

## ABSTRACT

BLEDSOE, LISA M. The Importance of Expressive Design in Orthopedic Braces. (Under the direction of Dr. Traci Lamar).

Previous research shows that fashion and appearance can affect self-esteem, body image, and mood. However the appearance of functional clothing like orthopedic braces is often only a secondary consideration of its design, and there are limited colors and styles available on the market. The purpose of this research is to better understand how the appearance of orthopedic braces can influence user experience, particularly in regard to satisfaction and compliance.

Data was collected through a self-administered online survey. Subjects who had recently worn a brace answered questions pertaining to appearance satisfaction, purchase decisions, body image, and compliance in wearing their brace. Questions included a mix of scales and open-ended questions. Overall there is evidence, particularly in certain market groups, that there is a desire for more expressive design options in orthopedic braces and that the appearance of a brace influences a patient's decision whether or not to wear it as it was prescribed.

Compliance is key to the successful treatment of any condition requiring a brace. If the way a brace looks influences whether or not a patient wears it, aesthetic design becomes equally as important as functional design. This can apply not only to braces, but a wide range of medical apparel and accessories such as compression hose, hearing aids, asthma inhalers and walking canes.

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The Importance of Expressive Design in Orthopedic Braces

by  
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## **DEDICATION**

This work is dedicated to anyone who has ever worn an orthopedic brace and thought that there must be something better out there.

## **BIOGRAPHY**

Lisa Bledsoe is a native of Raleigh, North Carolina where she was born in 1987. She has a background in theater design and production including a Master of Fine Arts degree in Stage Properties from the University of North Carolina School of the Arts. Lisa spent many years in theater making every strange thing imaginable (and a few things that weren't all that imaginable until she made them) in regional theaters across the United States. After wearing unsatisfying and ugly wrist braces for sixteen years, she decided that the market for orthopedic braces was not going to change on its own and set out to change it herself.

## **ACKNOWLEDGMENTS**

I would like to thank my committee members — Dr. Lamar, Dr. Kate, and Dr. Mayhorn — for their help and guidance on this project. Also a special thanks to my fiancé whose loving support helped me keep my sanity throughout this process.

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## GLOSSARY

**Apparel:** Clothing, garments, and accessories worn on the body

**Compliance:** the degree to which a patient follows a treatment regimen; also called adherence (Aronson 2007)

**Dress:** The purposeful manipulation of the body's appearance through clothing, hair, accessories, adornment, and grooming (Damhorst 1990)

**Expressive Design:** a process of designing that takes into account the lifestyle, culture, and values of the target consumer in an effort to satisfy their emotional needs (Lamb & Kalall 1992)

**Fashion:** The way we wear our clothes and adorn our bodies to highlight the relationship between the body and its sociocultural environment (Lennon et al 2014)

**Functional Apparel:** Apparel that is specifically engineered to deliver performance or functionality to the user beyond the standard functions of apparel (Gutpa 2011)

**Medical Device:** An instrument, apparatus, or accessory which is intended for use in the cure, treatment, or prevention of disease or intended to affect the function or structure of the body and which does not achieve its primary intended purposes through chemical action (FDA 2018)

**Medical Wearables:** Any medical device worn on the body

**Orthotics:** A field of medical specialty involving the design, manufacture, and application of orthopedic braces and similar devices; also a term for those devices (Campbell & Canale 2008)

**Orthopedic Brace:** Medical devices designed to address musculoskeletal problems through the alignment and stabilization of affected body parts (Campbell & Canale 2008)

# CHAPTER 1

## Introduction

The combination of an aging population and a growing trend towards athleticism has been driving the expansion of the global industry for orthopedic braces (McClinton 2008). Market reports predict a considerable future need for braces and other medical devices. The number and variety of medical conditions that include at least some treatment with an orthopedic brace are substantial, which means a significant portion of the world population will need a brace at some point in their lives.

The focus of development for functional apparel is naturally on performance and physical comfort. Aesthetic components are often neglected or overruled by the necessity of function (Gutpa 2011). This is unfortunately the case when it comes to orthopedic braces, which are only widely available in a limited number of colors and patterns. However, appearance should be a more important consideration in functional product design. According to Lamb and Kallal, consumers are significantly more satisfied with functional products that are aesthetically pleasing and self-expressive (1992). What people wear communicates so much more than function, and appearance has an effect both on the wearer and the observer.

Expressive design is important because people need to be psychologically comfortable while wearing functional clothing. Otherwise they may choose not to wear medical devices as prescribed by their doctor. Apparel is a nonverbal way to communicate with others, and it also affects how people feel about themselves. Expressive design deserves as much attention as performance during the development of functional apparel. If a patient thinks their brace is too

ugly and chooses not to wear it, the brace becomes completely ineffective. No wearable medical device can provide effective treatment while it is sitting in a drawer.

### **1.1 Defining Expressive Design**

Apparel design is a complex process that requires balancing visual and functional elements according to consumer needs. Aesthetic considerations include the basic elements and principles of design such as line, value, color, form, space, shape and texture. A good designer uses these elements to create a product with a sense of visual balance and harmony.

However, something that is aesthetically pleasing may not necessarily be expressive and vice versa. According to the FEA consumer needs model, aesthetic design is separate from expressive design (Lamb & Kalall 1992). Expressive design is not just about what is pleasing to the human eye. It takes into account the lifestyle, culture, and values of the target consumer. Good expressive design strives to satisfy emotional needs and allows the consumer to express some part of their personality.

There are numerous conditions that might require wearing an orthopedic brace, and while there are no official reports on the subject, the assumption is that the target consumer market for orthopedic braces is likewise diverse. Because individual needs for expression change from person to person depending on culture and personality, expressive design inherently requires multiple color and pattern options from which consumers can choose.

## 1.2 Research Questions

The design process begins with identifying a problem then establishing user wants and needs as criteria for solving that problem (Lamb & Kalall 1992). This is an exploratory study to identify problems with user experience regarding the appearance of orthopedic braces and to better understand consumer needs. The first objective is to evaluate consumer satisfaction with current braces on the market:

- Is there a desire for more expressive brace designs?
- Are consumers satisfied with the options currently on the market?

The second objective is to learn more about how the appearance of a brace might influence the wearer's perception of self through appearance satisfaction as well as how brace appearance might influence social behavior.

- Does brace appearance have an effect on consumer appearance satisfaction and body image?
- Can the appearance of a brace impact social behavior and interactions with others?
- What sort of social situations deserve special design consideration?

Finally, because patient compliance in wearing a brace directly impacts the success of treatment, the third objective is to establish if there is any connection between the appearance of a brace and the decision to wear it.

- Does the appearance of a brace influence the decision to wear it in compliance with a doctor's recommendation?

### **1.3 Purpose of the Study**

Applied research studies attempt to gather information from many individual cases to explain how to better design a class of products (Buchanan 2001). There is currently little to no information available about how orthopedic braces fit into the daily lives and social interactions of consumers. Because braces are only an effective treatment if worn as prescribed it is important to design braces that offer a positive user experience.

By understanding user experience and user needs, companies can develop orthopedic braces that are more satisfying to purchase and to wear. It is possible that more expressive designs could help alleviate the stigma associated with functional apparel and encourage those who need a brace to wear it as prescribed. While this research focuses on orthopedic braces, it applies to other types of medical apparel as well. Any medical device or functional apparel from a hearing aid to a colostomy bag likely has an influence on the user's overall quality of life.

## CHAPTER 2

### Literature Review

This study falls at an intersection between many other areas of research, some of which is very new and some of which is well established. It is first necessary to have a basic understanding of the medical uses for orthopedic braces, since there are different braces for treating different types of conditions. The psychology of fashion is central to understanding the connection between appearance and user experience regarding medical wearables. Then of course it is important to recognize research and changing theories in the areas of design including product design, healthcare design, and - at the very heart of this study - expressive design.

### 2.1 Types of Orthopedic Braces

Doctors frequently recommend orthopedic braces as a first line of treatment for joint injuries because they are a low cost, less invasive alternative to surgery. Braces also have fewer possible negative side effects. The purpose of a brace might be to prevent an injury (prophylactic), improve joint function by stabilizing an area (functional), or prevent movement while an injury heals (rehabilitative). Most braces are for short-term wear to treat acute injuries such as sprains and fractures. However, some chronic musculoskeletal problems such as osteoarthritis may require a brace indefinitely (Gravlee & Van Durme 2007). Common locations for wearing braces are divided into upper and lower extremities. Upper extremities include the

neck, shoulder, elbow, wrist, and hand. Lower extremities include the knee, ankle, and foot (Hanger Clinic 2018).

There are essentially three categories of orthopedic braces. The type of brace used depends on the nature and location of the pain. Soft supports are the most common type of brace available over-the-counter at retail and drug stores. Common materials in soft supports include neoprene, canvas, and foam. Some models may contain a rigid insert to provide stability and limit range of motion. For more unique situations, physical therapists can make custom positional supports. This type of brace corrects the alignment of the joint, controls the range of motion, and limits painful movement. Thermoformable plastic is a common material in positional supports, although each unique brace may include a variety of materials. A fracture orthosis reduces or eliminates motion at the site of a fracture or other acute injury to promote healing (Faison & Schaible 2010).

### **2.1.2 Appearance and Compliance**

Compliance is the degree to which a patient adheres to a treatment regimen. Orthopedic braces are different from other wearable medical devices in that the patient generally has a choice of whether or not to wear one. A cast, for instance, is meant to be removed only by a medical professional. A diabetic needs to wear their insulin pump to stay alive and healthy. In contrast, braces are easy to remove, and the adverse effects of choosing not to wear them are not always immediate or dangerous depending on the underlying problem for which an individual is being treated.

