Research Article

Defining the design barriers to adaptive clothing

Abstract

The purpose of this research is to identify and organize the design barriers of adaptive clothing in order to increase its market availability. Adaptive clothing is garments designed specifically for people living with disabilities, endeavouring to increase quality of life and independence. Despite the benefits, adaptive clothing is not widely available for purchase because very little house-hold-name brands sell it, typically only available online from small companies. The aim of this research is to facilitate the identification of the design barriers by designing and testing apparel, which addresses the clothing related needs of an individual living with Down syndrome. By identifying the design barriers, this research produces a novel approach to product design. The new practice, titled Design for Inclusivity, is an interdisciplinary research method, not only focusing on user-centered design to satisfy clothing related needs of people living with disabilities, but also creating inclusion by marketing to both people living with and without disabilities.

Keywords: disability, design, inclusive, adaptive apparel

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Introduction

Women living with Down syndrome may have physical and intellectual characteristics different from the general population. As a result of their low muscle tone[1,2] and reduced fine motor skills,[2–3] they may have difficulty manipulating fasteners on clothing, such as buttons and zippers. In addition, women living with Down syndrome may be proportionately different in height[2,5] and weight[6] than the general population. These physical characteristics can cause challenges when trying to find appropriate clothing.[7] This study aims to design and test apparel, which addresses the clothing related needs of an individual living with Down syndrome. Through various interdisciplinary research methods, the participant's clothing related needs will be identified, garments attempting to satisfy those needs will be constructed, and both the final garments and the Design Phase will be evaluated. This aim not only proposes to identify the barriers of adaptive clothing design but also to promote inclusion.

Methods

Theoretical framework

The framework for this study is Design Thinking, an entrepreneurial approach to business development. Brown[8] defines Design Thinking as "a discipline that uses the designer's sensibility and methods to match people's needs with what is technologically feasible and what a viable business strategy can convert into customer value and market opportunity" (p. 2). Design Thinking will take into consideration a person's needs but will only satisfy those needs in a financially successful way. By ensuring financial success, the outcome for this research may go beyond just helping one participant and allow for a possible business venture, increasing market availability and reach in order to help other people that may have similar needs.

Design Thinking has three main stages, (1) empathy, (2) ideation, and (3) experimentation.[8] Cultivating empathy for the end user will allow for a deeper and more meaningful understanding of the problem. The FEA[2] model,[9] an expanded version of the FEA Consumer Needs Model,[10] will be used to organize the participant's needs. The original FEA model described the Functional, Expressive, and Aesthetic Needs of an end user, allowing fashion designers a reference when developing clothing for individuals with special needs. See Figure 1 for a visual representation.

Figure 1 FEA Consumer Needs Model, Lamb and Kallal, 1992.

The Functional Needs of an end user include fit, mobility, comfort, protection, and donning/doffing. The Expressive Needs facilitate the establishment of identities and selves within society, producing different forms of self-expression for the end user. Expressive needs also refer to the perceived opinion of one's self or identity by others. The Aesthetic Needs are the physical, visual characteristics of a garment, including color, fabric, and garment type. The original model describes the three consumer needs to be fluid and not siloed.[10] The FEA[2] expands the original model's definitions to include Accessibility Needs, depicted in Figure 2. These needs are described by the market price and market availability of a product.[9]

The ideation stage's purpose of Design Thinking is to develop as many possible ideas in order to satisfy the end user's needs.[8] During this research's Design Phase, the user-centered approach of Participatory Design is utilized to design clothing in collaboration with the participant in order to produce ideas that satisfy the participant's needs. Participatory Design allows the end user and the designer to be co-creators, having equal influence over the garment

design outcomes.[11] Further, exploration will reveal the participant's current or alternative solutions to the clothing related needs, a practice from Design Thinking. Design Thinking emphasizes determining alternative solutions so that the designer can (1) learn what length the end user has already taken to fix his/her problem and (2) use the current solutions to produce better, more efficient solutions. Participatory Design and alternative solution identification will allow the development of multiple, new ideas to solve the participant's clothing related needs.
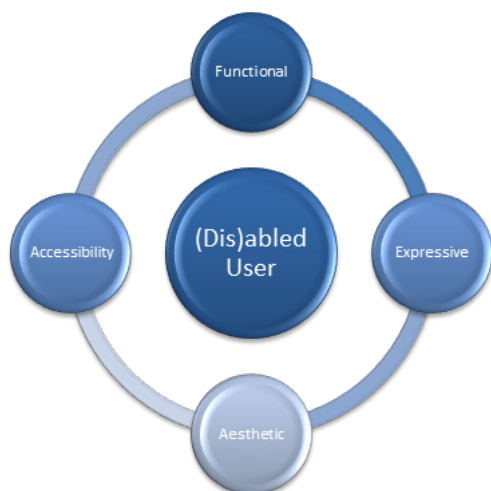

Figure 2 FEA2 Consumer needs model, Hall and Lobo, 2017.

The final phase of Design Thinking is experimentation. During this phase the designer rapidly develops multiple prototypes, reporting to the end user after each iteration. During this final phase, the designer may revisit the first and second phase in order to collect new data to develop an appropriate outcome for the end user.

Research design

A case study research design with three phases was utilized. Human Subject Research protocols were developed and approved by the University of Delaware Institutional Review Board before beginning. The Initial Interview Phase involved semi-structured interviews in order to determine the participant's clothing related needs and current alternative solutions. The Design Phase employed the user-centered approach of Participatory Design. The Exit Interview Phase included semi-structured interviews to evaluate both the Participatory Design process and the final garments. Finally, the participant wear-tested the clothing during her typical daily routine in order to determine if the clothing successfully satisfied her needs.

Initial interview phase

During the Initial Interview Phase, the participant and her caregiver were interviewed separately. The expanded consumer need model, FEA[2] (Hall & Lobo,[9]) was used to identify and organize the participant's clothing related needs. Alternative solutions were identified in order to align with the principles of Design Thinking.[8] To ensure all clothing related needs were identified, the participant's caregiver was also interviewed. This second interview facilitated communication with the participant and provide insight into clothing related responsibilities held/not held by the participant, including clothing care and purchasing.

