cm, facilitating greater elbow extension. Subject A began to rotate the cymbal around and position it so that the manufacturer's name that was printed on the surface became his target for hitting, thus autonomously tuning the accuracy and quality of his movements.

Following an episode of playing TIMP 1, the subject demonstrated to his wife his improved range of movement, touching his mouth with the palm side of his hand. This movement is the final item of the ARAT gross movement subscale, indicating that he was not only demonstrating increased capacity to perform ADLs, but also possibly linking this to the assessment. His hand began to tremor as he did this, possibly due to the effort required to stabilise the shoulder and the angle of elbow flexion. There were no tremors as he played the cymbal and bongos in synchrony with the music when positioned extreme right above head height, requiring the same movement and elbow flexion as with hand to mouth, but made with repeated rhythmic movements as oppose to being held in a sustained position.

8.4.5 Results

Subject A time-point for ARAT	ARAT score of 57
Week 1 Pre treatment	12
Week 6 Post treatment	13
Week 9 washout	17
Week 15 Follow-up	16
Week 18 Follow-up	16

Table 37. ARAT scores at five timepoints for subject A.

ARAT scores showed only slight improvement, as the subject was unable to complete most tasks at all, or unable to do so within the 60 seconds permitted (120 seconds for the 9HPT), including the gross section. Only the water-pouring task, arguably the one most obviously linked to ADLs, was achievable throughout the study and showed a marked improvement in completion timing. The subject scored 2 for this, completing the task with difficulty and using compensatory movements. The time taken to complete the task changed dramatically and remained approximately 50 per cent faster until the final assessment as shown in the table below. The normative data for the timing of this task has been reported as 7.9 seconds (Van, 2001).

ARAT Time-point	Time to complete ARAT task 7 in seconds
Week 1 pre treatment	44
Week 6 post treatment	13.16
Wekk 9 washout	15.78
Week 15 follow up	24.73
Week 18 follow up	19.08

Table 38. ARAT 'Grip' subscale task 7 score (pouring water).

The increased overall ARAT score in follow-up measures at time-points three to five was due to grasping and lifting the 10cm block (task 1, Grasp section), picking up the washer from the tin lid (task 10, Grip section) and touching palmer side of hand to mouth. The time taken to perform tasks does not necessarily affect the score and in

the case of the water pouring task for this subject it did not. In the third assessment the researcher noted that the subject was able to lift up the blocks in the grasp section and extend his reach almost to the target shelf. As the researcher was not, and could not be, present when the blind assessor conducted pre and post treatment assessments, it is not known whether or not he was able to reach this far at those points, but the subject reported his reach had improved quite significantly during assessments with the researcher.

Subject A Time-point for 9HPT	Time
Week 1 Pre treatment	1 in 60secs
Week 6 post treatment	1 in 60 secs
Week 9 washout	2 in 60 secs
Week 15 follow up	0 in 60 secs
Week 18 follow up	4 in 60 secs

Table 39. 9HPT scores.

Although this subject achieved only 1 peg in the 120 seconds allowed for the 9HPT, by the final assessment he was able to achieve 4. The subject was so driven towards improving his arm function that he asked to continue the 9HPT beyond the time limit. He inserted 7 pegs by 2 minutes, all 9 pegs by 2.50 minutes and completed the test in 3.30 minutes. The subject was pleased with his performance and enquired about purchasing a 9HPT for his own personal use. His scores indicate the potential to continue improving finger dexterity and his response showed great motivation.

8.4.6 Summary and conclusion

Subject A was highly motivated, self-monitored throughout the study (not only the treatment period) and showed great resilience in coping with such medical complications in addition to the effects of his stroke. TIMP 1 was the most used pattern over the course of treatment. Drumsticks and adaptive beaters were used and towards the final sessions hands were used in order to maximize range of movement.

Quantitative outcome scores did not show any significant increases, but task performance time for ARAT task 7 did show significant improvement, indicating improvement in movement quality for a task closely linked to ADLs. This would indicate that further fine motor exercises may have brought continued improvement and that further exercises that combined such distal motor tasks with extension and other proximal movements would have benefitted the subject's ability to perform ADLs. TIMP 12, requiring grip and release of the cabasa, wrist deviation and elbow extension and flexion may have improved this sequence of movements, but was not feasible over the six weeks of treatment as the subject did not advance far enough with consistency in range, quality (less compensatory movements) and movement timing with the less complex exercises such as TIMP 1.

8.5 Case Study subject B: Waitlist group, 88 years old, moderate dysarthria, visual impairment and possibly experiencing 'emotionalism'

8.5.1 Background

Subject B was British, of Indian heritage, 88 years old and estimated to be within the third of seven identified social class categories of 'traditional working class' (Savage et al., 2013). However, she had held a position of responsibility within an academic institution and so had probably attained a higher level of education than would be expected within this SES category. The subject was right hand dominant and suffered a left hemisphere CVA 10 months before joining the study. In several sessions she became suddenly tearful and anxious, asking the researcher about her potential for recovery and the risk of having another stroke. Although these symptoms could be easily understood given the traumatic impact that stroke has, they may also fit the description given for 'emotionalism' (House et al., 1989), also known as emotional lability (Allman, 1991) which is one of the most commonly reported psychological effects caused by stroke (Stroke Association, 2015). The subject was also moderately dysarthric, able to communicate but expressing some frustration and distress when struggling to pronounce words and make herself understood.

An important consideration throughout subject B's participation in the study was any age-related onset of fatigue and her additional psychological and communication symptoms. The researcher ensured that time was available for the subject to talk about

her life events that spontaneously came to mind, family and recent activities at the beginning of sessions. However, it was also important to maintain focus on the functional objectives and avoid emotional disruptions that could result from too much time reflecting on other matters. On the occasions when the subject appeared tearful and anxious, the researcher listened to her concerns, reassured her and moved the focus towards playing music together, to which she responded positively.

Gender	Age	Type	Site	Post stroke period	Dominant hand	ARAT	
F	88	Hemorrhagic	Left hemisphere	10 months	Right	43	50

Table 40. Case study subject B demographic and assessment data.

8.5.2 Methods/treatment

The subject's baseline ARAT scores indicated that she could complete tasks in all categories, but with some compensatory shoulder movement and/or at a speed below the five-second threshold deemed to be 'normal' for completion of each task. Some tasks were hindered by additional visual impairment, in particular tasks in the grip subsection, requiring longer elbow extension, distance judgment and precision in order to place the tubes over wooden plinths (tasks 8 & 9). Performance was similarly affected in the 9HPT, particularly post music therapy intervention; when she was due to receive treatment for the visual impairment. The fifth and final assessment score shows an improvement over all previous scores, which also followed her treatment for visual impairment.

Most of the TIMP patterns used targeted fine motor control using the iPads and touchscreen instruments, which were positioned on a table surface for subject B to play as this positioning allowed more isolation of finger movements, with her forearm resting on the table. The table below reflects this, showing which patterns were used in number of sessions.

TIMP pattern number	Number of sessions in which pattern & variations used
1. Elbow flex/ext. Shoulder abd/add	1
2. Elbow flex/ext.	0
3. Shoulder flex/ext. Shoulder abd.	0
4. Shoulder flex/ext. Shoulder abd	0
5. Shoulder add/abd. Elbow flex/ext	0
6. thumb ext/flex	3 (once using index finger instead of thumb)
7. finger ext/flex, wrist deviation	(TIMP 7a, 7b, 7c & 7d). 10
8. finger flex/ext	6 (2 X iPads arranged in table one above the other and left/right)
9. all finger flex/ext, pinch	All (9a, 9b, 9c, 9f)
10. finger flex/ext	11 (variation expanded to include index, middle, ring finger and thumb)
11. wrist deviation, grip	1
12. pron/sup of wrist/forearm	0

Table 41. TIMP patterns used by subject B.

Session number (S)/metronome tempo setting range (bpm)
(S1)/60
(S2)/60
(S3)/60
(S4)/60

(S5)/60
(S6)/50 - 60
(S7)/50 - 60
(S8)/50 – 60
(S9)/50 – 75
(S10)/60 – 75
(S11)/50
(S12)/50

Table 42. Tempo ranges for subject B.

8.5.3 Descriptive detail of sessions

8.5.3.1 TIMP exercise selection

TIMP 8, 9 and 10 were predominantly used. In the first session it was determined that limited benefit would come from the gross motor exercises and that we should proceed with exercises targeting finger dexterity. The subject explained that this was what she wished to improve and described activities that she had undertaken to help achieve this, such as playing solitaire (this may also have been supported as a useful exercise by the community stroke team occupational therapist). TIMP 6 was used on one occasion for index finger rather than thumb; this was in an earlier session in order to practice synchronisation for this particular movement within the simplest musical framework. Following this the subject was able to proceed with TIMP 7-10 with good synchronisation. Using the plectrum on the smartguitar, the subject was able to adjust its positioning without the aid of her unaffected hand between each completed chord sequence (TIMP 9).

8.5.3.2 Tempo

TIMP 9, which was used in all sessions, increased towards normal from 50 to 75bpm, with good sustained focus on the exercise and synchronisation with the music. TIMP

10 also showed good increase in movement frequency, using index, middle, ring finger and thumb combinations.

8.5.3.3 Verbal support

The researcher used a verbal cue ('get ready and play', or 'stretch your finger and play'), sung in time to the music, in order to support synchronisation. This was used more in the first six sessions, then it was faded as the subject was able to use the temporal structure of the music only to cue movement timing and duration.

8.5.3.4 Self-monitoring

It was noted during session two that the subject appeared to be thinking more about focusing her finger movements whilst performing TIMP 7, pinching her index finger against her thumb and then slowly flicking (extending) it up across the chord on the smartguitar. The subject commented that she had to concentrate during sessions, which the researcher observed as she initially showed some confusion in her movements to play to the music and synchronise the playing of each chord in TIMP 6, 7, 9 and 10.

8.5.3.5 Tolerance

The subject reported aches in her affected shoulder, either in the days between sessions or at the end of sessions. In session ten, in which she held the plectrum using her opposing thumb and ring finger (as oppose to index finger, which was easier for her) she reported shoulder pain, which was reported again with the same exercise in the following session. Where such reports occurred during sessions, we would pause and then switch to a different exercise requiring a different focus or movement sequence, for example TIMP 8 which requires bilateral playing, so as not to work the same muscle groups too intensively.

8.5.3.6 Subject's self-stated goals

It was noted that in the earlier sessions subject B spoke about what she would like to do at home in terms of ADLs, but couldn't, such as cleaning and preparing vegetables

for meals. As sessions progressed, she began to talk about what she had been doing around the home between sessions, which came across to the researcher as showing an improvement in self-confidence. These activities included picking up pills, cleaning ornaments and operating light switches using her affected hand. Her engagement throughout sessions as well as her discourse reflected her personal determination and motivation to recover functional hand use and this is reflected in her continued improvement in assessment scores.

8.5.3.7 Researcher's non-musical responses

There is no doubt in the researcher's mind that his music therapy training background, previous support receiving clinical supervision and experience of employing psychodynamic models in order to address clients' psychological and emotional problems was invaluable in providing appropriate support for this subject. The researcher noted the importance of being able to combine both the neuroscience framework and methodology necessary for delivering NMT interventions with the social-science, psychodynamic grounding common to UK music therapy practice.

8.5.4 Results

Subject B time-point for ARAT/9HPT	ARAT score of 57	9HPT scores
Week 1 Baseline	43	NA
Week 6 Baseline	39	NA
Week 9 Pre treatment	43	18 in 84 seconds
Week 15 post treatment	50	5 in 120 seconds
Week 18 Washout	54	18 in 58.32 seconds

Table 43. ARAT and 9HPT scores for subject B
(NA = not available).

As can be observed, ARAT scores were not stable between weeks one and six, but show improvement at weeks nine, fifteen and eighteen. Data was missing for 9HPT at weeks one and six. The subject's 9HPT score fell dramatically post treatment, which could be explained by a deterioration in her visual impairment, affecting hand-eye coordination on her right side. Her 9HPT score showed great improvement in the final measure, at which point she had received treatment for her visual impairment. The subject's ARAT score also increased at this point by a further four points.

Overall the effects of visual impairment on assessment tasks and stability of scores slightly confounds conclusions about treatment effects for subject B, but given this subject's performance across sessions and increase in ARAT scores pre and post treatment she appears to have benefited from the intervention.

8.5.5 Summary

Visual impairment, which was possibly more age than stroke related, impaired this subject's performance of assessment tasks and so affected outcome scores. More detail regarding the damaged brain regions due to CVA would help to confirm this. The main focus of treatment was fine motor and this led to an increase of +7 in the ARAT. The subject was very motivated and able to sustain focus on exercises. Close monitoring of fatigue and shoulder pain was required, as the subject regularly reported these symptoms during and between sessions, which were possibly age related as well as symptomatic of stroke. Breaks were taken when needed in order to reduce these effects. There was some negative impact observed by the researcher from anxiety and emotionalism, which required attention usually at the start and end of sessions.

8.6 Case study subject C: treatment group, highly accomplished musician, loss of sensation in fingers

Subject C was a 74 year-old lady, who had an embolism post heart surgery, causing right hemisphere frontoparietal stroke. Her stroke occurred three months prior to joining this study and she was in acute care for six weeks. She was right handed and would be categorised between 'established middle class' and 'elite' class, with a high level of economic and social capital and very 'high highbrow' cultural capital (Savage et al., 2013).

Prior to her stroke she had been a highly accomplished, self-taught recorder player, achieving the highest instrumental examination grade attainable, performing as well as writing and publishing arrangements for recorder. Subject C was not initially approached by the community stroke team to participate, but herself asked if music therapy was available as an intervention. Following this the team invited her to participate by letter, she contacted the researcher and was randomized into the treatment group. The occupational therapist in the team explained that she had loss of

sensation in her fingers, affecting proprioceptive feedback. The impact of this was that she could not perform ADLs requiring the picking up and manipulating of objects such as cutlery.

Gender	Age	Type	Site	Post stroke period	Dominant hand	ARAT		9HPT	
F	74	Embolic	Right hemisphere, frontoparietal	3 months	Right	35	45	1 peg	63 secs complete

Table 44. Demographic data for case study subject C.

8.6.1 Methods/treatment

Subject C completed 11 of the 12 sessions over the six-week period of intervention. From the first session it was apparent that motor planning and sensation in the fingers was affected, for example she could not coordinate middle or ring finger movements with the same precision as with the index finger, which was also impaired as reflected in the 'pinch' subsection of the ARAT (see Table 48). One of the problems that she had reported when trying to play the recorder was remembering the note names, sometimes playing what she thought would be a 'C', but producing and hearing a different note. This indicates possible disruptions in procedural memory, whereby motor learning has taken place through many repetitions of motor movements. Such activity leads to predictive relations between stimuli and events, (Coleman, 2008) which appears to have been disrupted in this case. Table 45 shows the TIMP playing patterns used in the 11 sessions, which were predominantly patterns 8-11.

	Number of sessions in which pattern was used
TIMP pattern number	
1. Elbow flex/ext. Shoulder abd/add	T1a (with fingerpicks) 2
2. Elbow flex/ext.	0
3. Shoulder flex/ext. Shoulder abd.	0
4. Shoulder flex/ext. Shoulder abd	0
5. Shoulder add/abd. Elbow flex/ext	0
6. thumb ext/flex	0
7. finger ext/flex, wrist deviation	1
8. finger flex/ext	6
9. all finger flex/ext, pinch	9
10. finger flex/ext	10
11. wrist deviation, grip	5
12. pron/sup of wrist/forearm	0

Table 45. TIMP patterns used ny subject C in 11 sessions.

Session number (S)/metronome tempo setting range (bpm)
(S1)/60
(S2)/60
(S3)/60
(S4)/60
(S5)/60
(S6)/60
(S7)/55-66
(S8)/60-74
(S9)/62-75
(S10)/57-80
(S11)/60-70

Table 46. Tempo ranges in each session for subject C.

8.6.2 Descriptive detail of sessions

8.6.2.1 TIMP exercise selection

The focus throughout the six weeks of treatment was on improving proprioceptive feedback through the fingers by performing TIMP exercises that focused on distal movements and finger dexterity. The first five sessions included TIMP 11, which targets grip, release and ulnar deviation wrist movements, after which point exercises focused exclusively on pinch grip and finger dexterity using TIMP 8. 9 and 10 with all variations and finger combinations.

8.6.2.2 Tempo

As can be seen in table Table 46, subject C's tempo range began to increase from session 7 right through to the final session. This was possible as her quality and consistency of movement improved steadily. The tempo for TIMP 10 showed the widest range of tempo settings, 57-80, using various finger combinations. TIMP 9 tempo, using pinch grip to hold the plectrum, increased from 62-75, showing good improvement as initially this was a difficult exercise to perform. The pre-recorded music was not used in order to facilitate hand-over-hand support as this was not required. Sometimes the subject would rehearse a new finger combination for TIMP 10 without the music.

8.6.2.3 Monitoring progress

When using the plectrum, requiring 'pinch grip' using opposing thumb and index finger on the touch screen smartguitar for TIMP 9 in the first session, subject C could only manage to play four of the chords in the eight-chord sequence, but this soon increased to twice through the sequence without dropping the plectrum or adjusting her grip on it. In the second session she was able to complete three minutes of playing this pattern without dropping the plectrum or repositioning it once. In the same

session she began holding the plectrum using middle finger and thumb, but dropped it frequently. In session six she was able to use this finger combination and play twice through the sequence without dropping or repositioning the plectrum. Using TIMP 9a, b, c, d and e with the smartbass, the subject made rapid progress in improving finger coordination and in session three she reported playing four notes on the recorder for the first time since her stroke.

8.6.2.4 Subject self-selected goals

This subject's primary objective was to be able to play the recorder again, initially focusing on achieving the note 'C' requiring precise left and right hand finger coordination. Secondary to this was holding cutlery without dropping it in order to eat. The subject regularly volunteered information to the researcher in regard of these aims and demonstrated progress on the recorder.

8.6.3 Results

Subject C time-point for ARAT	ARAT score of 57	9HPT scores
Week 1 Pre treatment	35	1 in 120 seconds
Week 6 Post treatment	45	15 in 120 seconds
Week 9 Washout	49	All in 75 seconds
Week 15 Follow-up	48	All in 77 seconds
Week 18 Follow-up	50	All in 60 seconds

Table 47. ARAT and 9HPT scores for subject C

Table 47 shows that subject C made the most significant score increase in the ARAT out of all study participants pre and post treatment; +10 points. She also achieved the most significant improvement in the 9HPT, having only inserted a single peg in the pre treatment assessment, she achieved all pegs in 1 minute in the final follow up.

ARAT subscale	Week 1	Week 6	Week 9	Week 15	Week 18	Change (+/-)
Grasp (/18)	17	18	18	18	18	+ 1
Grip (/12)	7	11	12	12	12	+ 5
Pinch (/18)	4	7	10	9	11	+ 7
Gross (/9)	7	9	9	9	9	+ 2

Table 48. ARAT subscale scores for subject C.

The highest increase in score over the duration of the study for this subject was in the pinch subcategory, +7 (4 at baseline and 11 at final follow up, week 18), followed by the grip subscale, + 5. Both of these subcategories require greater finger dexterity, picking up and moving smaller objects using various finger combinations, which correspond with a wide range of ADLs.

ARAT subscale	Time to complete task	Time to complete task	Time to complete task
Grip	Week 1	Week 6	Week 9
Task 7	6.93s	4.58s	3.56s
Task 8	3.15s	3.5s	-
Task 9	4.32s	3.41s	-
Task 10	13.81s	9.72s	-
Pinch			
Task 11	Not completed	Not complete	60s (1) partially completed
Task 12	20.44s	15.31s	14.40s
Task 13	Not completed	Not complete	60s (1) partially completed
Task 14	Not completed	Not complete	31.67s
Task 15	13.87s	5.94s	10.86s

Task 16	4.35	4.25	13.46

Table 49. Subject C time taken to complete Grip and Pinch subscales.

As can be observed in Table 49 showing timings to complete ARAT tasks, there were significant improvements pre and post intervention in tasks 10 (+ 4.09 seconds), 12 (+ 5.13 seconds) and 15 (+ 7.93). Follow-up timings at week 9 for tasks 15 (- 4.92 seconds) and 16 (-9.21 seconds) were significantly slower, but task 14 (picking up ball bearing with middle finger and thumb) was completed, with difficulty, for the first time (31.67 seconds).

8.6.4 Summary

Subject C showed some disturbance in sustained attention and procedural memory over the period of treatment. There were no signs of anxiety, but a keen determination to regain musical skills. This subject's SES may have influenced her positive and sustained engagement, in addition to her prolonged musical training and high attainment of musical skills.

The majority of sessions focused on fine motor control using TIMP 8, 9 and 10, with TIMP 11 also used in the first five sessions in order to improve grasp and release. The results show the most improvement in ARAT subscales Grip and Pinch, which require not only elbow flexion and extension, but forearm pronation and supination, shoulder stabilizing and flexion, cylindrical grip and three-jaw chuck pinch grip using index, middle and ring fingers opposing the thumb. Grasp can be seen as largely intact for ARAT tasks 1-6. Pre and post treatment the grip subscale shows the most improvement, then pinch, which shows the most sustained improvement into week 9, up by 6 points from 4 to 10 out of 18 points.

8.7 Development of a new TIMP pattern variation

Subject C, whilst playing TIMP 9, placed the plectrum on the table surface and picked it up to play the chord sequence using her right, unaffected side. She did this in order to observe the difference in how it felt and looked between her affected and

unaffected side. Following this I suggested that she place the plectrum on the table top once more and pick it up using her affected side, rather than putting it into this hand using her unaffected hand. We continued to play through the pattern alternating left and right hand fingers. In addition, if the plectrum began to slip in her affected left hand fingers, she would reposition it by manipulating her left hand fingers, rather than reaching over to do this using her right hand.