Most available studies on orthopedic braces and compliance focus on scoliosis patients where bracing is a popular alternative to the complicated surgery for correcting the curvature of the spine. However, compliance is an “irreplaceable condition” of a brace’s success (Carus, Seifert & Selle 2010). One study used a special electronic device that can detect when a brace is worn and found that patients only wore their braces for about 70% of the prescribed time (Bowen et al 2015). The results came along with a note that the compliance rate might be higher in patients who know they are being monitored. Another study using anonymous surveys found that less than 40% of patients wore their scoliosis brace as it was prescribed (Carus, Seifert & Selle 2010). While comfort and the length of time prescribed for wearing the brace were also identified as factors for non-compliance, a lack of aesthetic appeal does influence how patients feel about their brace. One survey of adolescent scoliosis patients found that every single participant had a negative first impression of their brace because of the unappealing color (Cheung et al 2017).

One review of compliance studies in lower limb orthotics found that only about 50% to 60% of respondents across multiple studies wore their orthotic devices as prescribed. Anywhere between 6% and 80% of the respondents chose not to wear their orthotic device at all (Kerckhofs & Swinnen 2015). Reasons for rejecting the devices, which were orthopedic shoes as well as braces, included medical problems, issues with function, lack of comfort, and psychological reasons. The braces in particular had lower compliance rates than other types of orthotics included in the review. In almost every study reviewed, the list of reasons for non-compliance included “cosmetically unacceptable” (Kerchofs & Swinnen: 763).

## 2.2 What Fashion Communicates to Others

The general assumption is that fashion and dress are a means of communicating information about the wearer, and there are several theoretical perspectives on how that communication takes place. Symbolic interaction theory as developed in 1934 by George H Meade asserts that people assign meaning to symbols such as words, gestures, and clothing then use those symbols to communicate with one another (Lennon et al 2014). Cognitive social psychology suggests that people look for cues, which vary from person to person, to explain their social situations and then simplify those cues into previously conceived generalized categories (Kaiser 1983). The perspective of impression formation is very similar, stating that viewers will make inferences about others based on appearance then extend those inferences to determine how to behave (Lennon et al 2014).

In 1990 Damhorst conducted a meta-analysis of the available literature and grouped the type of information communicated through dress into the following categories: evaluation, potency, dynamism, quality of thought, and miscellaneous. Each category then broke down into multiple subcategories. Evaluation included information about positive or negative relationship perceptions such as moral character, sociability, and mood. Potency — information about status and skill — included power, competence, and intelligence subcategories. Dynamism and information about activity broke down into physical activity, self-control, and stimulation. Quality of thought contained information about intellectual flexibility, objectivity, and complexity of thinking. The miscellaneous category was a catchall for any remaining information including gender and culture (Damhorst 1990).

In 2014 a team of researchers conducted a new meta-analysis to include studies in fashion psychology conducted after 1990 (Lennon et al). They found that Damhorst's categories accounted for 74.7% of the information communicated through fashion. By adding two new categories for demographic information and physical characteristics, they could account for 94.8% of the information communicated to others through fashion. Overall, potency and evaluation together accounted for more than half of the information (Lennon et al 2014). According to Kaiser, dress can also provide information about a social situation beyond personal attributes of the wearer. Dress can help determine the degree of formality of a social interaction as well as the degree of importance the other individual places on the interaction (Kaiser 1983).

While the information attained from dress may not always be accurate or exact, there is plenty of evidence that fashion choices can affect social behavior. One team of researchers reviewed 93 studies and determined that appearance had an effect on human behavior in 85.3% of the studies (Johnson, Yoo, Kin, Lennon 2008). The types of behavior under study included helping, obedience, honesty, customer service, and aggression.

### **2.2.1 Novel Stimuli**

Within the framework of social interaction theories, a novel stimulus is simply an unusual cue that causes the perceiver to pay more attention (Kaiser 1990). An obvious physical impairment such as an injury, disability, or specialized clothing can serve as a novel stimulus, which increases the observer's tendency to make inferences based on appearance (Freeman, Kaiser, & Wingate 1985). Unfortunately, the desire to look at a novel stimulus may cause the viewer to stare, which is socially unacceptable. The result is that interactions are frequently

uncomfortable between those with a normative and non-normative appearance (Kaiser 1990). More fashion-oriented designs for otherwise medical looking dress could provide a convenient conversation starter and help facilitate nonjudgmental interactions (Vainshtein 2012).

### **2.3 How Appearance Affects the Self**

According to self-perception theory anything that can affect someone's impression of others can also affect perceptions of self, and this can include visual cues such as appearance and apparel (Kellerman & Laird 1982). Even cues as small as a pair of glasses or a necktie can make a difference in how people perceive themselves (Kellerman & Laird 1982, Howlette et al 2013).

According to self-discrepancy theory there are three different subsets of the self. The ideal self contains desired characteristics. The ought self contains ideal characteristics as they are constructed by society. The actual self is just that — a person's real attributes (Ridgway, Parsons & Sohn, 2017, Higgins 1987). Discrepancies between the different selves can cause negative emotions. Combine that with symbolic interaction theory and the result is self-completion theory, which suggests that individuals will use symbols such as apparel to reconcile differences in perceptions of self and feel more complete (Kaiser 1990). For example, someone feeling the pressure of society's preference for taller people might try to dress in a way that emphasizes height.

The process of displaying identity to others in social contexts is called self presentation, and the purposeful manipulation of self presentation is called appearance management (Kaiser 1990). Appearance management is particularly important in situations such as interviews that emphasize visual cues. The goal is to negotiate social outcomes, especially for those whose

appearance includes a novel stimulus such as a physical disability. There are a few basic strategies to appearance management. One is to conceal any unwanted attributes. Another is to deflect attention away from a negative attribute or towards a positive one. It is also possible to use appearance management to emphasize uniqueness to compensate for undesirable characteristics (Kaiser 1990).

While the understanding is that personality and mood lead to certain choices in dress, the relationship can also work the other way. Appearance management can also influence the wearer. Choosing certain clothing can help encourage feelings of assurance and comfort in the face of social appearance anxiety (Kang, Johnson & Kim 2013).

## **2.4 Changing Models of Disability**

The Americans with Disabilities Act defines a disability as “a physical or mental impairment that substantially limits one or more major life activities of such individual” (1990). The World Health Organization defines an impairment as “characterized by losses or abnormalities that may be temporary or permanent” (1993: 47) and a disability is “any restriction or lack (resulting from an impairment) of ability to perform an activity in the manner or within the range considered normal for a human being” (1993: 143). In the interest of not delving too deeply into the realms of law or medicine, disabilities and impairments go hand in hand for the purpose of this study and to some extent describe most if not all of the conditions that might lead to wearing an orthopedic brace. The goal is not to identify individuals wearing a brace as disabled but to point out how changes in views on disability might also apply.

In the medical model of disability, also sometimes called the biological or individual model, disability is an unfortunate personal tragedy requiring medical care to restore basic human function (Lamb 2001). Essentially, a disability is a flaw in need of correction (Hall & Orzada 2015). With the burden resting on each individual to find ways to adapt to society, the medical model tended to isolate people with disabilities. Medical professionals did most of the research into the required functional garments and devices, and therefore the results had an unfortunately medical appearance. Disabled people were subject to prejudice and alienated from fashion (Lamb 2001).

In the 1990s, a more social view of disability formed. The social model of disability places the burden of adaptation on society rather than the individual. Solutions to barriers emphasize lived experience over medical authority (Lamb 2001). The social model is much more inclusive than the medical model and empowers disabled people to be the architects of their own experiences. However, as a reactionary model, the assumption is still that disability is somehow negative.

The affirmative model of disability focuses on individuals as having innate self-worth. Disability is not a physical deficiency nor is it a burden of society. For those uninterested in identifying with the historically negative term “disabled,” the affirmative model offers empowerment through acknowledgement that being different can be a good thing (Hall & Orzada 2015).

During the same time period where views on disability changed from a functional problem to a systematic social problem to a positive personal identity, theories of product design underwent a similar transition. A product went from being a functional object to part of a human

system to a symbol of social identity. Where once design of medical wearables was purely a matter of function, now there is the possibility of creating products that fit into the lives of the people who wear them and help construct a positive sense of self.

## 2.5 Changing Theories of Design

There have been many developments in the research and understanding of how to design products that not only function but fit into the complex lives of consumers. In 1988 Don Norman published his book *The Psychology of Everyday Things* in which he stated that it was important to study the systems in which consumers used products. By observing product in use, designers can reconcile any differences between how consumers use the product and how it was intended to be used. It was a school of thought that would eventually become known as human centered design, but while the focus moved from the product to the consumer, there was no mention of emotion or personality (Norman 1988).

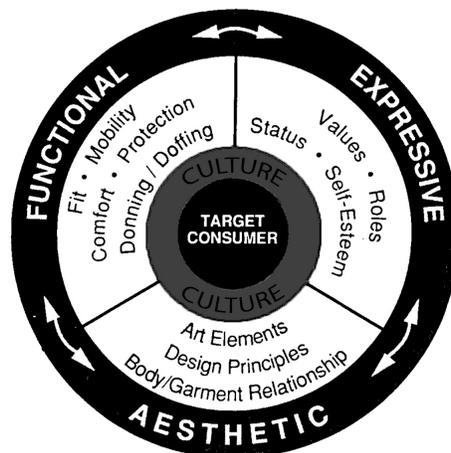
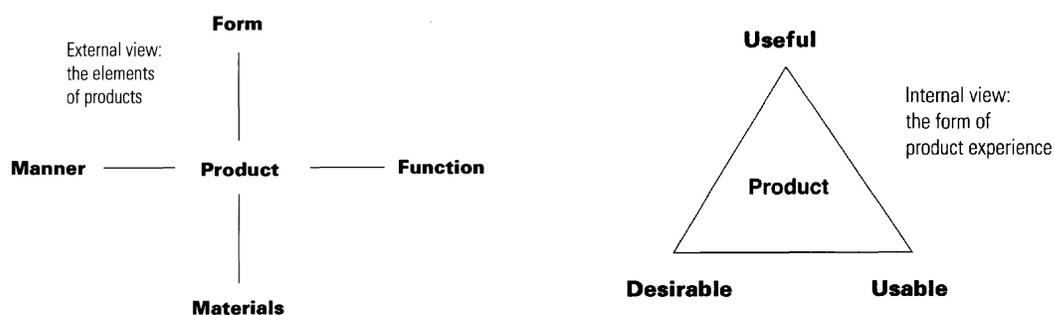


Figure 1: FEA Consumer Needs Model (Lamb & Kalall 1992)

In 1992 Lamb and Kalall introduced the FEA consumer needs model, which identified expression as an important consideration in consumer centered design. In 2001 Richard Buchanan called for a new approach to research in the field of product design that he called interaction design. Interaction design calls for the study of how human beings use and experience products in social and cultural environments. Buchanan put forward a model for an internal view of design saying that products needed to be more than functional. They must also be useful, usable, and desirable. Yet there was almost no information available about what exactly made products desirable (Buchanan 2001).

