Re-Designing a Versatile Mobility Aid

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ABSTRACT
Mobility aides for people living with lower limb amputations include crutches, hinged prosthetic devices and wheelchairs. The axillary crutch is a versatile prosthetic device, but has limited function and little aesthetic value. Through co-creation with a 35 year old female with an above the knee amputation and consultation with physiotherapists at G.F. Strong Rehabilitation Centre, the project objective is the redesign of an existing standard axillary crutch. The goal of portability will be addressed through explorations in collapsibility. The redesign is intended to meet the needs of our co-creator specifically, providing increased mobility and personalized aesthetics.

Author Keywords
axillary crutch, redesign, co-creation, collapsibility, amputation, prototyping.

INTRODUCTION
The purpose of this paper is to conceptualize the process of redesigning an axillary crutch to meet the needs of a thirty-four year old female with an above knee amputation. This project was part of a medical and assistive care design course at Emily Carr University of Art and Design. In collaboration with professionals at G.F. Strong Rehabilitation Center, we worked to redesign an existing axillary crutch to better meet the needs of our co-creator, Nancy Lafleche*. Through experiential investigation of disability, along with co-creation with a disabled individual and medical professionals, we intend to improve upon the design of the axillary crutch. This paper describes our developmental process to date.

METHODOLOGY
To understand the physical and emotional experience of a person with a disability, we temporarily disabled a limb over a period of time. In order to investigate this, members of the group (Angela Henderson and Dean Bennett) casted their bodies to inhibit limb function. We then met with our co-creator, Nancy Lafleche, a thirty-four year old female living with an above knee amputation. We interviewed Nancy to understand her needs and desires in a mobility aid, and her criticisms of existing products. Lastly, we visited Nancy’s home to educate ourselves regarding her daily life, routine and needs from this project. To further investigate mobility aides, we conducted a literature search to explore existing mobility aids, including pertinent side effects and standard criticisms found in the medical literature. Through literature research and interviews with Nancy and medical professionals at G.F. Strong, we explored the issues of portability, medical side effects and aesthetics with mobility aides. In doing so, several prominent constraints were realized. These included the potential for stress injuries associated with axillary crutch use--known as Crutch Palsy [1]--issues of portability, collapsibility, and issues of crutch aesthetics.

With the constraints related to mobility aides clearly identified, we began ideation through sketching, ranging from blue sky, to directly related concepts. Figure 1 shows one concept we developed regarding collapsibility and stress injuries.

*Permissions to use our co-creator's name and photographic information have been granted with a signed release form.
This process of ideating through sketching created new ideas throughout the project. With a range of ideations and feedback from our co-creator, we began to connect drawn concepts to physical form through prototyping.

An adjustable prototype (Figure 2) enabled us to map the ergonomics of Nancy’s body while static. To further understand Nancy’s interaction with a mobility aid, we mapped the ergonomics of Nancy’s body while dynamic.

**Figure 2.** Adjustable ergonomic mapping prototype

With the information from this process, we began to build a prototype (Figure 3). The process of mapping and prototyping with our co-creator narrowed our constraints.

**Figure 3.** Ergonomic findings prototype.

**FINDINGS: Current Mobility Aides**

Prosthetics, wheelchairs, and crutches have unique functions, but ultimately they enable those living with disabilities to navigate an able-bodied environment. Researching design of the axillary crutch revealed that although there have been initiatives to redesign this device, the most successful iteration is that currently in use. After extensive investigation, we realized that crutches fall into two main categories: forearm and axillary. A visit to G.F. Strong enabled us to examine both types of crutches, better understanding the benefits and problems associated with each of them. In discussion with
a Physiatrist at G.F. Strong we understood that while the forearm crutch enables a longer stride and a faster pace, many patients experience stress on the wrist, resulting in fatigue with extended use. This is particularly common, given that forearm crutches are considered standard for those with permanent disabilities. On the other hand, axillary crutches are considered standard for those with temporary injuries and are discouraged for those with permanent disabilities. While they are easier to use, axillary crutches are associated with brachial plexus injury, a condition colloquially known as Crutch Palsy [1]. Understanding the positive and negative elements of the crutch was essential to glean useful information from Nancy’s experiential understanding of crutch use.

Co-creation and collaboration educates designers while helping them manage constraints [4]. Moreover, the effectiveness of co-creation depends in part on the setting in which one gathers information [3]. We chose several settings for collaboration and co-creation. An information session with G.F. Strong helped identify universal issues and advantages associated with crutch use, both forearm and axillary. The professional setting of G.F. Strong offered a broad range of information that lent itself to universal design. An informal meeting with Nancy in her home revealed information of a personal nature. Nancy commented on her experience with frequent axillary crutch use, telling us about the side effects of pain in her shoulders and upper body. She also expressed her need for collapsibility in a crutch to facilitate ease of mobility while traveling; something she does on a routine basis as part of the national para-olympic basketball team. Finally, the issue of aesthetic arose. Nancy felt that the current aesthetic of her standard axillary crutch was not only unattractive but impersonal. Her desire for a personalized aesthetic revealed her relationship with her crutches as an extension of her body [5]. Collaboration with G.F. Strong and co-creation with Nancy Lafleche helped us to clearly define the constraints of the project. Firstly, to reduce the potential for stress injuries to the brachial plexus. Second to increase mobility through collapsibility and lastly to develop a more personalized aesthetic.

