http://researchspace.auckland.ac.nz

ResearchSpace@Auckland

Copyright Statement

The digital copy of this thesis is protected by the Copyright Act 1994 (New Zealand).

This thesis may be consulted by you, provided you comply with the provisions of the Act and the following conditions of use:

- Any use you make of these documents or images must be for research or private study purposes only, and you may not make them available to any other person.
- Authors control the copyright of their thesis. You will recognise the author's right to be identified as the author of this thesis, and due acknowledgement will be made to the author where appropriate.
- You will obtain the author's permission before publishing any material from their thesis.

To request permissions please use the Feedback form on our webpage. http://researchspace.auckland.ac.nz/feedback

General copyright and disclaimer

In addition to the above conditions, authors give their consent for the digital copy of their work to be used subject to the conditions specified on the Library Thesis Consent Form.

Balanced Brains:
An investigation of visuospatial ability and lateralization in musicians

LUCY L. M. PATSTON

A thesis submitted in partial fulfillment of the requirements
of the degree of Doctor of Philosophy in Psychology,
The University of Auckland, December, 2007.

Abstract

Musicians comprise a unique population whereby persistent musical practice involving complex cognitive and motor tasks dates back to childhood when the potential for neural plasticity is at its highest. Accordingly, it has been speculated that musical training results in neural structural and functional differences between musicians and non-musicians. In particular, there is evidence to indicate parietal regions are more equally lateralized in musicians, but research investigating visuospatial abilities and lateralization in musicians is scarce. Studies 1 and 2 aimed to assess the visuospatial ability and cognitive processing speed of adult musicians versus demographically and educationally matched non-musicians. Musicians performed more quickly and more accurately than non-musicians in two tasks of visuospatial ability, and completed more items than non-musicians in three tasks of processing speed, suggesting musicians had better visuospatial ability and a faster speed of processing. Studies 3 and 4 aimed to investigate visuospatial attention in these groups using a line-bisection task and a visual discrimination task. On both tasks musicians demonstrated more balanced visuospatial attention with a slight bias to the right hemispace, which was in contrast to the non-musicians' bias to the left hemispace, a natural phenomenon known as 'right pseudoneglect'. In Study 5, the laterality of visual processing in musicians and non-musicians was further investigated by comparing electrophysiological interhemispheric transfer time (IHTT) of lateralized visual stimuli across the corpus callosum. Non-musicians had faster right-to-left than left-to-right IHTT consistent with previous research, whilst musicians had more balanced IHTT in both directions and faster left-to-right transfer than non-musicians. Absolute latency patterns revealed similar results and consistently demonstrated more balanced visual processing in musicians. The behavioural data, analysed in Study 6, revealed a tendency (n.s.) for the musician group to respond more quickly to stimuli presented in the right visual field than to stimuli presented in the left visual field, whilst non-musicians did not show this pattern. Overall, the results indicate that musicians have enhanced visuospatial ability and are less lateralized for visuospatial attention and perception than non-musicians. The results are discussed in relation to plastic developmental changes that may be caused by extended musical training from childhood. Specifically, it is proposed that musical training in early life may elicit a process of myelination that is more bilaterally distributed than myelination in non-musicians.

Acknowledgments

Most importantly I would like to thank my supervisor Dr Lynette Tippett for your time, meticulous attention to detail, and much-needed encouragement. Your advice and guidance on all aspects of this project have been gratefully received and your patience correcting the same writing errors time and time again is most appreciated! Thank you also for the time and effort you spent helping me remain financially viable during this PhD. A huge thank you also to Prof. Michael Corballis, my secondary supervisor, whom I could always call on for experienced, sensible advice (with a twist of humour) for all the statistical tangles and niggling little issues I encountered.

I am sincerely grateful to Dr Ian Kirk for helping me with the EEG section of this project. Your kind generosity in time and knowledge helped me immensely, and I really appreciate your on-going interest in my work. Also, thanks to all the people who helped me with set-ups in the EEG lab and who assisted me with the technical aspects of EEG: Vanessa, Carolyn, Sarah Hogg, Sarina, Suz, Ben, Branka and Nick.