8.8 Comparative discussion of Case studies

8.8.1 Severity of stroke

The effects experienced by subject A following his stroke were clearly more severe than for subjects B and C. His ARAT baseline score was significantly lower and showed the least post treatment increase. These factors alone concur with previous research findings, that report severity of stroke as being a major predictor of upper limb recovery (Coupar et al., 2012)

8.8.2 Socioeconomic status

The three case studies presented were of contrasting socioeconomic status (SES) (Savage et al., 2013), which has been reported as affecting motor recovery up to six months post stroke, which subject C was within (Putman et al., 2007). Subject C was of the highest SES and experienced better recovery than A and B, however she did not make any more effort through her own problem solving in her own time to find ways of improving recovery than the other two subjects, which has been reported as an influence of lower SES (Putman et al., 2007). Also reported by the same source, is a correlation between SES and anxiety levels and subject C did not display high anxiety to a level comparable with the other two case studies.

There was significant variation between the home environments of these three subjects. For Subjects A and B, space was limited, with sessions taking place in the kitchen and communal living area within small dwellings. In contrast, subject C's sessions took place in a room solely used by her for music. As such, subject C did not experience distractions from other home dwellers and in each session the researcher

was able to leave equipment set up rather than having to pack things away before setting other equipment up due to a lack of room to maneuver.

8.8.3 Musical training

Subject C was also a highly proficient musician, which may have provided her with more neurological resilience in terms of plasticity, with more bilateral cortical representation of left and right hands, which could be hypothesized with reference to recent research (Lotze et al., 2003; Grahn and Rowe, 2009; Pantev and Herholz, 2011). In complete contrast, subject A stated that he did not like music and could not play it, which did not have any observable effect on his sustained high level of motivation to engage in treatment, but may have influenced the potential for neural reorganization within the treatment period. Progress through the TIMP playing patterns to those requiring more demanding movement sequences such as TIMP 12 may also have been impaired by his not having any previous musical experience in a practical or listening capacity, thus affecting his facility to synchronise movements to the facilitating music and benefit from any effects on movement timing and quality.

8.8.4 Handedness

Subjects A and B were affected on their dominant side, meaning that they were able to perform TIMP exercises more readily, with more cortical representation of the affected hand. Subject B made a greater increase in her ARAT score than A. Subject C was required to focus on using her non-dominant left hand, but had received many years of musical training requiring bilateral hand use and potentially leading to more cortical representation of the non-dominant hand.

8.8.5 Mobility, mood and other medical complications

Subject A was frequently visited in his home by health professionals due to his complex health needs and restricted ambulation, which impacted on his mood (isolation) and fatigue levels. His wife also worked, meaning that he was left home alone for extended periods. Subject B also experienced complications requiring repeated visits to hospital and her GP, but her higher level of mobility enabled her to

visit extended family and spend more time in the garden and out of the house. Her husband did not work, thus she was less vulnerable to feelings of isolation related to mobility. On the other hand, she did experience difficulty communicating due to her dysarthria, which would be likely to cause feelings of isolation. Subject C was fully mobile, attended concerts and over the period of participation was able to gradually extend periods of working in her extended gardens. Subject A was, therefore, more at risk of negative impact on mood through isolation.

8.8.6 TIMP patterns

Of the three case studies, subjects B and C were the closest matched with regard to TIMP patterns used, with subject C playing the most complex variations, again possibly due to her musical training, academic attainment and age. Subject A was able to perform some fine motor exercises, but the main focus over the treatment period was on range of movement, specifically elbow extension, shoulder abduction and adduction. He was the subject out of these three who most consistently commented on how he was using the instruments as targets to improve his upper limb use.

8.8.7 Tempo

All three subjects were able to begin playing TIMP patterns at 50bpm, which is the slowest tempo setting for the pre-recorded patterns on the iPad, used as and when hand-over-hand support was required (48bpm was used by subject A). This tempo setting has been found to be a good starting point for a wide range of upper limb impairments in the researcher's clinical and research experience. The upper tempo range was 100bpm, used only for single thumb movements across the touchscreen guitar. All three subjects advanced to between 75 and 100bpm as their movements improved in timing and quality. The researcher was required to quickly synchronise his playing of all TIMP music to these changes in tempo, which is a skill not necessarily common to all music therapists and may require some additional practice in order to deliver treatment effectively.

8.8.8 Conclusion

Conclusions from discussion of these three subjects, based on observations and information recorded in the research diary and quantitative outcomes have implications for future TIMP research and treatment delivery. All case study subjects engaged with similar levels of sustained motivation and tolerance regardless of stroke severity, age, time post stroke, SES and musical training. Anxiety levels may have been higher for A and B in relation to their lower SES, but this would also be related to other health complications and effects of stroke such as emotional lability and dysarthria. Prior musical training may be advantageous for people with stroke, with Subject C, who presented with a similar degree of impairment to subject B who had no musical training, making the most significant improvement in upper limb function, specifically in finger dexterity using predominantly the fine motor TIMP exercises. Further research focusing on SES data and the influence of musical training on rehabilitation outcomes with hemiparetic stroke patients would be necessary to confirm their effects.

8.8.9 Relevance of the research to the literature reviewed

The need for new and effective upper limb interventions to address the heterogenous effects of hemiparesis is well documented. NHS trusts aim to provide community rehabilitation in stroke patients' homes and still have a long way to go in order to meet this target across all trusts and to meet the needs of patients. Home-based interventions have not been widely research and their feasibility and effects are not adequately understood. Musical instrument playing and the use of music and rhythm to cue movement and support kinematics have been found to be effective in a number of studies. The frequency of music-based treatments has been from three to five days per week, usually under laboratory conditions and without facilitating music.

This pilot study has investigated the effects of TIMP, a relatively new intervention for treating upper limb hemiparesis, on a cohort of 10 participants. All were recruited from within an NHS trust, adhering to all ethical requirments and making this one of the first UK biomedical research studies to be conducted by a music therapist within the NHS. Three new areas have been explored that previous research has not covered,

those being: 1) using facilitating music, 2) home-based treatment, 3) dosage of twice weekly.

9 CHAPTER 9. Discussion and future studies

9.1 Introduction

The following section presents a discussion of the positive outcomes and limitations of this study, and reflections on the process of designing this research. The challenging process of obtaining ethical approval through the Integrated Research Application System (IRAS) is reflected upon, which is necessary before any research can be conducted involving NHS patients. All forms submitted to the ethics committee for review, together with the letter of approval, can be found in the Appendix (see list of appendices). There is also some reflection on social and neuroscience models of research by music therapists, implications for training in order that music therapists can employ NMT techniques in practice and research and the role of the music therapist in research of this type, particularly in light of the MST studies and other research that has not involved a music therapist in treatment delivery. Finally, a brief outline is offered for a larger TIMP study, based on the process and results of this pilot study.

9.2 Positive outcomes

As described in the Results chapter, individual scores from the ARAT and 9HPT show good improvement for some participants. Overall, seven out of ten participants showed improvement with the ARAT. Participant one in the treatment group, who scored zero in all ARAT assessments, reported that he used his affected upper limb more in ADLs, and most of the cohort were able to comment on increased use in similar ways. Participants' linking the treatment and perceived degree of change with ADLs may have been due to delivery taking place in their homes, where ADLs are most relevant and present, which could be viewed as a very positive effect of this particular home-based intervention. The researcher enhanced this process by encouraging participants to make these links, a practice common in all clinical work where neurologic music therapy interventions are administered. The degree of motivation that participants showed was remarkable and equal amongst the cohort members, seemingly unhindered by degree of hemiparesis, any presence of psychological and emotional trauma or other physiological, cognitive or medical

complications. Engagement and adherence to treatment also seemed comparatively equal within this cohort, comprising diverse socioeconomic status. Visiting the homes of participants was a privalage and the researcher was made to feel most welcome in every instance and every visit, again regardless of the hardships any participant may have been facing. The support received from Cambridgeshire Community Service NHS trust and its staff for this study with regard to planning, recruitment and extra funding was second to none, and many of the participants repeatedly praised the input that they had received from the community stroke teams. The research host never lost his enthusiasm for music therapy and its potential benefits for patients. Such feedback from participants and support from the NHS trust compels me to find some means of sustaining and building on the partnership that came about from this study, and integrating music therapy services to further enhance their excellent, existing services.

9.2.1 Publications and conference presentations resulting from the research

Street, A. J. Magee, W. L. Odell-Miller, H. Bateman. A. Fachner, J. C. 2015. Home-based Neurologic Music Therapy for Upper Limb Rehabilitation with Stroke Patients at Community Rehabilitation Stage - a Feasibility Study Protocol. *Frontiers in Human Neuroscience*, [e-journal] 9 (00480)

O'Kelly, J.W. Magee. W. Street, A. Fachner, J. Drake, A. I. Cahen, J. Särkämö, T. Ridder, H. M. Jungblut, M. Melhuish, R. Taylor, D. 2014. Music Therapy Advances in Neuro-disability - Innovations in Research and Practice: Summary Report and Reflections on a Two-Day International Conference. *Voices: A World Forum for Music Therapy*, [e-journal] available at: https://voices.no/index.php/voices/article/view/742

Conference: Developing 12 exercises using musical instruments and facilitating music for stroke patients with ‘upper limb hemiparesis’. *Music Therapy Advances in Neurodisability II: Dialogues in neuroscience, research and clinical practice*. Royal Hospital for Neurodisability. London.

Conference: Music Therapy for the Rehabilitation of Upper Limb Function in Stroke Patients. *Music therapy Advances in Neurodisability: Innovations in Research and Practice.* Royal Hospital for Neurodisability. London.

9.2.2 Music and instruments

The music for each TIMP pattern was composed for guitar and in some cases is idiomatic to the instrument, for example TIMP 11, in a Spanish idiom and TIMP 12

for pronation and supination forearm rotation, which utilises glissandi chords. The guitar is the researcher's first instrument and it is also portable, suiting the home-based study design. The TIMP protocol might not be effective if implemented by non-guitarists, for example keyboard players, or clinicians who are not competent enough to achieve the technical demands of each TIMP pattern. However, a challenge to delivering this intervention in the home is finding a portable instrument that can deliver the dynamic, harmonic and melodic range that effectively serves the required function of the facilitating music; to cue the movement and muscle force and mirror movement trajectories in order to aid patients' synchronization of upper limb movements to the music. The Yoo study (Yoo, 2009) utilized an autoharp, which is an instrument that was recommended for use with RAS in the researcher's NMT training. The autoharp offers a wide range of harmonic and dynamic possibilities well suited to movement cueing and synchronization, but still requires a high degree of musical skill and without the flexibility offered by the guitar in terms of melodic contour and rhythmic variation (for example strumming and dudding the strings to create staccato effects and accentuate rhythmic patterns).

9.3 Music therapy: social science and neuroscience models in research

A dilemma for music therapists is whether or not to adopt more functional goal setting approaches in order to demonstrate outcomes for patients more clearly or develop goals specific to music therapy (Magee, 1999). Magee illustrates how music therapists are capable of working in unique and flexible ways in order to assess and then provide the most appropriate and effective exercises for patients, ranging from expressive forms of free improvisation to exercises using familiar songs with personal meaning for patients, structured to elicit and rehabilitate speech. Techniques for treating and assessing patients now being grouped under NMT and the MATADOC provide clear frameworks for music therapists to formulate goals and, in some cases such as with RAS, structured protocols for administering interventions that bring about clear, physiological change, which has been evidenced through clinical trials.

The researcher, having invested much thought, time and energy in a research project that aimed at both equipping him with the tools to conduct research and investigating the efficacy of a NMT intervention, finds himself fully invested in both the social and

neuroscience models. The uniqueness and flexiblility described by Magee of music therapy approaches should, in the researcher's opinion, go hand-in-hand with administering goal driven techniques.

Through clinical experience, NMT training and now completing a three-year research project, the researcher finds himself evermore the advocate of applying the appropriate assessment tools in order to determine the most appropriate interventions, and measuring responses with tools capable of accurately measuring post treatment outcomes. Only through following such processes together with MDT liaison can the music therapist determine and monitor the most effective intervention type, frequency and duration. Particularly in the field of neurodisability, clinicians are increasingly required to set rehabilitation or treatment goals and measure outcomes, which are then reported back to hospitals, commissioners, case managers and solicitors in order to justify and secure funding for further treatment if required.

Neurologic music therapy training can be completed by those who have not followed a masters level training in music therapy. Some NMT interventions, such as RAS and Melodic Intonation Therapy (MIT), are currently being administered by medical staff and other health professionals in hospitals around the world. MST research has not involved music therapists, which is why it was not included in the Cochrane review of 2011, but it has involved highly trained and experienced musicians in its development. Both MST and RAS are very structured and do not involve any musical interaction between therapist and patient. Sarkamo (Sarkamo et al., 2008) showed how passive use of music in the form of self-selected music listening can significantly improve mood and cognitive function in stroke patients. Again, no musical interaction was required between participant and therapist. TIMP requires interaction between therapist and patient, and, in addition, it requires the therapist to play in-time to a metronome. How TIMP compares to MST remains to be seen, but the questions raised through this brief discourse are firstly; does neurorehabilitation need music therapists; secondly, if music therapists do significantly enhance outcomes is this through their combined use of both the social science and neuroscientific models, or is the former redundant in such settings? These questions are put to music therapy clinicians experienced and just qualified and the music therapy training institutions around the UK.

At a conference recently attended, the researcher was asked by another music therapist, after presenting his paper on TIMP, whether he felt that NMT training was worth doing. The response was ‘yes, of course, why would’t a clinician want to acquire training that would help meet the needs of each and every referral, whether it be in the emotional or psychological domains, or that of physical function?’ In other words, there are many more tools available to meet diverse needs and some that can be applied as short-term interventions.

Based on previous and current, on-going music therapy research it is clear that the social science model cannot, at least for now, be superseded by a neuroscience model. The researcher hypothesises that as models such as those offered by NMT are derived from neuroscientific and biomedical research, music therapists will be increasingly able to apply the interventions under it’s wing, but there will be instances where such models and the social science models must work in unison, whether at assessment or treatment stage and certainly throughout monitoring of patient progress, as patients can identify and prioritise their own needs at different stages of recovery (Street, 2012).

9.4 Recruitment from the three NHS community stroke teams

Had the researcher been able to spend one or two days per week with each community stroke team, he may have been able to more accurately identify potential participants more quickly and speed up the process. This would have required in-house training to use the NHS database systems, which was not discussed at any length with the host NHS manager, nor was it seen in a positive light by the ethics committee, who requested specific detail regarding what information would be accessed by the researcher from the database (see Protocol in Appendix 1. 2 p. 296). These factors were further impacted by the time constraints experienced by all NHS staff involved, i.e. they did not have time available within their working hours in which to identify patients for the study, send them the letter of invitation or contact the researcher in order to discuss their suitability within the prescribed inclusion criteria. All three stroke teams involved in recruitment had a folder containing 1) list of

inclusion/exclusion criteria, 2) participant information sheet (for their own information, not to send out), 3) envelopes and stamps. The researcher had an honorary research contract with the NHS trust, but it is likely that had he already been in the employment of the trust he would have been able to more effectively manage recruitment.

9.5 Assessment tools

There were times where the sensitivity of the assessment tools came into question and the variables presented by home environments with different seating and table heights, which compromise standardization of assessment delivery. In order to adapt round or oval tables in participants' homes to fit the oblong ARAT mat onto, which has the marks on it for the start and end target positions of each object to be lifted and moved, a wooden board was used, with two clamps that enabled it to be fixed securely and without causing damage to table surfaces.

A tool capable of detecting more subtle change in upper limb movement range and quality would be useful for a study such as this. The MST studies discussed throughout this thesis utilized several assessment tools as well as motion capture in order to assess on a much more sensitive level. Some patients in this study weren't able to lift the wooden blocks, particularly the larger one, and then extend their arm whilst holding it towards the table/shelf initially, but at the end of treatment they could. However, this still equates to a score of 1, as they were unable to complete the task by placing and releasing the block onto the shelf. For the stroke patient this increase in movement range may constitute significant progress as the implications for ADLs mean that they are more able to reach items, operate light switches, etc, that were previously not manageable. Whilst conducting the ARAT follow-up assessments post treatment, the researcher felt that it was important to feedback to participants that they had not failed or made little progress, but should continue trying to improve movement through daily use of the affected upper limb.

The question as to whether there should be a recommended upper limb assessment score for inclusion in such a study or for TIMP referral requires further comment. The MST groups had baseline scores of approximately 33 to 37 out of 57, some of the

baseline scores in this study were much lower, for example four of the participants scored 0, 8, 12 and 18 respectively, and all showed little or no improvement post treatment. With one participant scoring lower in the ARAT. Scores are influenced by the age of patient, with older patients sometimes scoring lower due to arthritis and speed of task performance, as well as visual and cognitive impairment in some cases. However, other older participants had less impairment and scored highly, leading to the conclusion that age was not a predictor of assessment scores but severity of stroke and possibly the lesion sites. Timing each task in the ARAT allows some measure of change in the quality of movements, particularly movement speed, with implications for indicating improved kinematics.

As previously mentioned, standard outcome measures for upper limb function such as the 9HPT, ARAT work well in recording reaching and grasping tasks which imitate ADLs, but do not accurately record qualitative changes in movement in the way that motion capture technology does, which is becoming increasingly affordable and portable. Studies using such technology, in portable form, have found that more than eight weeks post stroke upper limb rehabilitation shows further changes, but that these are not detected using standard assessment tools (de Groot, et al., 2012).

One study (Houwink et al., 2013) found that participants who could slide an object with their hand across a table using active control of the shoulder and elbow, which equates to a Stroke Upper Limb Capacity Scale (SULCS) score of at least 3, had a better prognosis for recovery by the time of discharge from rehabilitations centres than those lacking this capacity, and recommended that patients who can perform this task be offered intensive training to facilitate functional upper limb recovery. This research is optimistic towards potential hand recovery in the long-term for such patients, even in cases where there is minimal proximal shoulder and elbow control, but exactly what period ‘long-term’ this would be is unclear; possibly beyond 13 weeks (Houwink et al., 2013). One participant in this TIMP study (participant 1) showed no recovery of hand control and could not at any point lift an item to achieve a score of 1 in the ARAT before or after participation. In order to achieve a score of 1 in the first subsection some form of finger grasp and lifting of the object is required. If participants are able to reach and move the object across the table surface but not grasp and lift it, the score is 0. This participant showed great motivation and

improvement of upper limb range of movement whilst performing the TIMP exercises and attempted the third component of the fourth subcategory, touching his mouth but not with his palm. The ARAT scoring system does not facilitate the performance of the third gross movement task if the first cannot be performed correctly using the palm and this participant could not perform this nor did he perform the third entirely correctly, but he did manage to touch his hand to mouth, which has implications for improved ADLs. There are also implications for referral to rehabilitation programs, determined by which assessment is used, i.e. The SULCS score of this participant may have led to his entering into an intensive rehabilitation program, whereas his ARAT score would not have.

The 9HPT was useful for those who could achieve pinch grip and had some forearm rotation, but without both of these movements they could not achieve more than one or two pegs within the designated timeframe of two minutes.
This assessment tool was used as there was a need to measure finger dexterity specifically. Participants with minimal finger movement were unable to complete the assessment pre or post treatment, but some were able to place more pegs into the holes following treatment (participants 2 and 10, see Table 28). Participants with more fine motor control were able to complete the assessment, but those with more impaired forearm rotation and higher spasticity were less able to place the pegs into the holes, but able to pick up the pegs in some cases. Dystonia and tremors also impaired performance of this task.

A goniometer would have detected changes in range of movement by measuring joint angles at the shoulder, elbow, wrist and fingers. The goniometer was seen by the first ethics committee as too unreliable and requiring specialist training to be used effectively. The researcher consulted the clinical lead of one of the stroke teams, who confirmed that he could have been easily trained in its application.

Motion capture technology, which is available in portable configurations but beyond the limits of this research budget, would have provided the most precise data on movement trajectory, range and timing. This would have given qualitative data in terms of movement kinematics, which cannot be detected using standard assessment tools; only observed by the therapist administering the assessment.

The ethics committee would not approve the use of motion capture and EEG, which would have provided accurate data on movement quality and neural reorganization, because they saw the intervention (TIMP) and music therapy with this population in general as too novel, were concerned that the researcher would ask too much of participants as they would have needed to attend ARU labs at two time-points, and they felt that EEG was an outmoded method that would not provide valuable data. Had motion capture been approved, funding would have been required to transport participant to and from the ARU lab or to purchase portable equipment to transport in to participants' homes. Costs were calculated for these transportation costs and a request made to Anglia Ruskin University for funding in the event that the proposal received a favourable opinion from the ethics committee. The university confirmed that funding would not be available to cover participants' transport costs. The visual eye research lab agreed, provisionally, to the use of one of their motion capture labs and provided some training in its use to the researcher. Training was also undertaken in order to use the EEG lab.

9.5.1 Alternative outcome measures

From a purely scientific, as opposed to clinical, perspective motion capture technology (MOCAP) employing 3-D cameras and movement sensors or ultrasonic markers such as the Zebris system used in previous research of this type (Schneider et al., 2007; Altenmüller et al., 2009; Järvinen-Lepistö, P., Burger, B., Ala-Ruona. E., 2014) would focus on measuring changes in movement kinematics and joint range rather than ADL related outcomes. The latter outcomes, targeted using the ARAT, can be negatively affected by visual impairment and arthritis. In particular, MOCAP systems can provide accurate data regarding smoothness of movement trajectories, which standard assessment tools such as the ARAT cannot provide and which are an important influence of TIMP.

9.6 Reflections

9.6.1 Ethics

The researcher registered for this PhD on 17/09/2012 and the first IRAS on-line application form was opened on 16/10/2012. Following two applications via IRAS and two ethics review meetings with different regional committees, the researcher was advised by the second committee that because the proposed study fell into the category of biomedical research a detailed protocol would need to be written and submitted in addition to the IRAS form. The committee who first reviewed this study had not informed the researcher that such detail would be required and were criticized for this by the second committee. The third application was submitted with a 30-page protocol and the omission of EEG and MOCAP. Following some minor amendments the second committee approved the application and recruitment could begin.