Design phase

The Design Phase followed a traditional and industry-practiced collection development process,[12] while also employing the iterative Participatory Design process. This phase began with a clothing trend forecast specific to women's wear, determining future trends in relation to the participant's chosen product category (e.g., professional wear vs. active wear). Based on this forecast, the next step was to create a mood and color board for clothing style inspiration. The boards were presented to the participant, and concepts for garments were designed based on her preferences. Multiple garment illustrations were developed and presented to the participant. From these illustrations, the participant selected three ensembles. Throughout the Design Phase, the participant was consulted on design decisions such as color and fabric. Once the garments were constructed, the participant was given the ensembles in order to be wear-tested. Descriptive field notes documented the Design Phase.

Exit interview phase

During the exit interview, both the participant and her caregiver were interviewed after they had been able to test the clothing. The participant was interviewed separately from her caregiver, prompting her to describe each step of the Design Phase. Then, both she and her caretaker were interviewed together to ensure that all clothing related needs were discussed.

Based on the participant's experience during the Design Phase, she determined if the Participatory Design process promoted an inclusive atmosphere and equality in design decisions. Further, she also evaluated the clothing to conclude if her clothing related needs were met.

Participant

The participant of this research was an adult female living with Down syndrome between the age of 20 and 35 located in the Mid-Atlantic region of the United States.

Data collection

Data collection was conducted through all three phases. In the Initial Interview Phase, the participant and her caregiver were interviewed separately and audio recorded. During the Design Phase, any data was recorded with detailed field notes and other visual aids, including photos, illustrations, and prototypes. These visuals acted as aids during the exit interviews. Finally, the Exit Interview Phase was two interviews, one with the participant only and one with both the participant and the caregiver. Both interviews were audio recorded and analyzed using qualitative methods.

Data analysis

Data analysis was conducted on both the Initial Interview and Exit Interview phases. Audio recording was analyzed with qualitative research software, Nvivo, for keywords and phrases.[13] Grounded Theory methods were used to structure the analysis process. Keywords and phrases were organically grouped into larger themes and categories. Three levels of coding were used: (1) descriptive and axial, (2) selective, and (3) theoretical. Each new level of coding allowed the researcher to compare and contrast findings while creating notes and memos to define those themes and categories.[14] Final themes aligned with the FEA[2] model, identifying clothing related needs and potential satisfaction of the needs from the Design Phase. Further, satisfaction of the participant's role in the Participatory Design process

was evaluated. A coding protocol was developed to ensure accurate coding. The data was processed using two coders with a Cohen Kappa Coefficient of 0.4468 and inter-rater agreement of 92.4833%.

Results

My participant was chosen through community networks from both University of Delaware and the City of Newark, Delaware, United States. Laura is a woman in her late twenties/early thirties, working as a receptionist for Delaware State government. She also has Down syndrome and as a result of the physical and intellectual characteristics, she may have clothing related needs. Thus, after signing all IRB consent forms, a time and date were determined for the initial interviews. Results are presented in the form of the FEA[2] model and organized into the three phases of the research. However, it is important to note that the process was iterative and occurred concurrently, allowing data to be collected throughout all the processes.

Coding results

Both the initial and exit interviews' data was coding using NVivo coding software and Grounded Theory methods. The data were coded across three different levels. To facilitate the first level of coding, the initial and exit interviews' data were kept separate. Then, during the second and third level of coding, the two interview phases' data were combined in order to create general themes across the data. Category names, definitions, and reference amounts of the three levels of coding are represented in Tables 1–3, respectively. The reference amounts column refers to the number of comments made by the participants for that particular category.

Initial interview phase

For the initial interviews, Laura and her mother were interviewed separately. First, Laura was interviewed. Discussed topics included typical daily activities and associated challenges, clothing preferences, and current clothing options. Laura gave an account of her daily routines, including her typical outfit choices and job responsibilities. Some communication difficulties arose. As a result of her cognitive impairment, Laura had challenges responding to multiple questions at once and quickly stated questions. Laura also had difficulties expressing certain fashion items because she did not know the correct terminology (e.g., color blocking, jumpsuit, metallic). Thus, the interview techniques were modified, using visual social media, to help with understanding and expression. Laura's mother was interviewed after Laura. This interview was to confirm and/or add any details about Laura's life that were not brought up during Laura's interview. The same topics from Laura's initial interview were covered, in addition to discussing buying and shopping habits and preferences, revealing any additional Accessibility Needs.

Table 1 Descriptive coding level

Initial Interview

Category/Theme	Defination	Reference Amounts
Alternative Solutions	Actions being done or products being baught to help all eviate any problems Laura may hold.	21
Clothing Preferences	What types of garments does Laura wear. What styles and other physical characteristics are like/not like	55
Clothing related Needs	What are Laura's challenges or difficulties in relation to clothing and the act of dressing	51

Exit Interview

Category' Theme	Defination	Reference Amounts
Alternative Solutions	Actions being done or products being baught to help all eviate any problems Laura may hold.	23
Clothing Preferences	What types of garments does Laura wear. What styles and other physical characteristics are like/not like	20
Communication	Any communication difficulties or problems between Laura and interviewer	7
Problems	What are Laura's problems, including clothing, physical and intellectual	28
Process	Any comments made about the design process or the experience in general	71
Shopping	Details about shopping preferences, habits, or interests	41

Table 2 Axial coding level

Category/ Theme	Definition	Reference Amounts
Action to Solve Problem	What is the literal action being done to solve the problem, regardless of efficiency	27
Actual Solution to Problem	What is the physical item or product being used to solve the problem	17
Aesthetics	The physical characteristics of a garment in relation to color, garment type, etc.	52
Buying and Shopping	Details about buying or shopping preferences	79
Communication	Difficulties in communication	17
• Am I talking too Fast	Situations when the primary researcher was talking too fast for Laura's comprehension level.	2
• Miscommunication	Situations when Laura responded inaccurately, (e.g. off topic responses, inaudible responses)	1
• Please Repeat	Situations when Laura asked primary researcher to repeat the question	1
• Repeating my Words	Situations when Laura would simple repeat the question as a statement	4
Function of Garment	Functional characteristics of the garment, including fit, comfort, etc.	7
Garment Preferences	Details about the preferences of the style or type of garment	59
Problems	Any problems Laura holds, including clothing related needs and physical characteristics	106
Process Comments	Any comments relating to the development and design processes of the design phase	77
Why the Solution is Better	Details about the solutions and why they are better than previous solutions	7
Work Stuff	Any comments or details surrounding work	13

Table 3 Selective coding level

Category/ Theme	Definition	Reference Amounts
Accessibility Needs	Details outlining any clothing related needs involving market availability, product price, and restrictions of shopping opportunities	135
Aesthetic Needs	Details revolving the physical characteristics of garments	161
Expressive Needs	Comments relating to social role, self identity, and clothing	72
Functional Needs	Descriptions about the functional elements of a garment, including donning/doffing, comfort, and fit	195
Other	Comments that did not fall into either of the above categories	119

Functional needs

Laura. To determine her Functional Needs, Laura was asked a series of questions focusing on any challenges she facing during her typical daily routine. Clothing proportion and comfort were discussed as well as closure manipulation. Laura agreed when asked if the length of pants and sleeves were too long. Further, she also discussed an issue of "flashing" people when bottoms are too short, stating:

And one of the things that my dad yells at me too, as well, is that I can't wear very short things around my dad.

