Combined somatosensory and motor training to improve upper limb recovery after stroke

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STATEMENT OF ORIGINALITY

I hereby certify that the work embodied in the thesis is my own work, conducted under normal supervision.

The thesis contains no material which has been accepted, or is being examined, 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. 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 and any approved embargo.

Signed:

Name: Urvashy Gopaul

Date: 31st December 2018

ACKNOWLEDGMENT OF AUTHORSHIP

I hereby certify that the work embodied in this thesis contains published papers/scholarly work of which I am a joint author. I have included as part of the thesis a written declaration endorsed in writing by my supervisor, attesting to my contribution to the joint publications/scholarly work.

Chapters 1 and 2 were written with editorial support of my supervisors.

For Chapter 3, I conducted a systematic scoping review and write the first draft. This was followed by editorial support from my supervisors.

For Chapters 4, 5 and 6, I designed all aspects of the projects in collaboration with my supervisors. I conducted all outcome measures for Chapter 6, analysed all data for Chapter 5 and 6 and wrote the first draft of all three chapters. This was followed by editorial support from my supervisors.

Chapter 7 was written with editorial support of my supervisors.

By signing below I confirm that Urvashy Gopaul contributed to the following publications as stated above:

Gopaul U, van Vliet P, Callister R, Nilsson M & Carey L. COMbined Physical and somatoSEnsory training after stroke: Development and description of a novel intervention to improve upper limb function. *Physiotherapy Research International*. 2018;0(0):e1748.(Published)

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Last but not least, I dedicate this thesis to my lovely mother, who has taught me the true meaning of being strong and resilient. My passion and determination for improving care for any patient, I owe that to you Mum. I think you would have been proud of me.

PUBLICATIONS ARISING FROM THIS THESIS

This thesis is presented with the inclusion of four papers. I am the lead author on all papers. At the time of submission, one of these papers (Chapter 3) has been accepted in a peer-reviewed journal and another paper (Chapter 4) has been published in a peer-reviewed journal. At the time of submission, the other two chapters (Chapters 5 and 6) are being prepared for submission to peer-reviewed journals.

Manuscripts in peer-reviewed journals: Published

Gopaul U, van Vliet P, Callister R, Nilsson M & Carey L. COMbined Physical and somatoSEnsory training after stroke: Development and description of a novel intervention to improve upper limb function. *Physiotherapy Research International*. 2018;0(0):e1748.

Manuscripts in peer-reviewed journals: In press

Gopaul U, Carey L, Callister R, Nilsson M & van Vliet P. Combined somatosensory and motor training to improve upper limb function following stroke: a systematic scoping review. *Physical Therapy reviews.* DOI: 10.1080/10833196.2018.1553668

PRESENTATIONS ARISING FROM THIS THESIS

During my candidature, I presented results arising from this thesis at 6 conferences. This resulted in 4 oral platform presentations, 1 oral poster and 2 poster presentations. I was also invited to present at one research seminar.

Conference presentations

Gopaul U, Carey L, Callister R, Nilsson M & van Vliet P. Feasibility of the Combined Physical and somatoSEnsOry (COMPoSE) training to improve arm function after stroke: A single-case experimental study. *Presented at:*

World Stroke Congress Oct 2018, Canada. Oral presentation

Stroke Aug 2018, Australia. Oral poster presentation

Gopaul U, van Vliet P, Carey L, Hudson & Nilsson M. Description of a novel ''Combined Physical and SEnsOry training'' (COMPoSE) intervention to improve arm function after stroke, using TIDIER checklist. *Presented at:***World Confederation of Physical Therapy** July 2017, South Africa. Oral presentation.

Combined Stroke Conference Aug 2016, Australia. Oral presentation.

Gopaul U, Carey L, Callister R, Nilsson M & van Vliet P. Combined interventions for improving sensory-motor function of the upper limb (UL) post-stroke: a systematic review. *Presented at:*

Smart Stroke conference Aug 2017, Australia. Oral presentation.

Stroke Society of Australasia conference Aug 2017, New Zealand. Poster presentation.

Gopaul U, Carey L, Callister R, Nilsson M & van Vliet P. Feasibility of TactArray: A novel method for evaluating and retraining of sensorimotor control of finger forces post-stroke: a case report. *Presented at:*

Stroke Society of Australasia conference Aug 2017, New Zealand. Poster presentation.

