ECE1778 Project - Final Report

HelpingHand

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Word count: 2316 (not including Reference section)

1. Introduction

What?

Our goal was to create a therapeutic tool to help children with hemiparesis (1-sided arm weakness) develop improved bilateral skills by providing motivating feedback for their increased use of the weak arm during tabletop play.

Why?

Children with hemiparesis have a 1-sided weakness in their upper body, with a neurological origin (1). Their affected arm can be restricted in movement, strength, motor control, and muscle tone. These children often find compensatory methods of performing upper body tasks, minimizing use of their affected arm. Many factors contribute to avoidance of arm use, including: impaired communication between the brain and arm, a lack of motor memories for arm use, and learned avoidance (2). This neglect is important to address in childhood so that more efficient neuro-motor connections to the affected arm can be shaped while the nervous system has substantial plasticity (3). If left unchecked, a child's potential for affected arm use can deteriorate and become irreversible. This result can be due to both decreased neuroplasticity and the physical shortening of limb tissues over time (4).

Thus, methods are needed to help children increase functional use of the affected arm. Repetitive practice is required for consolidation of this motor learning, and often therapy and home-based activities do not provide enough of it (5). More opportunities are required for children to engage in functional activation of the affected arm. Other factors that can enhance a child's motor learning include accurate feedback provision and activities of interest to the learner (6)(7).

Thus, there is value in embedding arm use practice opportunities into playful games that are interesting to children and provide accurate feedback, while encouraging repetition. These factors can help motivate children to continue practicing with optimal engagement and greater learning.

The HelpingHand App incorporates these principles, as it presents activity options to the child, designed to elicit coordinated use of both arms. It provides feedback on how much the child activated his/her weak arm, incentives (challenging the child to beat his/her score) and rewards (on-screen stickers) for repetition with increased activation of the weak arm.

Thus, our app can help children with hemiparesis get extra practice that is needed for them to sustain long-term gains in bilateral arm function, supporting improved performance in their daily activities.

