Conceptual framework for and design prototype for Young Children's Assistive Technology (yCAT):

A novel approach to environmental access and control through an interactive human-building system

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ABSTRACT

When used in conjunction with the built environment, new and evolving technologies can empower users by enabling opportunities for independence, accessibility, and participation in meaningful activities. Some of the most notable assistive technology devices to foster unique human-computer interactions include the Amazon Echo, Google Home, tablets, and Smartwatches. While many of these products were not designed specifically for therapeutic applications, researchers have identified several benefits for people with disabilities. For instance, voice activated devices may help blind individuals carry out daily tasks, and body sensors may assist medically fragile users in monitoring their falls, vital signs, and proximity to objects in the home and community. Through literature review, pilot study, and community-based needs assessment, our team described criteria for successful assistive technologies geared toward very young users, and developed a wearable system prototype - "Young Children's Assistive Technology" (yCAT). This system could enhance independence and access for children with neurodegenerative diseases or limited movement, many of whom have full cognitive function but do not receive traditional devices until reaching school-age. Project yCAT incorporates a novel communication device with environmental sensors and home automation functions to allow the user to navigate and control the built environment, which may lead to improved well-being through increased agency/self-determination.

INTRODUCTION

Spinal Muscular Atrophy (SMA) is a rare inherited neuromuscular disease that causes a degeneration of the spinal cord, resulting in muscle atrophy, hypotonia of the trunk and limbs, respiratory weakness, and reduced head control [1]. Children with special healthcare needs, such as SMA, experience muscle weakness or fluctuations in neuromuscular tone, which limit their movements and ultimately inhibit their access and participation in desired activities within the home and in the community. Furthermore, such children often experience difficulty communicating with others or their environment through the typical approaches including speaking, using traditional switches or remote controls, or using input devices such as a mouse, keyboard, or touchscreen. However in addition to normal cognition, these children often have intact voluntary eye movements that may allow them to interact with eye-gazed based applications, or limited but voluntary finger and arm movements that may allow them to use special ultra-sensitive switches. Therefore, the aim of our research was to develop and test a wearable Augmentative Alternative Communication (AAC) device that allows children ages 2-5 with special healthcare needs such as SMA to communicate and control their environments more independently.

METHODS

We have utilized a multidisciplinary team consisting of computer science engineers and healthcare-based therapists. Members from each discipline brought their respective expertise in collaboration of creating the most efficacious application for children with neurodegenerative diseases. Our community-based needs assessment involved a pilot study and online discussions through an SMA community organization. The pilot study consisted of experimenting with various switches, sensors, and monitors as well as acquiring a list of desired outcomes for the application in regards to usability, durability, and customizability. Technology included affordable micro light switches, flex sensors, EMG based muscle sensors, and stretch sensors. The researchers examined a 3-year old child with SMA as he interacted with the various technologies. Variables measured were the response time and number of switches needed to complete an interactive video game. Results of this study provided the researchers a foundation of the varying, unique needs of children with neuromuscular diseases. The researchers of Project yCAT implemented these findings in the design of the application to ensure that the functions of the application were research-based. Findings of this pilot study led to our technical design of the application.

TECHNICAL DESIGN

User design was our main focus when developing our application. Along with speech and limited movement we had various other design constraints such as:

1. User age
2. Amount of Content

- User age: Here we are dealing with Kids aged 4-10. It is important to have our website designed in a way the kids understand.
- Amount of Content: The website had pictures related to daily life needs, covering every small movement, need and command. The website had 400+ images for the user to navigate. Dealing with a structure to accommodate all needs was challenging.

Starting from day one we implemented various designs. Tabular formats, dropdowns, Iphone like file structure but sometimes design aesthetics did not go well with the content or else the amount of content could not be supported by the design.

We wanted something that could cover up the content in a manner that is easy for user to understand and which further can be implemented in such a manner that the user can control it using at max two fingers. After four design fails we came up with the concept of a translucent carousel where the user could see options listed on the screen in a form of a circle and can rotate to select the desired option. Just on a single click the selected option would come to the center and be highlighted where as other options would stay on the screen with a lower brightness but equally visible. This supported our goal of content management and allowed user to manage large content with ease meanwhile also having accessibility and visibility of other available options on the same screen.

