Toward Optimization of Surface Electromyography Sensor Placement for Intuitive and Adaptive Assistive Device Control

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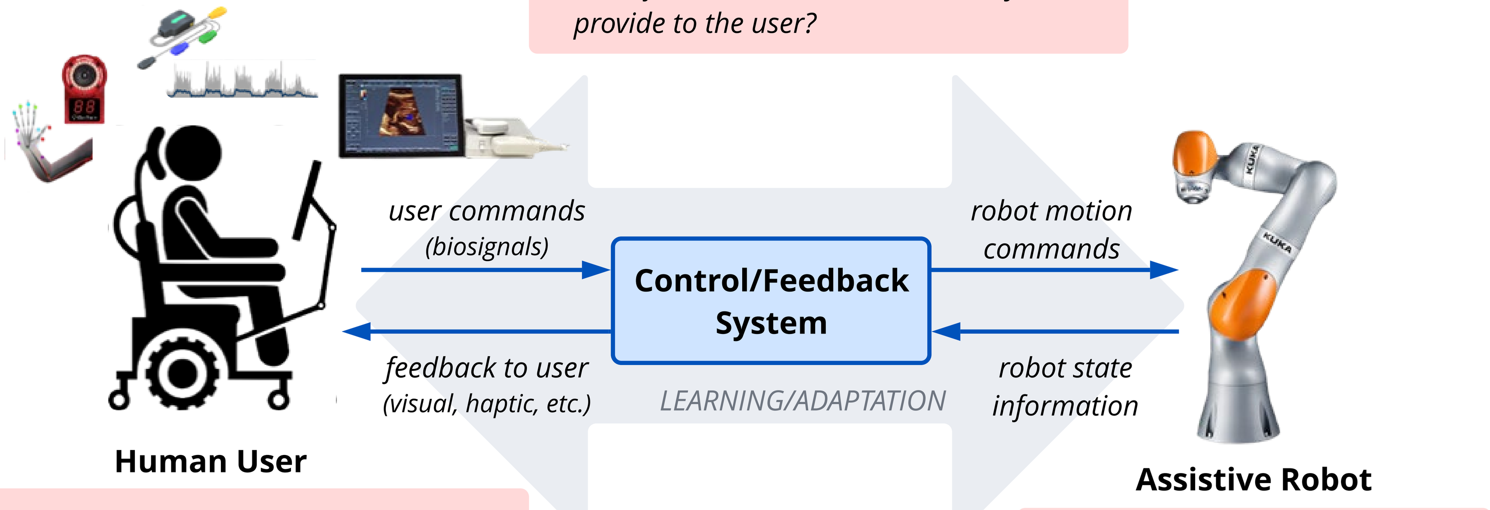
Motivation & Aims

Assistive robotic manipulators allow individuals with tetraplegia to interact with their environment and generally improve quality of life, but these devices remain **unintuitive to control** for those with physical impairments and are **insufficiently dexterous** to fully interact with real-world environments.

To build sufficiently intuitive and dexterous devices requires addressing many complex, integrated open questions (highlighted in red boxes to right).

In this work (toward addressing the bolded open questions), we perform a **preliminary empirical analysis of candidate biosensor interfaces** and their mapping to device degrees of freedom (DoF). Specifically, we propose and evaluate **varied combinations of surface electromyography (sEMG) measurement locations and mappings**. These interfaces and insights will be leveraged in future construction of a complete robotic assistance system.