2. Overall Design

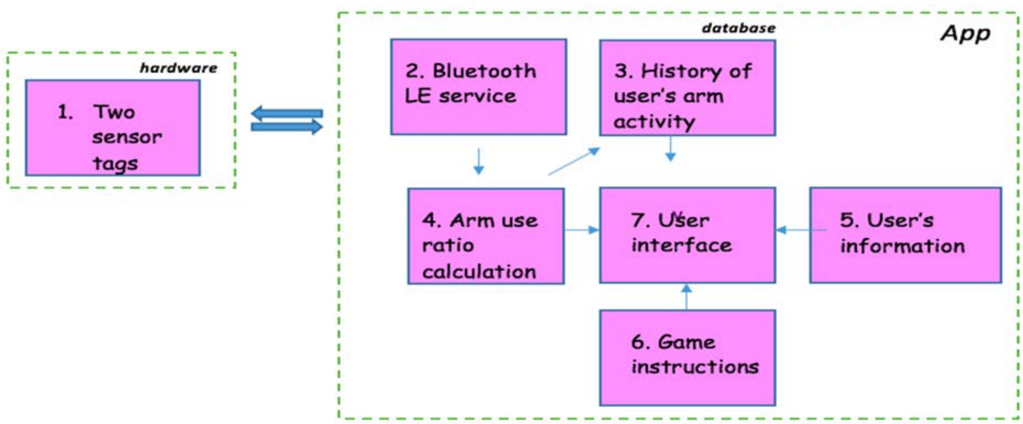


Figure 1. Block Diagram

Table 1. Block Diagram Components

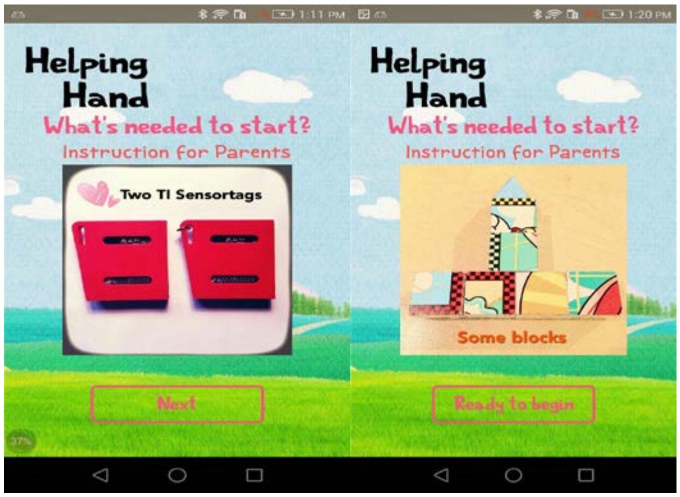
1.	Two wearable TI sensors, providing real-time monitoring and data generation of movement accelerations

2.	Bluetooth Low Energy Service, used to recognize and receive movement acceleration data from sensors.
3.	Database for storage of current arm use ratios, required for future analysis (i.e. comparing arm use ratios over time)
4.	An algorithm for processing the accelerometer data, to capture the frequency and intensity of arm movements, while removing noise effects due to gravity
5.	User information collection/storage - for recording nicknames, side of weakness, and ability to read
6.	Instructional displays - game choice menus, pictures, and text guidance during game-playing
7.	Dynamic UI design - modifying features based on the user's information (i.e. weak arm) and real-time performance (i.e. voice output activation if weak arm use is below 20%).

3. a) Statement of Functionality & App Screen Shots

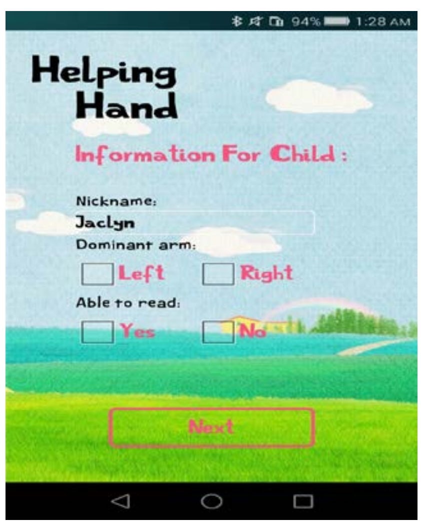
The functional components of HelpingHand app include:

3.1 Instructional set-up for parents:



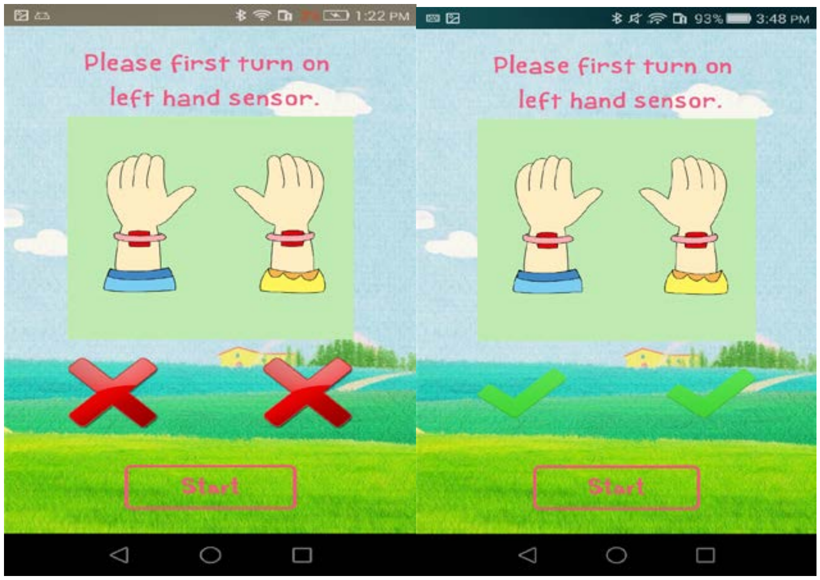
The app prompts parents to prepare the required off-screen materials (sensortags and blocks for Game 1), using picture and text displays.