Meetings with the Ethics committee took place as follows:

1. 10/05/2013 Frenchay national research ethics service – unfavourable opinion
2. 01/08/2013 Essex national research ethics service – unfavourable opinion
3. 05/12/2013 Essex national research ethics service – favourable opinion following minor amendments

Favourable opinion was granted on 17/01/2014 and the first participant began treatment on 11/04/2014.

Whilst immersed in the process of IRAS application the researcher was also required to fulfill certain criteria with the NHS trust hosting the research, including obtaining a research passport and fulfilling health check requirements. Approval from the trust's research and development department was also obtained.

The researcher wonders whether the unfamiliarity of the ethics committee members with music therapy and music therapy as any kind of intervention for stroke induced hemiparesis might have influenced decisions regarding the approval of this study and granting the opinion that the research protocol was ethically sound; separate from the

study design. The fact that no questions were asked by the panel about the protocol (the actual TIMP exercises) and the focus was on the research design, access to patient records, assessment tools and frequency might indicate this, i.e. the panel members asked about what they knew, rather than what they perhaps knew nothing about. One of the initial problems with the ethics application was the primary outcome measure (goniometer), which the first committee deemed as inaccurate and requiring specialist training and knowledge in order to obtain accurate data. This tool was used in a previous, similar music therapy study and assessments were conducted by an occupational therapist whilst the music therapist delivered the intervention (Paul and Ramsey, 1998). The host stroke teams did not use any specific assessments with patients, so the ARAT was selected based on it's use in research similar to this study and its standardization for use, which required no specialist training. The ARAT also reproduces ADLs and so was considered an appropriate tool for measuring outcomes.

Once favourable opinion was granted, all procedures laid out in the protocol were strictly adhered to, whereby the host community stroke teams contacted all potential participants by letter, who were then able to contact the researcher in order to enquire about the study and arrange a meeting if interested. Forms and letters used in the study went through consultation with the research host manager and university academic supervisors, as well as a group called Aspire, who are professionals and patients that volunteer to check research forms and procedures during the research design period and feedback to researchers.

9.6.2 Blind assessor

The scientific report submitted with the ethics application recommended that assessments be conducted by an assessor blind to participant allocation, and the ethics committee requested that provision be made for this. The researcher spent some considerable time researching options for this prior to the ethical review and was unable to secure an assessor. CCS, the host to this study, kindly offered to fund this provision and were able to allocate a therapist from their employees. CCS initially sourced two blind assessors who were ex-NHS occupational therapists and very experienced as both clinicians and research assistants. The researcher was required to

take them through the research passport application procedure and train them in standardized use of the ARAT. Following this, both therapists were unable to continue due to complications in their relationship with the host. Another blind assessor was sourced, who completed all assessments following training with the researcher. Whilst it was clearly an advantage to the study that funding was provided by CCS for a therapist to conduct pre and post treatment assessments, the process of seeking out and appointing one had some complications, which was time consuming in addition to the time taken to obtain ethical approval via IRAS.

9.6.3 The influence of previous, similar research on treatment delivery

One of the main influences on delivery of treatment in participants' homes was the MST studies. Because these studies employed the use of an electronic drum kit that was permanently set up in a lab, participants returned to targets arranged at the same distance and height each session and this provided references for both participants and researchers that indicated whether movements were improving in range or not and if improvement was consistent. Using the equipment for this study the researcher was aware from the offset that each home environment would be very different and that there was no way of reliably recording spatial positioning of instruments. Immediately after starting with participant two the researcher began using a tape measure to help give a rough indication of how much further instruments were being positioned from participants in order to facilitate greater range of movement. However, this proved unfeasible for every participant in all sessions as there was not enough time. On the one hand positioning and moving instruments in this way may have seemed less daunting for participants as they would have between one and four targets at any one time with the gross motor exercises, eight with fine motor, rather than eight at all times in front of them, as was the case with MST studies.

9.6.4 The influence of session length on treatment delivery

One hour was projected for each session, including setting up and taking down equipment and general notes (some notes were added post sessions). The majority of participants could have played for longer, or required more time in order to allow for breaks before continuing. With the repositioning of instruments the researcher felt

that more time would have been beneficial for participants, for example an hour and a half, in order that participants could have had more breaks, particularly in earlier sessions, where stamina was still developing as well as familiarity with the patterns, equipment and protocol. For those who could access the iPads, the researcher usually packed away the acoustic instruments whilst they had a break, then brought over the iPads for them to play, thus using settting up time to provide a break and using time more efficiently.

9.6.5 Playing time in each session

Participants played for 15 to 30 minutes each session, not including breaks for rest, setting up and repositioning. Due to the amount of time required to set up and position equipment, adjust the metronome, put the ear piece in, sit with the guitar (this was sometimes an aspect requiring more thought, as the researcher's playing movements and visual cues, such as swaying or foot tapping in time, provided visual cues to aid participants' synchronization), there was felt to be some urgency in getting participants to play as much as possible. Because of this the researcher did not always set the timer (stopwatch) at the start of each interaction to record episodes of playing. However, the majority of participants were timed in most of their sessions for each episode of playing.

9.6.6 Usefulness of the prerecorded music

The pre-recorded versions of the TIMP music for each TIMP exercise was an essential element as some participants required hand-over-hand support early on, in the first session or when a new pattern was introduced. This was in order to guide a movement that was less compensatory, for example reaching up to play the cymbal using more normal arm extension rather than using the trunk, which needed to be supported. Ideally, another therapist, such as an occupational therapist, would have been present in order to provide this support while the researcher continued playing the music. One participant was regularly supported in his playing by his wife, after the researcher had demonstrated how to guide the movement.

Sometimes the researcher played along live with the music playing from the iPad, while the participant played, creating a trio where the researcher could either emphasise the pulse and force cues (by building the intensity) or embellish the music with the aim of building or sustaining motivation and engagement. This prompted positive feedback from some participants.

9.7 The role of the music therapist in research of this type

For TIMP treatment design and delivery a high level of musical skill is demanded of the music therapist. In equal measure, therapeutic skills are required in listening and observation, with a capacity to respond to participants, whether musically or verbally, with sensitivity and empathy, all of which are the fundamental aims of music therapy masters training programs (this was discussed in the case studies chapter).

Whilst in this study TIMP music and exercises adhered to a protocol and participants had to synchronise to the music, there were times with each participant and in every session where the researcher needed to adjust musical parameters in order to assist participants in synchronising, re-synchronising, sustaining performance and motivation. This can only be reported based on the researcher's experience, training and observations throughout this study. Whether or not other music therapists and NMTs would agree that patients respond to increases in musical intensity with prolonged engagement, more accurate synchronization and improved movement kinematics, remains to be discovered through further case study reports and research. Whilst delivering RAS and TIMP to patients as part of his clinical caseload the researcher has worked conjointly with physiotherapists and found that this combination of training and experience best meets patient needs, if not in all sessions at least in initial ones and at some point before the end of treatment or where progress demands new input in order to update objectives and goals.

9.8 Discussion of TIMP music composition and selection

The process of composition for some TIMP patterns began through the researcher's application in clinical work of TIMP with adults with acquired brain injury. This experience led to the development of music patterns to support some upper limb

exercises similar to those used in this research to address hemiparesis. The recording of preliminary music patterns for this study and rehearsal of upper limb movements in synchrony with it was conducted by the researcher prior to trialing with the volunteer stroke patient. This process allowed exploration of how the music was representing movement trajectories, cueing and mirroring each sequence of movements. Following this the volunteer stroke patient completed 6 weeks of twice weekly TIMP, in keeping with the study design, over which time the researcher was able to observe how the music supported each exercise and obtain feedback from the volunteer regarding her experience of treatment. Modification of the music patterns then followed, resulting in the table of 12 patterns and variations used in this study. The specifically composed musical patterns can be manipulated freely by means of rhythmic strumming, arpeggiating chords, and accenting notes and chords using techniques idiomatic to the guitar, but also transferrable onto other harmonic instruments such as keyboards and, to a degree, autoharp. Simple variations, four of which are notated for TIMP 5, 6, 10 and 12 (Notation v, Notation vii, Notation xi, Notation xiv), may serve to sustain participant motivation and adherence, particularly for those who have previous musical training or who can meet the movement timing demands without becoming distracted by such variations due to impaired attention or sensory processing.

Whilst digitally sequenced music and metronomes have been found to effectively support improved synchronization and movement timing for tapping exercises (Drake, Penel and Bigand, 2000; Malcolm, Massie and Thaut, 2009a), participants in this study were required to play a range of musical instruments, including touch screen devices, with improved movement kinematics as part of real-time musical interactions and so it was considered more appropriate and potentially more effective to use facilitating music performed live. It should also be noted that other exercises required complex movement sequences, such as TIMP 11 and 12, which stroke patients find particularly challenging and frustrating. Rather than using a metronome, such movements are better supported by musical patterns that include dynamic contours to help cue the muscle force and trajectory, as well as motivate participants and help sustain focus. Harmonic progressions such as I, VI, IV, V (see TIMP 3 & 4), played with a clearly pulsed, simple rhythm meet relevant published recommendations (Grahn and Brett, 2007; Thaut, 2008; Abrams et al., 2013), aiming to maximize the potential for participants to anticipate melodic and harmonic patterns

and quickly synchronise the required movement patterns to them. Where possible pitch and dynamic contours serve to mirror extension (forward reaching), flexion (retracting arm movements), ascending and descending, and lateral arm movements, which is supported by existing research (Meijer, 1992; Eitan and Granot, 2006; Hidaka et al., 2013; Scholz et al., 2014).

The exclusion of pre-composed music, with the exception of TIMP 7, was intended to avoid distraction due to participants' personal associations or tastes; to reduce complexity in the musical frameworks, and because the researcher hypothesized that specifically composed music tailored to each movement pattern or sequence of movements would provide more support as a mirroring of muscle force and movement trajectories for participants to synchronise their movements to. The distraction sometimes elicited by songs or familiar music has been discussed earlier in relation to other research (Abrams et al., 2013) and the researcher's clinical experience as a music therapist. Furthermore, manipulating the tempo of precomposed, pre-recorded music is not possible and is a requirement in order to match the tempo to participants' existing frequency of upper limb movement. The Frere Jacques music was selected because it is a widely recognised, predictably structured melody, without links with popular culture (rather like a folk tune) and potentially less likely to offend personal preference or hold strong, negative personal associations for participants. Participants do not play the melody, but the harmonic accompaniment, allowing two levels of difficulty; playing the 'ding, dang, dong' section, requiring faster finger movements, with either 1) the unaffected hand or 2) the affected hand.

9.9 TIMP and MST

MST studies have reported significant gains for participants and did not include any music or other auditory cue to facilitate exercises. It has been reported by one of the MST authors that clarity is still required as to whether predictability and timing regularity play a crucial role in supporting MST exercises (Altenmüller and Schlaug, 2013a). The beneficial effects of MST have been repeatedly linked to the process of audio-motor coupling, where auditory, motor and proprioceptive neural networks become more integrated due to the auditory feedback that the participants received

from the instruments that they played (Schneider et al., 2007; Altenmüller et al., 2009; Rojo et al., 2011; Rodriguez-fornells et al., 2012; Grau-Sánchez et al., 2013; Amengual et al., 2013). The auditory feedback serves to correct errors, adjust timing and refine motor representations (Francois et al., 2015). In addition, facilitating music adds a further variable to any music-based intervention and, alongside MST might appear unnecessary, with limited evidence to support it's effects on upper limb hemiparesis within TIMP or similar protocols (Yoo, 2009).

Based on previous clinical experience and conducting this pilot study, the researcher suggests that in order to meet the heterogeneic population, including individual preferences and pathologies, an appropriate intervention, for example MST or TIMP, should be selected following assessment. For some patients, facilitating music will be preferred or necessary in order to motivate and address deficits in initiation of movement, movement timing and proprioception, for others it could cause a distraction and be detrimental to treatment effects that may come about through unaccompanied instrumental exercises. Some participants in this study, who initially struggled to coordinate their movements in order to perform an exercise, played without music in order to rehearse the required movements, after which the facilitating music was added for more extensive repetition. If no music is used, then the intervention should follow the MST protocol, possibly adapting the folk songs used to suit the culture of the patient and using the same equipment. Particularly pertinent to a comparison between TIMP and MST is the use of electronic drums that trigger different notes, which can be played to create melodies. It would be reasonable to assume that this would be more motivating for some patients than hitting and hearing acoustic drums and requires the auditory processing of pitch and melody as well as rhythm, which may more effectively drive audio-motor coupling.

9.10 Instrument selection for fine motor exercises

Particularly relevant to this study was the sourcing of portable instruments, suitable for use in various home environments, which can target fine motor, finger flexion and extension movements and effectively improve dexterity and movement trajectories in ways that improve ADLs. In addition, the inclusion of exercises requiring use of a plectrum held with a pinch grip, which can be performed using index, middle or ring

finger opposing the thumb, enabled participants to exercise this specific grip whilst playing music. Changes in pinch grip performance could then be recorded using the pinch subscale of the ARAT and the 9HPT. Using a touchscreen plectrum and touchscreen smartguitar met the need for portability and potential preferences of participants for more contemporary instrumental sounds such as electric guitar and bass. Also, the physical effort required in order to strum a plectrum across real guitar strings is greater than that required using a touchscreen guitar. Positioning a real guitar is much more complicated than for an iPad or tablet, as there are no commercially available guitar stands offering the spatial arrangements and positioning that the iPad stands used for this study do. Guitars do not rest securely on table surfaces as their backs are slightly convex, causing the instrument to rock and slide around. Plectrums can also be easily dropped between the strings of a guitar directly into the soundhole, which can be tricky to retrieve and potentially more frustrating for participants. Without the resonant Bluetooth speaker, the sounds generated from iPad built in speakers would not have given sufficient auditory and tactile feedback for participants and its use is recommended for similar clinical or research work in conjunction with tablets and touchscreen instruments.

9.11 iPads and other devices for fine motor control and finger dexterity

Through the course of this study the movements that presented the most challenges with regard to instruments and equipment were distal, such as wrist and forearm rotation and wrist ulnar deviation, and finger extension and flexion. The iPads are extremely flexible and accessible tools and provide good audio, visual and tactile feedback when connected to an external speaker such as that used for this study, which is extremely resonant, particularly when participants played with the iPad and speaker on a table surface. One problem that did frequently occur with the iPad was accidental activation of other touch screen menus and functions. Unfortunately it is not possible to deactivate all of these in both the Garageband and the Thumbjam music software. In order to address this problem the researcher was vigilant with regard to touchscreen instruments suddenly not responding or sounds changing, the best way of doing this was being able to see the screen as each participant played. For participants with only very slight finger movement, the iPads were not effective and could not be activated. Single switches or sensors, which could be mounted on

stands and table surfaces in flexible ways and that respond to subtle finger movements, triggering a range of sounds, would be more effective and accessible to more severely impaired patients. This problem was similarly reported in a previous study (Schneider et al., 2007).

9.12 Future TIMP research for fine motor movement

A study that specifically investigates finger movements using a metronome or rhythm only for cueing priming and timing of movements compared to complete musical patterns, building on evidence from previous research (Drake, Penel and Bigand, 2000), would help identify which best supports these much finer, more complex motor movements compared to those employing larger, proximal muscle groups. Whilst some reports state that time since stroke is not a predictor of hand recovery (Coupar et al., 2012), others state that in up to 70% of stroke cases where there is some recovery of hand movement at four weeks post stroke have a high possibility of regaining full or good hand use (Medscape, 2013). So, whilst being highly resistant to treatment, particularly where there is minimal use, developing interventions for improving hand function, including finger flexion, extension and dexterity, should be a priority. Meaningful and motivating tasks using the fingers that elicit high repetition require more specialized and sensitive equipment, and this is an area requiring further, more focused research and development. Previous studies focusing specifically on improving hand function have included participants with mild to moderate impairment and used standard midi keyboards and roll-up keyboards (Villeneuve and Penhune, 2014; Floris Tijmen and Jens, 2014), but, in the researcher's experience, this equipment is not accessible to those with more severe impairment and limited finger movement and so cannot facilitate effective exercises.

9.13 Additional participant information relevant to results

The information given below helps to clarify the results of the data analysis for this pilot study, and informs criteria for future TIMP studies in areas such as inclusion criteria and assessment tools.

9.13.1 Treatment group

Participant one did not develop any fine motor movement nor was he able to perform voluntary grip or release at any point in the study and was unable to pick up any item in the ARAT assessments. He was able to hold a drumstick in order to perform TIMP exercises, which he would push into his affected hand using his unaffected one. During exercises, which included only large motor movements (TIMP 1-5), the participant's range of movement, particularly in the shoulder, was observed by the researcher to improve. The participant was particularly motivated by the treatment, finding it enjoyable, supportive and perceiving and reporting it to have improved his upper limb use in ADLs much more than his outcome scores reflected. For this participant in particular, more sensitive assessment tools such as 3-D motion capture may have indicated improvement due to treatment effects.

Participant two shows some inconsistent changes in scores, managing to insert one peg at points one and two, none at point four and four at point five. The pinch subscale of the ARAT shows that he could consistently pick up the marble using thumb or middle finger and index, but this task required accurate placement of pegs into holes. Over the assessment period reported here the participant was unable to develop enough fine movement control and combined grip, arm extension and release in order to perform such tasks. In addition, the participant suffered from tremors, which required a pause in activity in order to ameliorate.

Participant three's post treatment ARAT score increased by three points, which were all in the grasp subscale. Fine motor control did not show any improvement in scores, with the ARAT pinch subscale maintaining the same score throughout the five measures and 9HPT scores dropping slightly post treatment and improving by the final measure. Timings for pinch subscale did improve (see Table 1) from 97.1 secs to 64.51 post treatment, a 32.59 sec increase. This participant suffered from dystonia in addition to hemiparesis, causing unintentional movement in the effected arm when performing tasks and presenting a further challenge during assessments and treatment. Onset of dystonic movements was unpredictable and varied in severity from day to day. This was reported by the participant and observed by the researcher. The

researcher also observed that these unintentional movements would diminish whilst the participant was playing to strongly pulsed music during TIMP exercises.

Assessment number	1	2	3	4	5
ARAT pinch timing (secs)	97.1	64.51	74.5	52.33	69.51

Table 50. ARAT 'Pinch' subscale scores for participant three.

Participant four suffered from high spasticity and had never received any pharmacological intervention such as Baclofen or Botox at any point over the four-year post stroke period. This meant that her assessment scores were much lower than most other participants and did not show any improvement over the duration of the study. Post treatment ARAT scores dropped from 8 to 4, before rising again to 8, 9, the 8. The participant frequently reported shoulder pain on the affected side, which may have been exacerbated by the treatment, but also due to daily swimming.

Participant five improved by four points in the ARAT post treatment, which dropped at timepoints four and five possibly due to Botox wearing off (as reported by the participant). She had received a Botox injection approximately one month before beginning the study and also took Baclofen orally three times per day. Improvements were in the ARAT pinch subscale (3 points) and grasp section (1 point). The 9HPT was too difficult for this participant. Due to a particularly high level of motivation and tolerance, good baseline and post treatment scores, and good movement timing during finger exercises (TIMP 6-10) the researcher believes that this participant may have improved had she received more intensive (three or more times per week) treatment over a longer period, with more practice of forearm pronation supination and wrist ulnar deviation (TIMP 11 and 12).

Participant six showed the most improvement in ARAT and 9HPT scores out of all participants, which was sustained over the five timepoints. She was the only participant to improve in both outcome measures so significantly and was able to tolerate high levels of repetitive finger exercises (TIMP 6-10). The improvement may have been attributed to her time since stroke (three months), severity (moderate with loss of sensation in fingers) and high degree of musical training.

9.13.2 Wait list group

Participant one in the waitlist scored second highest in the study for ARAT, achieving an increase of seven, from 43 to 50. As can be seen in Table 28 by the final 9HPT participant one completed the task in just under a minute. The previous, end of treatment test, scored much lower, with only five pins inserted in sixty seconds. The blind assessor felt that this was due to visual problems experienced on that day. The participant was due to receive pharmacological intervention the following day for her visual problems, which may have impacted on the improved final score. However measures two and three also indicate a gradual improvement, which may have been due to spontaneous recovery and assessment practice effects.

Participant two in the waitlist had a bilateral stroke, but his left side showed more impairment in upper limb function as well as some visual neglect or proprioceptive impairment on the left. In addition this participant suffered considerable cognitive deficits, presenting at times as highly disorientated and requiring a high level of prompting in order to carry out each task in the ARAT. He also suffered a TIA between the first and second assessments and the ARAT scores reflect deterioration in bilateral upper limb function. Both sides scored higher in the third assessment, indicating recovery, although this may have been more in the cognitive domain than sensorimotor. The neglect affected his performance in assessment as he could not judge distances to pick up and place objects on his left. His post treatment score dropped by three points, which may also have been due to cognitive issues.

Participant four suffered from high spasticity. His pre-treatment ARAT score was low, increasing by four points post treatment. His degree of finger dexterity did not allow him to score using the 9HPT. Improvements were in the pinch subscale where

he was able to begin picking up smaller objects using index finger and thumb, and in the grasp subscale, where he was able to pick up the smallest block more easily and complete this task more quickly. The ARAT scores indicate improved pinch grip and elbow extension. The low score in the 9HPT was due to lack of forearm pronation supination, which was observably improving as the participant played TIMP 12 during sessions. The participant received a Botox injection approximately one month prior to beginning treatment.

9.14 Outliers

As pointed out in some of the literature for music therapy research, outliers can help identify suitability of treatment within the included population and should not be ignored (Wheeler, 2005). As can be seen in the quantitative results participant one, also discussed in this chapter, was the only participant who did not achieve a score on the ARAT. It is important to acknowledge and explain the reasons for his zero ARAT score, inclusion in the study and response to the intervention. The zero score was not due to an error in the data or data collection, but the sensitivity of the ARAT. The subject was included in the study as he was identified by the community stroke team as meeting the inclusion criteria. The researcher observed in the home visit that the participant was able to perform a range of movements enabling access to the instruments and that he might be able to improve shoulder and elbow range of movement and score in the gross movement subsection of the ARAT. The participant observed over the course of treatment that he was able to perform more ADLs and reflected this in his post treatment Likert rating. This outlier, therefore, represents a member of this cohort and patient population that could benefit from TIMP following the protocol under investigation and for whom gains could be recorded using more sensitive assessment tools such as MOCAP.