Greatest thanks to all the people who participated in the studies involved in this thesis and who gave their time and energy to help me.

I am grateful to the University of Auckland Doctoral Scholarships and the University of Auckland Psychology Department for providing me with funding towards tuition, research, and conference travel costs.

Sincere thanks to Hamish, for your hours of dedicated and attentive help bouncing ideas around during the initial phases of the project, for your academic and musical opinions and ideas, and for your excel formulae masterpieces that saved me so much time! Thanks to Sarah Webb for being such a great sounding board, for bearing the brunt of my frustrations and for attempting to keep up with all the goings-on during our daily walks home. And finally, to Suz, thank you for all the chats, personal and academic advice and help you've given me, and for always being there for me to lean on and relate to.

And finally, to all my other friends, especially Steve, Pani and Anneli, to my family, Mum, Dad, Wendy, Philip and Jem, to my office buddies, Christina, Sharon, Sylvia, Sandra, and lastly to Emiel, thank you all for your encouragement, good wishes, patience, and support throughout the duration of this PhD.

Table of Contents

Abstract ii

Acknowledgements iii

Table of Contents..... iv

List of Tables vii

List of Figures viii

List of Appendices x

Chapter 1: Introduction 1

Cognitive ability in musicians 2

The Mozart effect 2

Music training and cognitive abilities 5

Plasticity in musicians 10

Structural and functional differences between musicians and non-musicians 11

Nature versus nurture 18

Lateralization in musicians 22

The language-left music-right dichotomy 23

A general network for music and language 24

Leftward lateralization for music processing in musicians 25

Thesis aims 29

Chapter 2: Visuospatial abilities and cognitive processing speed in musicians 31

Introduction 31

Study 1: Visuospatial processing **32**

Method 33

Participants 33

Materials 35

Visual discrimination task 35
Visuospatial search task 36
Procedure 37
Results 38
Visual discrimination task 38
Visuospatial search task 40
Discussion 41
Study 2: Processing speed **44**
Method 44
Participants 44
Materials 45
Symbol-Digit Modalities Test 45
Symbol Search subtest 46
Colour Naming and Word Reading Test 46
Procedure 47
Results 47
Discussion 49
Conclusions 51

Chapter 3: Visuospatial attention in musicians 52
Introduction 52
Study 3: Line-bisection task **53**
Method 55
Participants 55
Stimuli and Procedure 56
Results 56
Discussion 59
Study 4: Visual discrimination task (vertical condition) **60**
Method 60
Participants 60
Stimuli and Procedure 61
Results 61
Discussion 64
General Discussion 65

Chapter 4: Electrophysiological interhemispheric transfer time in musicians 69
Introduction 69
Method 74
Participants 74
Stimuli and Apparatus 75
Analysis 75
Procedure 76
Results 77
Interhemispheric transfer time 77
Absolute latency of the N1 79
Discussion 80

Chapter 5: Behavioural interhemispheric transfer time in musicians: The Poffenberger paradigm 85
Introduction 85
Method 91
Participants 91
Stimuli and Procedure 91
Analysis 92
Results 92
Reaction time 92
Accuracy 94
Discussion 95

Chapter 6: General discussion 97
Enhanced cognitive abilities in musicians 97
Plasticity and musical training 99
Visuospatial attention and lateralization 101
Myelination in musicians 104
The CUD and simple reaction time 106
Conclusions 107

References 109

Appendices 133

List of Tables

Table 1: Demographic characteristics of musician and non-musician group participants for Study 1. 34

Table 2: Mean reaction times (ms) on the easy and hard discriminations of the visual discrimination task for the vertical and horizontal line conditions, for both groups of participants. 38

Table 3: Mean percent correct (SD) on the easy and hard discriminations of the visual discrimination task for the vertical and horizontal line conditions, for both groups of participants. 39

Table 4: Demographic characteristics of musician and non-musician group participants for Study 2. 45

Table 5: Mean scores (SD) for number correct and error data for the SDMT (written and verbal) and Symbol Search task for musicians and non-musicians. 48

Table 6: Averaged means (SE) for the written and verbal response modalities shown for musicians and non-musicians. 49

Table 7: Demographic characteristics of musician and non-musician group participants for Study 3. 56

