Design for One: A Game Controller for a Quadriplegic Gamer

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Abstract

This paper explores utilizing digital fabrication and electronic prototyping techniques to build a game controller and a mouse for a quadriplegic patient. We present two products (keyboard and mouse) and DIY electronic prototyping techniques, which were developed in a collaborative effort between the designers and a quadriplegic teenager. We suggest that DIY and personal digital fabrication techniques can be adopted by occupational therapists and assistive technologists in particular cases, or where the traditional techniques fail to support or meet patients' requirements.

Author Keywords

Occupational therapy (OT); assistive technology (AT); Do-It-Yourself (DIY); electronic prototyping; 3D printing; game controller

Introduction

Interaction design and HCI typically do not consider design for a single person. In contrast, within occupational therapy and Assistive Technologies (AT), designing for a single person is common. However, according to Scherer, a large percentage of AT for quadriplegic patients end up unused [10]. Several factors may lead to device abandonment by users, such as device performance, change in ability and preference of users [3]. This requires OT and AT professionals to be constantly designing and refining devices for a single person. Relatedly, personal fabrication within DIY has gained much attention recently, and it has been applied to various technology designs. Mota [8] discussed the DIY movement amongst individuals, and how a new industrial revolution is forming due to public access to digital fabrication tools such as laser cutters, 3D printers and CNC mills. Additionally, Mellis and Buechley [7] conducted a DIY workshop and discussed the implications of digital fabrication for the design and production of customized electronic products within HCI. This paper looks at how we employed rapid prototyping tools and DIY techniques for an AT need and the future potential of this approach. Other approaches in HCI literature investigate the potential for DIY designing in the making of AT and accessible rapid prototyping tools [9]. Further DIY designing can potentially empower individuals to make their own custom-made AT [4].

In this paper we discuss lessons we learned from a particular case of designing a game controller for a single person, namely Nick, a teenager who recently became a quadriplegic. We discuss how personal fabrication can support occupational therapists (OTs) duties with digital fabrication and electronic prototyping techniques, and in our case, developing a game controller for a quadriplegic patient that is typically beyond the scope of traditional occupational therapy. Further, we argue that in certain cases, designing for one is a preferable alternative in situations where the most optimal fit and granularity of design details is a necessity and that personal fabrication is a viable option to support this alternative.

Finally, we adopted a series of commitments in our design process that can be understood as "designing for one". The commitments helped to guide decision making and orienting us at any moment in the project. These commitments included:

- The uniqueness of the situation is the priority;
- Nick is the expert requiring his participation in the design;
- Design decisions are very granular that manifest materially throughout the process.

Limitations of Occupational Therapy and Inclusive Design

Although universal design offers important insights about designing appropriate products and services to be accessible by a broad range of users, implementing universal design features may have their own functional limitations and aesthetic problems. Some challenges of designers are noted as mainstream products become specialized, more expensive and aesthetically ugly [1].

In addition, one of the OT's and AT specialist's tasks is to search the market for potential existing devices to be fitted and adopted by patients. However, existing AT have high overhead cost factors; have limited resources to purchase; and can be accepted or otherwise abandoned easily by patients [12]. On the other hand, making an appropriate device for a particular patient can be time consuming, require particular skills, and is expensive [according to an interview with an experienced OT in the Vancouver area].

Figure 1: Initial meeting with Nick.

Figure 2: Designing with Nick in GF Strong Rehabilitation Centre.

Our Expert User

Nick is a seventeen year-old high school student. He is a highly experienced mountain biker who injured himself in a mountain biking accident. Like many, he enjoys video games, especially first person-shooter (FPS) games like Halo™. He is mechanically minded and has an interest in industrial design. Nick injured his spine at the C6 level: he lacks certain motor skills, and the particulars of his movement are unique to him. In addition, Nick's abilities are dynamic: they have changed, and will continue to change through rehabilitation, physiotherapy, and age.

In our project we involved Nick as an expert user, in terms of his unique physical abilities and demands. In general, experts refer to "people who are knowledgeable on a given topic" [11]. HCI literature qualifies a user as an expert according to the certain kind of domain knowledge the user has [5], or length of time a user has utilized a technology [6]. We began working with Nick soon after his accident and continued for approximately six months that included his initial stay at the hospital's spinal cord injury ward and his extended stay at the hospital's rehabilitation centre.