9.15 Limitations

9.15.1 Sample size

The ethics committee approved recruitment of 14 participants within the timeframe for this study. The sample size was calculated through discussions with academic supervisors and the NHS host manager, through which it was decided that such a

number would allow investigation into the management of treatment delivery, since this was in participants' homes and presented new challenges when compared to standard care community rehabilitation. The number was also deemed large enough to represent the heterogeneity of the patient population, and a manageable number given the time and resource constraints of the NHS community stroke teams identifying suitable patients and a three year PhD. This sample size was not large enough to derive statistical significance, but the intention in addition to measuring intervention effects was to test feasibility and pilot the protocol for the intervention in the home setting.

9.15.2 Inclusion criteria

The criteria for inclusion was broad in terms of time since stroke, introducing enormous variability regarding potential learned disuse and misuse (maladaptive plasticity) between participants. However, this criteria is in keeping with other recent research of a similar nature (Bunketorp Kall et al., 2012; Villeneuve and Penhune, 2014).

The amount of community rehabilitation that each participant had received was also not controlled for, as there were such variations between each patient and each stroke team in this regard. In other words, standard care was not clearly defined from patient to patient and between stroke teams, as patients present with such unique individual needs. This may explain why the review of research into home-based stroke rehabilitation reported insufficient detail in treatment protocols (Fens et al., 2013). Factors affecting the duration and intensity of rehabilitation for each participant were such things as the approach of the therapist whose caseload they were under, the degree of proactivity in securing continued rehabilitation of each patient and the availability of therapists to deliver treatment either in patients' homes or at specific centres where the patient would have to go to.

The possibility of setting a minimum ARAT score for inclusion in the study was discussed with the supervisory team, as well as other NMTs and therapists from the stroke team. This was not considered feasible due to the constraints of time and resources. Funding was not available to provide assessments for patients put forward

for the study by the stroke teams and if it had been then this would have significantly lengthened the recruitment process.

9.15.3 Qualitative analysis

The extracting of themes by the researcher may have produced some bias towards themes related to music therapy, or commonly associated with the profession by its members. An example of this would be 'relationship' (post-treatment), based on responses such as 'it was nice having one-to-one attention', or 'it was nice, as we played I could pick up the music'. It might have been possible to extract the sub-theme of 'reducing isolation' or 'learning through practice' perhaps from these responses. However, with the additional sub-themes 'musical interaction' and 'support' included in the table, the researcher does not feel that the extracting of these themes undermines or biases the focus intended by the question design, nor do these themes appear particularly inappropriate based on participant repsonses.

An improvement in this aspect for future research would be to have a blind assessor deliver the semi-structured interviews and an independent statistician, psychologist or analyst conduct the thematic analysis.

9.16 Preliminary thoughts for a larger TIMP study

9.16.1 Introduction

The following section provides a preliminary outline research proposal for a larger study with chronic stroke patients, which is based on the outcomes of this pilot study. The researcher understands that in order to formulate an effective research design, discussions would need to be held with study hosts, academic staff and a statistician, with a power calculation for sample size provided.

Designing larger studies within the NHS, particularly multi-site studies, is a complicated process requiring regular communication between diverse geographical sites and with managers and staff who are already under enormous pressure to fulfill their duties within the NHS. NHS trusts are also undergoing significant structural changes, including the contracting out of service provisions to private sector service providers through competitive process. The researcher has already attended several meetings with the NHS trust that hosted this pilot study and other members and researchers in his team, where the problems of recruitment and ethics have been discussed at length. These discussions continue and there is a need to find practical solutions that enable adequate recruitment numbers. Recruitment must be allowed to progress without compromising patient safety or confidentiality. All ethical requirements must be met throughout research design and recruitment in order that unbiased research can be conducted effectively for the benefit of patients and rehabilitation services.

9.16.2 Research design

The researcher proposes a RCT comparing standard community rehabilitation and TIMP plus standard community rehabilitation. The experimental group would receive TIMP twice per week. Participants would be recruited as soon as referred to community services and randomized into one of two groups for home-based treatment:

A standard care
B standard care + 2 X TIMP per week.

The researcher proposes that participants are recruited through a maximum of three geographically separate NHS sites in England. This would be in order to ensure adequate numbers within a timeframe of approximately five years for completing data collection (this period would depend on the power calculation and research team staffing levels).
The design for the research would need to be discussed with the statistician appointed for analysis of data before being finalized, in order to answer the research question with a robust design and means of analysis. Only through such a process could reliable results be produced through a repeatable experiment that reflects group treatment outcomes.

9.16.3 Research team for recruitment, treatment, data collection, analysis

The researcher would coordinate the research and train music therapists in TIMP and how to use the TIMP table of exercises.

In order to effectively recruit, deliver treatment and conduct assessments the researcher proposes that a team be assembled including:

- 3 recruiters/stroke team liaison contacts: one person on each site for at least one day per week in order to help identify and contact potential participants and to liaise with rehabilitation team members

- 3 assessors blinded to the condition, one working for each NHS trust. The assessors would need to be trained to use the assessment tool such as portable MOCAP, ARAT and 9HPT. All data would be collected in participants' homes. Any therapist, preferably already employed by each NHS trust, would be able to take on this role and data collection could be scheduled around their clinical work and separately funded. The blind assessor in this study was employed in this way

- 3 music therapists or NMTs, trained in TIMP and who would receive instructions on how to follow this TIMP protocol

- 1 statistician to conduct the MOCAP and all other analysis

9.16.4 Quantitative measures

Pre and post measures using ARAT, 9HPT, MOCAP and EEG would be made by an assessor blind to the condition pre and post treatment period and then at six weeks as a follow-up to measure for any sustained effects. Portable EEG and MOCAP would need to be provided, requiring additional funding. Assessors would need to be trained in the use of this equipment.

9.16.5 Control group interventions

Therapists delivering standard community rehabilitation would be required to record their treatment program for each participant in order that all variables can be accounted for and meaningful data extracted and analysed. It has been previously reported that problems in quantifying treatment effects have been caused by a lack of detail regarding standard care implementation procedures (Fens et al., 2013).

9.16.6 Inclusion criteria

A minimum ARAT score of 23/57, with a total score of 6 in the gross subscale, which indicates that the participant can complete at least one task in one of the other three subscales, would be an effective criteria for inclusion in a study using the same TIMP protocol, with treatment twice a week for six weeks. Achieving this score requires a degree of proximal and distal movement that would facilitate greater access to the exercises in the TIMP table.

1. Hemiparesis
2. 23/57 ARAT score
3. 3-60 months post stroke
4. 18 to any upper age where the MDT and GP deem the patient fit to participate
5. able to consent to participate

6. able to follow instructions for each TIMP exercise
7. absence of visual neglect

9.16.7 Outcome measures

Portable 3-D motion capture would be used in order to record changes in movement quality. This equipment will be transported into each participant's home in order to conduct pre, post and follow-up assessments; three different time points in total. A Polhemus Liberty, Polhemus, Colchester, Vermont, or similar equipment, such as that used in a previous, single case study (de Groot et al., 2012)would be used.

Motion sensors will be attached to the thorax, scapula, upper arm, lower arm, hand, and nails of the thumb and index finger ((de Groot et al., 2012)p. 145) and will record data whilst each participant reaches forward whilst seated at a table to pick up the largest block from the ARAT and place it on the shelf (task 1 in the grasp section).

Motion capture will allow accurate monitoring of:

Trunk movements, specifically changes in compensatory trunk use during reaching

Elbow angle during extension

Grasp: distance between the thumb and index finger tips

9.16.8 Potential addition of EEG

A portable EEG could be used, with recordings conducted in each participant's home. The actiCHamp system by brain products could be used, incorporating the acti64Champ system (BP-100-2110 recorder, BP-200-1620 amplifier, BP-09410 cap, 2 X BP-04242-32 electrode set), which is a 64 channel system

Portable EEG would enable pre and post measures in order to detect any neural reorganization in auditory and temporal cortices during passive listening to the cueing music pre and post six weeks intervention. We would expect to observe increases in frontal midline Theta (FMT) and an increase of brain connectivity between central and temporal regions post TIMP treatment.

Portable EEG would be more comfortably delivered in participants' homes, rather than in a lab, and they would be able to use their own facilities to prepare for the EEG and wash out the gel afterwards.

The full protocol for the study, particularly the MOCAP and EEG, would need to be concisely written and supported with references to previous research of a similar nature. For the EEG and MOCAP equipment to be used it may also be necessary to conduct a pilot study with a small cohort. This would help to substantiate its importance for the purposes of obtaining ethical approval via IRAS.

9.16.9 EEG procedure

The participant is seated comfortably in the EEG room, separate from the control room in the lab. Before testing, the researcher places a fabric cap with integrated electrodes on the participant's head and applies small amounts of hypoallergenic electrolyte gel to their scalp through small holes in the cap where the electrodes were to be connected. The electrodes that were integrated into the cap would be used to record electrical activity across the participant's scalp during the experiment.

Under circumstances where the hair is too greasy or due to warmer temperatures there would be an increase in perspiration and participants would be asked to wash and dry their hair using the EEG lab facilities. The electrode gel (to secure conductance) is applied using a plastic syringe with sterile blunt metal tube. Whilst applying the gel, the participant is regularly asked if they are comfortable or if they feel any discomfort.

To control for heart rate, eye movement and muscle artefacts (erroneous physiological influences on the EEG), a set of external electrodes are applied. Therefore, areas around the eyes, ears, neck and wrists are cleansed using a safe detergent application, this removes any perspiration that may interfere with conductance for the recording.

Figure 34. EEG cap in position on a subject's head.

The fabric cap shown in Figure 34 illustrates the electrodes and wires attached. Also visible are two of the external wires under the eyes, which control for artefacts. (Photo retrieved from http://www.biosemi.com/pin_electrode.htm)

There are pauses between the recordings. During the pauses participants make themselves comfortable, change posture and take refreshments as required.

9.16.10EEG recording procedure

1. The participant closes their eyes for about 10 minutes for a *rest recording*, for vigilance control they are asked to open their eyes after 5 minutes for 1 minute and then to close them again for 5 minutes (11 minutes total)

2. Next, headphones are placed on the participant's ears and a sound check conducted, identifying a convenient loudness level (2 minutes)

3. The participant listens to the music used for each TIMP exercise, requiring approximately 15 minutes, with eyes closed

4. After this, the headphones are removed and participants instructed for the *Go/No-Go Task*. For this task participants are asked to press a button on a hand held devise if a star appears on a screen in front of them, but not to press the button when a circle appears. Between these events they focus on a rectangle. After a short training phase of 1 minute, the recording begins and lasts for 16 minutes (17 minutes total)

5. Following this there is a short pause to prepare for the *music listening* with headphones again. During the music listening task participants listen to a set of short film music clips (representing musical emotions). This lasts for about 7 minutes

6. After the headphones are removed participants sit quietly with eyes closed for a rest recording for 5 minutes

EEG requires approximately 1 hour and forty minutes, including setting up and all procedures.

9.17 EEG analysis

EEG analysis of the pre/post *resting state* EEG recordings would be treated with NeuroGuide Software (www.appliedneuroscience.com; Version 2.6.2) including an age, gender and condition-matched normative EEG database (N=678 matched controls) utilising power spectral analysis (PSA), topography, coherence, Region of Interest Analysis (ROI) and Low Resolution Tomography (LORETA) to enable localisation estimates, connectivity patterns and neural reorganisation.

Neuroguide would be used for rest state comparisons analysis, and
EEG lab software for rest and listening responses analysis. The hypothesis was: that there will be a different pattern of activity after treatment in parietal lobes, motor cortices and auditory cortices.

We would compare:

1. stroke related ROIs (Stroke areas reported in the patient data)

2. pre-defined ROI (Central; sensory/motor areas) against a normative EEG / LORETA database in order to detect intra-individual changes (in- or decrease of z-scores) over time points of measurements within the delayed intervention frame. Topography and coherence data would inform about in- and/or decrease of connectivity (with focus on central data). Pre/post paired t-test would indicate the

probabilities and directions of change. We would expect the post-intervention measures to show a lowering of z-scores (i.e. normalisation) and an increase of connectivity to/within central areas.

Pre/post *music listening data* of TIMP patterns to be employed in the intervention; 1.) LORETA ROI analysis on central areas based on PSA and values projected into LORETA space; 2.) Analysing topographical shifts of pre/post power and frequency changes. We would expect the post-intervention data to show increased connectivity in centro-parietal areas.

Go/No Go task (presented with e-Prime) would be performed to track improvements of reaction time (measured with button press) and contingent negative variation (CNV) between signals as a marker of attention processes. We would expect reaction time to shorten.

The data would be analysed in cooperation with the Institute of Psychology of ARU. We would compare all resting state, music and Go-No-Go recordings of participants.

9.18 Epilogue

My decision to undertake this research was driven by my clinical experience and training, and the questions and problems that this work brought over a number of years working as a clinician with patients with neurological impairment. Whilst conducting the study I maintained a busy caseload of patients in a variety of settings, predominantly within the neurodisability population but also in special schools. My work and research experience so far has prompted feelings of tension between the research process and clinical thinking that on the one hand has informed the research but on the other has impaired it; the latter being in regard of maintaining a position of equipoise and adhering to the research design, whilst also trying to factor in each participant's individual needs. To summarise, my experience as clinician with this patient group has demanded the application of NMT protocols, but in a single case study design, whereas this research has demanded the application of a protocol to a cohort, albeit small, and the analysis and interpretation of data for the two groups it

comprised. The aim of this was to see if what had been, in my and most music therapists' experience, applied to an individual patient and found to be effective could be applied to this patient population and achieve the same results. The protocol for treatment was, to a degree, informed by the NMT model (TDM) and TIMP description, but it was through patient collaboration and my clinical experience of using this intervention that enabled me to design a protocol that, it was hoped, would eventually be applied to each participant.

At this point I am pleased to say that I have applied the TIMP protocol from this study to my current clinical work and in one case the patient, using TIMP 8 to 12 from the chart, increased his 9HPT score threefold in 10 weeks. As this protocol is now published I sincerely hope that it will be used effectively by other music therapists and health professionals.

Conducting this research in participants' homes made the focus on improving ADLs ever present in every session. This was the place where participants lived and strived to improve their paretic upper limb use in order to help them achieve the best possible quality of life. At times I wished that an occupational therapist were there with me, to help identify tasks that they could practice about their homes and help carry-over from the exercises that they worked so hard at (without exception). Thankfully I had worked alongside OTs over the years and the NMT training helps to identify purposeful musical exercises that are clearly linked to ADLs, so this task was achievable.

As part of my work as a NMT over the years I have conducted home visits in order to assess different environments and set up home programs, so I was aware of the process of entering patients' homes. However, for this research I was visiting each participant twice a week for six weeks, then returning for follow up assessments and putting the blind assessor in contact with them I order to schedule pre and post treatment assessments. All the time, it was apparent that I would not be returning to see them after their participation was complete; after 18 weeks. This was a different process to that of working as a clinician and prompted a different relationship with each participant in their home. I was mindful of entering their personal space, lugging various bags of equipment. Furniture that required repositioning had to be put back

where it had previously been. Some participants offered to help carry equipment in, which I was grateful of and mindful of what this might mean for them in terms of wanting to be ‘useful’ as they may have viewed a change in their value since their stroke. But I also had injured myself by banging the bag of heavy and bulky cymbal and bongo stands on my ankle and wanted to avoid this happening to any participants or other people in each household.

Finally, delivering this protocol of exercises with the facilitating music was enjoyable for me and appeared so for all particpants throughout their participation. Whilst the music for facilitating each TIMP playing pattern was pre-composed for the study, there was room for spontaneous modifications at times, prompted by individual responses that kept very much alive the central elements of relationship, collaboration and creativity that is unique to music therapy.

10 APPENDICES

10.1 Appendix 1. Ethics forms

10.1.1 Letter of favourable opinion

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10.1.2 Protocol accepted by the ethics committee

Title: **An investigation into music therapy for the rehabilitation of upper limb function in adult stroke patients: a pilot study**

Date: 24/10/2013 Ref: 13/EE/0400 Version:3.5

Chief Investigator (CI): Mr Alex Street. Music therapist and PhD student with Anglia Ruskin University, Cambridge.

PROJECT SUMMARY

Impairment of arm function is more common than lower limb in stroke patients and is also more resistant to treatment. Several clinical trials with stroke patients have produced statistically significant gains in upper limb function when using instrumental playing and treatments where rhythm supports the priming and timing of movements. Based on the positive results from controlled and non-controlled trials, the Cochrane review of music therapy for acquired brain injury (Bradt et al, 2010) recommends further investigation into rhythm based techniques to treat hemiparesis in stroke patients, and that future studies need to examine the relationship between the frequency and duration of interventions and treatment effects.

The aim of this study is to examine whether or not a thirty minute, twice weekly, six week, home music therapy treatment, playing set musical patterns on instruments to music is feasible to deliver, and will lead to improved coordination, dexterity and activities of daily living in hemiparetic stroke patients.

Twelve patients will be recruited from Cambridgeshire Community Services NHS trust (CCS) who are between one month and two years post stroke with hemiparesis. Participants will have completed and been discharged from community rehabilitation for their upper limb and not be receiving any other treatment for arm function. They will be randomised into two groups: treatment (for immediate treatment following discharge from community rehab) and waiting list (beginning 9 weeks after baseline measure). Participants will be assessed at the beginning and end of treatment (just before starting and just after completing 6 weeks of treatment) by one of two experienced community occupational therapists under contract with CCS, who are also experienced in working with stroke patients and who will be blind to the experiment. The other three measures will be conducted by the chief investigator. The assessment tools will be the Action Research Arm Test (ARAT) and nine hole peg

test (9HPT). There will also be a pre and post treatment semi-structured interview for each participant, which will be conducted by the chief investigator. ARAT and 9HPT assessments will be administered to all participants at the same time points: baseline and then at week 6, 9, 15 and 18. Data will be analysed to determine if the treatment is effective compared to no treatment (wait list) following community discharge, and whether earlier intervention (treatment group) yields better results for participants, all of whom will eventually receive treatment.

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INDEX

1. General Information
2. Rationale and Background Information
3. Study Goals and Objectives
4. Study Design
5. Methodology
    5. 1 Recruitment
    5.2 Randomization
    5.3 Assessments
    5.4 Frequency of Assessments
    5.5 Duration of each assessment and participant fatigue
    5.6 The relationship between upper limb impairment, the primary and secondary outcome measures and the music therapy treatment
    5.7 TIMP pattern chart
    5.8 Guide for using TIMP chart
    5.9 Metronome settings
    5.10 Guide for using iPad
    5.11 Equipment setup time
    5.12 Floor space and seating
    5.13 Monitoring patient performance
    5.14 Musical support
    5.15 Demonstration by the therapist
    5.16 Preparation before each TIMP session
    5.17 Verbal support
    5.18 Physical support
    5.19 Psychological support
6. Participants dropping out

7. Safety considerations
8. Follow up
9. Data management
10. Quality assurance
11. Expected outcomes of the study
12. Dissemination of the results and publication policy
13. Duration of project
14. Problems anticipated
15. Project management
16. Ethics
17. Index
18. Appendix

1. GENERAL INFORMATION

Title: An investigation into music therapy for the rehabilitation of upper limb function in adult stroke patients: a pilot study

Date: 23rd September 2013

Sponsor: Dr Penny English, Anglia Ruskin University, East Road, Cambridge, CB1 1PT

Chief Investigator (CI): Mr Alex Street, Anglia Ruskin University, East Road, Cambridge, CB1 1PT

Research Host: Dr Andrew Bateman, Cambridgeshire Community Services NHS Trust, Princess of Wales Hospital, Ely, Cambridgeshire CB6 1DN Contact: 01353 652165

2. RATIONALE AND BACKGROUND INFORMATION

There are approximately 152,000 strokes in the UK every year, causing more disability in adults than any other disease or condition, and with more than half of this

population being left with long-term dependency on others for support with daily activities. The mean length of stay in hospital for stroke patients has fallen from 32 days (2000) to 20 days (2010). ESD teams and other community based rehabilitation teams improve outcomes for stroke patients, but only 36% of hospitals in the UK provide such services (data gathered from: http://www.stroke.org.uk/sites/default/files/Stroke%20statistics.pdf).

The rationale for treating motor impairment resulting from stroke has shifted in the last decade, to a 'top down' approach, whereby the neurological damage incurred by stroke on the motor and peripheral systems involved in movement planning is addressed rather than the visible, physical impairment alone (Ujette, 2005). It has also been reported from within the occupational therapy profession that exercises which have a clear purpose and meaning for patients, rather than rote exercises, elicit significantly higher levels of motivation and engagement, resulting in better outcomes in rehabilitation (Paul and Ramsey, 1998).

Over the past decade scientific evidence has been gathering from clinical trials to indicate that rhythm and playing musical instruments significantly increases motor learning and induces neural reorganisation in stroke patients, initially in the domain of gait rehabilitation and now in upper limb movement (Thaut et al, 2002; Schneider et al, 2007; Altenmueller et al, 2009; Rojo et al, 2011, Grau-Sanchez et al 2013). Some of these studies have recorded data from participants using EEG recordings and fMRI scans that indicate neural reorganization as a result of the treatment and the unique coupling effect it has had over the motor and auditory cortices; referred to as 'audio-motor coupling' (Altenmueller, 2009, p. 403). Rhythmic Auditory Stimulation (RAS), whilst proven effective in the rehabilitation of gait following brain injury and with Parkinson's patients, has also been trialed in post stroke upper limb rehabilitation and found highly effective (Malcolm et al, 2009) including both 'in' and 'out' patient participants ranging from 6 months to 1.6 years post stroke. In another study where stroke patients were required to tap with their fingers on marked targets for 30 second intervals, in-time with a metronome beat set to their existing frequency of movement (Thaut et al 1999), elbow range of motion (ROM), wrist velocity and trajectories were all statistically improved, recorded using motion analysis cameras and software.

