Interference During Simultaneous Performance of a Motor and Cognitive Task Involving the Upper Extremity After Stroke

G.B. Prange-Lasonder, V. Robles-García, S. Brown, J.H. Buurke, J. Whitall and J.H. Burridge

Abstract After stroke, the ability to perform two tasks concurrently is diminished, which may contribute to less pronounced gains on activity level after rehabilitation. The current study investigated whether upper extremity dual-task performance is compromised after stroke, as a first step towards examining whether cortical stimulation can reduce dual-task interference. Twenty stroke patients performed a single motor task (tapping targets), single cognitive task (memorising digits) and dual motor-cognitive task. Although motor performance was better when performing the dual-task compared to the single tapping task, it was at the expense of cognitive performance. These findings suggest upper extremity cognitive-motor interference after stroke. In ongoing work, we are investigating the potential role of cortical stimulation to improve motor and cognitive dual-task performance.

1 Introduction

Stroke results in impairments in arm and hand function in about 60 % of patients [1]. This often has a deteriorating impact on upper limb function in activities of daily life (ADL). Although after conventional or technology-supported treatment improvements on function level are achieved, gains on activity level have been limited so far [2, 3].

G.B. Prange-Lasonder (✉) · J.H. Buurke
Roessingh Research and Development, University of Twente, Enschede, The Netherlands
e-mail: g.prange@rrd.nl

V. Robles-García
Universidade Da Coruña, Coruña, Spain

S. Brown · J.H. Burridge
University of Southampton, Southampton, UK

J. Whitall
University of Maryland, Baltimore, USA

J. Ibáñez et al. (eds.), *Converging Clinical and Engineering Research on Neurorehabilitation II*, Biosystems & Biorobotics 15,
DOI 10.1007/978-3-319-46669-9_41

One reason may be the lack of automaticity achieved during motor relearning after stroke. This can result in a discrepancy between what patients are able to do with their paretic upper limb (i.e., capacity) and the actual use of this limb in daily life (i.e., performance), preventing them to reach a critical level of performance [4]. People with stroke have shown to experience a reduced ability to perform two visual attention tasks concurrently [5]. Such limited attentional resources are likely to affect performance of multiple motor and/or cognitive tasks simultaneously as well. This has been well researched and demonstrated for hemiparetic gait [6], but so far the upper extremity has received far less attention.

A way to enhance both motor and cognitive processes in healthy individuals and (neurological) patients is via application of transcranial direct current stimulation (tDCS) [7, 8]. Considering the proposed benefits of tDCS on both cognitive and motor processes, we conducted a study to assess whether tDCS can improve the ability to perform a cognitive and motor task, involving the upper extremity, at the same time (dual-tasking).

As a first step towards investigating the potential effect of tDCS on dual-tasking involving the upper extremity in stroke patients, the current paper aimed to examine whether upper extremity dual-task performance is affected after stroke.

2 Materials and Methods

2.1 Participants

Twenty individuals with stroke were recruited at the University of Southampton. Main inclusion criteria were that participants had a unilateral stroke at least 6 months ago, with hemiparesis of the arm/hand but being able to lift the arm actively from their lap to the table. Any participant was excluded in case of: severe aphasia; inability to understand and follow 2-step instructions; a history of epilepsy; co-morbidity of other conditions limiting arm function; metal implants in the head/neck region; pregnancy.

2.2 Study Design

The overarching study was a randomised cross-over study with a single session of cortical stimulation of either anodal or sham tDCS, repeated across two separate days. tDCS (Newronika s.r.l., Milan) was applied for 20 min at 1 mA using 35 cm^2, saline-soaked electrodes over M1 of the affected hemisphere (anode) and the contralateral supraorbital ridge (reference). In case of sham, a ramp-down after 30 s. was applied instead.

Motor and cognitive tasks were performed twice in each session; directly before and after stimulation. For the current analysis, only data from the pre-stimulation evaluation of the first session were used, regardless of tDCS allocation.

2.3 Evaluation

The dual-task paradigm involved a single motor task, a single cognitive task and a dual task performing the motor and cognitive tasks simultaneously (for 30 s).

The single motor task comprised a tapping task at maximal speed between two squares in an alternated pattern, with the objective to tap each square as fast and as accurately as possible. The motor task was displayed on a large horizontal touch-screen using custom designed software, which also recorded response times and accuracy. The single cognitive task consisted of an auditory working memory task, a forward digit span, where a random, computer-generated sequence of digits was read aloud by the researcher and people had to recall as many as possible after 30 s. The dual task involved execution of the tapping task as fast as possible, while remembering the digits spoken directly prior to execution of the motor task and naming as much as possible directly after the end of the motor task.

Both the motor and cognitive tasks were normalized to the abilities of each patient, and arm support was applied during the motor task so that all patients were able to perform the task. Each task was repeated 3 times with the affected arm.

2.4 Data Analysis

Motor task performance is represented by movement accuracy (MA; average distance from the centre of the target in mm) and movement time (MT; average duration between consecutive taps in ms). Cognitive task performance is represented by digit span length (SL; number of recalled digits with respect to the presented number of digits) and digit span accuracy (SA; proportion of correctly named digits with respect to number of recalled digits). Data from the 3 repetitions are averaged for all outcome measures.

All outcome measures were compared between single and dual task conditions using a paired-samples t-test ($\alpha \leq 0.05$).