But there are some times where I don't want to flash people as well as and their [skirts are] up to the knee.

Thus, Laura prefers her dresses "to the knee or close to a long dress, as well." When discussing fit and comfort of shirts Laura stated:

I can wear with these kind of [t-shirts] that I'm wearing right now. Because you can just put [it] over your head. But with the kind of [button down] shirts that might fit you, can, tend to fit you and like all that, as well. When they design those kind of shirts, as well, it's also kind of a little tight, as well. And I think I've been ripping some kind of shirts.

In addition to shirts that are easy don and doff, Laura also confirmed that she would like to wear button-down shirts to work but only, "if they're like big buttons, as well, and I could see them." Laura also discussed her fit and comfort preferences with work pants, after being questioned about work pant styles and fit, she responded:

Some [work pants] are [tight around the ankle] but I do like loose [around the thigh] pants…. I do like to let my thigh breathe a little bit, so I do like loose then.

Further, when questioned about avoiding clothing because it has zippers and buttons, Laura agreed, confirming the difficulty. She responded:

That does come up like a lot of times, of times I don't want, as well, to zipper or button anything, as well, but. But also I do like to breathe, as well, so I don't want to be tight from [mid-torso region] down.

Another problem Laura had been the position of buttons. She described the positioning of buttons on some of her work shirts:

Some of them have buttons up the front…. But also, this problem that I have with shirts though, as well. Some of the shirts put the buttons back [at the nape of neck].

Mother. Laura's mother summarized Laura's Functional clothing related needs to be (1) the proportion of clothing both in circumference and length and (2) the difficulty with manipulating closures easily and independently. She also mentioned Laura's challenge with "flashing" people:

Because I noticed I put the skirt on her, I actually put it in Goodwill because I think because she's a little heavier than last summer. It went up in the back a little so she'd bend over. I'm sure you get the picture.

In addition to short clothing causing "flashing" situations, Laura's mother described other instances of clothing length difficulties when shopping:

It's just not compatible to her body…. Dresses too are really, I bought dresses before where I thought they would go to her knee and when I actually put them on her and they went like down [her mid calf]…. And the sleeves of course for dresses, so I try to find three quarters sleeve stuff for her. Like, I try and buy her tops now for the winter because they have a lot of three quarter fall things and that would be long on her.

She also gave her opinion to explain why clothing doesn't always fit Laura, describing it as a physical characteristic of Down syndrome:

Since [individuals living with Down syndrome are] not proportioned as a typical person, the clothing's not proportional the way it should be.

So yeah, I think physically she is shaped funny. And typical sizes don't fit her typically. I think that's our biggest problem. I just can't go buy her a shirt or a pair of pants. Like I said I thought "Oh these look big enough and they stretch a little bit" and they just barely fit her and I'm like "Laura I thought I had a good pair of pants."

Laura's mother gave additional challenges that Laura did not mention related to proportion and fit, describing another difficulty with shirts:

This part [of her chest, from the neck to the belly button] is a lot shorter than yours or mine. So any low cut things go down to [her nipple line] on her. We have to be careful about not buying V-necks and I try not to let her cleavage show too much. Plus, she's not very body aware.

Further, Laura's mother described the fit issues associated with tights and stockings

Tights are really tough, they, to get them large enough to fit around [her waist] and they just, she gets elephant knees and elephant ankles because they're just too long, so tights are really tough.

Laura's mother also confirmed that buttons and zippers created difficulty when donning and doffing because of her visual impairments and nerve desensitization associated with Down syndrome:

Yeah, the big buttons [she can do]. Those little shirt buttons, she can't do. She might be able to do that if the holes were big enough. Because it's something to grab on to because she doesn't…. Laura can't. She has some depth perception problems. So she really can't look down. And so then she does it by feel a lot of time. She has a stigmatism, in her eyes not so much vision problems but…depth perception and some visual side visual things are distorted a little for her.

That's probably a big issue, is most of the time, I think kids with Down syndrome they're, since they are so hypotonic, they have very low muscle tone. Their nerves are also under the mushy muscles so they can't feel.

Expressive needs

Laura. Laura described her Expressive Needs in relation to her position at work. She agreed when asked if the dress code at work is business professional. Further, she described that:

There's no uniform that I have to follow. But I do have to, there's no uniform to follow, but I do have to wear something appropriate because it is a state building.

Laura also stated that she liked long dresses because she did not want to "flash" anyone. Despite her professional dress code, her favorite anytime outfit was:

Actually don't know why, but I'm think it's like a dress that was, [with a neckline that] comes down to [the bottom of the rib cage].

Mother. She also thought Laura's Expressive Needs were rooted in her female co-workers' attire. She believed that Laura wanted to wear dresses because the other women would wear dresses and skirts to the office, stating:

I think they all dress professionally because they are on the governor's floor. That's why she says she likes to wear dresses and skirts. Because, I think, that's what most of the women wear at work, especially in the summer.

However, when asked about Laura's dress code for work, her

mother described it as optional because Laura is in the background of the office team:

Well, she is out at the front desk for the governor's office. But it's his Wilmington office so they don't get as many visitors as they do down in Dover. Like I have in an emergency put on a Lula Roe flowered tights and a long top and nobody's ever said anything to me about it. She's basically in the foreground (*sic*) so she's not really up, like she's in the front but they're talking to the receptionist she's just sitting there doing her work.

Laura's mother also described Laura's issue of "flashing" others, describing the reason in more detail:

Plus, she's not very body aware. So if something's like, you know how you and I would fix our stuff, she just gets up and walks and I'm like, "Laura your underwear's showing. Pull your shirt down." [Laura's coworkers] probably have said that to her.