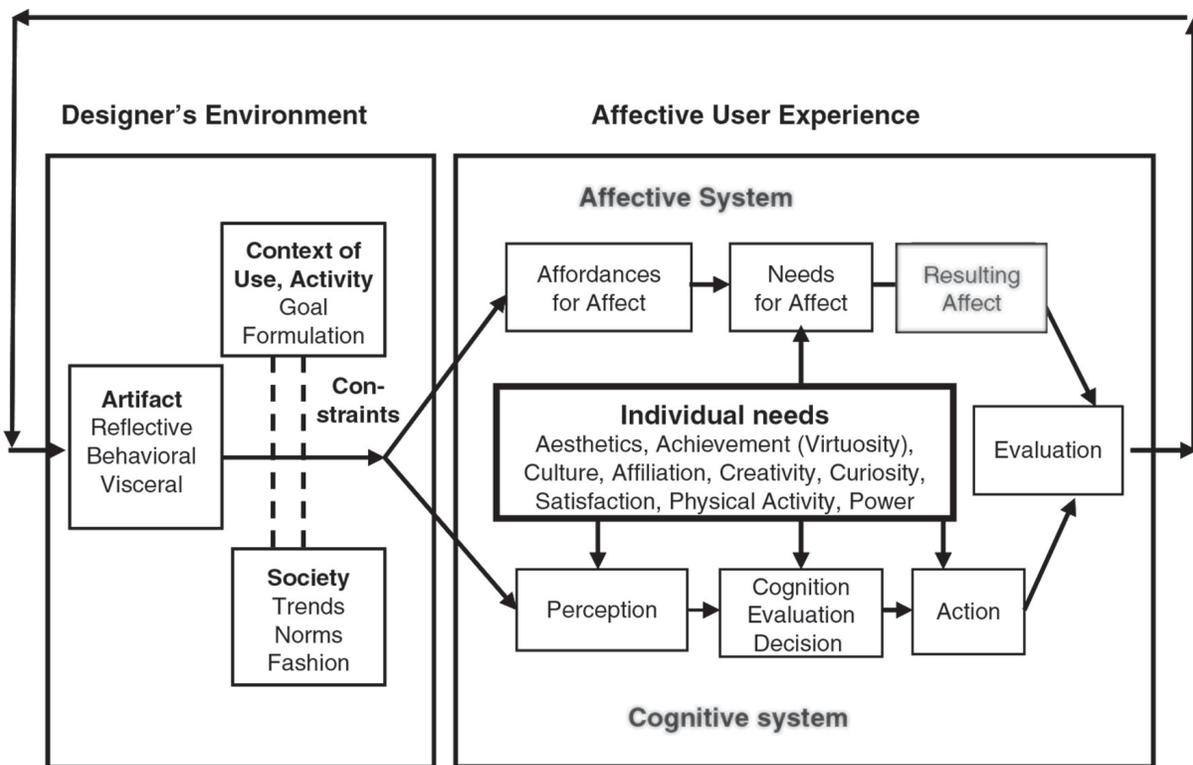


**Figure 2: Traditional vs. internal view of design (Buchanan 2001)**

Over time the field of cognitive science — the study of the human mind and how it works — brought forth insights into emotions and how they affect human behavior. This prompted Norman to write an additional book in 2004 about emotional design and its place in product development. According to Norman there are three levels to achieving good emotional design. The visceral level deals with the appearance of the product and its sensory appeal. The behavioral level includes how effective and pleasurable the product is to use. The third level,

reflective design, takes considers how consumers reflect on themselves through the product. Does it fit with their self-image? Does it provide personal satisfaction (Norman 2004)?

Khalid and Helander created a taxonomy of pleasure that fits well with Norman’s approach to emotional design. In addition to similar assertions that emotional design must be physically and reflectively pleasurable, their taxonomy suggests that good emotional design must also be pleasurable in the context of culture, social interaction, and societal values (Khalid & Helander 2006). Affective design, expressive design, and hedonomic design are alternate terms for design methods that center on the positive interaction between humans and products.



**Figure 3: Framework for assessing emotional design (Khalid & Helander 2006)**

### **2.5.1 Evidence Based Healthcare**

Medicine has also undergone a similar change in design thinking. The term evidence-based healthcare first appeared in 1991. On its face, the concept of using evidence to develop the best healthcare seems pretty obvious, but evidence based healthcare as a modern practice goes a little deeper than that. The goal is to integrate the clinical expertise of medical practitioners with the best available evidence from systematic research along with the lifestyle and social needs of the patient (Sackett et al 1996). Understanding how the patient fits into the healthcare system is a key tenant, and it requires the merging of medical and social science. Evidence-based healthcare in the media often centers around designing safer and more comfortable hospitals, but the practice applies to every aspect of medicine from treatment regimens to individual medical devices.

### **2.6 From Medicine to Fashion**

The history of eyeglasses goes all the way back to medieval Italy. From then on until the 20th century, eyeglasses were simply a medical tool meant to correct poor eyesight. As new materials for making frames and lenses emerged, a wide variety of styles for eyeglasses came onto the market. Eventually celebrities with unique eyewear pushed eyeglasses from the realm of medical device to popular fashion (The Eyes Have It 2001). These days luxury fashion designers like Dior have their own frame designs. Even protective eyewear such as goggles and sunglasses are available in a variety of styles to suit individual needs for expression, so it isn't out of the realm of possibility for a medical device to make the jump into fashion. For now, orthopedic braces are still squarely in the medical category, but new production methods for rapid

prototyping and mass customization can hopefully push down the design barriers and place braces on the fashion pedestal.

There is a small but growing trend in the development of expressive medical devices as part of a movement recently termed “proaesthetics” (Vainshtein 2012). Prosthetic limbs, for example, traditionally fall into two categories. A functional prosthesis prioritizes restoring operation of the missing limb. This type of prosthesis often pays little attention to aesthetic design. The second common type of prosthesis is cosmetic, which prioritizes restoring the natural appearance of the original limb over functionality. Orthopedic braces are similar in that the options currently available on the market tend to prioritize either function or camouflage. However a third style of expressive prosthesis that offers function and style is finding its way onto the market (Hall & Orzada 2013) and amputee fashion models like Aimee Mullins are helping to drive the development of ever more imaginative options.

The design of hearing aids has traditionally focused on discretion with small, clear, and flesh colored models dominating the market. Ellington and Lim noted in their study that there was a desire for more fashionable options, and the researchers began developing models that are meant to be both visible and expressive (2013). One company called Care + Wear designs expressive medical wear for patients undergoing chemotherapy treatments including covers for PICC lines (a type of catheter) and fashionable shirts with openings for chest ports (Longevity Network, 2017). There are even expressive asthma inhalers beginning to appear on the market (Sheth 2017). There are currently companies such as Surestep who make expressive braces for children, but expressive orthopedic braces for teens and adults are still rare.

## Examples of Wearable Medical Devices

Functional	Normative	Expressive
 <p>Brace by Ossur <a href="http://www.ossur.com">www.ossur.com</a></p>	 <p>Brace by Donjoy <a href="http://www.djoglobal.com">www.djoglobal.com</a></p>	 <p>Brace by Surestep <a href="http://www.surestep.net">www.surestep.net</a></p>
 <p>Flex-Foot Cheetah Blades by Ossur (Howarth 2012)</p>	 <p>Aimee Mullins modelling two prosthetic legs (Pikul 2015)</p>	 <p>Leg by Bespoke Innovations (Sorrel 2010)</p>
 <p>Hearing aid by Oticon <a href="http://www.hearingrevolution.com">www.hearingrevolution.com</a></p>	 <p>Minimalist hearing air <a href="http://www.accuraclinic.in">www.accuraclinic.in</a></p>	 <p>Prototypes for expressive hearing aids (Hutchins 2017)</p>

**Figure 4: Examples of wearable medical devices**

## CHAPTER 3

### Methodology

For such a large market there is virtually no consumer insight into orthopedic braces. Because there was very little information to build upon, this study was exploratory in nature. The goal was to collect information regarding different aspects of user experience including satisfaction with brace appearance, influence on appearance satisfaction and social behavior, and the influence of appearance on compliance. Because the target audience for this research is somewhat specific, a survey was the main instrument for collecting data in an effort to reach a wider audience.

### 3.1 Survey Design

Survey development and distribution was through Qualtrics, an online platform for market research. The survey was 49 questions long and estimated to take in between 10 and 15 minutes to complete. Because the purpose of the study was exploratory, the survey included a mix of scales, multiple choice and open-ended questions to provide a diverse set of data for analysis. The following sections describe the development of these questions in more detail. The survey was submitted to the North Carolina State University Institutional Review Board and the research was approved as exempt from further ethics review.

The first multiple choice section of the survey focused on the type of brace the respondent was evaluating, its intended function, and the duration of wear. In accordance with the first research objective, the second survey section used multiple choice and Likert style

scales to gauge consumer satisfaction with currently available braces. The third section targeted the connection between the appearance of the brace and the respondent's decision to wear it or not as laid out in the third research objective. The second research objective aligns with the next survey section containing a series of scales to evaluate appearance satisfaction, body image, and social behavior while wearing the brace. Since the purpose of this study is ultimately to enable the design of braces people want to wear, another series of scales aimed to establish how respondents prefer to use their clothing. The final section of the survey contained general demographic information such as age and gender identification.