**FINDINGS: Research on Axillary Crutches**

To further understand the physiology of the brachial plexus, we contacted a kinesiologist. This meeting helped us to not only better understand the potential damage resulting from long term crutch use, but to rethink ways of lessening risk of injury by facilitating neutral posture. The impact of regular misuse of the axillary crutch affects not only axillary nerves, but can also impact the ulnar and radial nerves [2]. This information led us to exploration of alternatives for the underarm piece of the axillary crutch. We began prototyping underarms pieces (Figure 4)

![Figure 4. Underarm Explorations](image)

to reduce impact on the brachial plexus and encourage neutral posture. These components were designed to be tested with the original, adjustable prototype (Figure 2). To further reduce stress we focused on the potential for impact on the forearm and wrist. The weight distribution of axillary crutches creates stress on the wrist. This is due to the angle of the crutch handle. Research has revealed the optimal angle for stress reduction to be 12 degrees below horizontal. This creates optimal weight redistribution on the wrist and forearm [2].

**FINDINGS: Prototype testing**

After testing underarm pieces with Nancy, we received extensive feedback. Nancy stated that none of the prototypes felt as natural to use as the current underarm piece of her standard axillary crutch. Nancy highlighted where there may be potential modification in the design, commenting on the comfort of a more minimal form. With this feedback, we met the physiotherapists at G.F. Strong. In discussion with our co-creator’s physiotherapist, we came to understand that we did not need to focus on a redesign for the underarm piece of the crutch since Nancy did not use her underarm crutch in a way related to stress injuries. With this feedback, we were able to narrow the constraints of the project. Our objectives became clearly defined as working to increase mobility through collapsibility, and personalizing the aesthetic.

**MANAGING CONSTRAINTS**

Redesigning the axillary crutch with our co-creator provided opportunity to design for her specific needs. The first meetings with our co-creator revealed her reasons for using the axillary crutch instead of the forearm crutch. The ability to travel a greater distance without tiring and to transition from crutch to hands free in social situations and while performing daily tasks was of primary importance to Nancy. Prototyping based on feedback from our co-creator allowed us to further refine the prototype.
and ask more directed questions. What is Nancy’s natural inclination when using the axillary crutch, how does this differ when in a stable position versus in motion? Does the attempt at creating hybrid between the forearm and axillary crutch offer further support? Is there a need for more forearm support?

Testing the prototype from our previous ergonomic findings revealed that the addition of the forearm support served little function in its current position. Decisions made in the construction of this prototype (Figure 4) were made with the feedback from our co-creator but construction took place in the absence of our co-creator. When we tested the prototype during construction, we found that we were more inclined to hold the crutch close to our person in both a stable position and while in motion – much the same way a new crutch user would do. As a result, when this prototype was tested with our co-creator she saw very little relevance in the placement of the existing forearm piece. However, the added support of a forearm crutch was of interest to Nancy and she saw potential in exploration of hybridizing the two forms. Additionally, we recognized the need for a new prototype that would facilitate adjustment much the same way as our first prototype (Figure 2). Ultimately, we recognized the need to redesign without compromising the functional elements of our co-creator’s existing crutches. With this non-negotiable constraint, and Nancy’s hopes for increased mobility through collapsibility and personalized aesthetic, we were able to focus on combining these elements into a new prototype (Figure 5).

Figure 5. Prototype Sequence

FINDINGS: A New Prototype
With clear constraints in mind, we focused on paring down the form to meet our new design criteria. Investigating the underarm, forearm and handle as they relate to the body meant experimentation with form through the use of wet clay. Holding the clay in our hands, we were able to see the form of the hand as it related to holding the handle of the crutch, as well as the curves of the body in relation to the underarm. This enabled us to pare down the form of the crutch in a way that fit the ergonomics of the body. To facilitate travel, collapsibility was of primary importance to our co-creator. This required that we design the crutch to facilitate collapse while maintaining ease of use. Using the existing mechanism in the height adjust on the standard axillary crutch, we employed the same mechanism in locking the collapsible crutch into an open and closed position.

As the form became pared down to meet the function of comfort and portability, we incorporated the collapsing mechanism to construct a testable prototype (Figure 5). At this stage we met with Nancy and the physiotherapists from G.F. Strong. While the issue of comfort required further modifications, the collapsible component has significant potential as a viable solution. While this prototype fulfills the requirements for the studio deliverables, this collaboration will continue, working to find a solution to meet the needs of a woman living with a disability.

CONCLUSION
The process of design involves gleaning information from a variety of sources. A source of valid information in the process of redesigning a mobility aid is medical literature, which facilitates a better understanding of the issues surrounding these devices. Meanwhile, collaboration with medical professionals allows one to better understand this information, by tapping the vast anecdotal experience and knowledge on the subject. Finally, through collaboration with the end user, one is able to achieve a more personalized and practical understanding of the issues surrounding product design. Through these sources, a designer is better able to understand the broad issues at hand, then gradually narrow the focus to a personalized, usable end product.

REFERENCES
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**IMAGE REFERENCES**

Figure 1. Angela Henderson, 2009, Concept drawing

Figure 2. Angela Henderson, 2009, Adjustable ergonomic mapping prototype

Figure 3. Angela Henderson, 2009, Ergonomic findings prototype

Figure 4. Angela Henderson, 2009, Underarm explorations

Figure 5. Angela Henderson, 2009, Prototype Sequence