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Research paper

Electric and acoustic stimulation during movement preparation can facilitate movement execution in healthy participants and stroke survivors

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HIGHLIGHTS

- Electric stimulation can facilitate movement execution in healthy people when delivered during preparation.
- We show that electric and acoustic stimulation can be used to facilitate movement in healthy participants and stroke survivors.
- Our results demonstrated that sensory stimulation can be combined with current devices available to assist people with stroke to engage in rehabilitation programs.

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ABSTRACT

There has been increasing interest in the use of loud acoustic stimulation (LAS) to gain insight into the preparation and initiation of motor actions. Typically, LAS presented during movement preparation in healthy participants culminates in the earlier than normal initiation of the prepared movement and an increase in the magnitude of the response. Recent reports have shown LAS can also facilitate movement in chronic stroke survivors. This suggests that current therapies for motor recovery after stroke might benefit from employing such alternate methods of triggering movement. In this study we sought to test a new way to facilitate motor actions that could be of relevance in clinical settings. Five individuals with chronic motor impairments due to stroke and eight healthy young adults performed a functional reaching task in response to a visual go-signal. On 30% of the trials, LAS or electric stimuli (collectively, sensory stimuli) were unexpectedly presented in synchrony with the go-signal. Both healthy and stroke participants reacted with shorter latencies and executed faster responses when sensory stimulation was synchronized with the go-signal. We have replicated previous findings showing acoustic stimuli can aid movement execution in chronic stroke survivors and demonstrated the same type of effect can be achieved using electric stimulation. Thus, these two types of sensory stimuli can be easily integrated with current devices available to assist people with stroke to engage in rehabilitation efforts.

1. Introduction

Task-related practice is widely regarded as a crucial step for recovering movement after a neurological injury [22]. However, a lack of sufficient voluntary movement after a stroke can be a limiting factor in the ability of patients to engage in intensive rehabilitation efforts [3]. As a result, there is great interest in investigating training opportunities that can assist stroke survivors in overcoming the limitations of voluntary movement in the early

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Table 1
Details of the stroke survivors.

ID#	Sex	Age	Affected limb	Months since stroke	Type of stroke	MAS total	Modified Rankin scale
1	Male	68	Left	59	Ischemic	13	2
2	Female	59	Left	18	Haemorrhagic	1	3
3	Female	20	Left	47	Ischemic	18	1
4	Male	49	Left	27	Ischemic	1	2
5	Male	63	Left	30	Ischemic	18	1

stages of recovery [12,13]. One option that warrants exploration is the combination of task-oriented training and loud acoustic stimulation (LAS).

Several experiments have demonstrated that LAS can facilitate the initiation and execution of motor actions in the healthy participants, as well as in people with neurological conditions [7,10,11,21]. Although, there is an ongoing debate about the specific neural mechanisms and pathways involved in the phenomenon [1,9,14–18,20,21,23], it is widely agreed that LAS can both speed the initiation and augment the vigour of prepared responses. In other words, the quicker and more forceful response observed when LAS is delivered is more than the simple observation of reflexes in specific muscles: it is the facilitation of the prepared voluntary movement [24].

Recent reports have shown that LAS can facilitate voluntary motor acts in chronic stroke survivors. For example, Honeycutt and Perrault showed that in stroke survivors LAS can improve movement initiation and execution to a level similar to that observed in aged matched controls with no neurological conditions [10,11]. This indicates that current therapies for movement recovery could benefit from employing alternate methods of assisting movement initiation, which is a factor that limits the engagement of stroke survivors in rehabilitation programs. Similar to LAS, we have recently found that unexpected electric stimulation can also facilitate movement initiation and execution in healthy participants performing arm supination and finger abduction tasks [16], suggesting this form of sensory stimulation could also be employed in rehabilitation settings and achieve similar outcomes to LAS.

