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Individuals with chronic hemiparetic stroke can correctly match forearm positions within a single arm

Netta Gurari [a,*], Justin M. Drogos [a], Julius P.A. Dewald [a,b,c,d]

[a] Department of Physical Therapy and Human Movement Sciences, Northwestern University, Chicago, IL 60611, United States
[b] Department of Biomedical Engineering, Northwestern University, Evanston, IL 60208, United States
[c] Department of Physical Medicine and Rehabilitation, Northwestern University, Chicago, IL 60611, United States
[d] Department of Biomechanical Engineering, Faculty of Engineering Technology, University of Twente, Enschede, The Netherlands

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HIGHLIGHTS

- Participants with chronic stroke had impairments locating each forearm during passive movements.
- Chronic stroke participants were unimpaired in locating each forearm during active movements.
- We do not know what neural impairment is assessed by common clinical forearm position matching tasks.

ABSTRACT

Objective: Previous studies determined, using between arms position matching assessments, that at least one-half of individuals with stroke have an impaired position sense. We investigated whether individuals with chronic stroke who have impairments mirroring arm positions also have impairments identifying the location of each arm in space.
Methods: Participants with chronic hemiparetic stroke and age-matched participants without neurological impairments (controls) performed a between forearms position matching task based on a clinical assessment and a single forearm position matching task, using passive and active movements, based on a robotic assessment.
Results: 12 out of our 14 participants with stroke who had clinically determined between forearms position matching impairments had greater errors than the controls in both their paretic and non-paretic arm when matching positions during passive movements; yet stroke participants performed comparable to the controls during active movements.
Conclusions: Many individuals with chronic stroke may have impairments matching positions in both their paretic and non-paretic arm if their arm is moved for them, yet not within either arm if these individuals control their own movements.
Significance: The neural mechanisms governing arm location perception in the stroke population may differ depending on whether arm movements are made passively versus actively.

1. Introduction

By 2030, approximately 10 million American adults will have been affected by a stroke, an estimated 84% of these individuals will survive, and many of these individuals will move on to long-term disability facing challenges in coordinating and controlling movements (Mozaffarian et al., 2015). According to clinical assessments, more than half of these stroke survivors may have a compromised position sense (Connell et al., 2008; Winward et al., 2002) that can result in devastating effects on their ability to control their movements (Cole, 1995; Ghez et al., 1990). Even so, our understanding about the reason for observed impairments during the clinical assessment is limited since the measurements: (1) lack sensitivity to identify the degree of an impairment (e.g., ratings are

* Corresponding author at: Department of Physical Therapy and Human Movement Sciences, Northwestern University, 645 N. Michigan Avenue, Suite 1100, Chicago, IL 60611, United States.
E-mail addresses: netta.gurari@northwestern.edu (N. Gurari), j-drogos@northwestern.edu (J.M. Drogos), j-dewald@northwestern.edu (J.P.A. Dewald).

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unimpaired, mildly impaired, severely impaired), (2) are subjective (e.g., a rater determines task performance based on visual inspection), (3) may not be reliable (e.g., ratings may differ depending on the rater and testing session), and (4) may be confounded by additional impairments (Carey et al., 1996; Sullivan and Hedman, 2008).

To address the limitations of currently available clinical sensory assessments, a number of research groups are employing robotic systems that standardize and automate the assessment of position sensing capabilities in individuals with stroke (Dukelow et al., 2010; Simo et al., 2014). Robotic systems offer numerous advantages including that sensors affixed to the robotic device can monitor the user's interaction and data can be processed off-line.

Here, we characterized the ability of individuals with chronic hemiparetic stroke to match forearm positions using two approaches: a between forearms position matching clinical assessment and a single forearm position matching automated robotic assessment. Our aim was to determine whether individuals with chronic hemiparetic stroke, who have impairments matching positions between forearms, also have impairments matching positions within a single forearm. Based on our findings, we suggest that a large number of individuals with stroke who have a compromised ability to mirror arm positions on a clinical between arms position matching assessment may not have impairments identifying each arm's location, separately, if these individuals actively control their arm movements. We also note that if the arms of individuals with stroke are moved for them, these individuals may have impairments identifying the location of both their paretic arm and their non-paretic arm. We conclude that the neural mechanism(s) causing impairments on clinical between forearms position matching assessments in individuals with stroke is not known.