3.2 Collection of User Data:



Parents are cued to enter the child’s nickname, dominant arm, and whether he/she is able to read. The app uses this data to provide customized cues to the child, such as using voice or text feedback.

3.3 Ensuring Activation of the Accelerometers:

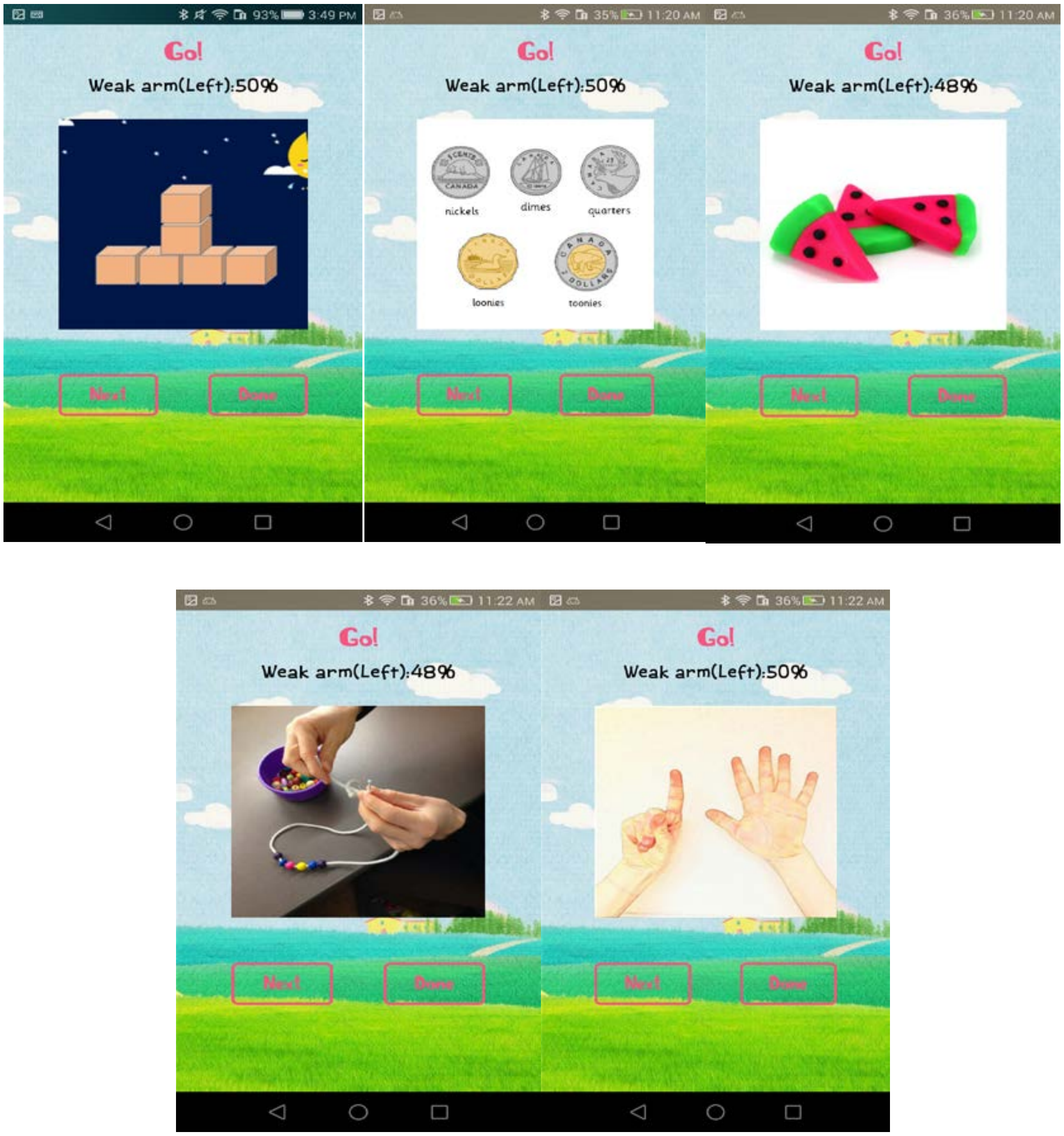


The user is prompted to activate the left arm sensor, then the right one. It displays checkmark indicators, confirming when both sensortags are ready for game-play.