Further to help children understand the content we added text and sound options. Whenever a kid would select an option it would automatically trigger an onselect sound file for the particular option. Arrow key was used to control the movement of the carousel and enter key to lower levels. Just with the use of the 2 keys user could navigate through the website. To support smart devices like iPads and Tablets we made the website responsive to touch such the the rotation of the menu and sound file respond to the touch screens similar to the onselect function on keyboard. The website was developed using HTML, Javascript and CSS. A bootstrap library was imported to integrate carousel design.

In addition to these methods, our design was heavily influenced by peer-reviewed literature. We found that though children with SMA present with varying deficits, all have normal cognition and average or above average verbal intelligence [5]. Evidence suggests that these children can maintain efficient communication using augmentative and alternative communication (AAC) and that young children within this population should begin AAC intervention before literacy skills develop by incorporating transparent pictures with their respective words [1]. AAC has also been found to reduce caregiver burden in areas of mobility and self-care, ultimately increasing the child's independence and participation in their everyday environment [6]. The family has the most impact on whether AAC will be implemented within the home, which is why it is essential to incorporate the family in the process of the technical design [2,6]. Additionally, current research shows that there is a need for existing AAC devices to integrate a clinical model of language acquisition and language structure that incorporate human communication [6]. The above research led to the communicative framework of project yCAT, which is further discussed in the 'communicative properties' section below.

Through these various methods, project yCAT has adopted unique characteristics to better suit the communicative needs of children with neuromuscular diseases. These characteristics include customizability, durability, affordability, accuracy usability, and accessibility. Ultimately, project yCAT's attributes surpass other existing devices as it strives to allow for maximal functional movement patterns and improve the quality of life of young children with debilitating neuromuscular diseases.

COMMUNICATIVE PROPERTIES

The framework for the communicative design of project yCAT combined existing evidence of what designs currently work with future implications for what is needed in an AAC device to promote the most successful communication. Current evidence proposes that applications with fewer steps or switches to the targeted icon reduces the user's fatigue and fosters participation, vocabulary development, and opportunities for increased language development [4]. Furthermore, our team created a unique feature on project yCAT that would promote the preceding and decrease the user's operational demands: The feature is a spoken output that produces fluent, syntactically accurate sentences. Since most of the children using yCAT are preliterate, this feature encourages the use of full sentences with just the click of a button. Existing AAC devices would require the child to use much more time and energy to create a full sentence. Unfortunately, within the population of children with neurodegenerative diseases, fatiguing during communication is quite common [5]. Therefore, this distinctive feature allows for children to exert less energy to produce more age-appropriate sentences. For instance, if a child uses an existing AAC device and chooses the image 'kitchen', the output is 'kitchen.' When a child chooses the image 'kitchen' with yCAT, the spoken output is, 'I want to go in the kitchen.' This supports age-appropriate prepositions, communicative requests, and syntax. Additionally, yCAT is unique because it incorporates the four purposes of communication, which are as follows: Requests, social closeness, sharing information, and social etiquette [4]. Image 1.1 shows an example of the setup of six categories within the application, which incorporates the preceding four purposes of communication. Many existing AAC devices rely solely on the child requesting objects, which does not generalize to all aspects of human communication [3,4]. For this reason, project yCAT incudes phrases such as "I love you", "Leave me alone!", "Excuse me", and "I'm feeling sad."

FUTURE METHODS

Examining the functional efficacy of project yCAT on children with special healthcare needs involves three stages of research: The first stage, which will occur in spring of 2018, assesses the speech-language components, design features, usability, and testing protocols on children ages 2-5 who are typically developing and are enrolled in a daycare program or preschool. Stage 2, occurring in summer of 2018, assess generalizability, user experience, and speech-language components of children ages 2-5 who have communication challenges and are enrolled in a community-based therapy program. Finally, stage 3, intending to occur in fall of 2018, examines family use of the device within home settings for children ages 2-5 with a diagnosis of a neuromuscular disorder.

DISCUSSION AND CONCLUSIONS

Though our team has not officially obtained data, our future methods are sought to examine the efficaciousness of our application across various communities. Our literature reviews and community-based needs assessments have shown that there is a demand for adaptable technology for young children with neuromuscular deficits. Ultimately, we hope to acquire a more comprehensive view of how project yCAT enhances communication and environmental navigation among children with neurodegenerative diseases.

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Image 1.1. yCAT system example – displays a child's icon options in the "In My Home," "Kitchen" and Help Cook" sub-levels of the communication application.