Design Orientation and Goals

This research continues in cooperation with OTs, AT resource personnel, and the medical staff, including doctors, nurses, and physiotherapists. Our original motivation in working with Nick was to help him interact with computational tools to allow communication through online forums. In addition to this goal, Nick asked us to design a game controller for him to play Halo™ and other First-Person Shooter (FPS) games with on the computer. We consulted with his OT and AT specialist to see if an existing technology exists in the market and is a viable option for Nick. The device that they recommended did not offer the flexibility to customize its design to suit Nick's unique needs.

Our design goals with this project were on the practical level to design and produce a high-fidelity prototype game controller, utilizing open source electronic prototyping processes [2] and digital fabrication techniques, for Nick, in order to achieve a level of game play proficiency that satisfied him. On a research level, our goal was to investigate the design process issues in designing for one that could provide credible recommendations for OTs and HCI researchers. We realize that the credibility of the latter goals relies on achieving the practical goal of designing a successful game controller for Nick. As a result, a series of prototypes, including a custom-built gaming keyboard and mouse with laser cut parts, were developed.

Design Process

Our design process was inspired through observation of how Nick's OTs designed his hand splint. We employed a research-through-design approach, which is an iterative process in which a series of experimental prototypes are designed, built and tested in a real life setting. Throughout the design process, we consulted with Nick's OTs and AT specialists on therapeutic, medical and technological matters. The prototype was designed in incremental stages to test each parameter with Nick, and allow for him to reflect on and co-direct the design process. This allowed us to fine tune the prototype to match his functional capabilities as they emerged as a result of the iterations. In other words, Nick needed to experiment with our prototypes to better understand himself, and his needs and capacity, so he consulted at every single stage. In the end, we

Figure 3: Final Game controller components.

Figure 4: Final prototype Mouse (place holder image).

Figure 5: Iteration of prototypes.

created a total of 8 controllers and 8 mouse prototypes. After every other prototype, the OT or AT specialist offered their feedback. The baseline for the success of the game controller was based on Nick's game performance and comfort level with the controller.

Initial Prototyping Decisions

Initial prototyping decisions were decided upon with Nick to better identify the specific needs of the project. These included form and shape of the prototype, derived from collaborative sketches and brainstorming. In addition to discussing the controller, we explored Nick's movement with his arms, wrists, hands, and fingers, as well as his positioning in relation to the computer and display. We took notes and video during these sessions for future reference. Given the challenge of designing a low-cost and robust prototype, we chose to use the MakeyMakey™ board, for the initial development over the commercially available product, the Stealth switch AT 5™. MakeyMakey™ is a plug and play solution that provides up to 17 possible switch inputs that switches can be made to be any shape or size.

Most of the ideation and design process was conducted with Nick in the rehabilitation centre; he never visited our studio. Utilizing simple crafting material such as foam sheets, foam core, aluminum foil, and wooden dowels, we were able to construct mock-up prototypes that we could improve upon later, using digital fabrication technologies in our studio, such as a 3D printer and a laser cutter.

Prototype 1: The Game Controller

Our initial prototype was built quickly out of foam to discover what changes to make, since mutual learning between designer and expert user is an important aspect in the early stages. The materials of the controller changed along with the design as the project progressed. The final product is comprised of a laser cut multi-element panel, sandwiched between conductive material made out of copper with adhesive backing. Circuitry was created using nickel conductive aerosol paint applied to a pattern on plastic. The final design allows Nick to access the most basic buttons for any FPS game, as well as an additionalreprogrammable button on its periphery. Size of the button was made to best suit his hand movement in order to maximize his performance in game.

Prototype 2: The Mouse

The decision to create a mouse rather than a joystick or trackball device was made in order to leverage Nick's familarity with using a mouse for gaming before his mountain biking accident. We first consulted with the AT specialist at the rehabilitation centre in order to discover a good existing option for a viable gaming mouse solution for a quadriplegic patient. They recommended the Expert Optical Trackball Mouse™, created by Kensington. We soon discovered that a trackball solution was not ideal for Nick to play first person shooter games. Due to his limited functional hand movement, he did not have the dexterity to control a trackball in a precise manner.

