Robotic Assessment of Cognitive and Motor Function in Adults with Sickle Cell Disease

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SCD is a blood disorder known to cause severe pain crises as a result of blocked blood vessels throughout the body, lasting from a few hours to multiple days. Despite this chronic pain, we observed clinical results suggesting that SCD patients were able to 'keep up' with the healthy controls in a variety of domains. Leading us to wonder, what is the main cause of this? How can we explain these scores? Our Haptic Thera-Drive robot is used as an objective measuring tool to help us better pinpoint the effects of SCD-related impairment.

Introduction

- Past studies have been able to uncover evidence of neurocognitive and motor impairments in Sickle Cell Disease (SCD) patients when compared to healthy controls [1].
- As medicine has advanced and the lifespan expectancy of SCD patients has increased, there is a significant need for continued diagnostic and rehabilitation efforts in this population.
- **Our goal is to better identify and understand the cognitive and motor impairment associated with SCD in adults while also exploring the relationship between both domains.**

Methods

		SCD Participants n=8	Control Participants n=8
Age		42.4 ± 14.8	41.9 ± 16.6
		n	n
Gender	Female	6	6
	Male	2	2
Education	<12 Years	0	1
	12-16 Years	6	1
	>16 years	2	6
Race	White/Caucasian	1	0
	Asian	0	1
	Black/African American	7	7

- **Subject Population:** 16 participants: SCD: 8 participants; Healthy: 8 participants (**Table 1).**
- We surveyed the population about their Life and then performed three types of Assessments: Cognitive and Motor Assessments followed by a Robot Assessment.



- **Robot Assessments:** Spatial Span Cognitive Task, Trajectory Tracking Motor Task (**Figure 1A).**
- **Cognitive and Motor Assessments:** Montreal Cognitive Assessment (MoCA), Color Trails 1/2, Digit Symbol Coding, and Hopkins Verbal Learning, Box & Blocks, Grooved Pegboard, 10m Walk, and Grip Strength (**Figure 1B-1C).**

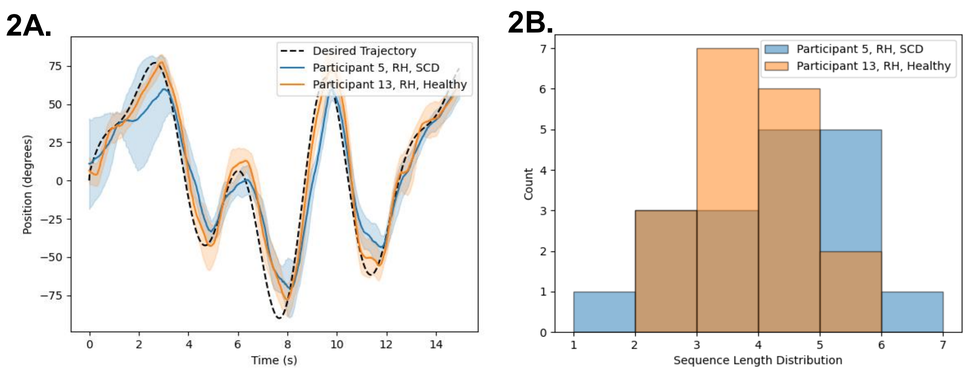


Figure 2. Trajectory Tracking (2A) and Spatial Span (2B) results of a study pair

- **Robotic Analysis**: Using Python scripts and Matplotlib, we processed raw data into meaningful graphs, generating plots that displayed paired results of the robotic assessment.
- **Clinical Analysis**: A Wilcoxon Signed-Rank test was used to understand the T-Score results of clinical assessments.

Acknowledgments & Financial Conflicts

- We would like to acknowledge Dr. Laura Stubbs and the University of Pennsylvania School of Engineering Office of Diversity, Equity, and Inclusion for their continued support of this project, as well as the Penn Medicine Comprehensive Sickle Cell Disease Program and other members of the Rehabilitation Robotics Lab and Recupero, LLC.
- Dr. Michelle J Johnson, who is the PI and/or Co-I leading this study, has a patent that uses devices inspired by the device being evaluated through this research. The PI is a co-founder of Recupero Robotics LLC and should appear before the acknowledgment.

Results

- In the Trajectory Tracking (TT) robotic assessment, both the controls and the SCD participants did not necessarily outperform each other but instead maintained varied results. **Figures 3A-3D.**
- In clinical assessments, on average, controls and SCD participants tended to score very closely to each other. The only significant result was in the Hopkins Verbal Learning assessment during the Retention and Delayed Recall sections. **Figure 4.**