Therapeutic Instrumental Music Performance (TIMP) (Thaut, 2005 pp 154-159) is a NMT treatment which combines the use of: 1. music to support the priming, timing and required muscle force for movements with 2. the selection and spatial arrangement of musical instruments in order to target and improve coordination and range of movements. With proprioception impaired in many people with stroke, the instruments may also provide clear visible targets, which give auditory feedback, counteracting the lack of spatial awareness and improving the planning of movements with specific regard to muscle force required to achieve a movement or activity of daily living using the paretic upper limb (Altenmueller, 2009).

NMT techniques (Thaut, 2005) for upper limb rehabilitation, such as TIMP, have not been widely researched and have not been delivered as treatment at the stage (post acute community rehab), frequency (twice weekly compared to daily) and location (patient homes) proposed for this study. It is, therefore, appropriate to conduct a small feasibility pilot study under these conditions.

In order to accurately record baseline measures and assess treatment outcomes it is necessary to use standardised assessment tools found in previous research of this nature, and commonly used by occupational and physiotherapists working with stroke patients. These assessment tools are: the Action Research Arm Test (ARAT) and the nine hole peg test (9HPT)

The reasons that the treatment is being delivered at community stage are:

1. TIMP, and music therapy in general, is not recognised in the UK as a 'short-term' intervention and so can not be delivered earlier in the care pathway

2. It is not possible to deliver any earlier in the care pathway within CCS because it might disrupt the standard care that CCS usually provide patients

Improvements in arm function following treatment similar to TIMP have been linked to neuroplasticity, recorded through the use of EEG and fMRI scans, which have revealed that music therapy has enabled the brain to become rewired (neural reorganisation) to enable much more efficient and better quality arm, hand and finger

movements (Altenmueller et al, 2009; Rojo et al, 2011). This indicates that it is not simply the high repetition of movements whilst playing the instruments that leads to improvement, but the emotional and cognitive feedback (the sound, rhythm, melody and music) resulting from patients playing the instruments and from the supporting music.

The Action Research Arm Test (ARAT) (Lyle, 1981) inter and intra-rater reliability has been reported as 'excellent' in several studies (http://strokengine.ca/assess/module_arat_quick-en.html). The test consists of four subcategories and a total of 19 tasks all of which recreate activities of daily living such as reaching, picking up, pouring and putting down objects of various dimensions and shape. The tasks follow a set protocol that tests the dexterity of each finger movement and the range of motion of shoulder, elbow and wrist. Each test is scored and also timed, which means that there is a good degree of sensitivity to change measured in the scoring and the time taken to perform each task.

The 9 hole peg test more specifically measures finger dexterity and is widely used in stroke rehabilitation and related research. Two studies have rated intra-rater reliability as adequate and three other studies rated inter-rater reliability as excellent (http://strokengine.ca/assess/module_arat_quick-en.html).This assessment will more sensitively measure for changes in finger dexterity than the ARAT.

CROSS-OVER DESIGN

After the stroke patients have finished their upper limb rehabilitation with CCS and are no longer receiving any physiotherapy or occupational therapy to improve it, this study aims to establish if their upper limb function is maintained, deteriorates, or

improves. In order to do this we will have a waiting list group who wait 9 weeks after the end of their CCS rehabilitation but are assessed at the same time points after their baseline measure as the treatment group. This enables us to compare the results of the treatment group with the waiting list group, in other words 'treatment compared to no treatment after CCS rehab has ended', and establish if the music therapy has been effective. We can also compare the results of both groups and determine if the participants who received music therapy earlier performed any differently than the waiting list group.

The five repeated measures using the ARAT and 9HPT also allow each participant to be measured against themselves, comparing treatment with no treatment and establishing how the exercises using the musical instruments (TIMP treatment) have influenced their paretic arm use during activities of daily living.

3. STUDY GOALS AND OBJECTIVES

The study goal is to investigate the feasibility of delivering this music therapy treatment in stroke patients' homes twice a week for six weeks with the objective of answering the primary research question, which is:

1. Does TIMP improve upper limb function after statutory rehabilitation has ceased to be effective and consequently ended?

The Secondary objectives are to try and determine:

2. Is TIMP more effective when delivered immediately after statutory rehabilitation has ended compared to 9 weeks later ?

3. How do participants experience TIMP?

4. STUDY DESIGN

In order to answer the research questions a wait list, crossover design will be used, with twelve participants randomly assigned to two groups:

A = treatment

B = wait list

Randomisation will be achieved using an envelope system, with twelve sealed envelopes containing folded pieces of paper, six with the word ‘treatment’ and six with the word ‘wait list’ written on them. Each time a patient consents to participation, the chief investigator will contact the statistician and ask him to open an envelope and read the piece of paper inside.

There can be enormous variability between patients in terms of speed of recovery following stroke and so the inclusion criteria for ‘time since stroke’ is quite broad. There is no clear data that fully confirms differences in degrees of upper limb paresis based on type or site of stroke and so all types and sites are included.

Inclusion criteria for the study is as follows:

1. Can consent to treatment
2. aged 18-70
3. has completed community rehabilitation for upper limb paresis
4. any type and site of stroke
5. between 1 month and 2 years post stroke
6. can lift paretic hand onto a table whilst seated, without assistance from unaffected hand
7. some finger movement, which could be extension of one or more fingers
8. not receiving any other treatment for upper limb paresis during the course of this study (18 weeks from baseline measure)

Once treatment begins, each participant will receive two, thirty minute music therapy sessions per week for six weeks. All participants will eventually receive treatment. Group A will begin music therapy immediately after completing their baseline assessment using ARAT and 9HPT and completing the semi-structured interview. This means that the first session will require approximately two hours in order to allow for setting up equipment and breaks for the participant. In the event that the participant is too tired following the assessment to continue with the treatment, then the music therapy session will be rescheduled for another day in the same week. The end measure will also take place on the same day as the twelfth and final session and if the participant is too tired to complete the end assessment then it will be rescheduled for another day in the same week

5. METHODOLOGY

5. 1 RECRUITMENT

Patients who have completed their CCS community occupational and physiotherapy rehabilitation will be sent a letter of invitation to participate in this study and an information sheet (see attached 'Letter of Invitation' and 'participant information sheet'). In the letter they will be asked to contact the chief investigator if they are interested in participating, explaining that he will answer any questions that they have about participation and arrange to visit them in their home in order to demonstrate some of the exercises. Then, if they are interested the chief investigator will leave a consent form for them to sign and return within a week.

5.2 RANDOMISATION

Once a participant has given informed consent, the chief investigator will contact the statistician (Mike Parker, medical statistician, Anglia University, Chelmsford) and ask him to open one of 12 envelopes, which will have either 'treatment' or 'waiting list' written on a piece of paper inside and indicate which group the participant will go into.

5. 3 ASSESSMENTS

The primary outcome measure will be the Action Research Arm Test (Lyle 1981. See diagram 12 under Appendix), which has been used in similar studies (Schneider; 2007, Altenmueller; 2009, Grau-Sanchez; 2013) thus enabling some comparison of data with this study. It is a 19 item measure that is divided into four categories: grasp, grip, pinch and gross movement. Each item, or action, is performed by the participant while seated a measured distance from a table (15cm), where all of the assessment items are placed (blocks of wood of various sizes, smaller items, etc). The test recreates the movements or sequences of movements common to activities of daily living, such as reaching up onto a shelf to pick up a can of soup. A table map for the ARAT is laid out flat on the table top and this has markers on it to indicate the start and end position for each object used in the test, thus optimising consistency between patients and setting.

The performance of each task is timed using a stopwatch, and scored according to the following scale:

0. unable to perform any part of the task within 60 seconds (an example of this would be if the patient could not lift his or her arm up and reach for a block of wood)
1. poor quality movements (for example compensatory movements from the trunk or shoulder instead of flexing and extending the elbow) and inability to complete the task within 60 seconds
2. task completed, but with difficulty; i.e. it took much longer than indicated in average scores for the same age group as the patient, and the arm, hand or finger movements that the patient performed in order to complete the task indicated difficulty in coordination
3. normal performance, where the task was completed in less than 5 seconds, with good body posture and normal hand, arm and finger movements. 'Normal' body posture means that there were no or minimal compensatory movements made in order to achieve the task, for example using trunk movements in order to help raise the arm high enough to reach an object on a shelf.

The ARAT protocol for each category begins with the most difficult task, if the patient can complete the task, scoring 3, then there is no need to continue with the other items in that category. If the patient fails to complete the first and most difficult task, they then continue with the easiest and progress through increasingly more difficult tasks until completing that category and moving on to the next. If the patient fails the second, easiest task, then they score zero in that task and the remaining ones in that category, without the need to complete them all.

The tasks in the ARAT are as follows, beginning with a demonstration from the chief investigator, then the patient performing tasks using unaffected arm then paretic arm:

GRASP

Task 1-4 10cm/2.5cm/5cm/7.5cm block of wood moved from target on table map to shelf above the table using any kind of grasp involving the thumb and fingers in opposition.

Task 5 cricket ball moved from table to shelf. Spherical grip.

Task 6 sharpening stone moved from table to shelf. Lateral grasp.

Arm movements for GRASP subcategory: elbow flexion and extension, shoulder flexion and stabilisation, thumb and finger extension to release each object.

GRIP

Task 7 2 cups, one filled with water to a mark on its side, cups positioned on markers on the table map. Patient lifts the cup with water in and pours it into the empty cup (the chief investigator brings clean tea towels to each assessment in order to protect patients from getting wet as well as table surfaces and floors). Cylindrical grip.

Task 8-9 move two different metal tubes (2.25cm and 1cm diameter) from starting plinth to target plinth. Any type of grip can be used.

Task 10 pick up a washer from inside a tin lid and place it over a target plinth. Pincer or 3 jaw chuck grip.

Arm movements for GRIP subcategory: forearm between mid position and pronation, elbow flexion and extension, wrist pronation and supination.

PINCH

Task 11-16 pick up a ball bearing and then a marble from a tin positioned on the table and place in a tin lid on the shelf. This is done using the following finger and thumb combinations: ring finger, index and then middle finger and thumb.

Arm movements for PINCH subcategory: forearm is between mid position and pronation, elbow flexion and extension, shoulder flexion to reach the shelf and shoulder stabilisation to maintain the position and release the object.

GROSS

Task 17	raise hand from lap to behind head
Task 18	hand from lap to top of head
Task 19	hand from lap to mouth

Score is out of a possible 57.

The assessment can take up to 30 minutes if the patient needs to complete all items in every subcategory, but this is rare. The test usually takes approximately 10 minutes.

The secondary outcome measure is the 9 hole peg test (Kellor et al, 1971). This is a test that the Cambridgeshire Community Services team (host to this study) use. It is a timed test measuring finger dexterity using standardised equipment comprising a rectangular plastic tray with a rounded, concave tray at one end containing nine small white pegs and at the other end nine holes into which the participant must (one at a time) place the nine pegs from the tray and then remove them, placing them back into the tray as quickly as possible. The patient practices with the unaffected hand first, then the paretic side. The patient is seated while performing the test. A non-slip mat is placed between the base of the peg test and the table surface. The participant may stabilise the test base if necessary using their unaffected hand. The test takes no more than 2 minutes to administer, depending on the age of the patient and their existing degree of finger dexterity.

SEMI-STRUCTURED INTERVIEW

Before beginning the music therapy treatment each participant will be asked set questions about it and to score how much they think it will improve their paretic arm use in activities of daily living. At the end of treatment participants will be asked the same questions. The chief investigator will write down responses during the interview for later thematic analysis. Interviews will not be recorded. Questions have been used that are as open as possible so as to give participants the opportunity to express their preconceptions and thoughts. Each question may lead to further questions, for example question 1 may prompt a response ‘I think it will help me” to which the chief investigator may respond “how might it help you?” The purpose of the semi-

structured interview is to gather qualitative data specifically regarding how participants experienced the treatment. The pre and post questions are set out below.

Pre-treatment Semi-Structured Interview

1. What do you think the treatment will be like?

2. How will it feel playing the instruments?

3. How will it feel playing to the music?

4. Please score how much you feel music therapy will change your arm and hand use in daily living.

   1 = not at all, 5 = very much

1	2	3	4	5

Not at all very much

Post Treatment Semi-Structured Interview

1. What do you think about the treatment?

2. How does it feel playing the instruments?

3. How does it feel playing to the music?

4. Please score how much you feel music therapy has changed your arm and hand use in daily living.

1 = not at all, 5 = very much

1	2	3	4	5

Not at all very much

5. 4 FREQUENCY OF ASSESSMENTS

Participants will be assessed using the ARAT and 9 HPT at five time points over eighteen weeks. Two of these assessments will be conducted on days when they also receive treatment; the baseline, which is before their first music therapy session, and the end measure, which is AFTER their final session. The other three will be assessments only, with no treatment before or after.

5. 5 DURATION OF EACH ASSESSMENT AND PARTICIPANT FATIGUE

The duration of each assessment has been described under the detailed protocol (above) for ARAT and 9HPT. The ARAT can take thirty minutes to administer, but only in the rare cases where participants are required to complete each item in all four sub-categories having failed to complete the first task in that category. In such cases, and particularly when the assessment is to be conducted on the same day as music

therapy treatment (twice) the participant will be asked if they would prefer to have a break before continuing with their music therapy or with the assessment (end measure AFTER final session), or if they would prefer not to continue with their music therapy after the baseline assessment, but begin treatment on the second scheduled day of treatment.
If a participant becomes fatigued during any assessment, then we will be able to have a break and then continue. If necessary we can stop the ARAT assessment and try to do it again at a later date, preferably in the same week it was scheduled.

5. 6 THE RELATIONSHIP BETWEEN UPPER LIMB IMPAIRMENT, THE PRIMARY AND SECONDARY OUTCOME MEASURES AND THE MUSIC THERAPY TREATMENT (Therapeutic Instrumental Music Performance, or TIMP)

The chart of TIMP exercise patterns (below), intended for use in this study, describes the arm movements used for each instrumental exercise, the instrument/s and equipment to be used, the positioning of each instrument and how it should be played (hand, beater, plectrum etc). It can be seen that the musical exercises require arm, hand and finger movements that are the same or similar to those required to perform tasks in the ARAT and 9 hole peg test, which are intended to simulate movements and movement sequences required to perform activities of daily living. Patterns will be selected for patients in accordance with how they perform these two assessments at baseline; their scores, the time each task takes and the quality of each movement or sequence of movements observed by the chief investigator.

The first and second music therapy sessions will also serve as assessments, helping to determine which TIMP patterns will be most effective for that participant and how engaged in the treatment they appear to be.

A metronome will be used for the chief investigator to play the supporting music in time with. Metronome settings will be adjusted to the speed at which patients can initially perform each musical exercise whilst employing the least compensatory trunk, shoulder or other movements and with the best quality of movement; i.e. slow enough for them to perform each movement with the best possible motor planning.

The metronome setting may then be gradually increased by amounts not exceeding 10% higher than the previous setting.

5. 7 TIMP PATTERN CHART

Chart 1. TIMP exercise patterns (please see appendix for photographs showing some of these exercises).

	TARGET MOVEMENT (bold) & ASSOCIATED MUSCLE GROUPS	INSTRUMENT/S & EQUIPMENT	POSITIONING	INSTRUCTION TO PARTICIPANT	PLAYING PATTERN & METRONOME SETTINGS (bpm)	FACILITATING MUSIC PLAYED BY THERAPIST ON GUITAR	VARIATIONS

1 1b	**Elbow flexion & extension, wrist extension or deviation finger extension**, wrist between pronation and supination, core muscles Grip, plus the above muscle groups	**10" Cymbal on boom stand**, adaptive beater and wooden drum stick, finger picks slotted over thumb and/or finger/s	Cymbal positioned at height approx. level with elbow when arm is resting at side, mid-line so that cymbal edge is just beyond knees. Gradually move the cymbal further away to facilitate longer reach	Relax shoulders, back against chair (or back straight), feet flat on the floor, reach arm and fingers, relax arm & rest hand on lap after playing	Paretic hand and fingers always play on beat 3 of each bar (no beaters). *Metronome settings should always be calculated based on existing frequency of playing, then usually reduced to allow time for motor planning. For example: baseline = 65bpm, reduce to 45bpm*	C, Am, F, G chord sequence, 1 bar on each chord arpeggiating & building the intensity of each chord towards beat 3 of each bar. PLAYED WITH A CLEARLY DEFINED PULSE.	**A**: using hand/fingers with finger picks to strike cymbal, **B**: Holding an adaptive beater, **C**: alternating paretic (cymbal with beater) & normal side (bell of cymbal with drum stick) **D:** using one iPad, drum kit touch screen instrument played with fingers, then iPad drum sticks

2	**Elbow flexion & extension**, slight shoulder adduction, wrist between pronation and supination, grip, core muscles	**Cymbal on boom & bongos on stand,** adaptive beater and 2 X wooden drum sticks, adaptive handle may be required	Bongos on paretic side, shoulder height & angled so that larger one is further from participant, cymbal midline, above bongo height. Begin with bongos close enough to facilitate elbow flexion (not full extension), gradually move further from participant for increase elbow extension	Try to focus on elbow bending & stretching, or on the focused movement related to the positioning of the instrument/s. Relax shoulders, back against chair (or back straight), feet flat on the floor, reach arm and fingers, relax arm & rest hand on lap after playing.	Paretic hand plays beat 1 & 2, normal plays 3. beat 4 is a rest.	Rhythmic, energetic, jazz idiom: G7, G♯Dim, Am7, D7	**A:** adaptive beater (paretic) drums stick (normal), **B:** drum stick both hands

3	**Shoulder flexion, elbow flexion & extension**, slight shoulder adduction, wrist between pronation and supination, grip, core muscles	**Cymbal on boom and bongos on stand,** adaptive beater and wooden drums sticks	As above, adjusting the height of instruments to facilitate greater shoulder & elbow extension	Back straight. encourage paretic arm to rest on lap when not playing	On each beat of the bar: paretic side plays bongo 1, then 2, then cymbal, then normal side plays cymbal bell	Any 1, 6, 2, 5 sequence played with strongly pulsed rhythm in 4/4.	**A.** adaptive beater (paretic) and drum stick (normal), **B.** two drum sticks
4	**Shoulder adduction & flexion**, elbow flexion & extension, grip, wrist between pronation & supination, core muscles	**Cymbal on boom and bongos on stand,** adaptive beater and wooden drums sticks	Cymbal in unaffected side and bongos on paretic side. Position varies to facilitate degrees of shoulder adduction and extension	Back straight, feet flat on ground, try to relax shoulders	Both hands crossing midline alternating paretic and normal side on beat 3 of each bar, progressing to beats 1 & 3	4/4 time, A bass over A, Bm, C♯m, Bm chords, played with a strong pulse.	**A.** Adaptive beater (paretic) and drum stick (normal)**. B.** two drum sticks

5	**Wrist and forearm pronation & supination,** shoulder adduction, elbow extension, core muscles	**Cymbal on boom and bongos on stand,** two drum sticks or beaters taped together so there is a tip at either end	Adjust cymbal and bongos to below elbow height, slightly less than a beaters distance apart, close enough so as to minimise the need for elbow extension and shoulder extension, focusing efforts on wrist movements	Back straight, feet flat on ground, “twist, twist” (spoken or sang in time with pulse of music where needed)	Paretic hand only plays bongo on normal side then cymbal on left on beat 1 and 3	4/4 time, A bass over A, Bm, C♯m, Bm chords, played glissando but with clear pulse.	**A:** holding just the adaptive beater and making full forearm pronation and supination movement to play cymbal then bongo

6	**Finger extension (any/all finger/s), wrist deviation** Participant may initially trigger the sound using knuckle or other part of finger and the therapist should encourage use of finger tip	**iPad 'Garageband' music software**, with smart piano virtual instrument selected and chords set to G (paretic side of screen) and G, D5, G in centre of screen, mounted on microphone boom stand, jawbone jambox blue tooth speaker	At height approx. level with elbow when arm is resting at side, mid-line so that cymbal is just beyond knees. Gradually move the cymbal further away to facilitate longer reach	Relax shoulder, reach with your finger/s, back straight and feet flat on floor	iPad: playing a single chord by sliding finger tip, knuckle, etc, vertically upwards and/or slightly away from body, over touch screen, triggering a piano chord Alternating paretic and normal, 1st beat of each bar. *sustain switch on	Frere Jacques in G major with clear pulse.	**A**: play the G, D5, G, chords on 'ding, dang, dong' lyrics of song. **B.** use a different finger for each playing of the chord

7	**Finger movements or finger extensions**, elbow flexion and extension, shoulder extension, abduction and adduction. Core muscles	**2 X iPads**: mounted vertically (one above the other) on vertical part of microphone stand. 'Garageband' music software. iPads connected to speaker using two mini jack leads and a splitter input	iPads one above the other or for variation **B.** next to each other both mounted on the horizontal bar	Sing: "G then Am then F then C, etc" in a melody to accompany the chords and ensure they are played correctly; stop when no longer required. A break may be required between each repetition of the 8 chords, observe and consult participant	Any finger or finger combination playing each chord individually in time to the music	8 chord sequence (with alternating chords on iPad 1 and iPad 2 as follows for participants): C, G, Am, F, C, G, C, C. with each chord arpeggiated. Clear accents on bass note of each chord to exaggerate pulse, sing the chord changes to begin with.	**A.** Boom and main stand adjusted to facilitate increasing elbow and shoulder extensions or shoulder abduction or adduction. **B.** crossing midline, alternating left and right hand to play each of the 8 chords

8	**Wrist supination & pronation** with elbow either flexed or extended, grip, core muscles	**2 iPads**, iPad drum sticks, garageband 'drum kit' touch screen instrument	Both iPads mounted on horizontal bar, close enough together so that both ends of the iPad drum stick can hit a drum on the screen. Drum stick held in the middle with wrist in prone position	Relax shoulders and "twist, twist, twist, twist" (spoken or sung in time to music)	Playing on the 1st and 3rd beat of each bar	4/4 time, Legato, A bass over A, Bm, C♯m, Bm chords. With strong accent on beat 1.	No variations
9	**Grip, Wrist ulnar and radial deviation**, elbow flexion	**Cabassa**: small, medium and large sizes. Bongos on stand	Hands westing on lap, held in normal hand, paretic hand over the top & gripping the beads	Relax shoulders, 'twist, twist, etc (spoken or sung in time with music)	Playing on 1st and 3rd beat of each bar, playing in ¾ time on the	Strongly pulsed, rhythmic and staccato music, for example Spanish idiom	**A.** Grip and twist cabassa, release and tap cabassa on large bongo, repeat

			around the cabassa with thumb and all four fingers and twisting them around in time to the music[2]		first beat of each bar	using E, F/E bass. In 4/4 or 3/4 time	
10	**All fingers/combinations:** Thumb, Index, middle and ring finger extension and flexion, shoulder stabilization, elbow flexion, core muscles	**iPad:** touch screen bass guitar using paretic hand	iPad positioned on stand, close enough to participant for minimal shoulder and elbow extension, focusing on finger coordination and extensions	Relax shoulders, back straight and feet flat on floor. 'Play' spoken or sung on first beat of each bar. Sing each chord name in a melody to accompany the chords until established	¾ playing on the first beat of each bar	Chord sequence: C. G. Am, Em, F, G, C:‖ (one chord per bar)	**A.** single notes using combination of thumb, index, middle, ring and little finger; **B**. finger combinations to play 3 individual strings on beats 1, 2 &3 in ¾ time signature

[2] This exercise is described and illustrated in Baker and Tamplin, 2006, p79.