### **3.1.2 Questions on Body Image and Appearance Satisfaction**

How products make people feel about themselves, or the reflective aspect of design (Norman 2004) is an important part of the user experience. People who do not feel good about themselves or their body while wearing their brace may choose not to wear it. The purpose behind the questions about body image and appearance satisfaction was to gauge how respondents felt about themselves and their appearance while wearing a brace. Questions on body image and appearance satisfaction were five point scales modified from the Satisfaction with Appearance Scale (Lawrence et al 1998) and the Multidimensional Body-Self Relations questionnaire (Cash & Pruzinsky 1990). Responses ranged from "strongly agree" to "strongly disagree." The survey included both positive and negative statements from each category to help reduce inherent bias.

- When I wear my brace I feel confident about my appearance.
- When I wear my brace I do not feel like my appearance is true to my personality.
- When I wear my brace, I feel satisfied with my body.
- I feel good about myself when wearing my brace.
- When I wear my brace I feel ugly
- My brace has no effect on how I feel about myself
- My brace has no effect on how I feel about my body.

### **3.1.3 Questions on Social Behavior**

As established in the review of literature, what people wear can influence the development of first impressions and may cause viewers to make assumptions about the wearer. Since there is no way to know just what other people are thinking, questions in this category focus more on how other people have treated participants while wearing a brace and how participants felt about those interactions. The goal is to establish whether or not participants perceive any difference or discomfort in their interactions with others and whether or not social situations influence the decision to wear a visible brace. Questions in this section are five point scales modified from the Social Comfort Questionnaire (Lawrence et al 2010) with response options ranging from “strongly agree” to “strongly disagree.”

- When I wear my brace I feel that my injury is conspicuous to others.
- People treat me differently when I'm wearing my brace.
- I am hesitant to wear my brace in social situations.

- I am uncomfortable when people ask me questions about my injury.
- When I wear my brace, I am afraid I will appear weak to others.

### **3.1.4 Open-Ended Questions**

While scales are very useful and easier to analyze, unscripted responses allow participants to mention ideas that the researchers may have otherwise overlooked. In a largely exploratory study, free responses can provide invaluable insight.

- Describe your ideal brace
- Please describe any modifications you have made to the appearance of your brace.
- Please elaborate on why you choose not to wear your brace due to appearance. Are there certain situations where you prefer not to wear it? Are there social or personal factors involved?

### **3.1.5 Questions on Clothing Function**

Styles of dress tend to be deeply personal, and not everybody chooses what they wear for the same reasons. Kwon and Parham identified five basic functions of dress: to be fashionable, to camouflage parts of the body, to provide self-assurance, to express individuality, and to be comfortable (1994). To better understand how future designs for orthopedic braces can better serve the target market, the survey included a set of scales to identify which functions of clothing are most important to the participants. In this case, the assurance function was included with the comfort function, since this study is more interested in psychological comfort rather than

physical comfort. Given the functional nature of the product under investigation and the growing availability of specialized technical textiles, a new function for performance was added for this study.

Fashionability function:

- I prefer to wear clothing that is fashionable and exciting
- I prefer to wear clothing that impresses people.

Concealment function:

- I prefer to wear clothing that conceals problem areas
- I prefer to wear clothes that do not call attention to my body

Performance function:

- I prefer clothing that is more functional than stylish
- I prefer to wear clothing with enhanced performance qualities

Uniqueness function:

- I prefer to wear clothing that makes me look unique
- I prefer to wear clothing that is unusual

Comfort function:

- I prefer to wear clothing that gives me self-confidence
- I prefer to wear clothing that makes me feel better about myself

### **3.2 Survey Distribution**

Participants accessed the survey through an anonymous link that was distributed primarily through social media. The link first appeared on a Facebook page created for the study where any interested party could access, share, and redistribute the survey. According to Facebook's analytics, the link reached 2,009 people. Some online support groups for medical conditions that frequently require braces agreed to share the link including groups for osteoarthritis, rheumatoid arthritis, and Ehlers-Danlos syndrome. The survey link also appeared at the end of an article about this study that was featured on the North Carolina State University College of Textiles website. The survey was active from January 9 to February 22, 2018.

### **3.3 Participants**

To participate in the survey, respondents had to be consenting adults age 18 or older. Because time can alter memory, the survey was also limited to participants who were either wearing a brace at the time of their response or had worn a brace within the six months prior to taking the survey. The goal was to get accurate and fresh responses based on orthopedic braces available to the public at the time of the study. Out of 71 recorded responses, only 58 met both requirements.

### **3.4 Scoring Methods**

The first round of scoring examined how the sample group responded to individual questions. Each level of agreement was assigned a score. A score of 5 indicated the highest level of agreement, a score of 3 indicated a neutral response, and a score of 1 corresponded to the

lowest level of agreement. There has been much debate in the academic community over whether it is better to use averages or medians as measures of central tendency for Likert data (Sullivan & Artino 2013). Because there were often less than five observations per level of agreement, the median is the measure of center for this study. Both frequency and median were examined to determine whether or not the sample group agreed or disagreed with the statement.

The second round of scoring examined the series of questions together to establish overall positive or negative user experience per each participant. Responses for appearance satisfaction and social behavior were assigned numerical values. Statements indicating a negative experience were reverse scored (marked with an asterisk in the appendix).

For example “When I wear my brace I feel confident about my appearance” was scored according to the table for positive experience, which would result in a higher score the more a response agreed with the positive statement. “When I wear my brace I feel ugly” was scored according to the table for negative experience. Agreement with a negative statement results in a lower score. When all the scores are totaled for an individual, higher scores correspond to more positive experiences and vice versa. Responses for social behavior were scored in the same fashion. The scores for appearance satisfaction were then added to the scores for social behavior for an overall indication of positive or negative user experience.

**Table 1: Scoring for scaled questions**

Scoring for Negative Experience		Scoring for Positive Experience	
Value	Answer	Value	Answer
1	strongly agree	5	strongly agree
2	somewhat agree	4	somewhat agree
3	neither agree nor disagree	3	neither agree nor disagree
4	somewhat disagree	2	somewhat disagree
5	strongly disagree	1	strongly disagree

To analyze preferences for clothing function, answers were once again assigned numerical values. Every statement for clothing function was positive, so nothing was reverse scored. There were two questions that corresponded to each distinct function, so the values for each pair were added together to create a total score for that function. Higher scores correspond to stronger preferences for that function. Three questions for comfort were included in the original survey, creating an unintentional bias for comfort. One question was eliminated during scoring so that totals for comfort could not be higher than totals for any other function.

### **3.5 Thematic Analysis for Open-Ended Questions**

Thematic analysis for open-ended responses followed Braun and Clarke's 2006 method. First, responses were transcribed and read through multiple times. General categories were produced based on common themes. Responses were reviewed again and marked according to the themes. The number of times each theme occurred defined how important the theme was to consumers. Only individual concepts were counted, not reiterations or explanations clearly related to the initial statement. Responses detailing the ideal brace were categorized into statements about

- cost
- fit
- comfort
- quality
- appearance.

Reasons for choosing not to wear a brace were grouped into statements regarding

- social events
- negative attention from others
- outfit matching
- formal wear
- Fit

Types of modifications that respondents have made to their braces include

- color changes
- application of accessories
- functional changes.

### **3.6 Developing Prototypes**

After examining the survey results to understand what could make a brace more desirable to consumers, development for expressive prototypes began. The first step was to evaluate current fashions for clothing and accessories via sources such as Pinterest and Fashion Snoops, which is a fashion forecasting tool. Several trends were marked as possibilities for developing an orthopedic brace. Responses about the ideal brace served as a filter for which designs moved forward.

After sketching four designs, two for a wrist brace and two for a knee brace, the concepts that best fit user needs and available production methods were produced. The step-by-step production process is available in the appendices.

## CHAPTER 4

### Results

Each heading follows the order of the original survey, which is located in the appendix. The only exception is demographic information, which appears last on the survey but first in the results.

#### 4.1 Demographics

The age range of participants fell in between 18 and 64 years old with the largest represented group falling into the 25-34 year old category. Although the survey distribution did not specifically target one demographic group, the overwhelming majority of participants were white American females. Australia and Canada were also represented.

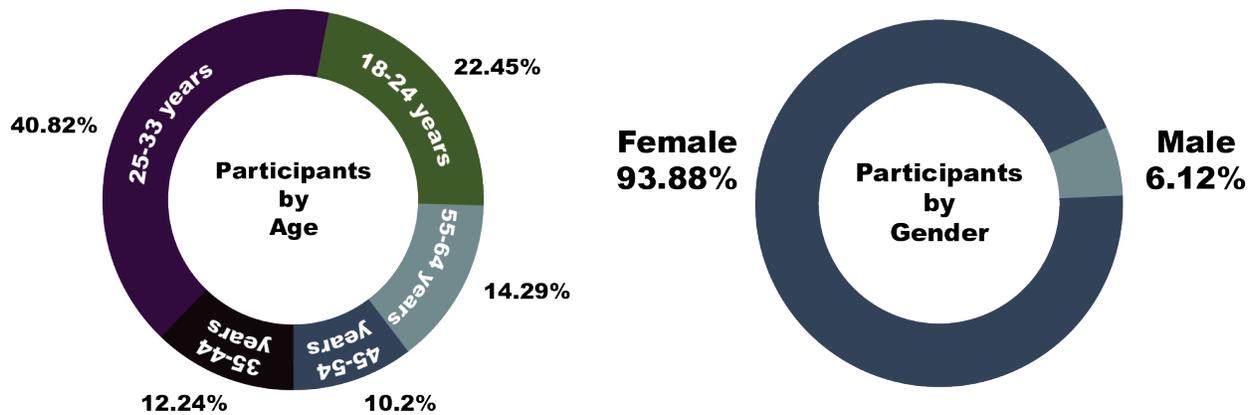
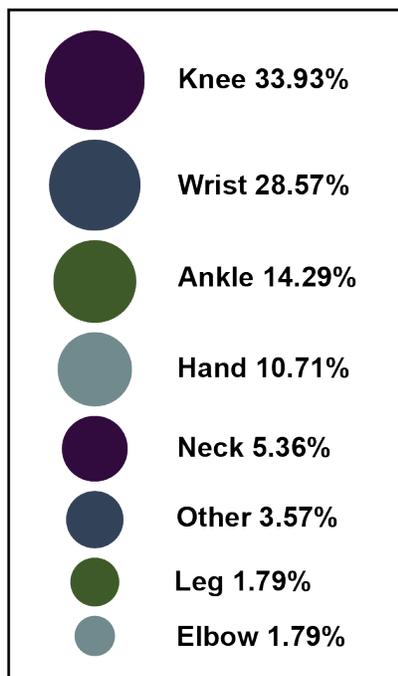