Aesthetic needs

Laura. Clothing preferences were also discussed in order to determine her Aesthetic Needs. Topics included favorite garment styles, favorite prints and colors, and preferred fabrics. Laura's favorite garment style changed depending on the season:

I normally wear like…right around the fall and wintertime, is like pant and shirts, but in the spring and summer time, I wear like skirts and dresses.

Laura described herself as "I am a bright color girl, but a bright color girl from just from the simple side of that," preferring "some… blue and greens maybe a little red." In addition, Laura said, "I do like, I do like a little black and tan, maybe a little white in there, maybe off-white." She also liked specific prints, "I do like cheetah or zebra… and Hawaiian floral." Other fabric preferences included tulle, leather, lace and "flowy" fabrics. However, garment embellishments needed to be simple, "not actually like bedazzled, but I do like a little simple [beading] like." Laura's mother did not comment on Laura's Aesthetic Needs.

Accessibility needs

Laura. Laura has Accessibility Needs, as a result of her mother doing most of the shopping. Thus, she does not have the opportunity or access to buy clothing for herself. However, when discussing recent purchases and brands she stated:

There's this new company that I think came out of California that actually fits me…. It's called Lula Roe.

Laura wears that brand's dresses to work. Further, Laura described a jacket/blazer style garment that she said she recently bought:

I did just bought (*sic*) a jacket, that kind of jacket. Not that long ago for the fall…. It's like a burnt gold or something.

Thus, Laura may have some purchasing power when buying her clothing.

Mother. Laura's mother performed most of the shopping. Thus, Accessibility Needs were presented in more detail during conversations with the mother. She stated various clothing brands that she buys from for Laura, including Old Navy, J.C. Penny's and Lula Roe. When questioned about Laura's interests in shopping, her mother responded that Laura does not enjoy shopping or trying on clothes

stating, "no, she will not try stuff on unless I force her to."

Design phase

Descriptive field notes were taken during the Design Phase in order to document the Development Stage and Design Stage. The Design Phase was an iterative and non-linear progression, involving constant prototyping and feedback. Two concurrent goals were accomplished during this phase, (1) develop accurate fit of garments and (2) design aesthetically pleasing and expressive clothing.

Design stage

The Design Stage occurred simultaneously with the Development Stage. First, current trends within the fashion industry were researched, a technique traditionally used by the fashion industry when developing clothing collections.[15] Digital, visual platforms (e.g., WGSN, a fashion forecasting website) were used to collect data and graphics. Trends included prospective colors and cultural themes, influencing the women's professional wear product category. Next, the research was presented to Laura in the form of mood/trend boards and an inspiration/color board. Figure 3 shows a modified version of the mood/trend boards.

Current cultural trends included "people first" designing, "investing in imperfections" and "design doing," all with the common trend of humans inspiring design. These themes created a parallel between the human-centered design and research methods used in this research and the themes of "people first" and "design doing." Further, the theme of "investing in imperfections" helped promote this research's aim of inclusivity and designing for unrepresented market segments.

Inspiration/color board evoked pictures of melting flowers, playing with the idea of distorting perfection to create new beauty. The colors were then drawn from the inspiration/color board pictures depicted in Figure 4.

Six ensembles were then designed, influenced by Laura's clothing related needs, according to the Initial Interview Phase data. See Figure 5 for presented potential ensembles. They were then presented to her, during which she chose three final ensembles: (1) a jacket and pant combo, (2) a skirt and button-down shirt pair, and (3) a dress. Using the original inspiration/color board, Laura chose each garment's color.

Fabric swatches were then sourced from an online distributor to determine if appropriate for final garment use. Once an adequate amount of appropriate fabric choices were collected by the primary researcher, they were presented in combination with fashion illustrations that mirrored Laura's physical features. This visual display was to help Laura envision the potential fabric and color choices in relation to herself and the garments and also facilitate the creation of empathy by the primary researcher. Laura then chose the fabrics for the final ensembles. See Figure 6 for fashion illustrations and final fabric choices.

To facilitate ease of dressing, white knit fabric was used in the shirt of both the first and second look and a swatch can be seen in the First Look of Figure 6. The fabric was chosen for its weight and stretch components but did not match Laura's preferred color. Thus, the primary researcher garment dyed both the t-shirt of the First Look and the button-up shirt of the Second Look to match Laura's color preferences.

All these design decisions were made in-person by Laura, but also in the accompaniment of her mother. In addition to fabric, small

notions (i.e., the buttons on the button-down shirt) needed to be picked out. Digital visuals were created to present the sourced notions to Laura. In order to expedite the design decision, the visuals were sent to her mother's email because "[Laura] tends to rely on me, [the mother], a lot."
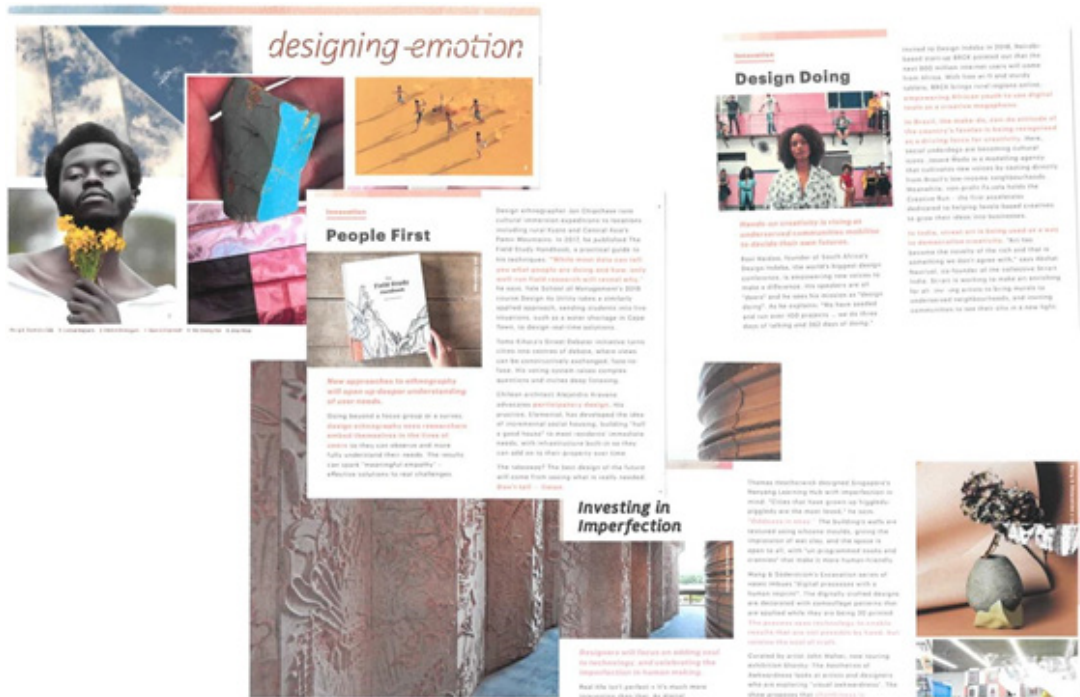

Figure 3 Modified mood boards. Copyright WGSN.