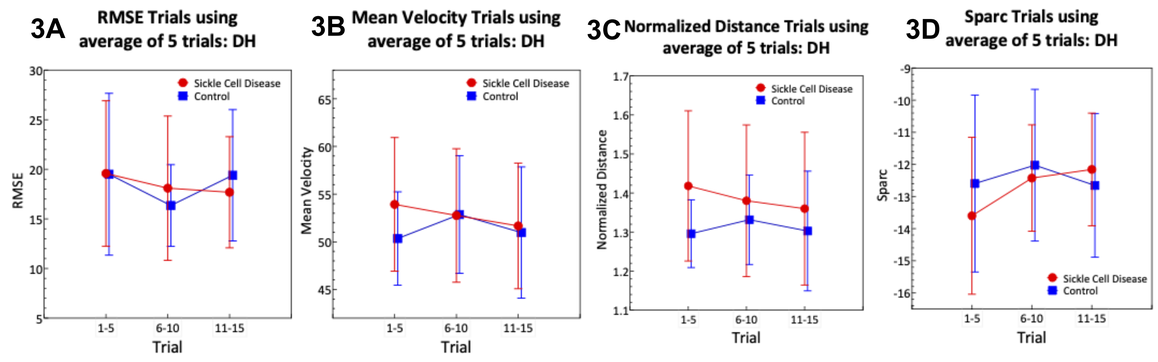


Figure 3. Robotic Assessment results between groups (Across groups of 5 trials at a time): Root Mean Square Error (RMSE), Mean Absolute Velocity (MAV), Normalized Distance (ND), and Spectral Arc Length (SPARC)

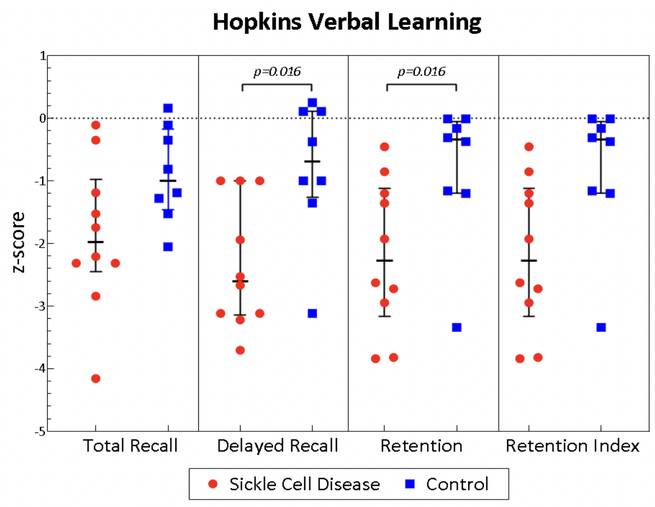


Figure 4. Hopkins Verbal Learning Results SCD vs Controls

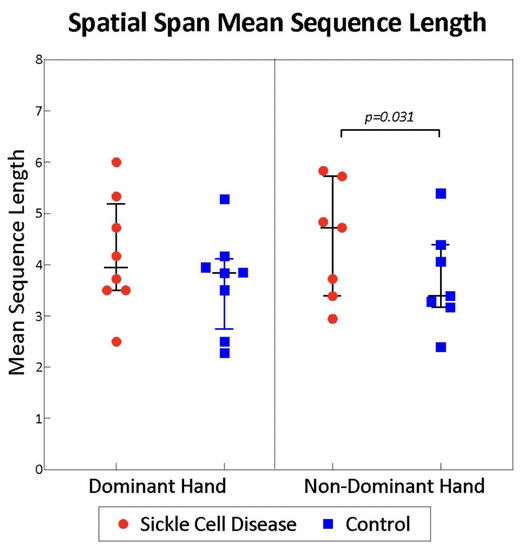


Figure 5. Spatial Span (SS) Mean Sequence Length Results SCD vs Controls

- To the left, we display the Spatial Span (SS) Mean Sequence Length Data. An unexpected result was the SCD participants outperforming the controls in number of squares in a sequence remembered. This brings to question which aspect of memory is impaired, short- or long-term.
- **Figure 2A-2B** marks the desired trajectory alongside the actual distances traveled for both participants (healthy & control) as well as the frequency of the different sequence lengths over 18 trials. In this case, depicting a more accurate trajectory for the control. We also see that while the healthy participant was able to be more consistent in patterns of 3-4, the SCD participant was able to reach a pattern of 7 trials at least once, depicting learning.

Discussion

- We can infer from the Trajectory Tracking results of the robotic assessment that some motor impairment was present. **Figure 3A-3D.** While we expected that SCD–related pain could hinder performance, what we did not account for was the possibility that SCD participants could learn to work around their pain over the years.
- While trying to understand the relationship between cognition and motor function, we did not uncover much evidence of one domain influencing the other, rather, each domain seemed to be influenced individually by SCD.
- **With evidence of some significant differences in memory between groups, will we be able to identify more differences in other domains within a larger population? If so, can we also identify stronger arguments for one domain influencing the other?**

References

[1] M. C. Kral, R. T. Brown, and G. W. Hynd, "Neuropsychological Aspects of Pediatric Sickle Cell Disease," *Neuropsyc. Rev.* 11(4), p.179–196, Dec. 2001.