11	**Finger extensions,** slight wrist, elbow extension and flexion, shoulder stabilization with slight adduction, core muscles	**iPad**: touching single notes on virtual screen, improvisation, participant chooses either guitar or piano and plays to set, repeated guitar accompaniment	iPad positioned on the stand at a distance and height that requires minimum elbow and shoulder extension. Alternatively, seated at a table, knees just underneath, resting with the edge of iPad on participant's lap and the back of iPad leaning against table edge	Relax shoulders, back straight and feet flat on floor	Various finger patterns spontaneously performed by the participant	C, Am, F, G, six note fingerpicking pattern in style of 1950's rock and roll ballad	No variations

5.8 GUIDE FOR USING THE TIMP CHART

In the appendix (at the end of the protocol) there are several photographs showing instrument positioning and playing for patterns 1 – 7, but not including all playing and positioning variations.

All musical patterns used to support participants whilst they play the instruments should be recorded onto an iPad using 'Garageband' music software. They should be recorded at a metronome setting of 45 to 55 beats per minute (bpm); the virtual microphone input will facilitate this, using the iPad built in microphone. Having recorded each pattern and numbered them on the iPad under 'songs' appropriately, it will be possible to play the pattern and demonstrate all exercises to each participant, as well as allowing the participant to play along to the recording whilst the music therapist physically supports their posture and movement. *NOTE. Not all participants will play all the patterns over the course of treatment.*

All musical accompaniment for these patterns have been composed for classical (nylon string) guitar and will be played by the chief investigator using this type of guitar. Music can be adapted for other instruments and if this is done then consideration should always be given to providing music with a clear pulse, containing appropriate force cues within the melodic, harmonic and dynamic structure, that is clearly and consistently reproducible in each music therapy session and for each TIMP pattern.

Some patterns, for example 3 and 4, have a variation where the participant uses hands only after they have initially used beaters and drum sticks during the exercise in the initial phase, this is because initially stroke patients can lack the coordination, muscle strength and stamina required to generate volume whilst playing using their hands. Using the beaters and sticks can give more audio feedback and be more satisfying as a joint music making experience. Conversely, participants may struggle to grip beaters initially and need to begin using hands only; assessment outcomes (ARAT, 9HPT) and clinical judgment should be used to decide which is best suited to their needs. iPads can be used to substitute acoustic instruments in some exercises, for example pattern 1, which will give much more satisfying audio feedback and may help counter proprioceptive impairment, thus improving motor planning.

5. 9 METRONOME SETTING

Using a metronome with ‘tap’ facility, each participant’s speed (frequency) of playing will be calculated by tapping into the metronome in time with their playing. If the movements involve a high level of compensatory movements, for example from the trunk or shoulder, then the metronome speed will be reduced until the participant can be observed having more time to plan movements, and move (playing the instrument/s) in-time with the music, with more control. Once performance of exercises is seen to become more fluent and the timing of playing is more in keeping with the music, then increases of approximately 10 bpm can be made to the metronome setting, or no more than 10% increments.

5. 10 GUIDE FOR USING iPad

Before setting up iPads for participants, go to SETTINGS:
set 'auto-lock to 'never'
with the screen in landscape position (where display is across the width of the screen) select 'lock rotation'
Set 'multitasking gestures' to 'off'

If these instructions are not followed then participants may cause the GarageBand screen to move when attempting to play the touchscreen instruments, at which point they will be unable to trigger a sound until the screen is moved back into position. This can be frustrating for participants and disrupt their progress.

Smart piano chords should be set so that the chords are separated by a blank chord in order to minimise error in participants' playing. Start piano chords should be played with finger movements starting at the bottom of the chord (bottom of screen) and stroking vertically up the screen to gradually play the full chord. The 'sustain' switch should be set to 'on' (see diagram below).

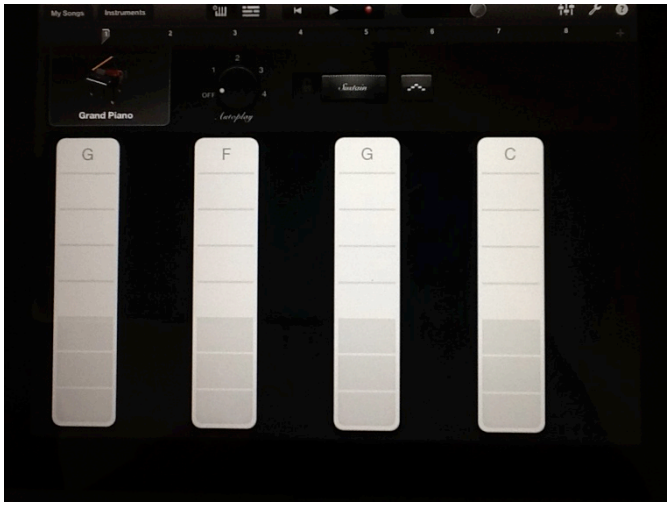

Diagram 1. Setting up the chord spacings for the smart piano in Garageband music software for iPad.

When removing iPads from the stands always support them underneath so that there is no risk of it falling onto the floor.
A pair of special drum sticks are used, which are made from synthetic materials that trigger sounds on the touch screen. These must be touched on to the screen in order to function correctly, they can not be used as conventional drum sticks are, where the sticks bounce off the drum. The plectrum is made from the same material and must be touched on the screen firmly and pulled across I order to trigger the touch screen guitar strings.

When using the touch screen drum kit the iPad must be connected to the Bluetooth speaker with the lead, otherwise there is a delay in hearing the sound after touching a drum on the screen (this does not occur with the other touch screen instruments).

5. 11 EQUIPMENT AND SETUP TIME

10 minutes are required for setting up all equipment, then a further 10 minutes for packing away, making a total of 20 minutes each session. The bag containing the bongos, cymbal and all hardware, beaters and drum sticks weighs 16.7kg. Then there is another shoulder bag containing two iPads and paperwork, the microphone stand and classical guitar in a hard case.

5. 12 FLOOR SPACE AND SEATING REQUIRED FOR THIS INSTRUMENTAL ARRANGEMENT

A total minimum area of 2 metres squared is required to set up the cymbal on boom stand and bongos on stand and including space for the participant to sit. The area increases depending on how far the instruments are moved back from or to either side of the participant in order to facilitate greater extensions from the upper limbs.

5. 13 MONITORING PATIENT PERFORMANCE

Initially each exercise can be played by patients for periods of up to 2 minutes, at which point the chief investigator will stop and ask the participant if they would like to continue. The chief investigator will also ask more specific questions to determine if the patient is experiencing any aches or pains possibly related to each exercise, for example n the back, shoulder, elbow, wrist, fingers, not normally present, or if they are feeling tired. If the participant feels that they are experiencing pain or discomfort related to the musical exercises then we will stop the treatment and discuss whether there might be a need for a GP consultation or physiotherapist appointment.

5. 14 MUSICAL SUPPORT FROM THE MUSIC THERAPIST

The music therapist will play music that is clearly structured and with a clear pulse or beat to provide an audio cue for the start and duration of each movement that the patient is required to perform in order to play each instrument. The music will also contain changes in intensity by increasing and decreasing the volume and fullness of the harmony; i.e. from single notes to louder chords. This is intended to help the patient increase muscle force in order to lift and reach with their arm, hand and fingers to play each instrument.

5. 15 DEMONSTRATION BY THE THERAPIST

The music for each musical pattern is recorded on the iPad used in each session. The music therapist will play the supporting music from the iPad and demonstrate each pattern using the instruments for each participant. Having the music on the Ipad will also enable the music therapist to provide hands on support for the participant, for example supporting the shoulder position.

5. 16 PREPARATION BEFORE EACH TIMP SESSION

Ensure that iPads and Bluetooth speaker are adequately charged. Check that all instruments and equipment are clean and ready for use.

5. 17 VERBAL SUPPORT

For all exercises participants should always be encouraged to keep their back straight, using their core muscles, with feet flat on the ground. The therapist (CI) may sing instructions along with the music that are synchronised with the music, for example, "lift hand, reach out and cymbal, relax" delivered with a clear rhythm in keeping with the music. These verbal cues will be faded once the patient becomes more used to each exercise and the movements more attuned to the structure of the music.
Instruction should be given where necessary to support the participant in reducing compensatory movements whilst playing the instruments, for example: 'try to relax your shoulder when lifting the beater to the cymbal'.

5. 18 PHYSICAL SUPPORT

The therapist may provide hand-over-hand support initially, in order to enable the patient to learn the movements for each exercise and be aware of which muscles are active and which are overactive for each movement within a sequence; the therapist will ask patients if they are comfortable with this beforehand.
In order to facilitate this guidance with optimum clarity, the music for each exercise in the study is recorded onto an iPad. The therapist can simply play the music from the iPad, demonstrate the exercise and then, if necessary and with patients' consent, guide their movements to perform exercises following the cues in the music.

5. 19 PSYCHOLOGICAL SUPPORT: MANAGING PATIENTS' FRUSTRATION OR ANXIETY DURING THE TREATMENT

The music therapist will be acutely aware that for some stroke patients there will be a level of anxiety or frustration at some point, related to a movement that is particularly challenging for them. Breaks during sessions will be scheduled according to how each participant responds, and the chief investigator will fully support participants with encouragement to use breaks, asking them to describe how they are experiencing the treatment and whether they would like to continue.

The musical exercises (see chart above) have been designed to isolate and combine specific muscle groups, so they can be tailored to each participant's existing ability and gradually adjusted as they become used to each exercise and able to more consistently perform each one.

Whilst verbal cues and physical guidance may be introduced for some participants, this will be kept to a minimum as the structure of the music is intended to provide all the cues required to facilitate each exercise. Some participants may prefer not to have any hands on or verbal support, and this will be monitored and accommodated accordingly, in order to provide an optimum environment in which they can engage in the treatment and fully benefit.

The chief investigator (CI) will be sensitive to the mood of each participant at all times during sessions and schedule breaks and encouragement accordingly. At the beginning of each session the CI will enquire as to how the participant is feeling and specifically ask if they experienced any aches or pains following the previous session. During sessions the CI will constantly monitor participant condition, asking how they are feeling and if they would like a break or if they are able to continue. The CI will time each period where the participant is playing and initially limit playing periods to two minutes, extending this period depending on how the participant feeds back regarding their condition and how the CI observes their engagement levels.

6. PARTICIPANTS DROPPING OUT

On the participant consent form it is stated that should participants wish to cease participation in the study at any point, they may do so without their entitlement to treatment being affected. Should a participant decide to drop out, then another patient from the CCS database who meets the criteria will be recruited and randomized into either group A or B. This will be done through exactly the same process as described in section 5.1 of the methodology in this protocol, with Cambridgeshire Community Services sending a letter of invitation, inviting potential participants to contact the chief investigator in order to find out about the study, receive an information sheet, see some of the exercises and sing a consent form.

7. SAFETY CONSIDERATIONS

Instruments should be set up for each session in each participant's home with great care and consideration for the participant's safety and comfort, and without causing any damage to their property or obstruction to them or others in the property whilst the session is taking place. Stands for instruments must be set up correctly, tightening all adjustments so that they will hold position and not fall and ensuring that the instruments are mounted safely so that they are stable and there is no risk that they will topple or be knocked over. Once instruments and equipment used for each session have been unpacked and assembled, all cases must be stored out of the way so that they cause no obstruction to any person in the property and that there is no risk whatsoever posed to any person at any time before during or after treatment.

Where cables are used to connect iPads to the speaker, these should be short and not long enough to trail onto floors.

The speaker used with iPads must be mounted onto a small shelf clamped onto the side of the microphone stand and held firmly in place on the shelf with Velcro and/or other secure straps; speakers must not be on floor surfaces.

Under no circumstances should participants or other persons in the property where the session is taking place be allowed to assist in carrying instruments and equipment in to or out of the property, this will be done by the music therapist (chief investigator).

The chief investigator will be working as an honorary member of the Cambridgeshire Community Services NHS trust team, and adhere to their lone worker policy at all times.

As participants will have reached the end of their statutory rehabilitation and be aware that this is the case, they may experience low mood or depression as part of the process of coming to terms with the impact that their stroke has had on them. This may negatively or positively influence their motivation to engage in further treatment and a treatment that is unfamiliar, involving the playing of music using a pre-selected range of musical instruments. I will reassure participants of the potential benefits of this treatment and demonstrate how it may help them by clearly demonstrating each exercise. There will be some opportunity for participants to choose sounds using the

iPad and other instruments, as well as methods of playing them that still maintain the aims of the treatment.

The pre and post treatment measures (session 1 and session 12) are scheduled to occur on the same day as music therapy treatment, the other three measures will be on non-music therapy days. If participants appear too tired to do both on the same day, then I will schedule the sessions or assessments for a different day in the same week that they were due, so as to separate treatment from assessment, but adhere to the research design. I will ask participants how they feel during music therapy and assessments and also ask if they would like a break or to stop.

The waiting list group may be put off by the 9 week wait. I will demonstrate the treatment to them if required and this may reassure them. I will also be visiting to conduct assessments in their homes using the ARAT, so we will be able to develop a relationship that will support them during the waiting period and in preparation for starting treatment.

The treatment is twice weekly, this is more frequent than standard community rehab from CCS. The treatment may be tiring for some participants, but I have found that patients generally enjoy it and are highly motivated. I will always support participants taking breaks whenever they need to and gradually building stamina.

There may be some weeks also when participants miss a session. I will do my best to plan to avoid this. It may be possible to catch up on a missed session, but due to the resource and time constraints of the study and its design, this will not always be possible.

Some participants may express frustration whilst performing the musical exercises as they will not be able to move and play the instruments in the ways they would like to. The CI is experienced in helping patients manage such feelings and associated behaviours and will be able to detect them at their onset and before they begin to negatively affect a participation. Breaks will be scheduled in these instances and if necessary the session can stop. In all of these cases the CI will be able to talk to

participants and reassure them that they can stop and continue next session or have as many breaks as they wish in sessions.

Should a participant report any pain linked to the treatment we will discuss this and try to establish if it is safe to continue or if there are ways of eliminating pain or discomfort. In some cases I may suggest the participant contact their GP or a physiotherapist from the CCS team for support and/or treatment. Participants will be closely monitored at all times whilst participating and the pace and intensity of treatment regulated according to how they feedback to the CI when he asks them about their condition at the beginning and throughout each session.

In any extreme case where a participant has another stroke or appears suddenly unwell during a session, the CI will call an ambulance immediately and remain with the participant until an ambulance arrives.

8. FOLLOW-UP

RESEARCH

Following completion of this research, writing up of the PhD thesis and any publication resulting, funding applications will be made for a follow-up study with a larger sample size. The study will require funding to cover the costs of recruiting a physiotherapist, a music therapist who has been trained in using TIMP, a statistician, and lab technicians and lab time for motion analysis and brain scanning – (fMRI) or EEG recording – in order to identify and record any change at a neurological level that can be linked to audio-motor effects.

9. DATA MANAGEMENT AND STATISTICAL ANALYSIS

All data will be recorded by the CI, and each participant will have their own folder in which to keep session sheets, assessment score sheets and other, anonymised, relevant information. For each session a session sheet will be used for recording which musical patterns each participant has used, the duration that they played them for, how they performed and any feedback that they give. Data from the ARAT and 9HPT will be recorded onto score sheets, which come with the assessments. For the ARAT this includes a score for each task, overall score and time taken for each task.

All data and information gathered during this study will be anonymised. Paper files will be stored at the CI's property in a locked filing cabinet, to which no other person has access. All computer files and data will be stored on a removable disk or a secure server.

For the primary outcome measures, for the appropriate analysis of the crossover design with repeated measures a linear mixed model approach will be used. This will be undertaken using the computer program R and will employ the R package lme4 which is sufficiently flexible to provide detailed analysis for this type of design, including the accommodation of missing values. The main result of this analysis will be the assessment of whether the music therapy has had an effect.

Semi-structured interview data will be analysed using thematic analysis, with themes derived from participant responses to a set of predetermined questions. Responses will be manually recorded by the chief investigator and later, manually entered onto a response sheet and coded. Themes will be discussed with and checked by the supervisory team.

Participants will also be asked to score how effective the treatment has been in improving their activities of daily living (see semi-structured interview sheet).

R Core Team (2013). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, URL http://www.R-project.org/.

Douglas Bates, Martin Maechler and Ben Bolker (2012). lme4: Linear mixed-effects models using S4 classes. R package version 0.999999-0. http://CRAN.R-project.org/package=lme4

10. QUALITY ASSURANCE

The chief investigator (CI) is experienced in delivering this kind of treatment and has specialist NMT training and follow up (fellowship) training for sensorimotor techniques used to rehabilitate patients with motor dysfunction resulting from

neurological injury or disease. The CI has also delivered the treatment described in this protocol to a volunteer stroke patient in their home, which has enabled refining of the exercises and all aspects of the treatment prior to recruiting for the main, pilot study with wait list crossover design.

The chief investigator has received training and advise on using the ARAT and 9HPT, and has practiced using these assessments on stroke and normal subjects. In addition the CI has attended ethics, project management and introduction to statistics training at Anglia Ruskin University, as well as a three day neuroanatomy course at University College London.

Regular, specialist supervision has been provided for the CI throughout the design of this study and the delivery of the treatment with the volunteer stroke participant. This has enabled careful thought and planning for the main pilot study. Regular supervisory support will be provided throughout this research, including the data analysis and writing up. The CI will also be meeting regularly with the CCS team and will be able to call on members for advice where necessary.

11. EXPECTED OUTCOMES OF THE STUDY

The aim of this music therapy treatment is to provide a clear target (the instruments) for participants to aim for using their paretic upper limb, and clearly structured music to cue the priming, timing and muscle force required for each movement or sequence of movements. The potential benefit for participants is that this treatment will promote new neural connections for them, resulting in improved motor-planning, upper limb coordination and movement range, and increased capacity to carry out activities of daily living.

A secondary benefit is that music therapy can be extremely motivating for participants, thus enabling them to engage in music therapy treatment and exercises targeting upper limb rehabilitation using the instruments for longer periods.

12. DISSEMINATION OF RESULTS AND PUBLICATION POLICY

The trial is registered with Anglia Ruskin University and The British Association of Music Therapy (BAMT). The CI will seek to publish parts of this research, under the guidance of his supervisory team, in peer reviewed scientific journals in the UK, USA

and Europe, as well as on peer reviewed websites. No identifiable personal data will need to be included in any publication or presentation of this research. Any reports or papers written or published resulting from this research will be sent to all participants, as well as those who have contributed to the planning and management of this project. All participants will be asked to give informed consent, which will be recorded, before participating, and the consent form explains that data from the study may be anonymised and used in publications.

13. DURATION OF THE PROJECT

Patients will be required to participate for eighteen weeks including all treatment and assessments. Each participant will receive six weeks of twice weekly treatment, five assessment measures and a pre and post treatment semi-structured interview. The semi-structured interview will take approximately fifteen minutes to complete and will not be audio recorded; the chief investigator will take written notes.

14. PROBLEMS ANTICIPATED

INCLUSION CRITERIA

This has been set broadly in order to ensure that patients on the CCS database have a fair opportunity to participate and benefit from the treatment.

ACCESSIBILITY OF PARTICIPANT HOME

There may be cases where there is not adequate space in a participant's home to safely and comfortable set up the instruments for sessions. It may also be the case that there is no parking close enough to the property to transport instruments in and out in all weather conditions. In both of these cases it may not be possible to begin treatment. CCS team members will be consulted by the CI at the selection stage, before patients have been contacted by CCS or the CI, in order to establish if the property will be accessible and provide a safe environment in which to deliver treatment.

DROP OUT

Some wait list group participants may become discouraged having to wait 9 weeks before beginning treatment and may lose interest. These participants will still receive assessments before treatment and the CI will support them in their wait and feedback as to how the research is progressing.
Some treatment group participants may become discouraged after treatment has finished and they are waiting for their follow up assessments; The CI will encourage them as much as possible. All participants may find the assessments useful as they provide them with clear feedback regarding how their upper limb is functioning in relation to activities of daily living.

15. PROJECT MANAGEMENT

Extensive reading of key and related literature has already been conducted and recorded by the CI as part of the ongoing literature review.

The research will be Managed with the regular supervisory support of the CI's three experienced supervisors and with support from the CCS team and clinical lead. The music therapy treatment will be delivered in accordance with the CCS lone worker policy.

Anglia Ruskin University schedules two research monitoring meetings per year in which the CI is invited to raise any concerns, report on progress and update timescales for completing the PhD research.