3.4 Offering Game Choices:

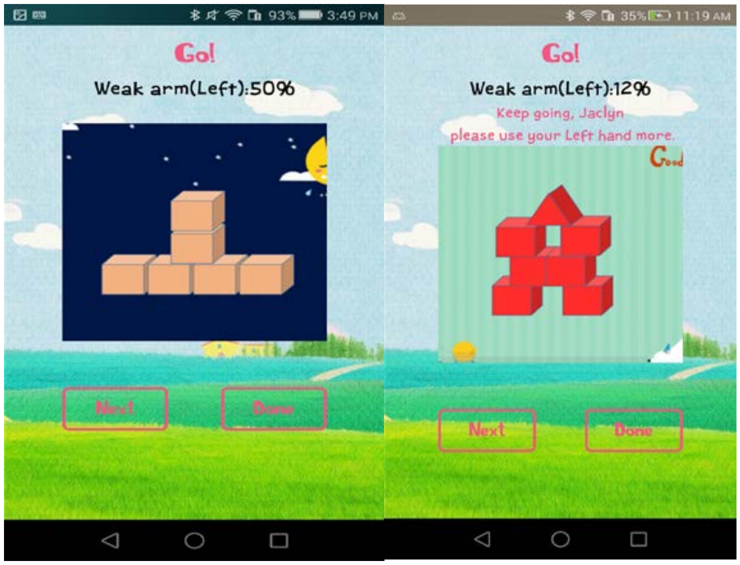
The app presents a menu of 5 game options. The user can return to this menu by clicking a button at the end of any game.

3.5 Providing Child-Friendly Game Instructions:



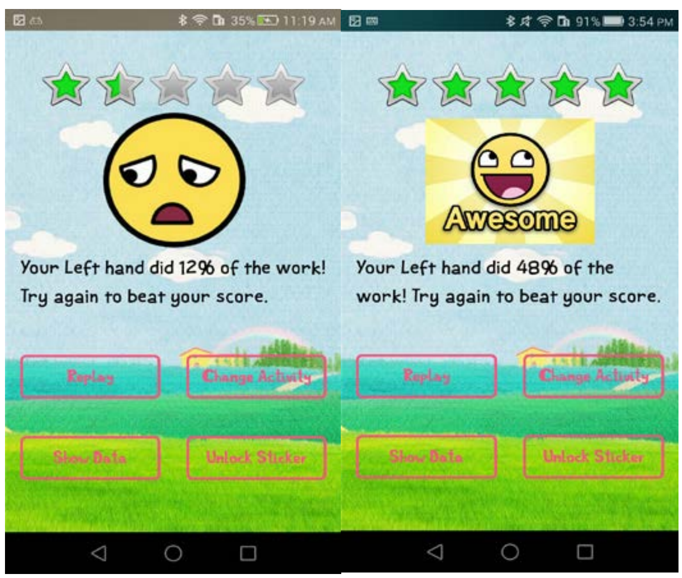
Dynamic (i.e. for block and pantomime games) or static pictures (i.e. for other games) display step-by-step instructions. Children are required to copy actions displayed on each screen. Users can press ‘Next’ to continue playing, or ‘Done’ to receive the final results feedback.

3.6 Providing Real-time Feedback (on weak arm use):



During each game, if the child’s weak arm use is less than 20% of total arm use, then he/she is instructed, via voice output, to try to use that arm more.