3 Results

MT (Fig. 1) was significantly different between single task and motor task conditions ($p = 0.008$), with a slightly better performance during dual tasking (1024 ± 90 vs. 959 ± 82 ms). MA didn't differ significantly. SA (Fig. 1) was

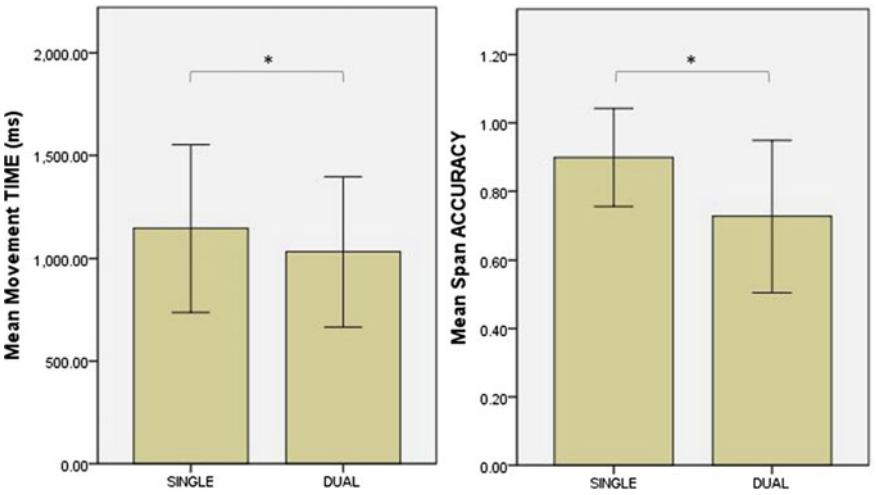

Fig. 1 Mean (SD) MT and SA during single and dual tasks (* $p < 0.05$)

lower during the dual task compared with the single task (89 % vs. 73 %; $p = 0.017$). SL didn't differ significantly.

4 Discussion

The current paper examined whether upper extremity dual-task performance is affected after stroke. This initial analysis showed that both motor and cognitive performance was influenced during dual-tasking. Remarkably, movement time was somewhat (65 ms) faster during dual-tasking, whereas correct recall was (16 %) less accurate during dual-tasking.

These findings showed slightly better motor performance during dual-tasking, but at the expense of cognitive performance. This suggests that the tapping task was performed better when memorising. Based on observations during the tests, this may be related to a rhythmic cueing strategy that benefitted motor execution. It has been shown that auditory cueing can have a beneficial influence on motor performance during gait after stroke [9]. It is also believed to have a positive effect on upper extremity function [10]. This strategy for the upper extremity did have a negative influence on the accuracy of memorising, however.

The current findings demonstrate upper extremity cognitive-motor interference after stroke. This is a well-recognized phenomenon for gait [6]. One study that examined dual-tasking for upper extremity functioning in stroke demonstrated cognitive-motor interference as well, during sub-maximal (dual) tasks [11]. The present findings, elicited during motor and cognitive tasks requiring maximal capacity (maximal speed and/or accuracy), are in support of this.

This information can ultimately provide input towards identifying post-stroke treatments that have a substantial impact on activity level, by addressing cognitive-motor interference and dual-task ability specifically. Whether tDCS can play a role in this is being explored in ongoing analyses.

5 Conclusion

The present findings suggest that performing a tapping task with the upper extremity together with a memorising task results in cognitive-motor interference in stroke. As a next step, ongoing analyses are examining whether cortical stimulation can improve dual-task performance.

Acknowledgments This study was partly supported by the European Network on Robotics for NeuroRehabilitation, through the European Cooperation in Science and Technology (COST) Action TD1006.

References

1. G. Kwakkel, B.J. Kollen, J. Van der Grond, A.J.H. Prevo, Probability of regaining dexterity in the flaccid upper limb: impact of severity of paresis and time since onset in acute stroke. Stroke **34**, 2181–2186 (2003)
2. P. Langhorne, M. Bernhardt, G. Kwakkel, Stroke rehabilitation. Lancet **377**, 1693–1702 (2011)
3. G.B. Prange, M.J.A. Jannink, C.G.M. Groothuis, H.J. Hermens, M.J. Ijzerman, Systematic review of the effect of robot-aided therapy on recovery of the hemiparetic arm after stroke. J. Rehabil. Res. Dev. **43**, 171–184 (2006)
4. M.E. Michielsen, M. De Niet, G.M. Ribbers, H.J. Stam, J.B. Bussmann, Evidence of a logarithmic relationship between motor capacity and actual performance in daily life of the paretic arm following stroke. J. Rehabil. Med. **41**, 327–331 (2009)
5. S.C. Marshall, D. Grinell, B. Heisel, A. Newall, L. Hunt, Attentional deficits in stroke patients: a visual dual task experiment. Arch. Phys. Med. Rehabil. **78**, 7–12 (1997)
6. P. Plummer et al., Cognitive-motor interference during functional mobility after stroke: state of the science and implications for future research. Arch. Phys. Med. Rehabil. **94**, 2565–2574 (2013)
7. A. Flöel, tDCS-enhanced motor and cognitive function in neurological diseases. Neuro Image **85**, 934–947 (2014)
8. F. Hummel et al., Effects of non-invasive cortical stimulation on skilled motor function in chronic stroke. Brain **128**, 490–499 (2005)
9. J.E. Wittwer, K.E. Webster, K. Hill, Rhythmic auditory cueing to improve walking in patients with neurological conditions other than Parkinson's disease—what is the evidence? Disabil. Rehabil. **35**, 164–176 (2013)
10. S. Whitall, M. Waller, K.H.C. Silver, R.F. Macko, Repetitive bilateral arm training with rhythmic auditory cueing improves motor function in chronic hemiparetic stroke. Stroke **31**, 2390−2395 (2000)
11. A. Houwink, B. Steenbergen, G.B. Prange, J.H. Buurke, A.C. Geurts, Upper-limb motor control in patients after stroke: Attentional demands and the potential beneficial effects of arm support, Hum. Mov. Sci. **32**, 377−387 (2013)