2. Methods

Neural mechanisms contributing to a position matching task may differ when positions are matched between arms versus within a single arm since the body's sensors and body's schemas must relay comparable information for each arm during the between arms task, yet not during the single arm task (Adamo et al., 2007; Goble, 2010; Hirayama et al., 1999; Proske et al., 2014). First, we characterized participant performance during a between forearms position matching task using a clinical assessment in both participants with chronic hemiparetic stroke (i.e., participants with stroke) and age-matched participants without neurological impairments (i.e., controls) (see Fig. 1). Next, we quantified task performance in both of these populations during a single forearm position matching task using a robotic assessment to determine whether impairments arise when participants match

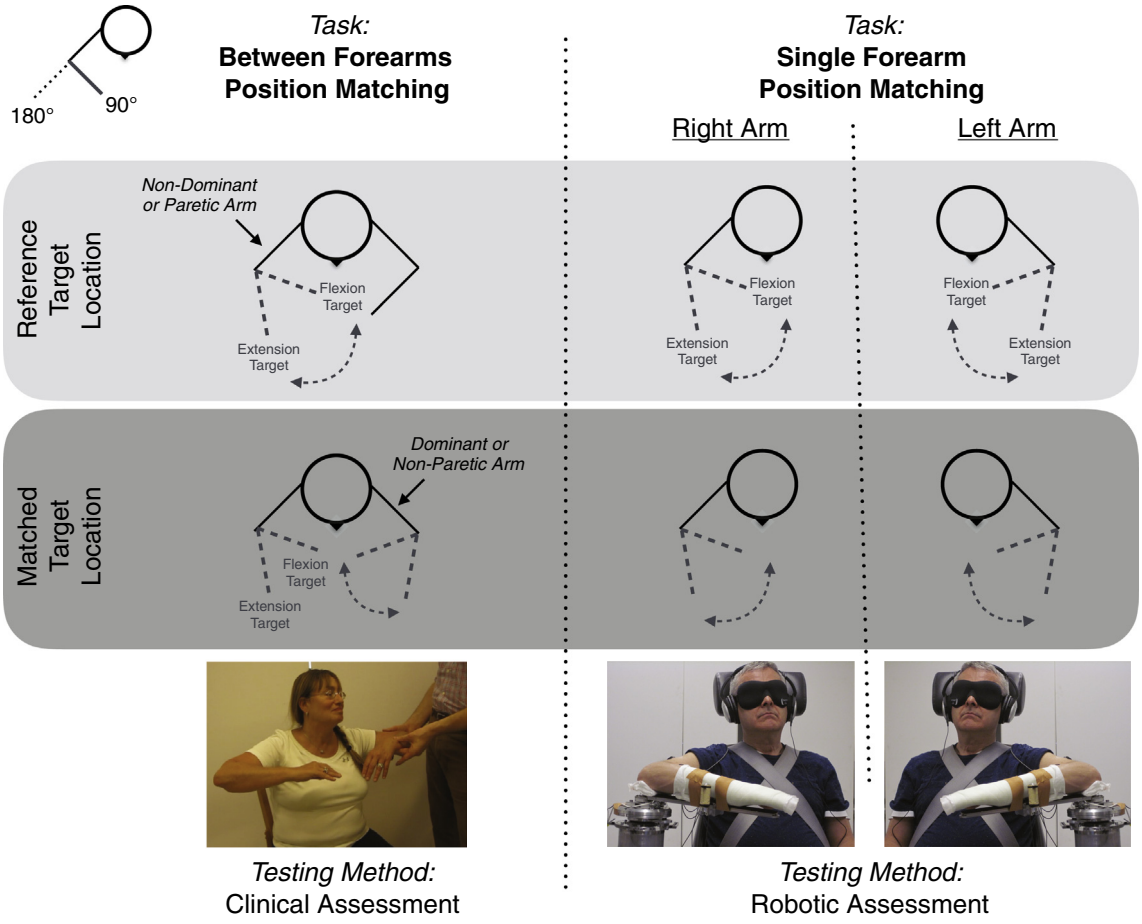

Fig. 1. Experimental Methods. The ability of a participant to match forearm positions is tested (Left) during a between forearms position matching task and (Right) during a single forearm position matching task. For each task, (Light Gray Box) the participant remembers a reference target location and (Dark Gray Box) then tries to match the reference target location without receiving feedback about task performance. The between forearms position matching task is performed using a clinical assessment (revised Nottingham Sensory Assessment); a licensed physical therapist places the participant's non-dominant (in controls) or paretic (in participants with stroke) forearm at the reference target location, and the participant then matches this reference target location by moving their dominant (in controls) or non-paretic (in participants with stroke) forearm to the mirrored location. The single forearm position matching task is performed using a robotic assessment, and the participant's task performance is quantified for both the left arm and the right arm.