3.6 Presenting Final Results:

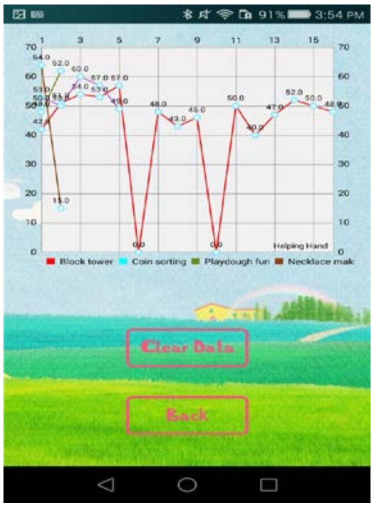


After the user clicks ‘Done’, feedback is provided on the amount of weak arm use via visual displays (stars and a happy/unhappy face) and text (indicating % of weak arm use) or voice output (encouraging the child to try again to beat his/her score).

3.7 Providing Visual Rewards:

By clicking a button at the end of each game, the user can see a set of grayed-out reward stickerst. Text instructions indicate how many game repetitions are required to unlock the next sticker. Games must be repeated with a score of at least 40% weak arm use in order to unlock these stickers.

3.8 Displaying User's History of Arm Use:



The parent can click 'Show Data' to display a line graph of the child's history of weak arm use. This feature provides an easy-to-read view of how much the child has progressed over time in use of the weak arm. It also allows parents to visually compare the child's amount of arm use for the different game types played.

3. b) Functional Analysis based on App testing

Based on our self-testing and child-testing (n = 2) of the app's functionality, it was reliably effective in all of the areas described above in 3.a), when users followed the on-screen instructions.

Issues with the app's functionality that we encountered included:

- Mis-reading of accelerometer data, when sensortags were activated in the incorrect sequence: This problem occurred due to the TI sensortag's instability. This sensortag can only make one connection at a time, and if two connections are made simultaneously, the program will crash or only receive one sensor's datastream. Thus, users need to wait for one sensortag to fully connect before turning on the next one. If a user activates the second sensortag too quickly, it will cause the first one to disconnect, and the app will not receive or display correct information regarding the user's arm use.

4. What we learned

Specific to the app's usability, we learned (via testing) that dynamic visual instructions would have to be modified to slower speeds, to accommodate usage by younger children (i.e. a 4-year old). In adapting the app, we found it was helpful to keep the final visual display screen static, to increase child users' comprehension of what was required for the block building games. We also learned that children (typically developing) found the games to be engaging, and were responsive to the verbal cues (i.e. "Try to use your left arm more") during game-play.

However, we did not yet test the app over long-term use, nor with children affected by cerebral palsy. We predict that, to maintain a child user's interest in use of this app over prolonged periods, we would need to include increasing levels of game difficulty, and add more customizable theme-based play options. For example, a block building game could prompt the child to select a desired theme such as 'castles' and then present options for castle-like structures, with graded difficulty levels. Furthermore, we would change our approach by testing the app on children with hemiparesis, to determine if the audio/visual feedback is adequate to induce changes in their voluntary use of the weak arm during game play.

5. Contribution by Group Members

Jaclyn Dawe (Specialist) contributed by suggesting ideas for the overall functionality and UI displays of the HelpingHand app. She devised the game content to be applicable to the targeted age group (3 – 7) and to involve arm movements that are often therapeutically targeted for children affected by hemiparesis (e.g. grasp/release, reach forward, pinch, extend at wrist). She shared her ideas with group members through discussion, emails, and by using the moqups software to display her concepts for the UI page sequence. Jaclyn also helped by producing photos for use in the visual game instruction displays. As well, she suggested incorporating more visual rewards into the game (i.e. on-screen stickers). After the app's development, she tested its usability on two children, gathering information to inform future iterations. For example, she discovered that the dynamic visual output for the pantomime game should be adapted to slower speeds for younger child users.