The CI will attend regular, weekly meetings with the CCS team on Thursday mornings, and will liaise regularly with the clinical leads within each CCS team from where participants are recruited.
Data collection will need to be completed by, at the latest, December 2014. If insufficient numbers have been recruited and completed treatment by September 2014, then the sample size will need to be reduced in order to allow for time to complete analysis and writing up the study.
Data collected from each participant will undergo basic analysis conducted by the CI, as soon as they have completed the baseline and end measures following treatment, and again when all measures are complete.

Mike Parker, statistician at Anglia Ruskin University, Chelmsford site, will manage the in depth analysis of data, together with the CI. Data from the semi-structured interviews will be analysed by the CI in consultation with professor Helen Odell-Miller (first supervisor at Anglia Ruskin University).

Writing up of a single case study will be prepared for publication before the main study is completed, with the guidance of the CI's supervisory team, who are all widely published in the field of music therapy as well as music and the brain (professor Jorg Fachner) and music therapy in neurorehabilitation (Dr Wendy Magee) and will be included in the main PhD thesis. Writing up of the research results will be prepared for publication under the guidance of the supervisory team.

16. ETHICS

The CCS team will approach patients on their database who they have identified as likely to meet the inclusion criteria, by sending a 'Letter of Invitation' (attached). In the letter, potential participants are asked to contact the chief investigator by phone or e-mail if they are interested in finding out more; if they call then the CI will answer any questions that they have and send an information sheet to them. A home visit will be made to assess the home for suitability, show patients some of the exercise patterns and leave with them a consent to participate form, which the CI will go through with them. The CI will ask patients to sign and return the form within a week if they wish to go ahead.

CONFIDENTIALITY

I will not access the CCS database and their patient records until informed consent has been recorded from participants.

I have been recruited with a formal contract as an honorary researcher with CCS for the duration of this study and will adhere to all terms and conditions including data protection and confidentiality.

I will need to access participant records to obtain details of their stroke and any other medical information relevant to the treatment I will be providing. This is in order to ensure that: A. they meet the recruitment criteria; B. to help tailor TIMP treatment to individual needs; C. all information regarding variables between patients can be considered to enable accurate analysis of data gathered and discussion of the findings

in the PhD thesis and any publications resulting that would be published in peer reviewed scientific journals.

The information that I will need from patient records is: age, type and site of stroke, gender, time since stroke, length of stay in acute care, length of time since discharge from hospital, length of community rehabilitation, time since discharge from community rehabilitation, all cognitive, physiological, communication and behavioural scores from relevant acute and post acute assessments, for example Glasgow coma score, European stroke index, Barthel Index, nine hole peg test, name and address of GP.

I will need to have participants' addresses in order to visit them and deliver the treatment. I will keep these as encrypted files and stored on a removable disc or secure server. I will also do the same with phone numbers as I may need to contact participants if for any reason I am delayed whilst on my way to see them or unwell and unable to do the session.

Manual files will not contain names, addresses or telephone numbers and will be stored in a locked filing cabinet at the chief investigator's home.

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LINKS

http://strokengine.ca/assess/module_arat_quick-en.html

Diagram 2. TIMP Pattern 1.

Diagram 3. TIMP patterm 1b, with adaptive beater.

Diagram 4. TIMP pattern 1D, using iPad with touchscreen drum kit.

Diagram 5. TIMP pattern 1D using iPad drum stick.

Diagram 6. TIMP pattern 2.

Diagram 7. TIMP pattern 2a, using adaptive beater.

Diagram 7. TIMP pattern 4b, using hands only.

Diagram 8. TIMP pattern 4.

Diagram 9. TIMP pattern 5, with two beaters taped together and NOT full rotation of wrist.

Diagram 10. TIMP pattern 6, using fingers to play single chord to the melody of Frere Jacques.

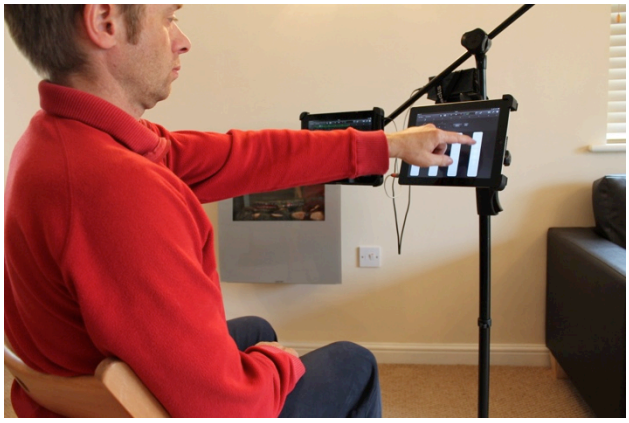


Diagram 11. TIMP pattern 7, playing an 8 chord sequence with the iPads mounted horizontally to facilitate shoulder adduction with elbow extended.

Diagram 12. The ARAT.

OTHER INFORMATION.

The microphone stand used to mount the iPads should be robust and of high quality; a Hercules MS533B will be used for this study.

All iPads need to be mounted in a rubber protective case, which fit around the base (not the screen). An iPad 2 and iPad 3 will be used in this study. The stand for iPads, which mount onto the microphone stand are a Hercules HA300 tablet holder and a tablet holder supplied by gear4music. The cymbal is a 14” crash DH-CM14B. The bongos are Meinl. Mounted on a percussion plus ‘headliner’ range adjustable bongo stand.

10.1.3 Scientific report

Evaluation for PhD Proposal Alex Street

Therapeutic Instrumental Music Playing TIMP

Colorado State University

School of the Arts
Department of Music, Theatre, and Dance
College of Liberal Arts
1778 Campus Delivery
Fort Collins, Colorado 80523-1778
(970) 491-5529
Fax: (970) 491-7541
www.sota.colostate.edu

1. Need and Background
   The research in the areas of music and auditory rhythm in relationship to gait rehabilitation have faster progressed than upper limb rehabilitation. Therefore a real need exist to extend those research efforts. However, there are several key papers in the past 10 years that have done research on various aspects of TIMP interventions so that the proposal actually does have solid – although – limited – reference base of preliminary result and designs. I have attached 1 more paper to extend the data base. Two other references for auditory rhythmic cuing without music al instruments:
   Whitall et al 2000. Repetitive bilateral arm training with rhythmic auditory cuing improves motor function chronic hemiparetic stroke. Stroke
   Luft et al 2004. Repetitive bilateral arm training and motor cortex activation in chronic stroke. J Americ Medic Assoc
   In conclusion, the study is sufficiently placed within a valid and important scientific and clinical framework.

2. Importance
   The study adds three new elements to the current scope of research. First, previous clinical training studies have used music instrument playing without external rhythmic cuing. The study by Thaut et al (2002) using external rhythmic cuing for paretic arm movements did not use musical instruments and also studied only immediate effects on arm movement without long-term training. Second, no study within the proposed topic has been conducted within a home environment, thus exploring new environmental and technical setup factors. Third, the study uses a less intense training paradigm, only 2 sessions @ week compared to mostly daily training in comparable studies, thus investigating if low dosage applications can also be efficient to change function.

3. Design
   The design of pretest – intervention – posttest – follow up test is standard and well accepted. The use of the ARAT and 9HPT is also standard and validated for arm assessments. Testing should be carried out by somebody blind to the treatment/control condition and stage of testing (*pre/post/follow up*). The design does not have an intervention-equivalent control group. The only temporally directly matched control group is the 'no treatment' group on the waiting list. Treatment data can be compared to the previous CCS data although caution must be applied in interpreting since the CCS treatment and the TIMP treatment occur at different stages of stroke recovery. CCS outcomes can be analyzed in regard to how much they were sustained over 9 weeks without further treatment. Treatment outcomes can also be compared at treatment endpoints between control/wait list and experimental group in terms of the effect of delayed entry into treatment. Important to know is how long each patient was in CCS treatment and if they all entered the study immediately after CCS discharge or at what common delay period.

4. Treatment
   Treatment protocols are well designed for functional applications. Appropriate musical instruments and cuing methods have ben described. Important is that all TIMP exercises have the same recorded music/rhythm stimuli as eternal cues for each patient, so a standard stimulus description is available.

5. Recommendation
   The study is important and conceptually sound. Design details should be checked to maximize standardized control over independent and dependent variables. It is well recognized that experimental studies in outpatient environments cannot fully control all external variables. Standard testing and standardized intervention protocols as proposed will go a long way to validate the study. The study would be an acceptable topic and design in an applicable PhD program at Colorado State University.

Michael H Thaut PhD - Professor of Music, Professor of Neuroscience – Director, Center for Biomedical Research in Music

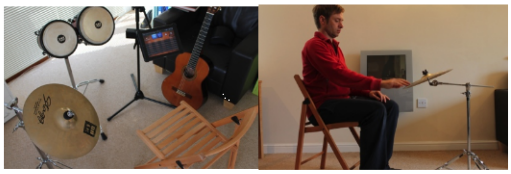
Colorado State University – Fort Collins CO - USA

10.2 Appendix 2. Research forms

10.2.1 Letter of invitation

LETTER OF INVITATION TO PARTICIPATE IN MUSIC THERAPY RESEARCH FOR UPPER LIMB REHABILITATION

(to be printed on Cambridgeshire Community Services headed paper)



Dear _____,

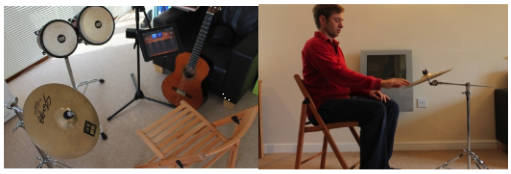
Cambridgeshire Community Services currently have an honorary researcher contracted within their team who is a PhD student at Anglia Ruskin University, Cambridge. His name is Alex Street and he is a music therapist experienced in working with people who have had a stroke. The treatment he is researching is arm, hand and finger rehabilitation, and participants would be required to do specific exercises using a small selection of percussion and electronic musical instruments (iPads). Previous research has found similar techniques to be very effective in improving paretic arm use with stroke patients, but this kind of research has not been conducted in participant homes before.
If you were to take part, Alex would visit you in your home twice per week for 6 weeks in order to help you do the exercises.

If you are interested in finding out more could you please contact Alex either by phone: 07799392838, or e-mail: alexander.street@student .anglia.ac.uk. He will be very happy to answer your questions. He would then arrange to visit you in your home in order to answer any questions that you have regarding the treatment and to show you some of the exercises. The visit would take approximately 1 hour.

Many thanks _____
(Cambridgeshire Community Services)

LETTER OF INVITATION TO PARTICIPATE IN MUSIC THERAPY RESEARCH FOR UPPER LIMB REHABILITATION

(to be printed on Cambridgeshire Community Services headed paper)



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Many thanks _____

(Cambridgeshire Community Services)

10.2.2 Participant information sheet

PARTICIPANT INFORMATION SHEET FOR PhD RESEARCH STUDY

Title of study: An investigation into music therapy for the rehabilitation of upper limb function in adult stroke patients

Investigator: Mr Alex Street. Music Therapist and PhD student at Anglia Ruskin University, East Road, Cambridge, CB1 1PT. Investigators e-mail address: alexander.street@student.anglia.ac.uk

We are inviting you to take part in a research study as part of Alex Street's PhD.

Please read the following information sheet carefully and discuss it with others. I will be very happy to answer any questions, come and see you and show you exactly what will be involved. If you would like to take part I will ask you to sign a consent form.

What is the purpose of the study?

I am trying to find out if exercising by playing musical instruments to music will help you use your affected hand and fingers better in your daily life after you have finished your rehabilitation with Cambridgeshire Community Services.

People who have had a stroke sometimes need more effective ways to make arm and hand movements better. Some recent studies have shown that stroke patients doing exercises by playing musical instruments has proven to be very effective in improving these movements.

Why are you being asked to participate?

Because you have finished your community rehabilitation but you might be able to improve the use of your affected arm and hand more by having this music therapy treatment.

What will the music therapist do?

I will:

1. Come to your house twice a week for 6 weeks and spend 30 minutes going through some exercises using musical instruments with you. You will not have to learn to play a musical instrument and you will not be asked to practice.
2. Bring some portable musical instruments: a guitar, bongos on a stand, a 10" cymbal on a stand and two Pads, plus a selection of beaters and brushes (see figure 1 below).
3. Play some music using a guitar while you do this, which will help you know when to start and stop playing and might make it easier for you to control your arm movements and use your arm for longer without getting tired. When you get better at moving your arm, hand and fingers to each exercise, then we will move on to the next exercise (see chart 1 below).
4. Assess your arm, hand and finger movements in your home, using two, standard tests: the Action Research Arm Test (ARAT) and the Nine Hole Peg Test (9HPT). This will be done once in your first session and once in you final session, and a further three times either before or after you begin your music therapy (see below).

The music will not be loud or too fast, but made to suit your home environment and the speed at which you can move your arm/hand/fingers.

Figure 1.1 A photograph showing the instruments we will use. From left to right: cymbal, bongos, iPad, guitar.

An example of an exercise.

Below is a description of one of the exercises that will be included in this study, detailing which muscle groups are involved, the instruments and their positioning, the instructions, musical accompaniment and some variations where different beaters can be held and used or an iPad touch screen instrument can be used. Figures 2 and 3 (below) further illustrate this exercise.

PATTERN 1:

TARGET MOVEMENT: bending and straightening your elbow and wrist, extending finger/s.

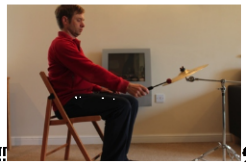
INSTRUMENT AND POSITIONING: Cymbal positioned at height approximately level with your elbow when your arm is resting at your side, mid-line so that cymbal edge is just beyond knees.

INSTRUCTIONS: Relax your shoulders, keep your back against the chair and feet flat on the floor, reach with your arm and extend your fingers, relax arm & rest hand on lap after playing.

MUSICAL PLAYING PATTERN: your affected hand and fingers always play the cymbal on beat 3 of each bar, I will demonstrate this.

FACILITATING MUSIC: rhythmic and with a clear beat: C, Am, F, G chord sequence played on an acoustic guitar, which may remind you of the song 'Stand By Me' by Ben. E. King.

VARIATION: figure 3 (below) shows 1b, using a thick handled (adaptive) beater. Other variations involve drum sticks and beaters of varying thickness, which can help you to develop a more effective grip.



10.2.3 Participant consent form

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!

!

!

!

Centre!Number:!!Anglia!Ruskin!1!!! ! ! ! Study!Number:!TIMP!1!

Patient!Identification!Number!for!this!trial:!RP1!

PARTICIPATION CONSENT FORM

Title of Project: An investigation into music therapy for the rehabilitation of upper limb function in adult stroke patients

Name of Researcher: Mr Alex Street

!

Please initial all boxes

1. I confirm that I have read and understand the information sheets dated **07/03/2014** (version **3.5**) for the above study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily. ☐

2. I understand that my participation is voluntary and that I am free to withdraw at any time without giving any reason, without my medical care or legal rights being affected. ☐

3. I understand that relevant sections of my medical notes and data collected during the study, may be looked at by the chief investigator, Alex Street, ☐

who is employed as an honorary researcher by Cambridgeshire Community Services NHS trust.

4. I agree to my GP being informed of my participation in the study. ☐

5. I understand that anonymised data from this study may be used in academic publications, documents, presentations and conferences. ☐

6. I agree to take part in the above study and consent to all of the procedures described in the information sheets. ☐

Name of Participant	Date	Signature
or		
Name spouse/relative signing	Date	Signature
Name of Person taking consent	Date	Signature

This form can be collected in person by the researcher or returned to:

Alex Street
The Oliver Zangwill Centre
The Princess of Wales Hospital

10.2.4 GP information sheet

GP INFORMATION SHEET

We are inviting _____
to take part in a research study and receive music therapy from a qualified and experienced music therapist, Alex Street (the investigator). The study is part of his Phd with Anglia Ruskin University.

Title of study: *An investigation into music therapy for the rehabilitation of upper limb function in adult stroke patients*

Investigator: Alex Street is currently a Phd student at Anglia Ruskin University and is conducting this study to see if a music therapy technique for upper limb rehabilitation will be effective or not when delivered twice a week for 6 weeks.
Alex is currently an honorary research member with Cambridgeshire Community Services NHS Trust Neurorehabilitation Team and has worked for many years as a music therapist in various neurodisability settings. He now runs a private music therapy practice based in Cambridgeshire and is one of thirty music therapists in the UK who have specialist training and experience in the use of NMT techniques for rehabilitating movement, communication and cognition.

For more information the Investigator's contact details are:
e-mail address: alex.street@anglia.ac.uk
address: Anglia Ruskin University East Road, Cambridge, CB1 1PT,
telephone number: 07799 392838

Participation in the study will be for a total of **18 weeks** and in this period there will be **6 weeks of twice weekly music therapy in the patient's home.** The patient will be required to play specific patterns, whilst sitting down, using their affected and unaffected upper limbs on a selection of musical instruments. The instruments will be positioned in order to improve range of movement and coordination. Rhythmic music will be played by the music therapist using a guitar in order to support the priming and timing of movements.

Informed consent will be recorded from your patient, after they have read a participant information sheet, spoken with the investigator, and had a demonstration of the musical exercises in their home.

Details of the treatment and assessments

- 30 minute one-to-one music therapy sessions (with breaks scheduled depending on participant fatigue)
- two sessions per week for six weeks (12 sessions in total)
- all music therapy sessions will take place in the patient's home
- 5 assessments using the action research arm test (ARAT) (Lyle, 1981) and the 9 hole peg test (9HPT) (Keller, 1971) conducted in the patient's home.

Pre and post treatment assessments will be conducted by a therapist employed by Cambridgeshire Community Services NHS Trust (CCS) who will be blind to the randomisation groups. Pre and follow-up assessments will be conducted by the investigator, who is also trained and experienced in using these two assessment tools.

The ARAT can take up to 30 minutes, but usually 10 minutes as most patients are not required to complete all tasks. The 9HPT takes approximately 2 minutes to complete.

The Action Research Arm Test is divided into four parts and there are 19 tasks for the patient to complete in total. The test involves the picking up and moving of different shaped objects from one target marker to another, either on the table or a shelf on top of the table (provided in the ARAT kit).

The 9 HPT is a timed test and comprises a board with nine small holes at one end and at the other end a small tray with nine small pegs in it. The nine pegs are picked up and put into the holes, then taken out again and put back into the tray as quickly as possible.

What is the purpose of the study?

The purpose of this study is to see if a technique, which is called Therapeutic Instrumental Music Performance (TIMP) (Thaut, 2005), will improve upper limb function in stroke patients or not.
Some recent, similar studies (Schneider, et al., 2007; Altenmueller, et al., 2009; Rojo, et al., 2011) have resulted in significant improvements in paretic arm function.

This study introduces three variations on previous research of this nature:

1. treatment is home based; 2. the exercises are supported by set musical accompaniment; 3. treatment is twice weekly for six weeks rather than daily for three to four weeks.

Who has reviewed this study?

The study has been reviewed and approved by the NRES East of England Essex Research ethics committee via the NHS Integrated Research Application (IRAS), where all research must be approved and receive ethics clearance.
An additional scientific evaluation of the research study design has been made by Professor Michael Thaut (professor of music, professor of neuroscience and director of the centre for biomedical research

in music at Colorado state university, USA) and he has written a report supporting the research design and protocol.

Why is your patient being asked to participate?

Because he/she has hemiparesis resulting from a stroke and completed community occupational therapy rehabilitation with (CCS).

When will the music therapy treatment begin?

The study design involves two groups: A: treatment, B: wait list.

After informed consent has been recorded the patient will be randomised into one of the groups:

1. A. begins within 1 week
2. B. begins after 9 weeks

NOTE: for study purposes please do not communicate the randomisation process and study design to the patient as this may influence blind assessment outcomes

What are the possible disadvantages of taking part?

Playing the instruments may be tiring, however most people find this activity enjoyable and relaxing. The five assessments with the ARAT and 9HPT may be repetitive, but they can be useful and need to be done in order to see if there have been changes. The therapist (blind assessor) and I will always check that the patient feels OK before beginning assessments or music therapy and ask regularly if they would like a break.

What are the possible benefits of taking part?

The patient may, if the technique works, be able to move their arm, hand and fingers more and do more things each day, for example dressing, cleaning teeth, preparing food, reaching and picking things up. The patient may really enjoy exercising in this way by playing music with the investigator.

The arm assessments will help us understand more precisely whether or not the music therapy has made a difference.

Can the patient stop participating in the study at any point?

Yes, if they decide that they no longer wish to continue with the study at any point then they may stop. This will not affect their entitlement to further treatment with CCS.

Will participant information be kept confidential?

Yes. No names or personal details will be used or published during or after the study.

Who will have access to the patient's medical records?

Alex is an honorary member of the Cambridgeshire Community Services National Health Trust Neurorehabilitation team and may, in collaboration with CCS NHS clinicians, need to access the patient's medical records in order to check the following information that is relevant to this study: age,

date of stroke, type and site of stroke, any previous stroke, other condition affecting general movement and specific upper limb movement, length of time admitted to hospital, time since discharge, length & type of acute treatment (physio, speech and language, psychological, cognitive), length and type of community treatment, Glasgow coma and other assessment scores on admission to hospital following stroke, assessment scores at the end of all rehabilitation treatment., any other diagnosis that may affect participation such as psychological, physical or cognitive.

What will happen to the results of the research study?

Patients will be informed of their results at the end of the study. Results might be published in a peer reviewed medical journal, a music therapy journal or on a medical or music therapy website. Results might also be presented at music therapy conferences and research seminars; in all of these cases prior consent will be given by the patient, and personal details will not be shown.

Thank you for reading this information, your assistance and collaboration is very much appreciated.

Alex Street (BMus, MtDip, NMT fellow). Chief Investigato

References

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and Clinical Applications. New York. Routledge.