Platform Design

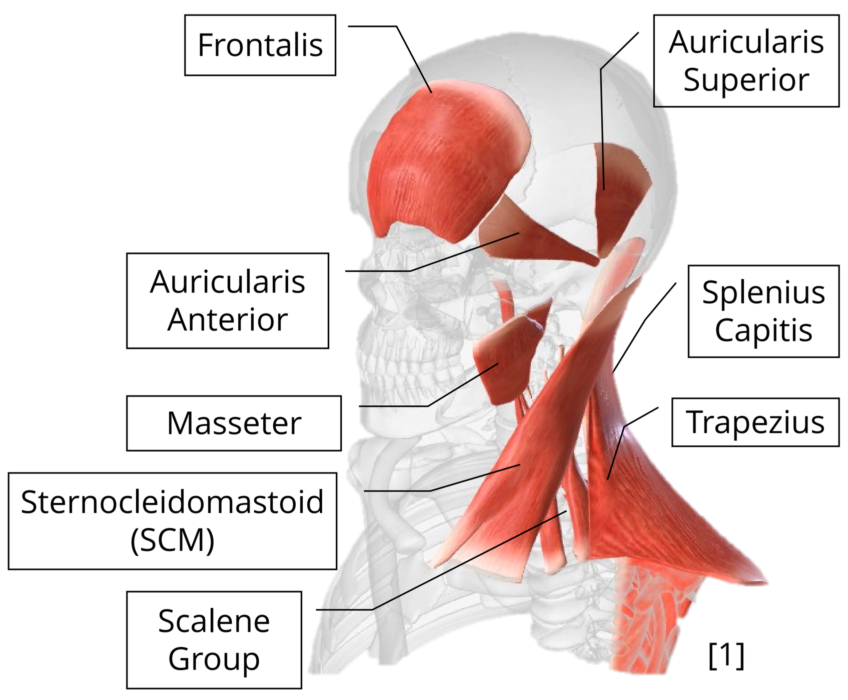
Design Constraints

Considering **use by tetraplegic individuals** (e.g., spinal cord injury survivors), we require that the control interface:

- minimally interferes with the user socially;
- only uses muscles of the head, neck, shoulders, and upper back;
- comprises **sufficient independent signals to control a high-DoF device**;
- is reliable across multiple users;
- does not generate undue fatigue; and
- requires placement of only a few electrodes (here, 4).

Candidate Configurations

Based on these constraints, we tested the following combinations of muscles:



	Participant 1			Participant 2		Participant 3	
Muscle	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**
Frontalis	x		x		x	x	x
Auricularis				x	x		
Splenius	x		x		x		x
Masseter			x		x	x	
Trapezius	x	x	x	x		x	
SCM	x	xx		x		x	xx
Scalene		x		x			

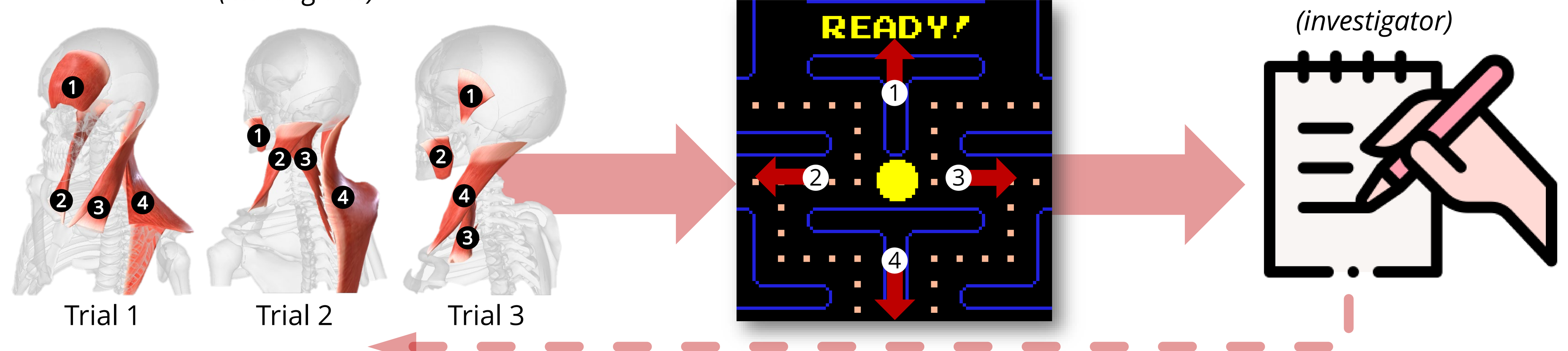
* Double "x" indicates use of both left and right symmetric muscles.