Figure 5: Survey participants by age and gender

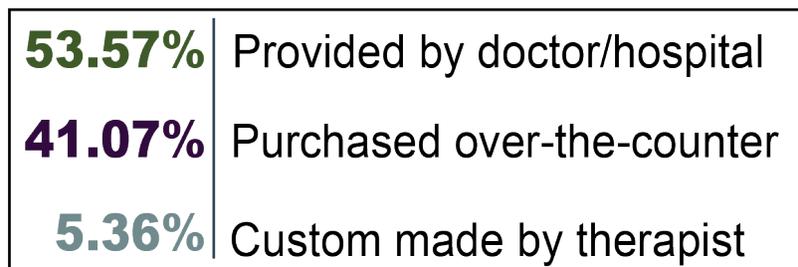
## 4.2 Types of Braces Represented

The majority of participants responded in regard to a wrist or knee brace, although several other types of braces were represented. Most participants had a brace that was provided by a hospital or a doctor rather than purchased over the counter. Only about 5% of respondents wore a brace prophylactically, while about 13% wore a rehabilitative brace following an acute injury or surgery. 82% of respondents wore a functional brace to stabilize an area with ongoing problems. More than half of respondents wore their brace on a daily basis, and most of them continue to wear their brace indefinitely. In all but three cases, the brace was worn in such a way that it was visible to others. There may be some influence of voluntary response bias, since people who wear a brace often and will continue to wear it for a long time are more likely to have strong opinions about their brace and respond to the survey.

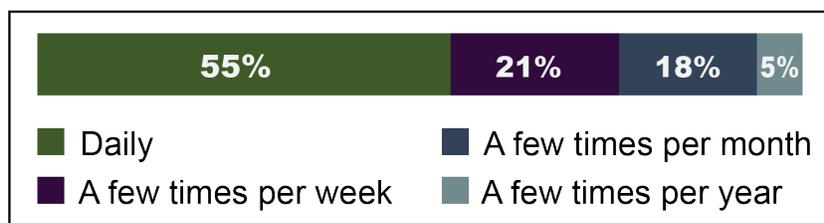
### Braces by Location



### Braces by Source



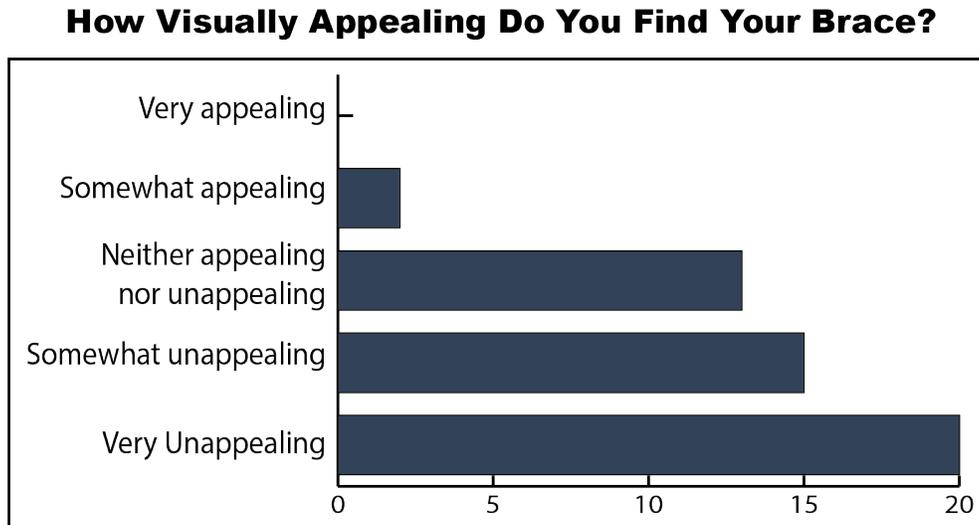
### How Often Do You Wear Your Brace?



**Figure 6-8: Location of participants' braces; Breakdown of braces by source; Frequency at which participant wear their braces**

### 4.3 Satisfaction with Brace Appearance

General satisfaction with the appearance of current orthopedic braces was low. When asked to evaluate how appealing their current braces were, the majority of respondents chose a negative answer.

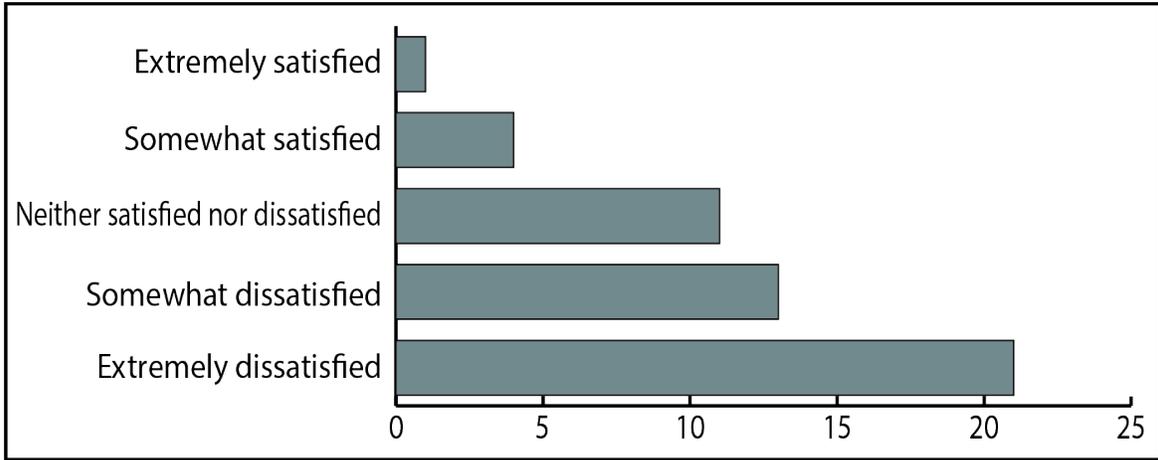


**Figure 9: Evaluation of brace appearance**

“Visually unappealing” was the most common choice with 20 responses, and “very appealing” was the least common with 0 responses. When each response was assigned a score with “very unappealing” equal to 1 and “very appealing” equal to five, the median response was 2, which is below the neutral score of 3.

When asked about satisfaction with the variety of design options available on the market, responses were once again mostly negative. “Extremely dissatisfied” was the most common choice with 21 responses where only a single respondent reported that they were “very satisfied.” Once scored the median response was 2, which is below the neutral score of 3.

**How satisfied are you with the variety of design options available for your brace type?**



**Figure 10: Satisfaction with brace designs**

**4.4 Purchasing Decision**

In order to understand consumer purchasing decisions, respondents ranked 7 items in order of importance when choosing a brace to purchase. 60% of respondents chose fit/size as the most important factor in choosing a brace. As braces are worn against the body and function best when they fit properly, it makes sense that size would be a high priority.

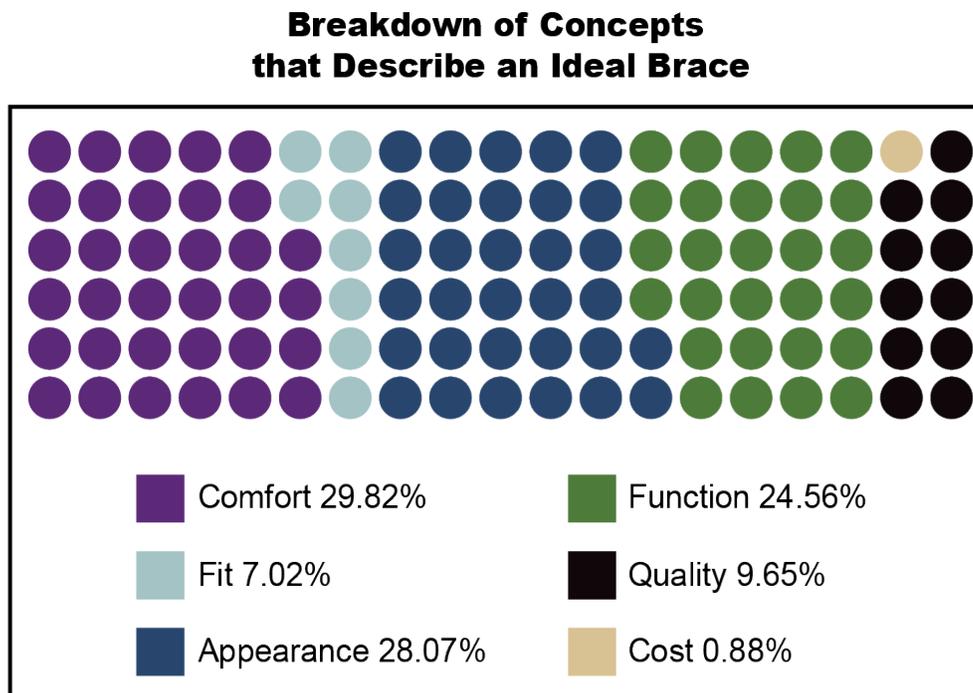
**Table 2: Consumer rankings for importance of product attributes**

#	Field	1	2	3	4	5	6	7	Total
1	Price	24.00% 12	22.00% 11	14.00% 7	22.00% 11	6.00% 3	4.00% 2	8.00% 4	50
2	Color	0.00% 0	2.00% 1	8.00% 4	10.00% 5	48.00% 24	26.00% 13	6.00% 3	50
3	Bulkiness	4.00% 2	24.00% 12	42.00% 21	16.00% 8	10.00% 5	2.00% 1	2.00% 1	50
4	Pattern	0.00% 0	2.00% 1	0.00% 0	8.00% 4	18.00% 9	40.00% 20	32.00% 16	50
5	Fit/size	60.00% 30	26.00% 13	8.00% 4	6.00% 3	0.00% 0	0.00% 0	0.00% 0	50
6	Fashionability	2.00% 1	0.00% 0	6.00% 3	6.00% 3	16.00% 8	20.00% 10	50.00% 25	50
7	Durability	10.00% 5	24.00% 12	22.00% 11	32.00% 16	2.00% 1	8.00% 4	2.00% 1	50

Beyond fit and size, there was very little agreement on rankings. Fashionability overall did not appear to be important with half of respondents placing it as their lowest priority. As for durability, pattern, bulkiness, color, and price, the rankings appear to vary from consumer to consumer. The takeaway is that choosing a brace is a complicated and personal process. There is no one particular attribute that is a top priority for every customer.

