USE OF AN ENRICHED ENVIRONMENT POST-STROKE: 
TRANSLATING FROM BENCH TO BEDSIDE

Ms Heidi Janssen
BPhysio (CSU), MHlthSc (USyd)

Thesis by publication submitted for the degree of 
Doctor of Philosophy (Human Physiology)
School of Biomedicine and Pharmacy
Faculty of Health
The University of Newcastle
2009/10/11/12/13

Submitted May 2013
I Heidi Janssen hereby declare that this thesis contains no material which has been accepted for the award of any other degree or diploma in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text. I give consent to the final version of my thesis being made available worldwide when deposited in the University’s Digital Repository, subject to the provisions of the Copyright Act 1968.

I Heidi Janssen hereby certify that this thesis is submitted in the form of a series of published papers of which I am a joint author. I have included as part of the thesis a written statement from each co-author; and endorsed by the Faculty Assistant Dean (Research Training), attesting to my contribution to the joint publications.

In addition, ethical approval from the University of Newcastle Human Ethics Committee was granted for the clinical study presented in this thesis. Participants were required to read a participant information document and informed consent was gained prior to data collection.

Name Heidi Janssen
Date: May 2013
SUPERVISORS

Dr Neil Spratt
B Med Sci (Hons), B Med (Hons), PhD, FRACP

Staff Specialist Neurologist at John Hunter Hospital, Newcastle, NSW, Australia.
Senior Lecturer and Stroke Research Fellow, School of Biomedical Science and Pharmacy, University of Newcastle, Newcastle, NSW, Australia.

Professor Louise Ada
BSc, GradDipPhty, MA (Motor Learning), PhD

Professor of Neurological Physiotherapy
Head of Discipline of Physiotherapy, The University of Sydney, Sydney, NSW, Australia.

Associate Professor Julie Bernhardt
BAppSc (Physio), MAppSc, PhD

Co-Head, Stroke Division, Director, AVERT Early Intervention Research Program
The Florey Institute of Neuroscience and Mental Health, Melbourne, VIC, Australia.
ACKNOWLEDGMENTS

I would like to extend my sincere thanks and appreciation to Dr Neil J Spratt, Professor Louise Ada and Associate Professor Julie Bernhardt for agreeing to be my supervisors and for so generously sharing their research knowledge and time (which is scarce to them all) with me. Each played an important role in nurturing and developing the research skills I have today. I am extremely grateful and lucky to have had them as my mentors. Merely talking with them and bouncing around research ideas was at times all I needed to re-charge, regain focus or importantly, re-build waning self-belief.

Thank you to Dr Emily S Sena who was involved at the beginning of this PhD. Her patience during the conduct of the animal model meta-analyses will always be remembered. Thank you too to Dr Patrick McElduff who calmly provided statistical advice and support for the majority of publications included in this thesis.

I wish to thank my work colleagues who have supported me during my PhD. Thank you to Associate Professor Michael Pollack who first introduced me to the topic of environmental enrichment. He was instrumental in enabling investigation of our human equivalent model of this paradigm in the clinical setting. His commitment and enthusiasm was pivotal in maintaining my motivation. Thanks also to Professor Michael Nilsson who is always working to raise the profile of environmental enrichment after stroke. His support and belief in me during the later stages of this PhD was a big help.

Thank you to my colleague and office buddy Di Marsden. She has been a great support, tolerating much colourful and irrational (and at times rational) ranting.

Many thanks to the staff of Rankin Park Centre North Ward. In particular, to Nursing Unit Manager Robyn Walker, who welcomed me and my research ideas into her
rehabilitation team and onto their ward. Many thanks importantly to all the stroke survivors who were formally and informally involved in the work undertaken during this PhD.

I must acknowledge the generous contributions made by those who provided funds to support my studies. The National Heart Foundation Postgraduate Scholarship and the Emlyn and Jennie Thomas Postgraduate Medical Research Scholarship supported me as an individual, and the National Stroke Foundation Small Project Grant 2010 and the John Hunter Hospital Charitable Trust Grant 2010 provided funds for the pilot study associated with this thesis. A ‘big Jennie-hug’ and thank you to Jennie Thomas herself. Her passion and commitment to make a difference to people’s lives, especially stroke survivors, continues to inspire me to continue on during the challenging times.