Figure 4 Inspiration and color board.

Figure 5 Potential ensembles.

Figure 6 Fashion illustrations and final fabric choices.

Development stage

To develop accurate fit, first, Laura's measurements were taken. After measurements were recorded, foundational templates, or "slopers," were drafted. Slopers are the basic foundational shape of any garment, which can then be manipulated to create various garment styles. A pant, bodice, and skirt sloper were drafted. Figure 7 and Figure 8 show the various iterations of the fronts and backs of the bodice and pant slopers, respectively.

Using the slopers, inexpensive-fabric prototypes, also known as "toiles," were constructed to test the accuracy of the measurements.

Laura then tried on the first set of sloper toiles. However, they did not accurately fit, specifically in the shoulder/ armhole area of the bodice sloper toile (Figure 9) and the crotch and hip area of the pant sloper toile (Figure 10). Thus, the process began again, starting with new measurements. Alterations were made to the second set of sloper toiles to inform the third set. The third set of sloper toiles yielded an acceptable and comfortable fit in the pant, bodice, and skirt slopers. However, due to time and project constraints, an accurately-fitted pant sloper was never produced. This issue did not cause any challenges or dissatisfaction for the final pant because the final garment was a looser-style pant, contrary to the tight fit of a sloper.

Figure 7 Front and back bodice iterations.

Once the sloper toiles were confirmed as acceptable and comfortable, patterns for the final garments could be drafted. Final garment toiles were then constructed, using inexpensive fabrics with similar qualities to the final fashion fabric. Only one fitting was needed in the final garment toiles. Alterations were needed to correct the length both at the shoulders of the tops and the hems of all the garments and the circumference size at the waist of all the garments. Figure 11 shows the alterations needed after the first fitting.

Once final garment toiles were completed, construction of garments in the participant's chosen, final fashion fabric began. The research team constructed six total garments, including (1) Pant/ Jacket ensemble with a t-shirt, (2) Skirt/Button-up Shirt ensemble, and (3) Dress ensemble. Visuals of each final garment set can be seen in Figure 12.

Figure 8 Front and back pant iterations.

Once the garments were complete, Laura had one final fitting in the final garments, requiring minimal alterations. One alteration was the color of the t-shirt. Laura wanted the final garment to be a cream or beige colored top, rather than the original off-white fabric (First Look in Figure 6). In addition, some of the garments needed front/back indicators, such as tags on the back inside waist and front pockets on the chest.

Exit interview phase

The Exit Interview Phase took place after the final garments were completed and Laura wore each outfit at least once. First, Laura was interviewed individually and then both Laura and her mother were interviewed together. By interviewing separately and then together, caregiver/dependent relationship and communication characteristics could be recorded.

During the exit interview with Laura, visual media from the Design Phase were used to create a chronological recreation of the design and fitting processes. See Figures 4–12 for examples. Prompts were given with each visual aid, however many of Laura's responses were limited. Examples of limitations include single word answers like "yeah," "right," and "OK" and asking for the question to be repeated. Additionally, Laura's mother gave examples of trying to influence Laura's decision-making during the Design Phase, stating:

We would have planned 'Springy-er,' (*sic*) I would have encouraged 'Springy-er' (*sic*) materials, I think, then what you picked.

Topics for both exit interviews included final clothing evaluation and Participatory Design process evaluation.

Figure 9 Iterations of bodice toile.

Functional needs assessment

As identified in the initial interview, Laura's main Functional clothing related needs included inaccurate fit/proportion and donning/doffing difficulties. However, some unexpected Functional Needs arose during the exit interview including weather and seasonal appropriateness of the final ensembles.

Fit and Proportion. According to Laura's mother, the jacket fitted better than previously bought commercial jackets:

The [jacket] sleeves fit her fine, so it's nice. You know, all of her other jackets, we have to, the sleeves are down [past her fingertips] on coats and we have to roll them up, so she has this big bulge around her wrist.

However, two issues arose, according to Laura, in relation to the

fit of the skirt and the pants. The pant cuffs were too small and Laura was walking atypically as a result:

Figure 10 Iterations of pants toile.

Figure 11 Alterations needed after first fitting (highlighted with red arrows).

[The pants not fitting correctly] did not make me feel bad. But, but when you made things just a little tight around [the upper ankle/lower calf area], as well, I was walking funny, as well, and I don't want my mom to have that inspiration that it was something on me, as well.

In addition to the improper fit of the cuffs, the seams of the pants also revealed a new Functional Need. Upon inspection, in several spots, the side seam of the pants had "popped," revealing holes in the seams. After pointing them out to Laura and her mother, Laura explained, "oh it's wait, yeah I'm at work, I do walk round a lot, as well, but I am all up and down like all day." Her mother described further saying:

Figure 12 Pant/Jacket ensemble, skirt/shirt ensemble, and dress ensemble.

I think what you're seeing is she tends to, her feet don't like to dangle, so she tends to pull her feet up as she's sitting, so then that's putting a lot of strain [on the seams].

However, when asked if the pants are too tight and if she would like the seams taken out, Laura denied that they were too small. Furthermore, according to Laura, "the skirt was a little too big" at the waist and needed to be made smaller. These fit and durability issues were resolved through minor alterations.

Laura expressed additional concerns in relation to the proportion of the garments when wearing them separately from the designed ensemble. Laura stated, "I've been wearing the shirt outside of the skirt [ensemble], as well, and it the skirt, as well, and it [the shirt] kind of comes up a little bit," meaning, the button-down shirt is proportionately too short when worn with other bottoms outside the Skirt/Button-up Shirt ensemble.

Laura did note two concerns, occurring during the fitting sessions. She did not like the designated fitting area because of a lack of privacy when walking to the room, causing Laura to feel uncomfortable.