#### 4.5 The Ideal Brace

Responses for describing the ideal brace were coded according to statements about cost, fit, function, comfort, quality, and appearance. 40 responses yielded 114 separate concepts about what would constitute as an ideal brace. A transcript of the responses is available in the appendix.



**Figure 11: Descriptors of the ideal brace**

Statements related to properties of comfort were the most common and appeared 34 times. Many of the comments about comfort included references to bulk and a desire for more lightweight options. It is common for braces to include multiple layers of fabric and foam that can build up into a bulky product. Because of the bulk and types of materials used, braces can also become very warm. Sometimes the warmth is intended to improve circulation and promote healing, but for many respondents the ideal brace would not cause them to sweat.

Comments about appearance were the second most common, appearing 32 times. However the ideal appearance tended to split in between a desire for nearly invisible, sleek options that are easier to hide and colorful, stylish options that are fun to wear. Other statements like “doesn’t make me look like a robot” were less clear but still indicated a desire for a different appearance than what is currently available.

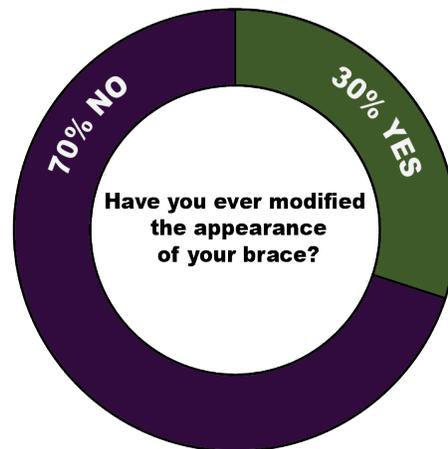
There were 28 statements regarding the function of an ideal brace. Many respondents called for braces that were more supportive and better at stabilizing the area where they are worn. Another function that appeared repeatedly in the comments was washability. The layers of fabric and foam can generally be hand washed but do not dry easily. Other types of braces may be made out of materials that are difficult to wash, or the brace does not come apart easily to facilitate washing. No matter the reason, many respondents reported wanting a brace that could get wet either through sporting activities or through washing.

11 comments included statements about quality, especially in regard to durability. Suggestions included harder materials, replaceable parts, and a general animosity towards velcro. Braces can undergo a lot of stress, particularly if worn often and for a long period of time as is the case with the majority of this particular sample group.

Although it ranked fairly high on the question about purchasing decisions, cost only appeared in a single comment for the open-ended question. One respondent used the phrase, “doesn’t cost a million dollars” to describe their ideal brace. Why cost only received one mention would be conjecture, but it is surprising given the results of the purchasing decision ranking.

#### 4.5.1 Brace Modifications

Only 30% of respondents reported making any modifications to the appearance of their brace.



**Figure 12: Percentage of participants who have modified their brace**

Participants were then asked to elaborate on what sort of modifications they have made. Responses were categorized into functional modifications and aesthetic modifications. Aesthetic modifications then broke down into changes in color and the application of accessories. The application of accessories was the most common method of modification.

## Modifications Made to Braces

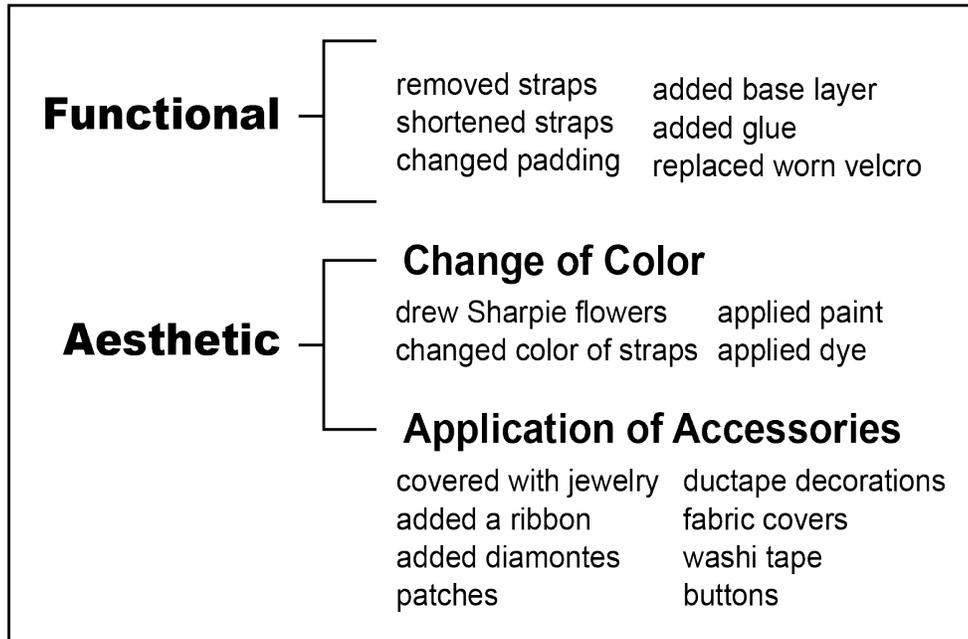


Figure 13: Classification of brace modifications

### 4.6 Compliance

When asked if they ever choose not to wear a brace because of the way it looks, 64% of respondents claimed that they did.

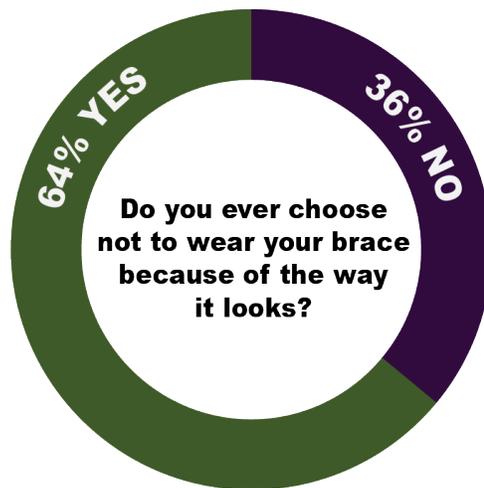
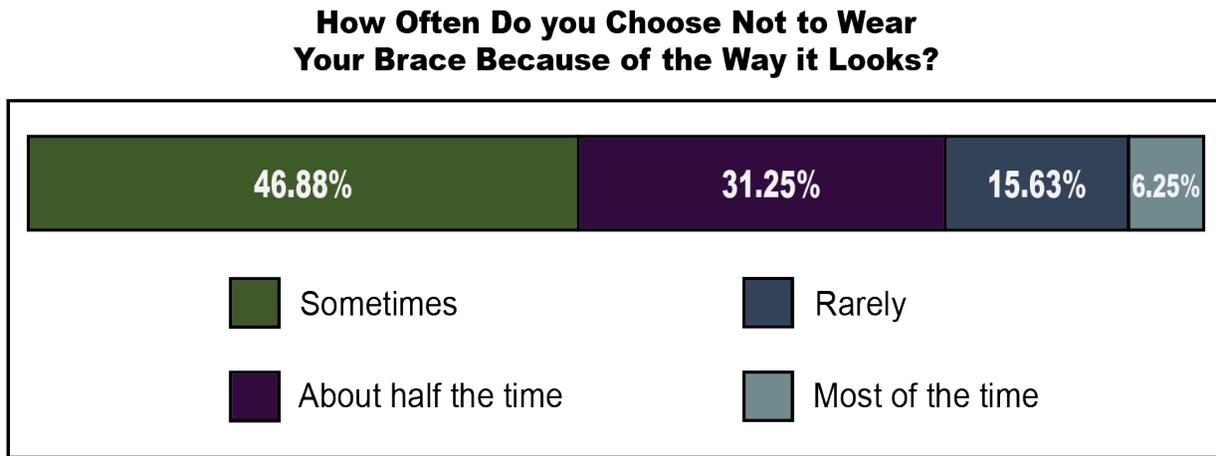


Figure14: Influence of appearance on compliance

When asked to clarify how often they chose not to wear a brace due to appearance, the most common response was “sometimes” which was situated below “about half the time.” It is difficult to arrange increments of time for the purpose of a survey. The results may not be particularly meaningful since “sometimes” has no specific numerical definition.



**Figure 15: Frequency of the decision not to wear a brace due to appearance**

#### **4.6.1 The Decision Not to Wear**

Participants who chose not to wear a brace because of how it looks, regardless of how often, then had a chance to elaborate on the context for that decision. Reasons for not wearing a brace due to appearance ultimately broke down into the following categories: outfit matching, negative attention from others, problems with fit, social gatherings, and formal wear.

The categories for this section are difficult to separate. For instance, someone may not want to wear a brace to a social gathering because it might draw negative attention from others. Responses claiming that they prefer not to wear a brace with formal clothing could be

construed as a problem with outfit matching. In cases where a statement could fall into multiple categories, the context of the statement itself served as a qualifier for which category was most appropriate.

