

ProAesthetics: Changing How We View Prosthetic Function

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ABSTRACT

There are multiple perspectives that must be considered while designing a limb: The engineering requirements, the visual and aesthetic appeal, the needs and wants of the client, and how these designs impact users physically, socially, and mentally. Historically, the main focus of design has been on the engineering requirements while neglecting the individual's needs or desires for aesthetics which are seen as secondary concerns. However, these aspects still hold important roles in how the user views and connects with their own limb. In order to better understand the impact that aesthetic design has on the individual, this exploratory case study aimed to create custom-designed prosthetic limb covers for lower limb amputees. This poster includes the findings of the research and design process, including related works, the interview, design, and prototyping processes, as well as issues that occurred during the project and how they were either overcome or could be addressed in the future.

CCS CONCEPTS

- **Human-centered computing** → Accessibility.

KEYWORDS

3D Printing, Assistive Technology, Co-Design, Aesthetics

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1 INTRODUCTION AND BACKGROUND

In *Design Meets Disability*, Graham Pullin argues strongly for the need to explore how design and disability can inform and inspire each other, and in particular why it is important to explore the incorporation of aesthetic design into the construction of varying types of assistive technology [11]. When it comes to the design of prosthetic limbs, the main area of focus has often been on improving the mechanical capabilities of the device to replicate biological capabilities as closely as possible. While this is not inherently a bad thing, it can lead to some level of neglect towards the visual and aesthetic aspects of the prosthesis, often viewing the appearance as secondary to restoration of movement. Furthermore, the

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creation of the prosthesis often involves the end-user minimally, outside of measurements for size and tests for comfort much of the prosthetic limb is already prefabricated. There is great potential in exploring how users view the appearance of a prosthetic limb and how involvement in the design process of a cosmetic limb or limb cover can lead to designs that are personalized and reflect aspects of a user's identity. In this project, we adopted a participatory interdisciplinary approach to study how input from prosthetic users can be combined with technical knowledge of the prosthetics manufacturing process as well as an eye for visual composition to create aesthetically pleasing prosthetic designs. We engaged in the prototyping and fabrication of three customized lower-limb prosthetics that focused on aesthetic appeal and personalization and found that users had innovative ideas for how to customize their devices.

This project is informed and inspired by previous research that has studied the impact of aesthetic appearance on individuals with limb loss as well as effective methods for pursuing the design process. Customizing prosthetics and assistive technologies (ATs), more broadly, has been studied for the past few decades in the context of the work of Do-It-Yourself (DIY) AT communities [4, 5, 8, 9]. Of particular relevance to this project is the work of Profiti et al. that showed customization practices within the deaf community that went beyond functionality and used aesthetic aspects of hearing aids to represent aspects of identity [10]. Other projects have shown how online communities create and share customized ATs [4, 9] and also identified the challenges of balancing practical, aesthetic and political considerations when creating customized ATs [7]. Other efforts have focused on developing co-design methods where people with disabilities, AT experts, and designers come together to create customized and personalized designs (e.g., [1, 6]). Finally, Bekrater-Bodmann et al. developed a Prosthesis Embodiment Scale [2, 3] used to describe how prosthesis-users connect with their prosthetic limb and how to evaluate that connection. These projects motivated the current exploratory case study that focuses on inquiring into aesthetic preferences and considerations of lower-limb prosthetic users to augment existing devices to make them more appealing. Our findings show that prosthetic users may have personally meaningful preferences for what their devices look and feel like that if incorporated into prosthetic design may make them more appealing and aligned with one's identity.

2 METHODS

Five individuals with lower-limb amputations participated in semi-structured interviews regarding their interest in cosmetic covers as well as how they felt about their current limb appearance. Each interview was approximately an hour, occurring during a regularly scheduled appointment at the clinic where they receive care for their prosthetic limb. Three women and two men were interviewed, all were white and above the age of thirty. Notes were taken during



