Designing a Scalable Robotic Exoskeleton and Tablet Gaming Suite for Hand Function Rehabilitation

Authors: Jennifer Hunter, Kristen Fernandez, Jonathan Tuck
CREU Student: Jennifer Hunter
Mentor: Brittney English
Faculty Advisor: Dr. Ayanna Howard
Laboratory: Human-Automation Systems (HumAnS) Lab
Research Blog: http://jhunter35.wix.com/creu

1. Goals and Purpose of the Project

There exist many debilitating neurological disorders that reduce motor function; a few common examples of these disorders are cerebral palsy and stroke [1-2]. However, patients who participate in physical therapy sessions, a common treatment for these conditions, may be able to regain or retain some motor function. Patients undergoing physical therapy commonly exhibit pain and boredom with their rehabilitation regimen, which studies have shown decrease a patient's participation in physical therapy and therefore lengthen recovery time. Furthermore, these studies demonstrate that physical therapy regimens that keep the patient engaged are more likely to shorten patient recovery time by helping that patient stay motivated to contribute in physical therapy sessions [3-5].

Robot-aided therapy is a new technology that has shown promising results for facilitating motor learning in stroke patients [6-9]. However, existing systems are large, heavy, and expensive. Another problem with these systems is that they are created to be one-size-fits-all. Most are designed to fit the average adult male and only allow for minimal adjustment to tighten or loosen the device. Since children are considerably smaller than the average adult male, this option is not feasible for use with children. Furthermore, significantly more women suffer from strokes than men [2]. Since women are often smaller than men, many of them are also not able to benefit from these new therapeutic technologies. Currently, there is no known robotic arm exoskeleton with these therapeutic capabilities available to smaller women and children.

Last year the goal of this project was to design a robotic exoskeleton and tablet gaming suite that promotes engagement and productivity in at-home therapeutic exercises. To achieve this goal, the team developed a robotic wrist exoskeleton that communicates via Bluetooth with a tablet and acts as a video game controller. The exoskeleton has an onboard microcontroller and potentiometer. The potentiometer is located at the wrist joint and is turned when the wrist is moved. The microcontroller reads the value of the potentiometer and sends that value, via a Bluetooth module, to the tablet. The team also created fun and engaging tablet games that facilitated therapeutic wrist exercises. This year, the team's goals were to expand the design in the following ways:

- Develop a squeeze exercising exoskeleton that can play the same tablet gaming suite.
- Develop a new multiplayer tablet game in which players traverse a board game and complete mini-games each time they land on a square.

2. Methods and Procedures

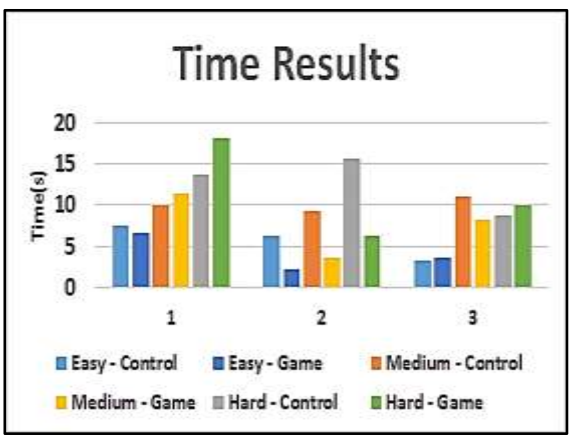
The team expanded on the design of the wrist exoskeleton by creating an alternative finger bed that can attach to the arm brace to facilitate finger rehabilitation. This new finger bed allows sensors to be pressed, like a button. This new attachment connects to the same microcontroller and Bluetooth module as the wrist exoskeleton and can be used to control games.

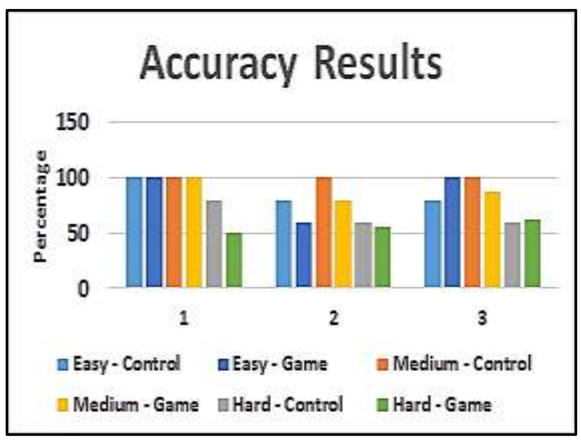
This year, the team developed a new game to function with the exoskeletons and to allow for group play. The team hypothesized that allowing rehabilitation patients to complete their therapy protocol together would provide additional engagement, much like a "workout buddy" does for healthy individuals when endeavoring to exercise more regularly. The game was designed similarly to Nintendo's Mario Party, where the players roll a die and traverse a board game path. Every square that the player lands on launches a mini-game. There are a variety of mini-games, which require the user to complete simple tasks, such as tracing a picture, winning a footrace, or knocking down bowling pins. The winner of each mini-game collects points and at the end of the path, the player with the most points wins. For this party game, a collection of simple mini-games were designed, each of which required the user to complete a therapeutic motion in order to play the game.