### Please Elaborate on Why You Choose Not to Wear Your Brace Due to Appearance

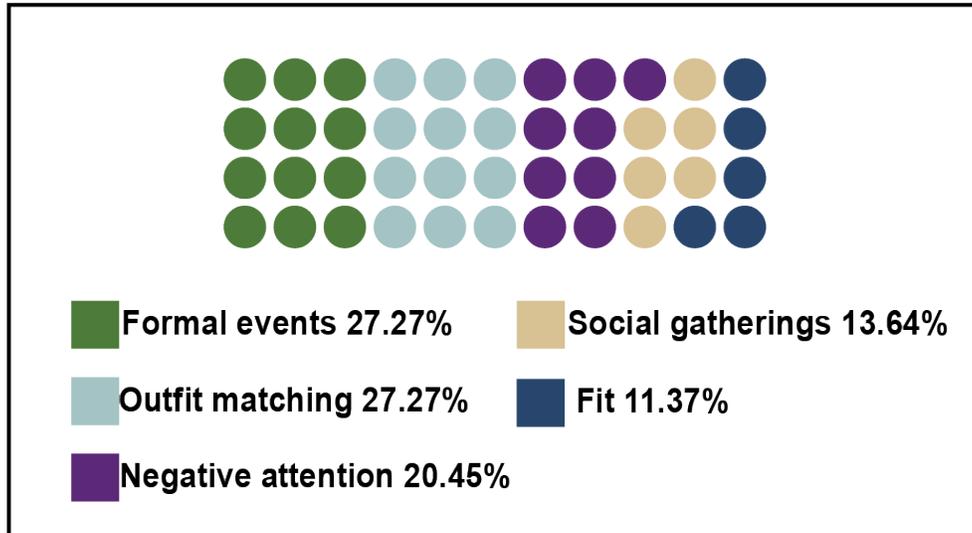


Figure 16: Reasons given for not wearing a brace

Out of 32 responses there were 44 distinct statements about why the respondent chose not to wear the brace. The most common situation in which people chose not to wear the brace was formal events, which was mentioned 12 times. Formal events included professional work scenarios with a dress code and more elegant events such as weddings. Braces at formal events may be problematic because there are no brace designs that would match a formal ensemble, or it may be because formal events are generally also social gatherings where a brace might draw negative attention from others.

In a similar vein, outfit matching was another common reason for not wearing a brace due to appearance. Outfit matching was also mentioned 12 times. In some cases the problem was with the limited range of colors available for orthopedic braces. In other cases the problem was that the brace was too noticeable when paired with the outfit. Or one respondent put it very simply saying, “Would you ever change a shirt if you saw it didn't match your outfit? It is this situation.”

Negative attention from others was mentioned 9 times. Four respondents commented that wearing a brace seems to invite unwanted questions from strangers which can be difficult or uncomfortable to answer. One respondent claimed that, “The bulky white brace becomes the only topic of conversation and all that people see about me.” Another respondent noticed that wearing the brace caused other people to subconsciously talk slower. As mentioned in the literature review a brace can serve as a novel stimulus, which means it is more likely to attract attention and influence the impressions of others. Several respondents showed a preference for not wearing their brace to social gatherings. Reasons for not wanting to wear a brace to a social gathering are likely related to the unwanted attention from others.

Although it doesn't directly qualify as a problem with appearance, 5 responses mentioned fit. To clarify, fit in this case most often meant that the brace didn't fit underneath clothing and could therefore not be concealed. Or in some cases, the brace could not physically be worn with the preferred garments for a specific outfit.

#### 4.7 Body Image and Appearance Satisfaction

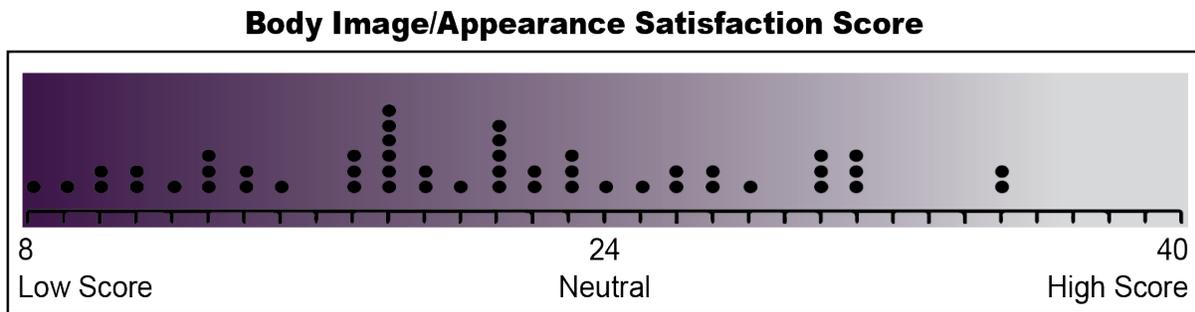
The following table is a breakdown of the responses for each question on appearance satisfaction. Because there were not always more than 5 observations per group, the median was the measurement of center rather than averages. A median higher than 3 indicates overall agreement with the statement. A median lower than 3 indicates overall disagreement with the statement, and a median of 3 indicates neutrality.

**Table 3: Responses for questions about appearance satisfaction**

Question	Highest Percentage Answer	Median Score	Overall Agreement
When I wear my brace I feel confident about my appearance	somewhat disagree (34%)	2.5	Disagree
When I wear my brace I do not feel like my appearance is true to my personality	neither agree nor disagree (38%)	3	Neutral
When I wear my brace I feel satisfied with my body	neither agree nor disagree (42%)	3	Neutral
I feel good about myself when wearing my brace	neither agree nor disagree (32%)	3	Neutral
When I wear my brace I feel ugly	somewhat disagree (32%)	2.5	Disagree
When I wear my brace I feel self-conscious about my appearance	somewhat agree (38%)	4	Agree
My brace has no effect on how I feel about myself	somewhat disagree (30%)	2	Disagree
My brace has no effect on how I feel about my body	somewhat disagree (34%)	2	Disagree

On the whole, respondents appeared to be ambivalent about statements regarding appearance satisfaction. The last three statements would appear to contradict the other mostly neutral responses, which could mean that either the other statements were not strongly worded or that the responses were distributed evenly enough towards the extremes that the center fell in the neutral middle.

To get a different perspective that included the variation between participants, responses from individuals were scored and totaled together to indicate overall appearance satisfaction while wearing a brace. Higher scores correspond to more positive feelings while lower scores correspond to more negative feelings. The highest possible score for this section was 40. The lowest possible score was 8 with 24 representing a completely neutral score. The median score was 20, and the average score was 20.48. Both the median and the average fall below the neutral score, which indicates generally low user appearance satisfaction while wearing an orthopedic brace.



**Figure 17: Appearance satisfaction scores by frequency**

#### 4.8 Social Behavior

The following table is a breakdown of each question about social behavior while wearing an orthopedic brace. Again, the median is used as the measure of center. A median higher than 3 indicates general agreement with the statement, and a median lower than three indicates general disagreement with the statement. A median of 3 indicates neutrality.

**Table 4: Responses for questions about social behavior**

<b>Question</b>	<b>Highest Percentage Answer</b>	<b>Median Score</b>	<b>Overall Agreement</b>
When I wear my brace I feel that my injury is conspicuous to others	strongly agree (66%)	5	Agree
When I wear my brace in public, strangers ask about my injury	strongly agree (62%)	5	Agree
People treat me differently when I'm wearing my brace	strongly agree (48%)	4	Agree
I am hesitant to wear my brace in social situations	somewhat agree (40%)	4	Agree
I am uncomfortable when people ask me questions about my injury	somewhat agree (30%)	4	Agree
When I wear my brace I am afraid I will appear weak to others	somewhat agree (36%)	4	Agree

Percentages for the most frequent response are much higher for statements about social behavior than for statements about appearance satisfaction. Agreement with statements regarding attention from others supports the idea of an orthopedic brace as a novel stimulus.

Again responses were scored and totaled per individual. “When I wear my brace in public, strangers ask about my injury” was not included in the individual scores, since it is not necessarily a positive or negative experience. It is simply a statement of occurrence. The highest score possible for this section was 25, and the lowest possible score was 5. The neutral score was 15. Higher scores correspond to more positive experiences regarding interactions with others while wearing a brace, and lower scores indicate more negative experiences. The median score was 10.5, and the average score was 10.66. Both the average and the median fell below the neutral point.

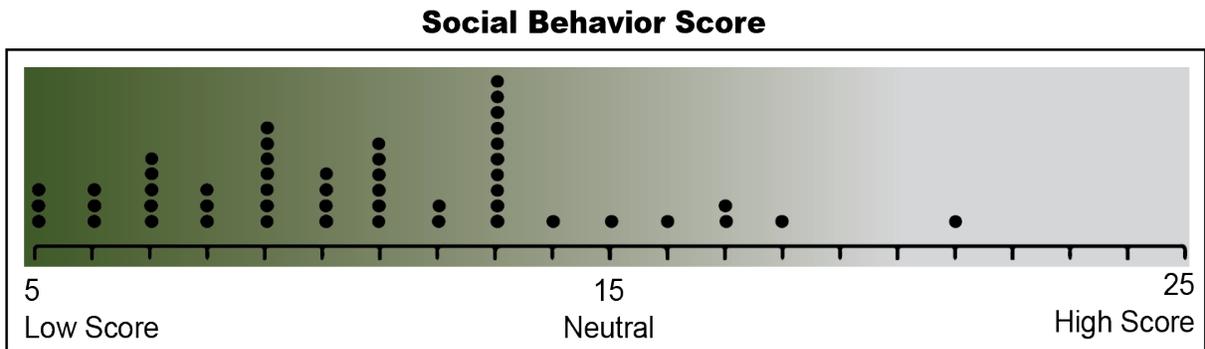


Figure 18: Social behavior scores by frequency

#### 4.8.1 Total User Experience

Scores from social behavior and scores from appearance satisfaction were added together for a grand score of user experience. The highest possible score was 65, and the lowest possible score was 13. A completely neutral score was 39. When it comes to scores for total user experience, the median is 29.5 and the average is 31.34, both of which fall below neutral.