The mouse we designed for Nick was in response to a lack of a viable solution amongst commercial pointing devices for gaming. The concept was to create a platform with a form better suited to Nick's movement capabilities that uses the existing functionality of a mouse. Throughout the initial prototyping phases, a wired USB mouse was retrofitted into the platform,

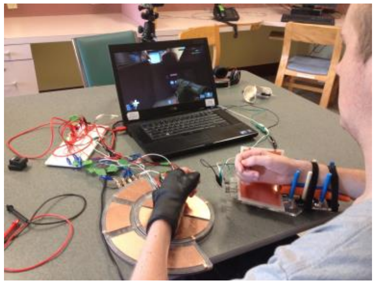

Figure 6: Nick playing FPS game with controller and mouse platform.

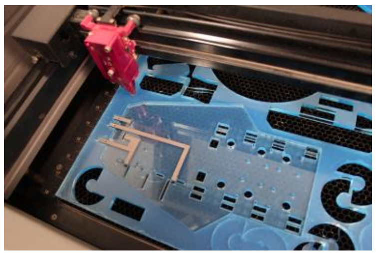

Figure 7: Laser cutting components.

achieved by using double sided tape and glue to achieve a firm hold on the platform. The final prototype was develped through numerous iterations to respond to the limited micro-movements of Nick's right hand. The mouse is made from durable 4mm thick laser cut plastic covered with six 3mm layer of felt for comfort. Additionally, it consists of three programmable buttons made out of dual-layer copper tape that connects to MakeyMakey™. These buttons can be activated by the thumb, knuckle and palm while his arm is securely strapped onto the platform. Supporting dowels were placed at the neck of the mouse to keep Nick's arm steady while strapped in. Metal omni-directional ball casters were added to the base for extra mobility on any surface, and extra support to the back of the upright mouse button and the bottom and sides of the platform.

These changes were informed by Nick's extended use of the medium-fidelity prototype, during which he struggled to keep the platform from collapsing to one side or another, slipping to the right and left while his arm was strapped down, and, other observations. Nick positively responded to the final product, when he was able to play an FPS game on his computer. We conducted two follow-up sessions and saw improvements in game play performance.

Design Reflection

From our study, we discovered that the extensive iterations that we created with our participant allowed for the emergence of tacit knowledge and new skills that were initally unknown. The continual iteration of the prototype achieved a degree of fit with Nick that could not be achieved purely by measurements or requirements-gathering alone. On many occasions, OT and AT specialists, as well as Nick's doctors, were intrigued by our approach in creating the game controller and mouse. They are currently interested in the potential opportunities of rapid prototyping for occupational therapy and AT. Our hope is that utilizing new personal fabrication techniques will increase adoption rates of AT devices and as a result, will significantly improve the lives of patients.

Implications

The study suggests several broader implications in employing digital fabrication with electronics in occupational therapy and AT practices. While existing AT have high overhead cost factors for patients [12], creating customized device be less expensive by making them available unassembled, as raw materials and components [8]. In addition, using 3D printers and digital fabrication provides the opportunity to make the device accessible to patients in any location. Furthermore, using 3D printers or laser cutting to fabricate an assistive device will take less time (typically one to two hours) to make, in contrast to searching, ordering, and waiting to receive an appropriate device by an OT.

DIY designing and personal digital fabrication techniques can be adopted by OTs and AT specialists, particularly where traditional techniques are not able to address the issue of high rates of abandonment of AT, or in critical and particular cases. We understand the need in AT and occupational therapy for extenisve additional training and learning to develop the proficiency with new skills, tools, and practices.

In addition, involving and treating a particular individual as an expert in a design process may result in better product attachment and fit with the device. Design for one, and employing DIY techniques and personal digital fabrication, can be a preferable alternative for OTs and HCI practitioners in situations where the most optimal fit and granularity of design details is a necessity.

Conclusion/Future Research

In this paper we explored utilizing electronic prototyping and digital fabrication technology to develop a game controller for a quadrapeligic teenager. We found that these techniques can support and augment occupational therapists in developing AT for patients beyond their normal scope. Considering the challenges occupational therapists currently face [12], DIY, digital fabricating and prototyping techniques have the potential to fill the gap between technologists and occupational therapists. An OT with the know-how and access to such tools could create unique AT for their clients quickly and inexpensively. More importantly, since every patient is unique in particular ways, an OT can tailor a device to their individual requirements. For future research, we aim to collaborate with OTs and AT practitioners, to incorporate digital fabrication and electronic prototyping techniques into their practices. We would like to investigate challenges that OTs may face while using DIY techniques and perosnal fabrication.

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