Wen Zhao (Programmer):

1. Applying the principles of a single sensor connection demo, she built up two BLE connections to the Android Phone. She got the accelerometer characteristics from two sensortags and built a separate callback function for each one. Further, she modified the data collection format into two data streams.
2. She built a dynamic picture display utility and realized the dynamic game instructions for the app's 5 games. Wen beautified pictures (contributed by other members) and also produced many other game pictures independently.
3. She contributed to the app's real-time feedback by implementing the text/voice output feature that is activated when the quantity of the user's weak arm drops below 20%. As well, she improved the data collection method for the final arm use ratio calculation.
4. Wen implemented the Voice Feedback feature, as the specialist requested. Wen used that feature to create real-time feedback, displaying game results according to user input.
5. She built the database for storing and displaying the results of previous games for each user. She designed and implemented the UI interface. As well, Wen compiled the content for the UI design, and transformed the entire UI style into a more aesthetic and child-friendly format by changing the font design and background screen.

6. Wen also collaborated with Jing in designing an algorithm for filtering the negative influence of gravity. They calibrated the factors to apply to both sensortags and compared the collective data from two sensortags.

Jing Wang (Programmer):

1. Jing set up a Bluetooth low energy service on the Android Phone for connecting to a TI sensortag and receiving accelerometer data from it.
2. He designed the block diagram and implemented the overall framework of the App accordingly (e.g. using different instructional fragments to display user prompts and collecting user's input to customize the game's output format). He processed raw data from accelerometers and updated a publicly available ratio for relative arm use.
3. He added an unlockable sticker reward feature by implementing a program to sum the arm use ratios (above 40%) for each game, and to display the number of game repetitions required to unlock the next sticker.
4. He retrieved historical arm ratio data from the database, displaying the data on a line graph API for parents to view.
5. He collaborated with Wen in designing an algorithm for filtering the negative influence of gravity. They calibrated the factors to apply to each sensortag and compared the collective data from two sensortags.

6. Specialist Projects: Specialist Context

Development of the HelpingHand app could potentially contribute to therapeutic design for individuals affected by hemiparesis (i.e. secondary to stroke or CP) in its objective measurement capacity, home-usability, and specific targeting of bilateral arm use.

Firstly, the app utilizes accelerometer-based technology to provide precise quantitative estimates of a person's relative weak arm use. This construct is difficult to ascertain with precision by observation alone. Therefore, the app allows increased accuracy in gauging a child's performance with incorporating weak arm use into functional play, contributing to quantitative assessments, on which sound treatment planning relies.

Secondly, the app allows users to complete therapeutic 'home exercises' on a regular basis, which are important components of therapy programs. It addresses the need for monitoring of the client's performance of home exercises, by electronically recording each user's history of use and performance scores, tracked over time. It could potentially be valuable to therapists who want to assign 'homework' exercises and require assurance of its completion and efficacy. The app's features make it feasible for clients to increase their performance of therapeutic activities at home, as they often do not have adequate time (or money) to attend highly frequent in-clinic sessions.

Finally, by targeting specific bilateral arm use (through accelerometer monitoring and real-time feedback) during functional activities, this app differentiates itself from the fine-motor skill apps on the market, that are not customized to the needs of children with hemiparesis. These children avoid use of their weak arm, even in the presence of physical capacity. Hence, they do not benefit from apps that target fine-motor skills, without cueing use of the weak arm. They are often adept at playing these games with compensatory over-use of the dominant arm.

In terms of rehabilitation for hemiplegic CP or hemiparesis, there is a need for more customized targeting of weak arm use, to directly address the consequences of affected arm non-use. This app could potentially contribute to approaches addressing this area of need.

7. Future Work

In further developing and improving this app's design, we would incorporate the following additional features:

- Allow users to customize speed of visual instruction presentation (in block and pantomime games, according to the child's developmental level)
- Increase game content to include greater progressions in difficulty levels, presented to the child based on his/her real-time performance
- Customize feedback provision (i.e. scheduling of verbal prompts during game, adding haptic vibratory or more visual feedback) to meet each user's needs
- Enhance motivating game elements to facilitate optimal engagement in users over long-term (i.e. base game options on child-friendly themes such as animals, castles, or magic)

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