Many thanks to Paula, Lorraine, Sue and the team at the School of Biomedical Science and Pharmacy Research Support Unit for arranging the purchasing of goods and travel and accommodation required throughout this PhD.

Lastly, much love and thanks goes to my family. My parents, Bev and Matt Janssen, for their belief in me and for encouraging me to follow my dreams (note to self, completing a thesis may not fall into the ‘dream’ category!) and to my sister Anna for helping with childcare and providing the editorial finesse I lack. ‘Thank you’ does not encapsulate how grateful I am for the support my husband Matt, and our two boys, William and Hamish have shown during the last 4 1/2 years. They have travelled patiently with me on this research journey, enduring many a day and night of ‘tap-tap tapping’ on the laptop. Special mention must go to William and Hamish who have selflessly taught me how much I can achieve on less than five hours sleep! Love you both ‘all much’.
PUBLICATIONS, PRESENTATIONS AND AWARDS

PEER REVIEWED PUBLICATIONS INCLUDED IN THIS THESIS


OTHER PUBLICATIONS AND PRESENTATIONS ARISING FROM THIS THESIS

Parts of the work presented in this thesis have been published and/or presented in the following forums:

PUBLISHED ABSTRACTS


**ADDITIONAL CONFERENCE PRESENTATIONS**


CONFERENCE WORKSHOPS AND SYMPOSIUMS

Janssen H & Stacey S.

Workshop title: Enriching the stroke recovery environment. What’s this all about?
Conference: 6th Smart Strokes Nursing and Allied Health Stroke Conference. Terrigal, NSW Australia, August 2010.

Nilsson M, Bernhardt J, Janssen H, Pekny M.

Symposium title: Neuroscience bench to bedside stroke recovery
Conference: Stroke 2012: Combined 23rd Annual Scientific Meeting of the Stroke Society of Australia and 8th Smart Strokes Australasian Nursing and Allied Health Stroke Conference. Sydney, NSW Australia, August 2012.

CONFERENCE PRESENTATIONS - POSTER

e-Poster (placed in top 100 of over 3000 abstracts submitted)

AWARDS

*Best Innovation / Implementation*


SCHOLARSHIPS AND GRANTS

- National Heart Foundation Postgraduate Scholarship 2010-2012
- Emlyn and Jennie Thomas Postgraduate Medical Research Scholarship (Top-up)
- National Stroke Foundation Small Project Grant 2010 - $20 000
- John Hunter Hospital Charitable Trust Grant 2010 - $23 025

WORK ARISING FROM COLLABORATIONS ASSOCIATED WITH THIS PhD


Buckley N, Karayanidis F, Drysdale K, Janssen H, Spratt NJ. The use of environmental enrichment to enhance patient rehabilitation post-stroke: A psychological perspective. Newcastle: School of Psychology, Faculty of Science and Information Technology, University of Newcastle; 2010 (Honours Project).


Raad S, Marquez J, Janssen H. The relationship between functional independence and physical activity during stroke rehabilitation. Newcastle: School of Health Sciences, Faculty of Health, University of Newcastle; 2011 (Honours Project).

OTHER PEER REVIEWED PUBLICATIONS COMPLETED DURING THE COURSE OF THIS PhD

OTHER PUBLICATIONS AWAITING DECISIONS

# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>DECLARATION</td>
<td>i</td>
</tr>
<tr>
<td>SUPERVISORS</td>
<td>ii</td>
</tr>
<tr>
<td>ACKNOWLEDGMENTS</td>
<td>iii</td>
</tr>
<tr>
<td>PUBLICATIONS, PRESENTATIONS AND AWARDS</td>
<td>v</td>
</tr>
<tr>
<td>ABSTRACT</td>
<td>1</td>
</tr>
<tr>
<td>CHAPTER 1: LITERATURE REVIEW</td>
<td>3</td>
</tr>
<tr>
<td>Table of contents</td>
<td>3</td>
</tr>
<tr>
<td>1.1 Introduction</td>
<td>6</td>
</tr>
<tr>
<td>1.2 Activity after stroke</td>
<td>22</td>
</tr>
<tr>
<td>1.3 Enriched Environment: In animals</td>
<td>36</td>
</tr>
<tr>
<td>1.4 Enriched Environment: In the clinical setting</td>
<td>50</td>
</tr>
<tr>
<td>1.5 Enriched Environment: Bench to bedside</td>
<td>61</td>
</tr>
</tbody>
</table>
1.6 Measuring activity levels in stroke survivors ................. 64