Figure 1: "Jersey Devil" limb cover (digital 3D model top Left, 3D printed model bottom Left), and 3D printed "Flame On" cover design (Right)

the interview process as recording devices were prohibited. From these notes key words and quotes were taken out to provide context for their relationship to their current prosthetic device as well as providing insight into what their interests were regarding cosmetic covers. The data from these interviews was then used to design aesthetically focused limb covers, beginning with digital sketches and 3D models of the limbs using Autodesk's Fusion 360. The participants had each given different criteria for their desired covers, whether it be certain colors to use or avoid, sports teams they liked, or activities that they enjoyed. Due to time constraints amplified by COVID-19 restrictions, we were unable to get feedback from the participants regarding the initial sketches. After initial designs were finalized, the models were printed utilizing additive 3D printing technology. Due to the varying aesthetic desires of each participant, each limb cover had its own unique challenges and prototyping needs that we will describe in the next section. Our university's Institutional Review Board (IRB) office approved the study before data collection began.

3 FINDINGS

Of the five interviews conducted, two of the participants stated that they currently had minimal to no interest in cosmetic covers while three stated that they had previously considered altering the appearance of their prosthetic. The three who had some previous interest in altering the appearance of their limb had varying levels of current interest, one was no longer interested in altering the appearance of their limb, another was still interested in it, but it was simply less of a priority, and the third was receptive to the concept of altering the appearance of their limb as it was something they

had thought of but had not really pursued. These answers were consistent with data from the literature review; some individuals were very narrowly focused on realism, others had an interest in more robotic or abstract appearances, and some were happy with their limbs the way that they were [5, 6]. From there they were further interviewed about what they might like to see in a limb cover for themselves, with varying answers given between each individual. Some were more interested in a realistic looking cover, while others had varying interest in less lifelike designs. Answers as to why they felt the way they did about their preferences varied. One participant responded "everyone wants to look normal" when asked about her preference for a realistic limb cover. Another participant mentioned she is around children often and is concerned about her prosthetic scaring them, she wants to make sure her limb is something that the children can connect with as well and a realistic limb cover would raise fewer concerns with these younger children. Two participants with bionic knees mentioned the importance of a cover acting as protection for the mechanical components inside their prosthetic limb and that such a focus was often considered more important than aesthetics due to insurance covering protective covers rather than aesthetic covers.

An overarching issue regarding prosthetic limbs is the expense of the limbs themselves with the additional cost of the amputation procedure if applicable. Many people feel like they cannot afford the additional cost of cosmetic changes, especially if they are paying out of pocket. Financial stressors can impact well-being and mental health and further medical costs of occupational therapy and limb maintenance can impact continued use of a limb [7]. While affordability and access to limbs is an important factor in both designing a



Figure 2: "Peace and Love" prosthetic limb cover, front (Left) and back (Center) of the model, detail of DIY glitter snow globe (Right)

prosthetic limb and continued acceptance of the limb into the body identity of the individual, this research is focused more narrowly on the aesthetics of the limb and how that impacts the user, areas relating to public policy and insurance are outside of the scope of the research in this project.

From the five designs described by participants, we selected a total of three design concepts, based on their practicality and possible aesthetic appeal, to proceed to the design and prototyping stage. The designs ranged from more simple colors with minor additions to requiring different types of materials and separate prototyping artifacts. The most simplistic design was the one titled "Jersey Devil," (Figure 1, Left) as all that was requested was something in red and black that contained the logo of the participant's favorite hockey team. This design required little additional prototyping and was fairly simple to model and print, the most difficult part was modeling the logo to be visible but also solidly connected to the body of the cover.

The second most complicated cover was the "Flame On" design (Figure 1, Right). The cover itself was simple to model as it was solid, but due to the fact that it was designed for an above-the-knee amputee it was much larger than the other two designs and had to be printed in two parts. There were several issues that occurred with the printing of this cover in which prints would fail in the middle of the print, taking extra time and troubleshooting to complete. For the flame design, a few different avenues were explored. Vinyl stickers were explored as an option; however, it was discovered they do not stick well to the PLA material and would eventually peel off. Further research was done into how they do flame decals for cars and motorcycles and made some attempts with painting on the design. From this research the vinyl flame stickers were then repurposed to act as a stencil for the flames, using tape to further define the edges of the shape. Glossy black spray paint was used over the remainder of the cover.