Research seminars

Gopaul U, Carey L, Callister R, Nilsson M & van Vliet P. Combined physical and somatosensory training intervention to improve arm function after stroke. **Scientific conference of the Centre for Interdisciplinary Research in Rehabilitation of Greater Montreal** May 2017**,** Canada

PUBLISHED ABSTRACTS FROM THIS THESIS

- **Gopaul U**, Callister R, Carey L, Nilsson M, Sampson C, P vV. Feasibility of TactArray: A novel method for evaluating and retraining of sensorimotor control of finger forces post-stroke: a case report. International Journal of Stroke 2017;12(3S):3–59.
- **Gopaul U**, Van Vliet P, Carey L, Hudson I, M N. Description of a novel ‘‘Combined Physical and SEnsOry training’’ (COMPoSE) intervention to improve arm function after stroke, using TIDIER checklist. International Journal of Stroke. 2016; 11(1S): 3–31.
- **Gopaul U**, Carey L, Hudson I, Nilsson M, Callister R, P vV, editors. Description of a novel COMbined Physical and SEnsory training (COMPoSE) intervention to improve arm function after stroke, using Tidier checklist. World Confederation of Physical Therapy Congress 2017 conference proceedings; 2017; Capetown, South Africa: World Confederation of Physical Therapy.
- **Gopaul U**, Callister R, Carey L, Nilsson M, van Vliet P. Combined interventions for improving sensorymotor function of the upper limb following stroke: A systematic review. International Journal of Stroke,. 2017;12(2S).
- **Gopaul U**, Carey L, Callister R, Nilsson M, van Vliet P. World Stroke Congress Abstracts, 2018. International Journal of Stroke. 2018;13(2_suppl):3-217.

AWARDS

Throughout my candidature, I have been supported by a University of Newcastle Research Scholarship and University of Newcastle Top-up Scholarship.

In 2015, I was successful in acquiring a travel scholarship(AUD 5,000) from the National Health and Medical Research Council Centre of Research Excellence in Stroke Rehabilitation and Brain Recovery. I also won a research equipment grant (AUD 4,000) from the School of Health Sciences. I was also successful in acquiring a Research Higher Degree student exchange grant (AUD 4,500).

In 2016, I contributed to a successful Linkage pilot research grant (AUD 9,600) from the University of Newcastle as a co-investigator.

In 2017, I was awarded a Research Support grant (AUD 5,735) and a Clinical Research Design, Information Technology and Statistical Support grant (AUD 2,500) from the Priority Research Centre For Stroke And Brain Injury.

In 2018, I won travel a Travel Support Grant (AUD 2,000) from the Priority Research Centre for Stroke and Brain Injury.

CONTRIBUTION STATEMENT

The body of work presented in this thesis has produced four papers. I was the sole PhD student responsible for this project and was involved in all aspects of this project. A summary of my contributions and involvement is outlined at the beginning of each chapter.

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COMMON ABBREVIATIONS

Abbreviation	Meaning
ARAT	Action Research Arm Test
BBT	Box And Block Test
CI	Confidence interval
CV	Coefficient of variation
COMPoSE	COMbined Physical and somatoSEnsory training
FAS	Fatigue Assessment Scale
FMT	Fabric Matching Test
FMA-UL	Fugl Meyer assessment upper limb
FTORT	Functional Tactile Object Recognition Test
ICC	Intraclass correlation coefficient
MAL-AS	Motor Activity Log-Amount Scale
MAL-HW	Motor Activity Log-How Well
MOCA	Montreal Cognitive Assessment
MTS	Modified Tardieu Scale
RCT	Randomised Controlled Trial
RTG	Reach-to-grasp
PVAS	Pain visual analogue scale
PPS	Pressure Profile Systems
SD	Standard deviations
SIS	Stroke Impact Scale
SFVAS	Stanford fatigue visual analogue scale
SPSS	Statistical Package For The Social Sciences
TDT	Tactile Discrimination Test
UL	Upper limb
WFMT	Wolf Motor Function Test
WPST	Wrist Position Sense Test

THESIS ABSTRACT

Background

Stroke is a leading cause of disability worldwide. Upper limb motor and somatosensory impairments are common following stroke, making performance of everyday tasks difficult. Interventions directed at motor deficits have traditionally been separated from interventions directed at somatosensory deficits. By treating motor and somatosensory impairments separately, the potential beneficial effects of combining somatosensory training to further enhance sensorimotor function and action are not utilised. Hence, there is a critical need for the development of new and more effective treatments addressing both somatosensory and motor function to improve long-term disability after stroke. Also, there is a lack of objective outcome measures with good responsiveness to evaluate sustained grasp performance in people with stroke indicating a need for new outcome measures to quantify grasp deficits after stroke.