1.7 Chapter conclusion............................................................ 70

CHAPTER 2: RESEARCH AIMS AND HYPOTHESES ..................... 71

2.1 Research aims ................................................................. 71

2.2 Hypotheses................................................................. 72

2.3 Bringing it all together .................................................... 73

CHAPTER 3: SYSTEMATIC REVIEW AND META-ANALYSIS OF
THE USE OF AN ENRICHED ENVIRONMENT IN
ANIMAL MODELS OF STROKE ............................................ 75

Introduction and statement of contribution......................... 75

Publication 1 ........................................................................ 79

CHAPTER 4: PILOT STUDY PROTOCOL......................................... 91

Introduction and statement of contribution......................... 91

Publication 2 ........................................................................ 97
CHAPTER 5: QUANTIFYING PHYSICAL COGNITIVE AND SOCIAL ACTIVITY LEVELS POST-STROKE................................. 103

Introduction and statement of contribution......................... 103

Publication 3 ............................................................................. 107

CHAPTER 6: PILOT STUDY RESULTS.................................................... 118

Introduction and statement of contribution.......................... 118

Publication 4 ............................................................................. 122

CHAPTER 7: DISCUSSION................................................................. 130

7.1 Questions still yet to answer in animal models of stroke .......................................................... 132

7.2 Implementing an enriched environment in the clinical setting: Lessons learnt ..................................... 141

7.3 Conclusion ........................................................................... 143

7.4 Where to now? ................................................................. 145

CHAPTER 8: REFERENCES ............................................................... 146
APPENDIX A: A BEHAVIOURAL STREAMING DATA SHEET AND AN ‘ENRICHMENT’ BEHAVIOURAL MAPPING DATA SHEET .......................................................... 161

APPENDIX B: COLLABORATIVE WORK Awaiting REVIEW IN PEER REVIEWED JOURNALS ................................................................. 168

APPENDIX C: OTHER RESEARCH PUBLISHED OR PREPARED FOR PUBLICATION DURING THE TIME OF THIS PHD .................. 210

APPENDIX D: COPYRIGHT PERMISSIONS ........................................................................................................ 255
ABSTRACT

Despite evidence linking higher levels of activity with better outcomes, stroke patients undergoing rehabilitation in hospital settings spend the majority of their waking hours inactive and alone. Environmental enrichment, through the use of equipment and organisation of the environment to facilitate physical, cognitive and social activity, is an intervention which has been used extensively in animal models of stroke. Results from these models have demonstrated the sensorimotor and cognitive benefits of recovering in an enriched environment, however there is conflicting data suggesting no benefit. The purpose of this PhD was to determine the efficacy of environmental enrichment in animal models of stroke, and then develop and pilot test a model of enrichment in stroke survivors.

Systematic meta-analytic methods were used to determine the efficacy of an enriched environment in animal models of stroke. Exposure to an enriched environment in animal models of stroke was associated with significantly better sensorimotor function and a trend towards better learning. Recovering in an enriched environment was also associated with a small but significant increase in lesion size (larger damaged area). However, the importance of this finding at an experimental level requires further investigation.

To explore the feasibility of translating this paradigm from the bench to the bedside, a model of environmental enrichment incorporating both communal and individual enrichment was developed for use with stroke patients in the clinical setting. Behavioural observation was used to evaluate its effect on stroke patient activity. Patients exposed to individual and communal environmental enrichment were more
likely to be active and were less likely to spend time ‘inactive and alone’ or sleeping than those recovering in a non-enriched rehabilitation unit.

This thesis outlines the research undertaken in the first known attempt to translate the use of a model of environmental enrichment from the laboratory into a clinical stroke rehabilitation setting. Evidence presented demonstrates that this model of environmental enrichment can increase activity levels of stroke patients. This preliminary research sets the foundations for further exploration of the efficacy of environmental enrichment on post-stroke function, mood and quality of life.