Similarly, the team added multitasking as a major component within the mini-games, since many stroke victims suffer from multitasking disorder as a result of brain trauma [10]. To account for this in the research design, these mini-games required the user to complete a cognitive task in addition to the basic motor function task. For example, the goal of one of the mini-games is to control a spaceship to collect stars. The motor task of the game involves using the exoskeleton to control the motion of the spaceship. To add a cognitive task, there is a simple math problem on the screen, such as "2 + 2 = ?" The spaceship will approach a group of stars; each star has a unique number on it. In this example, the user must catch the star labeled "4," as it is the correct answer to the math problem. Therefore, this mini-game facilitates the practice of multitasking by requiring the user to complete the motor task of moving his/her wrist to the correct position to collect a specific star while completing the cognitive functions of calculating and answering a simple math problem in order to determine which star to select. Other mini-games included a color matching game, where players must catch falling fruit that match a certain color using their wrist to move the character across the screen, and a copycat game, where the player has to push the exoskeleton fingerbed sensor buttons in the same pattern that appear on the screen. The last mini-game focused on pattern completion. In this game the player is given a simple pattern, such as "red, red, blue, blue, green, ____", and the player has to move the character through the correctly colored hallway to complete the pattern and find the prize. In this example, the user must traverse the green hallway, as it is the correct answer to complete the pattern.

3. Preliminary Results and Conclusions

To validate this method of multitasking was comparable with multitasking activities in the real world, the team did a preliminary study in which three participants were asked to solve three sets of fifteen math equations (five easy, five medium, five hard) and select the correct answer via a motor task. The control group only performed motor task sets in the real world, but for the game (experimental) group, the second set was completed within the within the star collecting math mini-game.





Figures 1 and 2. The graphs show the time and accuracy of both groups for each math equation series.

Preliminary results showed that while the experimental participants were slower and less accurate in the beginning, their results were comparable by the last set of the study. This suggests that the developed multitasking game is comparable to real world multitasking.

References

[1] “NINDS Cerebral Palsy Information Page." *National Institute of Neurological Disorders and Stroke*. National Institute of Health, 21 July 2014. Web. 23 September 2014.
[2] “NINDS Stroke Information Page." *National Institute of Neurological Disorders and Stroke*. National Institute of Health, 25 July 2014. Web. 23 September 2014.
[3] Zimmerman, M.A., and S. Warschausky. "Empowerment Theory For Rehabilitation Research: Conceptual And Methodological Issues." Rehabilitation Psychology 43.1 (1998): 3-16. Scopus®. Web. 18 April 2014.
[4] Dunn, D.S., and S.B. Dougherty. (2005). Prospects for a positive psychology of rehabilitation. Rehabilitation Psychology, 50, no. 3, 305-311.
[5] Paolucci, S., et al. (2012). Impact Of Participation On Rehabilitation Results: A Multivariate Study. European Journal Of Physical And Rehabilitation Medicine, 48.3, 455-466.
[6] Nancy G. Kutner, Rebecca Zhang, Andrew J. Butler, Steven L. Wolf, Jay L. Alberts. (2010). Quality-of-life change associated with robotic-assisted therapy to improve hand motor function in patients with subacute stroke: a randomized clinical trial. Physical therapy, 90.4, 493-504.
[7] E. J. Koeneman, R. S. Schultz, S. L Wolf, D. E. Herring and J. B. Koeneman. (). A pneumatic muscle hand therapy device,” Proc., IEEE/EMBS Int, Conf, pp 2711-2713.
[8] Colombo, R., Pisano, F., Mazzone, A., Delconte, C., Micera, S.,Carrozza, M., Dario, P., and Minuco, G. (2006). Design strategies to improve patient motivation during robot-aided rehabilitation. Journal of NeuroEngineering and Rehabilitation.
[9] V. Squeri et al. (2014). Wrist rehabilitation in chronic stroke patients by means of adaptive, progressive robot-aided therapy. IEEE Transactions on Neural Systems and Rehabilitation Engineering, vol. 22, no. 2, pp. 312 – 325.
[10] Lazar, Ronald M., PhD, Joanne R. Festa, PhD, Allison E. Geller, MA, Gina Marie Romano, MA, and Randolph S. Marshall, MD. "Multitasking Disorder From Right Temporoparietal Stroke." Cognitive & Behavioral Neurology 20.3 (2007): 157-62. National Center for Biotechnology Information. U.S. National Library of Medicine. Web. 18 Oct. 2015.
[11] B. English, J. Hunter, J. Tuck, and G. Tzintzarov, "Designing a Scalable Robotic Exoskeleton and Tablet Gaming Suite for Hand Function Rehabilitation," in Rehabilitation Engineering and Assistive Technology Society of North America Annual Conference. Denver, CO. 2015.
[12] B. English and A. Howard, “Engagement study of an integrated rehabilitation robotic tablet-based gaming system.” *Advanced Robotics and its Social Impacts (ARSO), 2014 IEEE Workshop on* , vol., no., pp.14,19, 11-13 Sept. 2014