There's nothing I wouldn't change, change about [the Design Phase], as well, except for finding the right place to undress. And, you know, that one time, they're having a meeting back in that room I, I felt just a little bit uncomfortable.

Also, Laura commented on the length of the fitting sessions, agreeing that they could have been shorter saying, "you had to measure every length of me and pin it as well. I remember it, it did take like a couple of hours to do it all."

Donning and doffing: According to Laura, all the garments were easy to don and doff. However, when putting the dress on she stated:

I just have to make sure I'm not putting it on, it on when not, not checking it first before putting it on, with the trust of knowing which is the front or the back.

Thus, she must double check the front and back of the dress before wearing it in public to ensure that she is wearing it properly.

Weather and season appropriateness: Both Laura and her mother described the benefit of the jacket being made of a heavier material because the mother struggles when buying winter clothing for Laura:

It's only when you get into the winter. Winter, I think, is the hardest time to buy clothing…. Shorts are easier to buy for her in the summer and summer dresses are a little easier to buy. Winter is tough to buy clothing for.

According to the mother, "the jacket was gorgeous and it's so heavy she could, she wears it as [an outerwear] jacket, not as a suit jacket." Furthermore, Laura also agreed saying, "Because you made [the] jacket a little heavy, as well, I do know that might just be like the fall and winter coat, as well." Thus, the seasonal duality of the coat was an unexpected way to satisfy Laura's weather-related Functional and Accessibility Needs, not previously discussed in the initial interview.

However, other weather and seasonal concerns arose, especially when Laura's mother discussed the ensembles and the Design Phase:

You know I think the only thing…is just I think people would appreciate a timeline…. Only because a lot of stuff she picked out was last fall, and it's heavier stuff…. And now she's not going to be able to wear it…. So like the dress, I thought about putting it and I'm like, "well she probably can't wear that in the warm weather because…it's heavy looking," and the pants probably not too much longer because they're a winter-type style.

The Design Phase began in the fall and the clothing was not finished until early spring, as a result, Laura did not have as great an opportunity to wear the fall-inspired clothing as if the ensembles were designed for the spring/summer season. Further concerns discussed the practicality of the skirt during the colder months:

I think the skirt, while it looks pretty, isn't useful to her right now, like, she might wear it in the summer…. But she, it's really hard to buy like stockings and tights for her…. So wearing a skirt in the winter is not practical…. Plus with, she has orthopedic issues with her feet and she likes to have heavy socks on all the time…. So pants and stuff like that or are better for her in the winter.

Thus, Laura's Expressive Needs (i.e., wearing garments like a dress in the winter) are restricted as a result of her Functional and Accessibility Needs (i.e., not finding appropriately fitted stockings).

Expressive needs assessment

Laura explained her Expressive Needs to be related to her wearing appropriate clothing both at work and at home, including not "flashing" anyone and professional work wear. Laura's mother also confirmed that Laura wants to wear clothing similar to her co-workers. Thus, three professional-wear ensembles were designed for this research. Laura confirmed that the ensembles were appropriate for work by stating, "where I work, I have to wear stuff like this, [the pants from research]." After wearing the clothing to work, Laura described the comments her co-workers made about the ensembles. Comments included "cute," "beautiful," "smart," "sweet," and "cool." Laura also described the Pant/Jacket ensemble as having a "conservative look" that others would like.

However, as a result of Laura's Functional Needs when wearing the skirt (i.e. wearing heavy socks, wearing stockings in the winter), the mother described the Skirt/Button-up Shirt ensemble as "not professional looking," specifically when Laura has to wear socks instead of stockings with it. The mother explained the challenge of the ensemble further:

With the dress, she could wear legless, feetless tights and put boots on. With that blue skirt, it's not kind of a boot kind of a thing…[the skirt is] a little fancier so other than [the challenge of finding similarly styled shoes], I think everything turned out good.

Aesthetic needs assessment

Aesthetic Needs were addressed during the Design Stage of the Design Phase by allowing Laura to decide aesthetic features of the garments, including garment styles, the color and fabric of the garments, and the notions of the garment (i.e., buttons). However, her choices could be seen as restricted because the primary researcher decided the options from which Laura chose. The purpose of this decision was to ensure that the garment materials had the appropriate characteristics. Garment styles were discussed in Functional Needs Assessment because of Laura's mother's opinion about the seasonal appropriateness of the ensembles.

Colors and fabrics were chosen by Laura, according to the inspiration/color board presented during the Design Phase. She positively responded to the final garment colors by saying, "I do know that some of these colors are some of my favorite colors to date." She spoke about the material of the button-up shirt positively:

The thing that I like most about [the button-down shirt], as well, jeans is my go-to thing that I wear like every day, day, as well, so I was just thinking about that, the color jean would look really good in a shirt.

When asked about the final outcome of the Dress ensemble, Laura responded, "It did came out how I expected it to, as well, and I do know that purple is up there as one of my favorite colors, as well." When questioned about the Pant/Jacket ensemble, Laura raised a concern, "the only thing is, well I saw the shirt, as well…as well, and you dyed it wrong." During the Design Phase, Laura expressed that she wanted her t-shirt to be dyed to better match her pants. After the dying process, the t-shirt did not come out the intended color. To correct this error, the primary researcher had to re-dye the t-shirt a darker color, going against what Laura originally picked.

Further, button options for Laura to choose from were decided by the primary researcher based on the aesthetics of the final shirt fabrics. However, Laura made the final decision from those options.

Accessibility needs assessment

Laura's Accessibility Needs were, in part, defined by her and her mother's alternative solutions to Laura's clothing related challenges. Market availability was identified by Laura's mother's need to buy three-quarter length sleeves and capris-style pants, showing the lack of options for Laura's body shape:

So I do buy some of her stuff from Old Navy and Gap. She can wear a lot of their tops, especially spring and summer ones that are three-quarter sleeves or short sleeves.

I would wait…and try and find capris pants because I'm not good about hemming things or even taking them to get hemmed…So I tried

to find capris but again you have to find certain lengths because if they're not quite long enough then they, they're too short on her and they look funny.

Also, Laura's mother does most of the shopping stating, "[Laura is] not a great shopper. It's just easier for me [to go alone]." Further, her mother explained Laura's lack of interest in shopping:

She doesn't like to shop…. No, she won't try things on. If we are shopping and I pick stuff up, she doesn't want to be bothered looking…. So she's not a shopper…. If she needs something, [she will] pick it out. But Laura tends to gravitate towards jeans and t-shirts. She doesn't pick out fancy stuff too often. If we're shopping and she sees a T-shirt she likes that has a cool logo on it or something, she'll pick that up but otherwise I'm forcing her to pick stuff out.