Building on these two approaches, LAS and electric stimuli, we sought to determine whether somatosensory electric stimulation could induce movement facilitation in healthy and chronic individuals with stroke during performance of a functional reaching task [2,8].

2. Methods

2.1. Participants

Eight healthy young volunteers (mean age = 25, SD = 5.6) and five chronic stroke survivors (mean age = 51.8, SD = 8.5, see Table 1 for further details) with elbow contracture <15° participated in the study. Participants gave written informed consent prior to commencement of the study, which was in accordance with the Declaration of Helsinki and approved by the local Ethics Committee of the University of Queensland. Healthy participants reported normal or corrected to normal vision and stated that they were right hand dominant. Stroke survivors were all right hand dominant and had impairments to the non-dominant arm.

2.2. Procedures and design

Participants were seated on a chair beside the device, which offered support to the tested arm as shown in Fig. 1. They were restrained by a seatbelt to restrict trunk movements. Bright white and green light emitting diodes (LED) were embedded in a Perspex block (10 cm height by 3 cm depth) to serve as warning and go-signals, respectively. The LEDs were mounted at the rear end of a linear slide to which a potentiometer was attached to transduce displacement. Participants made movement toward the Perspex block which was placed beyond arm's length. The tested arm (affected arm for stroke survivors and non-dominant arm for healthy young) was positioned in pronation and wrist extension (0° to 45°) in a customized thermoplastic splint that prevented active movement. The splint had an aluminium frame that was fixed to a manipulandum connected to the linear track. Participants started their movements from a standardized position and were told to push along the linear slide in the direction of the LEDs until they reached a comfortable distance. The request to reach a comfortable distance rather than the maximal range was to allow examination of whether acoustic and/or electric stimulation can induce participants to move further than normal. Based on previous studies with the Sensorimotor Active Rehabilitation Training (SMART) arm, the number of repetitions during the experimental phase was 60 trials [2,5,8], plus 6 no-go trials introduced to control for potential false starts (66 trials total).

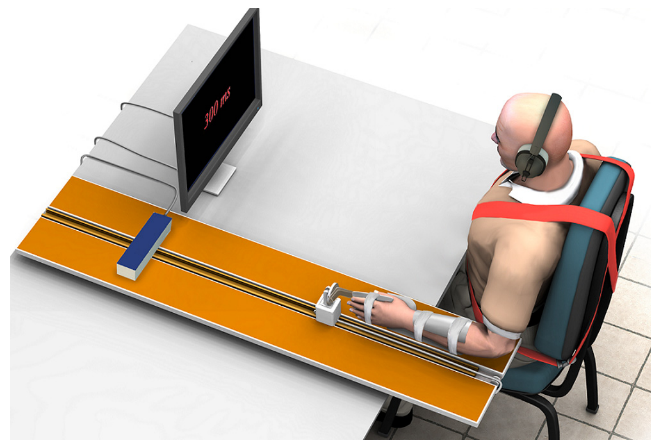

Fig. 1. Illustration of the experimental set-up.

In some trials (probe trials), acoustic or electric stimulation was physically synchronised with the go-signal. In control and probe trials, go-signal presentation was always preceded by the warning signal appearance (200 ms duration). The interval between warning and go-signals was 1.4 s (±200 ms). Participants were asked to reach a comfortable distance forward as quickly as possible upon the presentation of the go-signal and remain stationary otherwise (no-go trials). Probe trials comprised 30% of the total number of trials. Feedback on reaction time was given after control trials but not after probe trails. If participants made any movement during no-go trials, the message "*Pay attention*" was presented on the monitor screen. Participants were asked to ignore acoustic and electric stimulation and respond only to the go-signal. If reaction times were shorter than 100 ms in control trials, the message "*Do not anticipate*" was displayed.

Before the beginning of the experiments, participants performed 15 practice trials with the right limb (opposite to the limb tested during the experiment) to familiarise themselves with the task. Acoustic stimulation was presented twice during familiariza-