Overall aim

This thesis aimed to investigate whether combined somatosensory and motor training improves upper limb recovery after stroke.

Objectives

This thesis studied the effects of combining somatosensory and motor training to improve upper limb recovery after stroke. This thesis also investigated the reliability of measures of maximal tactile pressures and forces during grasping using the TactArray device in healthy people and people with stroke. There are four distinct but complementary studies included in this thesis to address these research objectives.

Methods

Study 1: A systematic scoping review was conducted to identify combined somatosensory and motor training interventions for the upper limb and their training components, and to review the efficacy of the combined interventions.

Study 2: This report describes the rationale and development of a new upper limb stroke rehabilitation intervention known as COMPoSE: "COMbined Physical and somatoSEnsory training" and, designed to improve somatosensory and motor deficits in the upper limb after stroke. A standardised training matrix was developed to facilitate intervention delivery.

Study 3: A trial was conducted to assess the feasibility of the COMPoSE trial using a single-case experimental study design. The outcomes from this feasibility trial included: 1) feasibility of the recruitment of participants; 2) review of intervention protocol and feasibility of study design; 3) acceptability of the intervention and trial; 4) appropriateness of data collection procedures; and the 5) evaluation of resources required. The preliminary impact of the COMPoSE intervention on somatosensory and motor deficits and upper limb function after stroke were also assessed.

Study 4: A test-retest reliability study was conducted to evaluate the reliability of measures of maximal tactile pressures and forces during sustained grasping using the TactArray device in healthy participants and participants with stroke.

Results

Study 1: Ten studies (n= 219) were included and the interventions consisted of combinations of tactile stimulation/discrimination, proprioceptive stimulation/discrimination, haptic object discrimination/recognition, movement training, and functional training. Only one group study (n=45), a non-randomized controlled study with multiple active components and the largest dose of treatment (72 hours), found significant improvements in fine motor and somatosensory measures.

Study 2: The essential features of COMPoSE include: combined somatosensory-motor training variables (grasp pressure, distance, object size, crushability, surface texture and friction),

feedback using a haptic device providing measures of grasp pressure, and high dose repetitive task practice with and without vision. It was planned for ten treatment sessions to be delivered over three weeks, using a standardised matrix for treatment delivery.

Study 3: Findings from this feasibility trial (n=5) indicated that training with the combination of somatosensory and motor variables synchronously, i.e., within the same task, was feasible. The delivery of the COMPoSE intervention using the standardised training matrix was feasible, however modifications to allow more specific tailoring to participant deficits is recommended. This trial identified components of the COMPoSE intervention such as the combinations of somatosensory-motor variables, amount of practice, and the duration of treatment, that would need to be modified in order to maximise improvement of upper limb function after stroke. Additionally, operational aspects of the trial methods, such as the number of outcome measures and timing of outcome measures were identified that would need to be addressed prior to subsequent trials.

Study 4: The TactArray device demonstrates satisfactory reliability for measures of maximal tactile pressures during complete grasp duration of 8s (from finger contact to grasp release) for within-day and between-day testing sessions using an average of three trials with and without vision, in healthy people and those with stroke. Measures of maximal tactile forces are less reliable than maximal tactile pressures.

Conclusion

Findings from this thesis makes an important contribution to advancing our understanding of various factors that influence the effects of combined somatosensory and motor training interventions. So far, there is little consistency across "combined somatosensory and motor training" interventions to improve upper limb function after stroke. The individual studies in the systematic scoping review and the COMPoSE trial provide preliminary evidence that combined somatosensory and motor training interventions have the potential to improve upper limb recovery after stroke, if they incorporate the appropriate active ingredients and dosage. Findings from this thesis identified research questions still to be answered with regards to active ingredients, recruitment capability, responsiveness of outcome measures for people with severe deficits after stroke, individualised somatosensory-

motor training, dosage and intensity of intervention. Furthermore, results from this thesis indicated that it could be beneficial to deliberately train for somatosensory and motor training synchronously to improve upper limb recovery after stroke. Additionally, a novel means of measuring maximal grasp pressures during a sustained grasp using the TactArray device has been evaluated, which can be further explored in larger trials. Recommendations have been provided on optimisation of the intervention contents and study design of the COMPoSE intervention and trial in the future.