10.2.5 Normal scoring averages for the 9HPT

Table 1. Average and Standard Deviation of MALE Participants' Scores (314 total)

Age	*N*	*M*-right (seconds)	*M*-left (seconds)	*SD*-right	*SD*-left
21–25	41	16.41	17.53	1.65	1.73
26–30	32	16.88	17.84	1.89	2.22
31–35	31	17.54	18.47	2.70	2.94
36–40	32	17.71	18.62	2.12	2.30
41–45	30	18.54	18.49	2.88	2.42
46–50	30	18.35	19.57	2.47	2.69
51–55	25	18.93	19.84	2.37	3.10
56–60	25	20.90	21.64	4.55	3.39
61–65	24	20.87	21.60	3.50	2.98
66–70	14	21.23	22.29	3.29	3.71
71+	25	25.79	25.95	5.60	4.54
All Male Subjects	314	18.99	19.79	3.91	3.66

Table 2. Average and Standard Deviation of FEMALE Participants' Scores (389 total)

Age	*N*	AVG-right (seconds)	AVG-left (seconds)	STDEV-right	STDEV-left
21–25	43	16.04	17.21	1.82	1.55
26–30	33	15.90	16.97	1.91	1.77
31–35	32	16.69	17.47	1.70	2.13
36–40	35	16.74	18.16	1.95	2.08
41–45	37	16.54	17.64	2.14	2.06
46–50	45	17.36	17.96	2.01	2.30
51–55	42	17.38	18.92	1.88	2.29
56–60	31	17.86	19.48	2.39	3.26
61–65	29	18.99	20.33	2.18	2.76
66–70	31	19.90	21.44	3.15	3.97
71+	31	22.49	24.11	6.02	5.66
All Female Subjects	389	17.67	18.91	3.17	3.44

The tables above show 9HPT averages for Males (table 1) and females (table 2) (Oxford Grice et al., 2003).

10.2.6 ARAT normative data

Chronic Stroke: (van der Lee et al, 2001)

- Mean (SD) intake ARAT score 29.2 (12.5)
- Mean (SD) intake Fugl-Meyer Assessment score 49.2 (9.9)

Item norms (based on healthy elderly adults):

Subtest:	**Item**	**Time Limit (s)**
Grasp	Block 2.5cm	3.6
	Block 5cm	3.5
	Block 7.5cm	3.9
	Ball 7.5cm	3.8
	Stone	3.6
	Block 10cm	4.2
Subtest:	**Item**	**Time Limit (s)**
Grip	Tube 2.25cm	4.2
	Tube 1cm	4.3
	Place washer over bolt	4
	Pour water from glass to glass	7.9
Subtest:	**Item**	**Time Limit (s)**
Pinch	Large marble first finger and thumb	3.8
	Large marble second finger and thumb	3.8
	Large marble third finger and thumb	4.1
	Small marble first finger and thumb	4
	Small marble second finger and thumb	4.1
	Small marble third finger and thumb	4.4
Subtest:	**Item**	**Time Limit (s)**
Gross Movement	Move hand to mouth	2.4
(Van, 2001)	Place hand on top of head	2.7
	Place hand behind head	2.7

Time limits (mean + 2 SD of the performance times of 20 healthy elderly subjects)

If performance is slower than the time limit or if the patient loses contact with the

back of the chair during performance, the score is 2 instead of 3.

10.3 Appendix 3. Participants' semi-structured interview responses transcribed

Anglia Ruskin University
Cambridge & Chelmsford

PARTICIPANT NUMBER: 01

DATE: 15/04/2014

Pre-treatment Semi Structured Interview

1. **What do you think the treatment will be like?**
   Using music to get my hands and arm moving.

2. **How will it feel playing the instruments?** *Really good, using the arm for anything practical, doing something musical again.*

3. **How will it feel playing to the music?**
   Very stimulating to keep to a beat, help focus the mind on it. Hugely different from being asked for no reason to hit a table.

4. **Please score how much you feel music therapy will change your arm and hand use in daily living.**

   1 = not at all, 5 = very much

1	2	3	4	5

Not at all **very much**

24/10/2013 Version 3.5 13/EE/0400

Anglia Ruskin University
Cambridge & Chelmsford

PARTICIPANT NUMBER: 02

DATE: 07/05/2014

Pre-treatment Semi Structured Interview

1. What do you think the treatment will be like? *Testing, to see if ia can lift my hand up.*
2. How will it feel playing the instruments? *Funny, weird, I'm not musically minded, never played instruments.*
3. How will it feel playing to the music? *I don't like music.*
4. Please score how much you feel music therapy will change your arm and hand use in daily living.

1 = not at all, 5 = very much

1	2	3	4	5

Not at all very much

Anglia Ruskin University
Cambridge & Chelmsford

PARTICIPANT NUMBER: 03

DATE: 29/04/2014

Pre-treatment Semi Structured Interview

1. What do you think the treatment will be like? *No idea.*
2. How will it feel playing the instruments? *Used to play keyboard and accordion. Frustrating.*
3. How will it feel playing to the music? *Hopefully enjoyable, depends if I can do it.*
4. Please score how much you feel music therapy will change your arm and hand use in daily living.

1 = not at all, 5 = very much

1	2	3	4	5

Not at all very much

Anglia Ruskin University
Cambridge & Chelmsford

PARTICIPANT NUMBER: 04

DATE: 21/10/2014

Pre-treatment Semi Structured Interview

1. What do you think the treatment will be like? *Open to trying. Left side I can feel, right is weaker, less sensation and strength.*
2. How will it feel playing the instruments? *I don't know.*
3. How will it feel playing to the music? *The week before I was rubbish.*
4. Please score how much you feel music therapy will change your arm and hand use in daily living.

1 = not at all, 5 = very much

1	2	3	4	5

Not at all very much

Anglia Ruskin University
Cambridge & Chelmsford

PARTICIPANT NUMBER: 05

DATE: 13/11/2014

Pre-treatment Semi Structured Interview

1. What do you think the treatment will be like? ***Helpful, not about learning music. Good to have things to do with my hand.***

2. How will it feel playing the instruments? ***Good, keep me on track playing musical instruments, otherwise it might be hard. It'll give me set times to play.***

3. How will it feel playing to the music? ***Good.***

4. Please score how much you feel music therapy will change your arm and hand use in daily living.

   1 = not at all, 5 = very much

1	2	3	4	5

Not at all — very much

Anglia Ruskin University
Cambridge & Chelmsford

PARTICIPANT NUMBER: 06

DATE: 16/03/2015

Pre-treatment Semi Structured Interview

1. What do you think the treatment will be like? *Interesting I hope. It may help with playing recorder, anything, holding knives and forks.*

2. How will it feel playing the instruments? *Good. Nice to feel involved again with playing music. A challenge.*

3. How will it feel playing to the music? *Good, because I'm playing with somebody involving skills I've not used for a while. Pleasing I hope.*

4. Please score how much you feel music therapy will change your arm and hand use in daily living.

   1 = not at all, 5 = very much

1	2	3	4	5

Not at all very much

24/10/2013 Version 3.5 13/EE/0400

Anglia Ruskin University
Cambridge & Chelmsford

PARTICIPANT NUMBER: 07 (WL)

DATE: 26/06/2014

Pre-treatment Semi Structured Interview

1. What do you think the treatment will be like? *Not easy.*
2. How will it feel playing the instruments? *Fun, nice.*
3. How will it feel playing to the music? *Alright.*
4. Please score how much you feel music therapy will change your arm and hand use in daily living.

1 = not at all, 5 = very much

1	2	3	4	5

Not at all very much

Anglia Ruskin University
Cambridge & Chelmsford

PARTICIPANT NUMBER: 08WL

DATE: 01/07/2014

Pre-treatment Semi Structured Interview

1. What do you think the treatment will be like? *No coherent response.*
2. How will it feel playing the instruments? *No coherent response.*
3. How will it feel playing to the music? *You probably play better than me, one sided. It will be enough to play sometimes and approximate the corresponding sound.* **Note: this response reflects the participants cognitive problems as it was not clear whether he understood the question, not whether he comprehended what the treatment was.**
4. Please score how much you feel music therapy will change your arm and hand use in daily living.

   1 = not at all, 5 = very much

1	2	3	4	5

Not at all very much

Anglia Ruskin University
Cambridge & Chelmsford

PARTICIPANT NUMBER: 09WL

DATE: 30/11/2014

Pre-treatment Semi Structured Interview

1. What do you think the treatment will be like? *Hard, difficult because of lack of grip and twist in wrist. Should become easier to reach and touch with skin.*
2. How will it feel playing the instruments? *Some benefit, looking forward to it, get movement back.*
3. How will it feel playing to the music? *Hard, not very 'beatsified'. Music is soothing that I play, relaxing.*
4. Please score how much you feel music therapy will change your arm and hand use in daily living.

1 = not at all, 5 = very much

1	2	3	4	5

Not at all — very much

Anglia Ruskin University
Cambridge & Chelmsford

PARTICIPANT NUMBER: 10WL

DATE: 09/04/2015

Pre-treatment Semi Structured Interview

1. What do you think the treatment will be like? *A bit of fun. It will do some good. Someone to talk to.*

2. How will it feel playing the instruments? *From my previous experience I think a bit painful in my fingertips. I'll probably make a fool of myself. I'm not really sure what you're asking me to play. I'm pleased it's come along out of the blue in my life.*

3. How will it feel playing to the music? *I don't think I'm very good at it but I'll try. I can move my fingers to the music in my right hand, but not his hand.*

4. Please score how much you feel music therapy will change your arm and hand use in daily living.

   1 = not at all, 5 = very much

1	2	3	4	5

Not at all — very much

Anglia Ruskin University
Cambridge & Chelmsford

PARTICIPANT NUMBER: Pt01

DATE: 28/06/2014

Post Treatment Semi Structured Interview

1. What do you think about the treatment? *Positive, engages my arm unlike any other treatment, movements that are unachievable in other exercise workouts. I don't want to spoil the outcome. It encourages the goal of holding a fork. I can put my arm into a position that aids getting dressed.*

2. How does it feel playing the instruments? *Fun mostly. Hard work at times. Compelling, worthwhile.*

3. How does it feel playing to the music? *The music makes it. I can participate. Aesthetic pleasure. Keeping to the beat. The same with no music wouldn't work.*

4. Please score how much you feel music therapy has changed your arm and hand use in daily living.

   1 = not at all, 5 = very much

1	2	3	4	5

Not at all very much

Anglia Ruskin University
Cambridge & Chelmsford

PARTICIPANT NUMBER: 02

DATE: 11/06/2014

Post Treatment Semi Structured Interview

1. What do you think about the treatment? *Good. Helped movement, more reach. Learning to get in time, beneficial.*

2. How does it feel playing the instruments? *Strange, never played any before. They are good, hitting the cymbal mainly became a target.*

3. How does it feel playing to the music? *Strange, got used to the rhythm. I went faster and slower than the beat sometimes.*

4. Please score how much you feel music therapy has changed your arm and hand use in daily living.

   1 = not at all, 5 = very much

1	2	3	4	5

Not at all very much

Anglia Ruskin University
Cambridge & Chelmsford

PARTICIPANT NUMBER: 03

DATE: 05/06/2014

Post Treatment Semi Structured Interview

1. What do you think about the treatment? *Enjoyed it. I think about using my left hand, noticing it's not working possibly because I'm trying to use it more. Nice having one-to-one attention.*

2. How does it feel playing the instruments? *Takes a lot of concentration, I get quite achy sometimes. Fun, seeing Alex struggle with various stands. Enjoyed the tablets. I feel bongos should be played with hands not sticks.*

3. How does it feel playing to the music? *Enjoyed this. I'm used to it anyway, as a musician.*

4. Please score how much you feel music therapy has changed your arm and hand use in daily living.

   1 = not at all, 5 = very much

1	2	3	4	5

Not at all very much

Anglia Ruskin University
Cambridge & Chelmsford

PARTICIPANT NUMBER: 04

DATE: 28/11/2014

Post Treatment Semi Structured Interview

1. **What do you think about the treatment?** ***Fun.***

2. **How does it feel playing the instruments?** ***Beginning it was harder to get my arm to move, now less so.***

3. **How does it feel playing to the music?** ***I liked the beat, helped me know when to play.***

4. **Please score how much you feel music therapy has changed your arm and hand use in daily living.**

   1 = not at all, 5 = very much

1	2	3	4	5

Not at all **very much**

Anglia Ruskin University
Cambridge & Chelmsford

PARTICIPANT NUMBER: 05

DATE: 18/12/2014

Post Treatment Semi Structured Interview

1. What do you think about the treatment? *Really good because I feel like my fingers have become more active, especially my thumb, opening and closing has definitely improved. It's quite like the attention on my arms, it hurts but in a good way. It's doing something and that's always good.*

2. How does it feel playing the instruments? *Really good and fun. I liked the bongos especially because they're real as opposed to Pads, they were OK but the bongos you know you're hitting. Also you can do little or big taps with the bongos that new movement is very good. On the piano you can do little and big notes, depending on your effort, unlike electronic instruments, which were fun. Also, you can hold the beater and feel the vibrations.*

3. How does it feel playing to the music? *Definitely better playing with the music than without. The rhythm was quite important. Also important to play with someone else, someone who can pressure you into doing it right. The repeated patterns are important, with songs they're already in your head, i.e. The Beatles are playing it and you've got to play along. Something to do with the anonymity of a pattern, doesn't make any difference if you play to the pattern right or wrong.*

4. Please score how much you feel music therapy has changed your arm and hand use in daily living. *I think about my hand how when I do every activity, instead of leaving it, getting involved.*

1 = not at all, 5 = very much

1	2	3	4	5

Not at all very much

24/10/2013 Version: 3.5 Ref: 13/EE/0400

Anglia Ruskin University
Cambridge & Chelmsford

PARTICIPANT NUMBER: 06

DATE: 22/04/2015

Post Treatment Semi Structured Interview

1. What do you think about the treatment? *Very encouraging.*
2. How does it feel playing the instruments? *Good, satisfying. The addition of harmony is good, from me and the instruments.*
3. How does it feel playing to the music? *Satisfying, nice playing with other people, that's what I miss most.*
4. Please score how much you feel music therapy has changed your arm and hand use in daily living.

   1 = not at all, 5 = very much

1	2	3	4	5

Not at all very much

Anglia Ruskin University
Cambridge & Chelmsford

PARTICIPANT NUMBER: 07

DATE: 04/08/2014

Post Treatment Semi Structured Interview

1. What do you think about the treatment? *Very good. Helped a lot. I couldn't move my fingers at all, my wrist was swollen. It didn't make me tired.*

2. How does it feel playing the instruments? *Nice, I liked it. Plectrum was hard to use.*

3. How does it feel playing to the music? *Nice. As we played I could pick up the music. I knew the chords that were coming next. When I missed a note I was able to know when the next note was coming.*

4. Please score how much you feel music therapy has changed your arm and hand use in daily living.

   1 = not at all, 5 = very much

Anglia Ruskin University
Cambridge & Chelmsford

PARTICIPANT NUMBER: 08

DATE: 07/08/2014

Post Treatment Semi Structured Interview

1. What do you think about the treatment? No coherent response.

2. How does it feel playing the instruments? *I was trying to do it alright.* Question from researcher: 'do you think you did?', *not the most alright, not when second best. When I was going up to 30, it doubled, then back again.*

3. How does it feel playing to the music? *Nicer to play double* … response incoherent. The participant may have been referring to 'playing together', when saying 'playing double'.

4. Please score how much you feel music therapy has changed your arm and hand use in daily living.

   1 = not at all, 5 = very much

1	2	3	4	5

Not at all very much

Anglia Ruskin University
Cambridge & Chelmsford

PARTICIPANT NUMBER: 09

DATE: 19/12/2014

Post Treatment Semi Structured Interview

1. What do you think about the treatment? *Better than I thought it would be. I'd recommend it. I was moving my arm without having to think about it. I didn't realise I was moving my arm and fingers.*

2. How does it feel playing the instruments? *Enjoyable, hitting something, you realise you are doing something.*

3. How does it feel playing to the music? *Calming, soothing music, counting to keep to the rhythm of the guitar. Pre-empt movement for the next bash.*

4. Please score how much you feel music therapy has changed your arm and hand use in daily living.

   1 = not at all, 5 = very much

1	2	3	4	5

Not at all very much

Anglia Ruskin University
Cambridge & Chelmsford

PARTICIPANT NUMBER: 10

DATE: 14/05/2015

Post Treatment Semi Structured Interview

1. What do you think about the treatment? *Because of spasticity I have extra problems. It's quite fun, cheers you up. How will I know if it does any good. Not sure it's helped.*

2. How does it feel playing the instruments? *Quite fun, I'm not musical, something new. I don't play an instrument. I'm stuck here all day, it breaks up the tedium.*

3. How does it feel playing to the music? *It helps you get into a sort of rhythm. Things always go more smoothly if you get into a rhythm even when you're clipping a hedge or digging.*

4. Please score how much you feel music therapy has changed your arm and hand use in daily living. *Left hand tries to help the right. Can't hold things terribly well.*
   It's given me a more positive attitude.
   It's made me more conscious of doing things with my left hand.

   1 = not at all, 5 = very much

1	2	3	4	5

Not at all — very much

10.4 Appendix 4. Photographs of the researcher performing some TIMP patterns

10.4.1 TIMP 1c

10.4.2 TIMP 8

10.5 Appendix 5. Extra tables from the data analysis

Table 2.3 ARAT overall score at time point 1 by Intervention type

Intervention type	Mean	Standard deviation	Percentiles					Number of values	Number of missing values
			Smallest 0%	25%	Median 50%	75%	Largest 100%		
Waitlist	38.00	12.629	16.0	31.3	43.00	46.0	46.0	5	0
Treatment	21.17	17.116	0.0	7.3	20.00	35.8	44.0	6	0
Overall	28.82	16.958	0.0	12.7	35.00	43.8	46.0	11	0

Table 2.4 ARAT overall score at time point 2 by Intervention type

Intervention type	Mean	Standard deviation	Percentiles					Number of values	Number of missing values
			Smallest 0%	25%	Median 50%	75%	Largest 100%		
Waitlist	33.00	10.100	18.0	25.5	37.50	39.0	39.0	4	1
Treatment	23.50	20.637	0.0	3.7	22.50	45.2	47.0	6	0
Overall	27.30	17.166	0.0	12.2	34.00	39.5	47.0	10	1

Table 2.5 ARAT overall score at time point 3 by Intervention type

Intervention type	Mean	Standard deviation	Percentiles					Number of values	Number of missing values
			Smallest 0%	25%	Median 50%	75%	Largest 100%		
Waitlist	36.25	12.285	18.0	27.2	41.50	43.6	44.0	4	1
Treatment	25.50	20.423	0.0	7.3	24.50	47.2	49.0	6	0
Overall	29.80	17.687	0.0	16.2	36.00	44.2	49.0	10	1

Table 2.6 ARAT overall score at time point 4 by Intervention type

Intervention type	Mean	Standard deviation	Percentiles					Number of values	Number of missing values
			Smallest 0%	25%	Median 50%	75%	Largest 100%		
Waitlist	39.25	12.093	22.0	29.9	42.50	47.5	50.0	4	1
Treatment	24.50	20.097	0.0	8.2	21.00	48.0	48.0	6	0
Overall	30.40	18.198	0.0	15.4	33.50	48.0	50.0	10	1

Table 2.7 ARAT overall score at time point 5 by Intervention type

Intervention type	Mean	Standard deviation	Percentiles					Number of values	Number of missing values
			Smallest 0%	25%	Median 50%	75%	Largest 100%		
Waitlist	39.00	14.095	20.0	28.3	41.00	49.0	54.0	4	1
Treatment	24.67	20.530	0.0	7.3	21.50	47.2	50.0	6	0
Overall	30.40	18.846	0.0	15.3	33.50	47.2	54.0	10	1

Table 2.3 9HTP pegs per minute at time point 1 by Intervention type

Intervention type	Mean	Standard deviation	Percentiles					Number of values	Number of missing values
			Smallest 0%	25%	Median 50%	75%	Largest 100%		
Waitlist	3.98	7.635	0.0	0.0	0.25	9.2	15.4	4	1
Treatment	2.31	4.061	0.0	0.0	0.50	3.2	10.4	6	0
Overall	2.98	5.416	0.0	0.0	0.50	3.2	15.4	10	1

Table 2.4 9HTP pegs per minute at time point 2 by Intervention type

Intervention type	Mean	Standard deviation	Percentiles					Number of values	Number of missing values
			Smallest 0%	25%	Median 50%	75%	Largest 100%		
Waitlist	1.50	2.179	0.0	0.1	0.50	3.4	4.0	3	2
Treatment	3.27	6.838	0.0	0.0	0.25	3.3	17.1	6	0
Overall	2.68	5.586	0.0	0.0	0.50	2.7	17.1	9	2

Table 2.5 9HTP pegs per minute at time point 3 by Intervention type

Intervention type	Mean	Standard deviation	Percentiles					Number of values	Number of missing values
			Smallest 0%	25%	Median 50%	75%	Largest 100%		
Waitlist	6.99	7.237	0.0	0.6	7.18	13.3	13.6	4	1
Treatment	3.32	5.632	0.0	0.0	0.75	4.9	14.4	6	0
Overall	4.79	6.219	0.0	0.0	1.25	12.9	14.4	10	1

Table 2.6 9HTP pegs per minute at time point 4 by Intervention type

Intervention type	Mean	Standard deviation	Percentiles					Number of values	Number of missing values
			Smallest 0%	25%	Median 50%	75%	Largest 100%		
Waitlist	5.33	5.369	0.0	0.6	5.25	10.1	10.8	4	1
Treatment	4.51	6.818	0.0	0.0	0.25	12.7	14.0	6	0
Overall	4.84	5.967	0.0	0.0	1.00	10.9	14.0	10	1

Table 2.7 9HTP pegs per minute at time point 5 by Intervention type

Intervention type	Mean	Standard deviation	Percentiles					Number of values	Number of missing values
			Smallest 0%	25%	Median 50%	75%	Largest 100%		
Waitlist	7.65	8.655	0.0	0.6	5.99	15.2	18.6	4	1
Treatment	5.86	7.962	0.0	0.0	1.75	14.0	18.0	6	0
Overall	6.58	7.813	0.0	0.0	2.50	14.0	18.6	10	1

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