The most time-intensive cover was the "Peace and Love" design (Figure 2). The creation of the cutouts for this model was fairly time intensive due to limited features in the Fusion 360 program. Fusion360 does not yet have support for wrapping a sketch around a model, so shapes had to be created on individual sketch planes and cut out to prevent stretching. Nylon was used for this cover due to its flexibility and because it is a dyeable material. Nylon test dye sticks were printed to evaluate dying time needed for the material to achieve the most vibrant colors in the requested pink and purple. These sticks were then dipped in the dye for fifteen seconds to two minutes to see what time would produce the most ideal color for the covers.

This cover came with an additional area of prototyping due to the inclusion of a "glitter snow globe heart" in the cover. This snow globe was made using acrylic sheets, water resistant adhesive, glitter, and vegetable glycerin. A heart shaped metal cookie cutter and a heat gun to heat gun was used to cut the sheets clear acrylic, those that the cutter could not cut through fully were cut with scissors. These shapes created the top and bottom of the snow globe. Long thin strips of acrylic were cut out and heated up to then mold along the inside of the cookie cutter, creating the middle portion of the snow globe. These were then adhered to the heart cutout shapes and filled with vegetable glycerin and glitter. Varying concentrations of the glycerin were evaluated for flow and sustained movement for the glitter.

4 DISCUSSION

The results from the interviews show that some participants had an interest in cosmetic limb covers and creative and personal ideas for what they could look like. Each participant had their own reactions to the idea of custom cosmetic limb covers, whether it was immediate interest or indifference. And each came in with their own reasons for that reaction, be it financial, cultural, or personal. Additionally, we found that it is feasible to create custom limb

cover prototypes for individuals utilizing commercially available materials, making this a more accessible avenue for the user.

Involving the end-user in the process of design and understanding the impact of their involvement is important for future development of assistive technology. There is great value in the end user not only being involved in the design of their limb but learning how to design for themselves, having more agency in the appearance of their limb [8]. The interviews showed that individuals do have an interest in custom cosmetic covers and while follow up on the covers was not acquired, the criteria given by the participants was fulfilled through the project.

Another reflection that our research points to but needs further future exploration is questioning the assumption that a prosthetic limb is necessary for all individuals with limb differences. Much of the research shows that individuals with a congenital limb difference are less likely to want or need a prosthetic limb to function in daily life [5]. The same can go for amputees as over time they may find they are more comfortable, happier, and more mobile without a prosthetic limb. The purpose of this research is not to imply that this method is the only way for prosthesis users to experience the world or find comfort. Rather, the research is aimed at those who do want to use a prosthetic limb and find they are not happy with their device, specifically if that dissatisfaction stems from the appearance of the prosthesis. The goal of this research is to help individuals feel happier with themselves and how they present themselves to the world, and those who feel happier without a prosthesis have already reached that point.

This research also highlighted the need for an interdisciplinary lens when approaching prosthetic design. The task of designing these prosthetic limb covers required the use of disciplines like mechanical engineering, visual arts, psychology, and disability studies to both designs aesthetically pleasing and functional covers as well as provide contextual understanding of the micro and macro impacts that a prosthetic limb and disability has on the individual. These disciplines each worked to create a broader understanding of that context, beginning with the design process and needs of the limb itself to understanding the societal structures that influence the design of the device. Having a broad understanding of the factors that can impact both the user and their prosthetic device is important in the design of future assistive technology as the many physical, mental, and social factors that impact the individual's life will dictate the type of assistive technology they need. While this research took on an interdisciplinary approach, it was limited by the knowledge base of our team, a limitation that can be remedied by working with a broader team of experts in the future.

5 CONCLUSION AND FUTURE WORK

In this exploratory research, we studied how to co-design and prototype aesthetic elements for prosthetics using DIY method and consumer-grade prototyping materials, such that the designs reflect users' personal preferences and desires and go beyond functionality. We designed and prototyped three designs based on participant specifications.

There are several directions for future research. First, we can build on the current work to develop improved co-design models that bring together multiple perspectives into the design process.

Further research into this topic can also examine the role of public policy and regulations in how aesthetic aspects of assistive technologies are viewed and how does this interact with devices' affordability and functionality. We focused only on lower-body prosthetics in this study. Future work can explore devices designed for other parts of the body and with other fabrication methods. Finally, and more importantly, future research can seek feedback from individuals with disabilities on co-designed prosthetics in an iterative process.

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