However, when questioned about shopping, Laura responded:

I do like going to the store, like BJ's or something like that…. I'm not saying that I don't like shopping for clothes, but also my dad is of the same way as me though, as well. He likes to go in an out, as well, and [my mother is] the grazer, so yeah.

Laura's opportunity to shop is limited further by her disability. Her mother stated:

And since, she doesn't really handle money well. She probably wouldn't shop without her mother or her sisters or somebody who [she] knew and could watch and pay for her stuff.

Thus, Laura's buying is mediated by her family and friends that would ultimately decide to purchase a garment or not.

Additionally, Laura enjoyed being able to pick out the garment details for her ensembles, as a result of the Participatory Design process. She said:

For the very first time I did enjoy picking out my own colors from this [color] board because, because for the very first time, as well, it was my choice and not a parent choice, as well.

However, Laura brought up a challenge related to the Participatory Design process. She became overwhelmed as a result of the time restrictions and amount of options, stating, "it was hard like that because, yeah, so many options, but I did enjoy it as in three hours, as well." Despite the large number of options, Laura did not want her options to be reduced:

Not exactly less options but you, I will say, less options, as well, it just got very overwhelming at times…. A lot of stuff was happening around [the room], as well, and I didn't want to think a lot, as well…. I didn't want to think a lot but, I didn't want to think a lot, but, but I do want to think, Oh what. But. But I knew that I had to pick, like right away though.

She agreed when asked if giving her more time would have helped and potentially taking the samples home.

Discussion

Three main design challenges were discovered during this research, (1) Needs Determination, (2) Restrictive Communication, and (3) Experiential Knowledge. These themes increased the level of difficulty when designing and constructing the adaptive clothing ensembles. Needs Determination refer to the challenges that arose

when trying to identify the participant's needs throughout all three phases. Restrictive Communications refers to the challenges with both in-person and digital communication techniques when working with someone with an intellectual disability. Finally, Experiential Knowledge refers to the challenges that the primary researcher faced when designing the adaptive clothing ensembles. These three themes represent the design barriers this research aimed to identify. Also, the additional challenge of false or inaccurate responses from participants and co-workers, resulting from good-subject behavior or politeness, must be acknowledged. Table 4 summarizes the design barriers.

Table 4 Summary of design barriers

Category/ Subcategory	Definition
Needs Determination	Challenges relating to determining the needs of a participant
• Expanded Definition of Needs	Addition of "opportunity to shop" to the Accessibility Need of the FEA2 Consumer Needs Model
• Varying Interpretations of Needs	Needs interpretation can change depending on the speaker and the interpreter
• Others' Mediation of Needs	Outside influences that affect a participant's choices, usually limiting them.
Restrictive Communication	Communication challenges associated with determining needs during design phase
• Laura and Primary Researcher	Laura's cognitive limitations and lack of fashion terminology
• Laura and Her Mother	The mediation of Laura's responses by her mother
Experiential Knowledge	The experience level of the primary researcher
• Designing for Human Being	Lack of experience when designing on a person rather than a mannequin
• Designing for Laura	Lack of experience when collaborating with Laura both as a designer and an individual living with a disability

Needs determination

Expanded definition of needs

The Needs Determination barrier refers to the challenges of determining a participant's needs. The Functional, Expressive, Aesthetic, and Accessibility Consumer Needs Model was used to organize Laura's clothing related needs, during the Initial Interview and Exit Interview phases. However, this research discovered an additional need, the opportunity to shop, which is not defined in the FEA or the FEA^2 models. This opportunity to shop expands the definition of Accessibility in the FEA^2 model, explaining that individuals may have a lack of opportunity to shop or buy their own

clothing, creating a need. If one has limited access when buying his/her own clothing, his/her Expressive Needs can also be affected.

Laura and her mother gave evidence to support this expanded Accessibility definition. Laura explained that she enjoyed picking out the colors of the garments because for the first time, "it was her choice and not a parents' choice." She further explained that she "doesn't not like shopping," she just does not want to spend a lot of time shopping, contrary to her mother's "grazing" style of shopping, unfortunately leading her mother's to believe that Laura "is not a shopper" because she must "force her to pick out stuff."

Varying interpretation of needs

Another difficulty contributing to the Needs Determination barrier is the process of interpreting an individual's needs. Both Laura and her mother described Laura's needs to the primary researcher. However, both Laura's mother and the primary researcher had to interpret those needs. Despite Laura wanting a low-cut dress, her mother deemed showing cleavage as inappropriate, so an appropriate neckline was maintained on all the tops. Further, Laura wanted clothing without zippers or buttons, so the primary researcher designed a dress (1) with a modest neckline, which satisfied a Functional Need described by the mother, (2) with no closures, which satisfied a Functional Need of Laura's and (3) with a hemline down to her knees, which satisfied an Aesthetic and Expressive Need of Laura's. Thus, when addressing Laura's needs, the primary researcher had to also take into consideration Laura's mother's interpretation of Laura's needs.

Another example of multiple interpretations of needs includes the style of the skirt from the Skirt/Shirt ensemble. According to Laura, lace was a preferred fabric and the skirt a preferred silhouette and when shown together, Laura approved, resulting in the primary researcher using that fabric and that silhouette in order to satisfy an Aesthetic Need. Her mother discussed the skirt's lack of practicality because the lace makes the skirt fancy and Laura must wear heavy socks, making the ensemble not fancy. So, when worn together, the socks made the Skirt/Shirt ensemble look "unprofessional." Thus, Laura's Aesthetic Needs changed depending upon if Laura or her mother were describing the needs and depending upon if her mother or the primary researcher were interpreting the needs.

Others' mediation of needs

In the process of this research, Laura was influenced by others when making Aesthetic Needs decisions. During the Design Stage of the Design Phase, Laura was able to choose from a variety of options to fulfill her Aesthetic Needs (e.g. colors, fabrics, silhouettes). But, the primary researcher first sourced those options, creating a limitation of her options. Further, her mother revealed in the exit interview that she would have encouraged Laura to choose different fabrics and garment styles than originally picked. These two examples represent an outside mediation influencing Laura's choices when trying to satisfy her own needs. Further, Laura's Expressive Needs were limited when her mother revealed that Laura does not shop alone because "she doesn't really handle money very well." As a result, the ultimate decision to purchase clothing is not executed by Laura, but a friend or family member, further limiting her ability to create self-identities through clothing.

