

Ultra Adapt: Adaptive Modular Footwear with Interchangeable Backs

Lida Aflatoony & Kristen Morris, Colorado State University, USA

Keywords: Inclusive design, adaptive apparel, footwear, research-based design

Concept and Context: Previous studies have shown that the mainstream apparel industry's neglect of the disabled population and its failure to address their needs could affect their daily activity participation (Hammett, 2019; Lamb, 2001). Footwear is particularly challenging for people with disabilities (Zaino et al., 2023). Research indicates that shoes are challenging to don and doff, lack durability, and often fail to integrate well with assistive devices (Kabel et al., 2017). While exceptions like Nike's FlyEase, Billy Footwear, and Friendly Shoes exist, adaptive footwear for adults is scarce (Kent et al., 2023). Although some apparel scholars have explored this area (Aflatoony, 2019; Aflatoony, 2024), there are still relatively few examples of footwear solutions in apparel research. Thus, this research-based design scholarship aimed to investigate the footwear needs of individuals with disabilities using assistive devices and to develop a prototype addressing these needs. The specific target population for this research was people who identified as having paralysis (PWP) and use ankle foot orthosis (AFOs) for mobility assistance. Paralysis is "difficulty and/or inability to use arms and/or legs due to neurological conditions including but not limited to spinal cord injury, traumatic brain injury, stroke, cerebral palsy, multiple sclerosis..." (Paralysis in the U.S., 2023). Many PWP use AFOs to regulate foot and ankle movement, enhance stability, and support weakened joints. AFOs are worn below the knee and cover the foot. (Patient Information About AFOs, 2022). The footwear solution proposed in this study was developed through interviews with 20 participants, including 12 individuals with paralysis and seven caregivers from 12 Western U.S. states. The participants, aged 25 to 64, were female (65%), male (30%), and non-binary (5%). Their conditions included spinal cord injuries, cerebral palsy, Amniotic Band Syndrome, Spinal Muscular Atrophy, and others. Based on interview data, participants stressed the importance of increased independence in shoe donning and doffing. Participants sought footwear with adjustable closures, wider openings, and deeper footbeds to enhance accessibility and comfort. They stressed the need for shoes to accommodate different physical conditions, minimize pressure sores and discomfort, and emphasized the importance of durable materials suitable for ankle-foot orthoses (AFOs). They desired customizable options, like modular components and adjustable support, to meet individual needs and preferences. Participants emphasized that footwear should boost empowerment and normalize adaptive products by reflecting conventional aesthetics.

Artifact Development Methods: This footwear design, titled *UltraAdapt*, is a modular shoe with interchangeable uppers that is easy to don, durable at the AFO connections, and features a deep footbed. It can be worn in three styles: 1) as a mule, 2) as low-top sneaker, and 3) as a high-top sneaker. The design process began by procuring a shoe last with a wide toe box in Women's size 10.5 and Men's size 8.5, along with two styles of AFOs. The last was covered in leather and shaped for additional width at the toe box. The researchers 3D scanned the last with both AFOs and merged the scans in Autodesk® Fusion 360 to understand the shapes added by the AFOs. The shoe sole design, accommodating both AFO styles, was created in Fusion (Figure

1). The sole and tread were 3D printed using a Creality CR-10 FDM printer with Colorfabb Varioshore TPU (shore hardness 75A, partially foamed). The authors developed the shoe uppers by pencil sketching, then drawing directly on the shoe last covered in masking tape. Once the design was finalized, the masking tape was removed, placed on cardstock, and used to create patterns for the front upper and two styles of back uppers (Figure 2). The print design was created in Adobe Photoshop and digitally printed on 100% polyester scuba knit using dye sublimation. UV printing was used to add the logo to the lace guides, pull loops, and sole details, and the foot logo was UV printed directly on the leather toe box before sewing. The construction of the uppers involved 12 materials, including support and lining materials. The toe-box, mudguard, quarter on the lateral side, heel counter, and eyestay for the shorter version of the modular part were cut from cow leather in turquoise green color. The tongue, mule's eyestay, high-top's eyestay, and toe-box detail margin were cut from cow leather in gold saffiano. The mule's vamp, and the quarters of both low and high tops are cut from a 100% cotton twill fabric. The rest of the shoe components were cut from the 100% polyester scuba knit digitally printed fabric. The thin cream-colored lambskin leather lining was cut and prepared separately. All outer layer and lining pieces were fused with adhesive and topstitched using industrial footwear sewing equipment (Figure 3). The mule upper was fused to the sole with Tear Mender adhesive.

Artifact Function, Aesthetics, and Cohesion: UltraAdapt mirrors mass-market styles in color and silhouette, seamlessly integrating functional and aesthetic components to create a visually compelling and functionally inclusive shoe. Key functional features include a zipper entry and hook laces for easy donning and doffing. There are two zippers hidden on either side of the eyestay that open the entire front of the shoe, providing the user with an easy donning experience (Figure 4). The laces are elastic to provide both adjustability and ease of use. The design has enhanced durability where the AFO meets the shoe and a deep footbed both tailored through scanning AFOs and designing around them. The use of leather and canvas materials offers both durability and style, while the modular design allows for adjustable length and customization. Wearers change out the upper backs through velcro attachments applied on both the later and medial quarters, and if desired, can lace the top two holes of the mule to the desired upper back for a more permanent attachment. Aesthetically, UltraAdapt is a casual sneaker style suitable for everyday wear. The design includes options for different heights and eye-catching colors and prints that align with current sneaker trends, making the footwear visually appealing. The organic print and color choices are reflected throughout the upper front, interchangeable upper backs, and shoe sole design to reflect fashionable contemporary styles. The modular design not only serves a practical function, but it also adds to the overall aesthetic appeal results in a cohesive and versatile shoe that meets the diverse needs of its users.

Design Contributions: The adaptive modular footwear designed in this study enhances accessibility, personalization, and inclusion for people with disabilities and helps normalize adaptive products in fashion and promotes social inclusion. The research-based design process contributes to academic discourse by providing valuable data for study and innovation in materials, technologies, and methods applicable to other adaptive products. It also influences research in design, ergonomics, and social inclusion, and informs policy and advocacy for inclusive design standards in the apparel industry. Additionally, this study serves as a case study for teaching inclusive and adaptive design principles to future designers and researchers.



Figure 1. 3D modeling of the shoe sole and tread with AFOs.

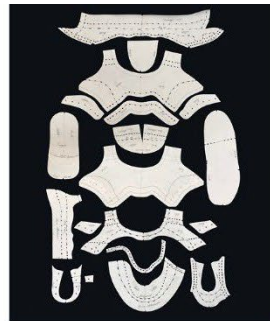


Figure 2. All the pattern pieces of the Ultra Adapt.



Figure 3. Assembly Process of the upper part.



Figure 4. Zippers hidden on either side of the eyestay.

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