Table 8: Demographic characteristics of musician and non-musician group participants for Study 4. 61

Table 9: Reaction times for easy and hard discriminations on the vertical line condition for both groups (SEM). 63

Table 10: Percent correct for easy and hard discriminations of the vertical line condition when dots were to the left and right side (SEM). 64

Table 11: Demographic characteristics of musician and non-musician group participants for Study 5. 75

Table 12: Demographic characteristics of musician and non-musician group participants for Study 6. 91

Table 13: Mean RTs (SE) for each hand to stimuli presented in the LVF and RVF for each group 93

List of Figures

Figure 1: Procedure for horizontal line condition of visual discrimination task. 36

Figure 2: Example design from the visuospatial search task. Correct answer = 1. 37

Figure 3: Mean reaction times for vertical and horizontal line conditions across easy and hard discriminations of the visual discrimination task for musicians and non-musicians. Error bars indicate standard error of the mean. 39

Figure 4: Mean number correct for the first and second trials of the visuospatial search task for musicians and non-musicians. Error bars indicate standard error of the mean. . 40

Figure 5: Example of the SDMT stimuli (Smith, 1991) (top = key, bottom = first response line). 46

Figure 6: Example of the Symbol Search task (first line = yes, second line = yes, third line = no). 46

Figure 7: Diagram depicting the theoretical underpinnings of right pseudoneglect. 54

Figure 8: Mean percentage deviation from the true centre in the line-bisection task according to position on the page (right, centre and left) and hand used. Negative numbers denote leftward bias, and positive numbers denote rightward bias. Error bars indicate standard error of the mean. *This bar is significantly different from all other bars. 57

Figure 9: Mean percentage deviation from the true centre in the line-bisection task according to group (musicians vs. non-musicians) and hand used. Negative numbers denote leftward bias, and positive numbers denote rightward bias. Error bars indicate standard error of the mean. 58

Figure 10: Mean reaction times for left- and right-sided dots for musicians and non-musicians. Error bars indicate standard error of the mean. 62

Figure 11: Mean percent correct for left- and right-sided dots for musicians and non-musicians. Error bars indicate standard error of the mean. 64

Figure 12: Stimulus presentations to the left and right visual fields and theoretical callosal crossover. Diagram also shows example ERP recordings for each condition and each hemisphere demonstrating typical fast and slow interhemispheric transfer. ... 72

Figure 13: Diagram of electrode positions for Electrical Geodesic 128-electrode net. Circles indicate electrode clusters used for the right and left hemispheres. 76

Figure 14: Grand mean waveforms averaged across hands in right and left hemisphere occipital electrode clusters for musicians and non-musicians recorded during stimulus presentation in the RVF and LVF. 78

Figure 15: Mean IHTT for each direction averaged across hands for musicians and non-musicians. Error bars indicate standard error of the mean. 78

Figure 16: Mean IHTT for each direction averaged across hands for males and females. Error bars indicate standard error of the mean. 79

Figure 17: Mean absolute latency for direct pathways averaged across hands for each hemisphere for musicians and non-musicians. Error bars indicate standard error of the mean. 80

Figure 18: Diagram depicting Poffenberger's theory of interhemispheric transfer time as measured by the crossed-uncrossed difference. Left panel represents uncrossed conditions. Right panel represents crossed conditions. 86

Figure 19: Mean reaction times (ms) for each visual field for the left and right hands. Left panel represents data for the musician group. Right panel represents data for the non-musician group. 94

List of Appendices

Appendix A: Visuospatial Search Task Examples 134

Appendix B: Raw Data for Study 1: Visual Discrimination Task 135

Appendix C: Raw Data for Study 1: Visuospatial Search Task.....136

Appendix D: Raw Data for Study 2 137

Appendix E: Raw Data for Study 3.....138

Appendix F: Raw Data for Study 4.....139

Appendix G: Raw Data for Study 5 140

Appendix H: Raw Data for Study 6 141

Appendix I: Musician Instruments Studies 1 and 4 142

Appendix J: Musician Instruments Study 2 143

Appendix K: Musician Instruments Study 3.....144

Appendix L: Musician Instruments Studies 5 and 6 145