Restrictive communication

The Restrictive Communication design barrier exists between both Laura and the primary researcher and Laura and her mother. Limitations of digital and in-person communication methods occurred.

Laura and primary researcher

As a result of Laura's disability, her speaking and understanding can be slowed. She has a lisp and stutter, making it difficult to understand her words. Further, her sentences were not always easy to understand, because she would repeat words and phrases (i.e., "as well" or "I didn't want to think a lot") or use incorrect words (i.e., I don't want my mom to have that *inspiration* that it was something on me as well).

Further, Laura has never designed clothing before, resulting in a lack of knowledge when trying to describe her Aesthetic Needs. As described in the Results section, Laura did not know the meaning of "color block" nor "jumpsuit." Thus, the most efficient way to elicit Laura's needs was to have visual cues and physical options from which to choose.

After choosing the garments' colors, Laura had the opportunity to see the colors together in an outfit as depicted in the personal ensemble illustrations, Figure 6. The illustrations were successfully used to help Laura envision the final ensembles and facilitate her choosing fabrics for the garments. She confirmed when asked if she was able to envision what the clothes were going to look like. She was also able to see and feel the fabrics before making the final decision. However, one problem occurred with this process, she became overwhelmed. She states in her exit interview that there were too many options and not enough time to choose, in addition to many environmental distractions. However, she clearly stated that she did not want her options to be reduced, showing an interest in having various options. She just wanted more time to choose (e.g., if she took the options home with her). Thus despite being under pressure, giving Laura the opportunity to "shop," successfully satisfied her Aesthetic and Accessibility Needs.

Laura and her mother

During the Design and Exit Interview phases, interesting caregiver/dependent interactions occurred.

Throughout this research process, any interaction with Laura also included her mother. Participatory Design process was used to include Laura in the Design Stage of her final ensembles. However, her mother gave evidence that she was trying to influence Laura's decision when the mother mentioned wanting "Springy-er (*sic*)" clothing. Another example of mother interference may have occurred when Laura was picking out the buttons for her button-up shirt. To facilitate timeliness and ease, the primary researcher emailed Laura's mother with a digital display of potential button options from which Laura could pick. However, because the researcher was not present when the decision was made, she cannot ensure that it was Laura's uninfluenced decision, reducing the effectiveness of the Participatory Design process.

Another communication theme arose between Laura and her mother: Laura's mother would explain further what Laura was describing. One example of this situation occurred during the exit interview after the primary researcher noticed the seams of Laura's pants had popped. Laura described the reason behind the seam pop as a result of her constantly moving, sitting down and standing up, while at work. However, her mother described the reason as being

the position that Laura sits in all day. This situation of varying explanations parallels the Needs Determination barrier of others' mediation of needs. Thus, not only is Laura's needs being mediated, but her interaction with others is also mediated, amplifying the difficulty when determining FEA^2 needs.

Experiential knowledge

Experiential Knowledge is the third design barrier experienced during this research. It refers to the lack of information the primary researcher had when designing not only clothing for a human but also for an atypical body shape.

Designing for human being

Formal apparel design education uses mannequins to teach the different design techniques.[16,17] However, challenges arise when trying to transfer mannequin-made garments to a human body. Humans breath, move, and fluctuate in weight, mannequins do not. These human factors influence and even change the Development and Design stages. One example of how moving versus not moving affects garment design is the fit of Laura's pants. The pants were designed according to Laura's measurements, so while standing the pants fit

her. However, once she started walking, the cuffs were too tight so it changed the way she walked, causing her mother to comment on her atypical walking pattern.

Further, Laura stated that the fitting sessions made her uncomfortable and were too long. This situation gives evidence of the primary researcher's lack of experience when conducting fittings. The researcher did not take into account Laura's personal wellbeing. Thus, the primary researcher was limited by her formal education and lack of experience when working with and designing for a human being.

Designing for Laura

Difficulties designing for Laura stemmed from two major themes, personal style and Down syndrome. Laura's needs were difficult to determine. Intellectual limitations related to her cognitive disability, her caregiver's mediation of needs, and her limited fashion knowledge made identifying Laura's FEA^2 needs challenging.

Laura's physical characteristics also created challenges during the Development Stage of the Design Phase. Her atypical body shape led to atypically shaped slopers. See Figure 13 for comparison of Laura's slopers and traditional slopers.

Figure 13 Comparing slopers.

As a result of these unfamiliar shapes, the primary researcher had difficulty creating an accurate fit. Further, when manipulating the slopers to create garment patterns, the predictability of design outcomes was challenging because of the atypical shapes. Thus, many iterations were needed during the Development Stage of the Design Phase to problem solve any design issues. The various iterations also resulted in alterations needed after the final garments were constructed (e.g., skirt size reduction).

Another unexpected challenge was created as a result of trying to satisfy Laura's Functional Needs. The button-up shirt was too short

to be worn with other garments outside of the designated ensemble. Laura described how the shirt would come up a little, exposing her belly, while she wore it with previously owned clothing. As a result, Laura's expressiveness is limited again by her Accessibility Need (i.e., previously owned clothing) and Functional Need (i.e., protection from skin exposure).

Further, orientation issues were discussed in the Results section. As a result of creating clothing with no closures, the orientation of the garments on the body became difficult to determine. Thus, donning and doffing became easier in respect to closure manipulation, but also

became more difficult because Laura did not know which was the front or the back of the garments. These situations show that although adaptive clothing can solve various needs of an individual, it can also create new needs.

Conclusion

The aim for this study was to design and test apparel, which addresses the clothing related needs of an individual living with Down syndrome. A multidisciplinary research method allowed the primary researcher to identify and address the clothing related needs of the participant. Laura and her mother enjoyed the Participatory Design process used during the Design Phase. Laura summarized her experience as:

It was a really good, amazing, and surprising, like, experience, as well, and I'm glad I could be a part of this.

Laura's mother described the experience:

It was a great process. We enjoyed coming and working with you…. I think Laura liked doing clothes this way…sitting here and pick[ing] it out, stuff and styles and all that, and I think she enjoyed that more [than traditional shopping].

Despite the success of the research outcomes, some limitations of the research design existed. This chapter's research was a case study, focusing on one person with one disability. Thus, the population size is limiting.

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Conflicts of interest

The authors declare there is no conflict of interest in publishing the article.

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