Iterative Interface Selection Process

Three healthy participants were instrumented with a starting sensor configuration, then used the system to play Pac-Man (our simple test platform preceding application to continuous manipulator control).

Participants were given the option to modify the mapping from sEMG signals to Pac-Man control DoF.

Investigators then selected an updated configuration based on **game performance**, **participant feedback**, and **investigator observations**.



Preliminary Results

Muscle combinations selected and preferred by participants varied, supporting the need for further principled study of performance and preferences:

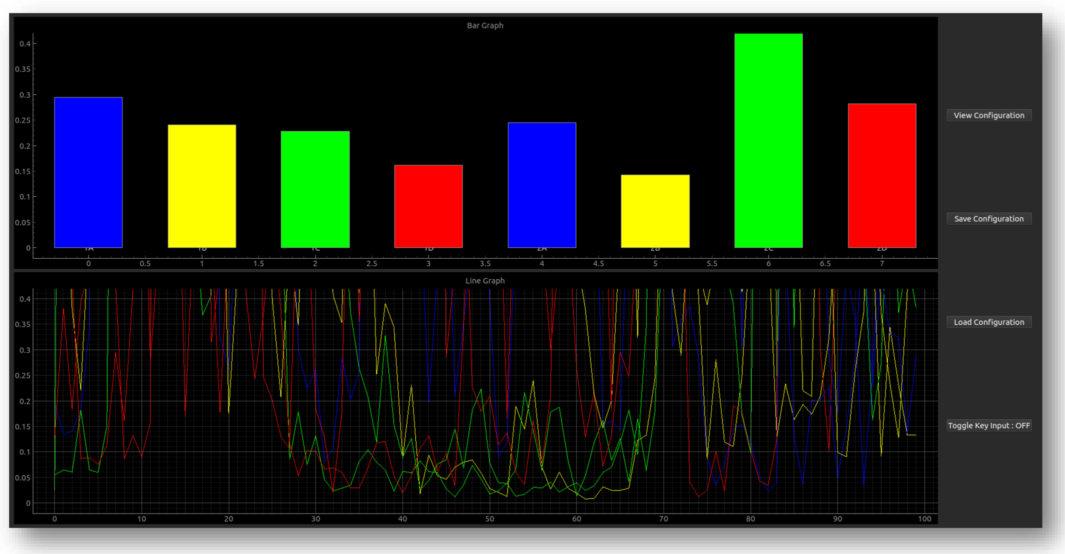
- The SCM and trapezius were consistently preferred (and thus heavily used) by all participants and provided consistently reliable signals.
- Some muscles (e.g., the auricularis superior, used to "wiggle" your ears) were preferred by some participants (not socially invasive or otherwise in use), but others were completely unable to activate it (i.e., generate a control signal).
- Some muscles were hard to accurately measure due to muscle depth (e.g., scalene group), but may be accessible via additional sensing (e.g., sonomyography).
- Symmetrical pairs of muscles (e.g., both sides of the SCM) always exhibit coactivation and thus cannot provide independent control signals but are a promising source of differential control signals that may be more reliable than a single absolute sensor reading.

These results highlight the **importance of sensor placement when designing assistive device control schemes**, the ultimate goal of this work.

Future Work & Development

Current System Improvements

To enable **real-time signal visualization** (both raw and processed), **rapid iteration of control mappings**, and **quantitative analysis of users' signal modulation capabilities**, we are developing a **GUI** for use in future, rigorous investigation of interface configurations.



Future Integrations

We are also developing the following expanded system components:

- **hybrid sEMG–sonomyography control schemes**;
- literature-informed mappings from biosignals to end effector motions, leveraging principles **of task space separability and integrability** [2]; and
- small-scale **training exercises** to build fine muscle control skills [3], [4].

These systems will ultimately form the basis of the **robust, modular, customizable assistive device control system** described in our motivation above.

Acknowledgments / Sponsors / References

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This work was supported by the Department of Mechanical Engineering and the Office of Undergraduate Research at the University of Utah.

The authors acknowledge Jono Jenkens, Ajay Anand, and Chad A. Berghoff for their contributions in getting the sEMG system working and recording data properly and reliably.