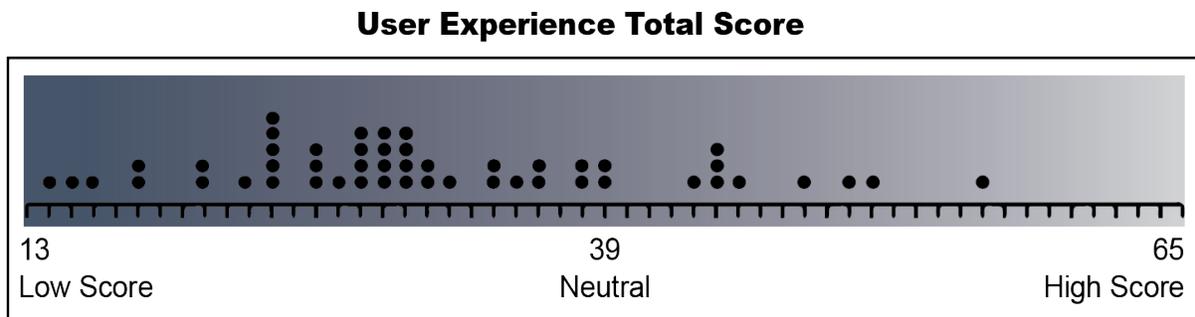
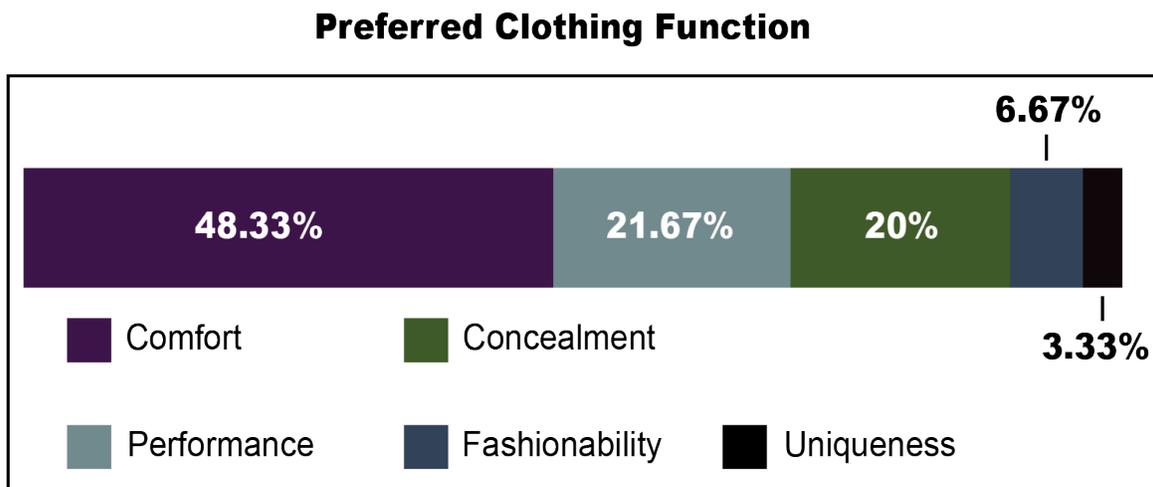


Figure 19: Total User experience scores by frequency

## 4.9 Clothing Function

Responses for clothing function were scored and totaled per individual. The function with the highest total score was established as the preference for that participant. Some participants equally favored multiple functions, although comfort was the most popular no matter how the preferences were counted.



**Figure 20: Target consumer preferences in clothing function**

## 5.0 Expressive Brace Prototypes

Two brace prototypes were developed according to the survey responses, one for the knee and one for the wrist, since knee and wrist braces were the most common braces under evaluation. To address compliance, prototypes needed to match a variety of outfits and not look out of place with the type of clothing worn at formal or social gatherings. Other attributes for the prototypes derived from responses about the ideal brace. For comfort, prototypes needed to address bulk and breathability and for appearance the prototypes needed to be either bright and playful or sleek and versatile.



**Figure 21: Expressive knee brace prototype**

Figure 21 is a knee brace prototype designed according to the desire for a low-profile brace that could match almost any outfit. The black color is very versatile, although the construction of the brace is reversible and would allow for an alternate color on the opposite side. The construction of the body contains two layers of 3mm thick spacer knit fabric, which has similar properties to neoprene (a common brace material) but is lighter, breathable, and easier to wash. The diamond quilting stabilizes the two layers and creates pockets for optional rigid supports along the side of the knee. Instead of velcro, the closure is laced ribbon for a look somewhat reminiscent of a corset. There is an optional layer that can be worn under the brace to

provide extra comfort so that the lacing does not irritate the skin. The base layer also provides opportunities to create different fashion looks through color, pattern, or the addition of trim.



**Figure 22: Expressive wrist brace prototype**

Figure 22 is a wrist brace with a low profile that can fit under clothing but can also stand out as a decorative accessory. Instead of multiple layers of fabric and foam, the body of the brace is a thermoplastic that can mold to the individual's body. The plastic is painted with a bright abstract design and coated in resin for durability. A spacer knit lines the body for additional comfort. A slide buckle integrated into the plastic body creates an adjustable, velcro-free closure. The advantage of this design is customizability in both fit and aesthetic design.

## CHAPTER 5

### 5.1 Summary

The overarching theme of the results from this study is that wearing a brace is not very pleasant. There are not many design options from which consumers can choose, and existing options are not very visually satisfying. Measures of user psychological experience while wearing a brace were generally low. Social interactions in particular stood out as negative. Where the distribution of appearance satisfaction scores spanned both the very high and very low range, scores for social behavior were much more heavily distributed towards the low end. Responses to questions about social behavior and open-ended responses support the idea that braces act as a novel stimulus and as such can generate unwanted attention. Ultimately, users prefer clothes that are comfortable and promote self-confidence, which unfortunately is not a description of the average orthopedic brace.

#### 5.1.1 Objective 1

The first objective was to evaluate consumer satisfaction with the appearance of orthopedic braces currently available. Based on the results, consumer satisfaction is generally low. When asked to evaluate the visual appeal of their brace, only 2 out of 50 respondents described their brace as having any amount of visual appeal. Most respondents described their brace as either “somewhat unappealing” or “very unappealing.”

Satisfaction with the design options currently available was likewise low with the majority of respondents expressing some level of dissatisfaction. Open-ended responses also

support the conclusion that the appearance of braces in the current market leave something to be desired. In describing an ideal brace, appearance was mentioned more often than fit, function, quality and cost. Given that many descriptions of an ideal brace included more variety of color and pattern, there appears to be desire for more expressive orthopedic braces.

### **5.1.2 Objective 2**

The second objective was to look for any influence of brace appearance on appearance satisfaction and social behavior. The results for social behavior were much stronger than the results for appearance satisfaction. When examining each question individually, responses to statements about appearance satisfaction were largely neutral. Only two statements resulted in strong disagreement. The first was, “my brace has no effect on how I feel about myself” and the second was, “my brace has no effect on how I feel about my body.” The conclusion is that braces likely have some influence on appearance satisfaction, but it is not entirely clear how much or why. Scores for individual participants had an average that fell below neutral, but without further research it is impossible to say that an orthopedic brace causes low satisfaction with personal appearance.

Both the individual scores and the results for the survey statements indicate that people who wear braces have generally negative experiences with social behavior. There was strong agreement that wearing a brace in public resulted in strangers asking questions about it, so it’s not surprising that there was also strong agreement that wearing a brace made respondents feel like their injury was conspicuous. In the open-ended responses, there were supporting statements

about negative judgement from others and a general unwillingness to wear a brace in social situations.

### **5.1.3 Objective 3**

The third objective was to find out if the appearance of orthopedic braces had an influence on the decision to wear it as prescribed by a medical professional. 64% of the participants reported that they have chosen not to wear their brace because of the way it looks. While it is difficult to gauge frequency in a multiple choice format, 27 participants chose responses that implied it was not a rare decision for them to make. For this sample group at least, there is a connection between compliance and the way a brace looks.

## **5.2 Designing Braces Consumers want to Buy and Wear**

The ultimate purpose of this study was to gain insight into the consumer experience for orthopedic braces and determine what factors might help manufacturers design braces and brace materials that consumers would want to wear. As per the first objective, there needs to be a wider variety of design options available. As Donald Norman mentions in his book about emotional design, no one design will satisfy every consumer (2004). Recommendations for designs generally split between two ideals. Many respondents expressed an interest in colorful designs that are fun to wear. Others wanted sleek, elegant designs that could match any outfit.

As far as preferences for clothing function, comfort was by far the most popular option. It is important to note that questions for the comfort function focused more on psychological than physical comfort with wording like, “I prefer to wear clothing that gives me self-confidence.”

However in the appearance satisfaction portion of the survey, half of the respondents indicated that to some degree they do not feel confident about their appearance while wearing a brace. Because dress can influence mood and self-perception, expressive brace designs could promote comfort. The second most popular function was concealment. There are essentially two ways to design braces that can be concealed. One option is to create minimal, low profile designs that can be worn easily under clothing. The other option is to create expressive designs that hide in plain sight as fashion accessories.

The two most common situations in which respondents chose not to wear their brace due to appearance were social gatherings and formal events. It is therefore important for designers to consider how a brace might accessorize with the type of fashion associated with evening wear and office attire. Choice of appropriate dress is an important part of appearance management, which allows people to influence the perceptions of others and negotiate social interactions.

While there were no questions specifically regarding the issue, velcro was a common grievance in the open-ended responses. Velcro was too scratchy, wore out too quickly, did not function all that well, and ruined other clothing through abrasion. Respondents described their ideal brace as having closures that do not include velcro. Although velcro is conveniently adjustable with one hand, perhaps it is time for designers to consider other solutions for closures on orthopedic braces.

### **5.3 Conclusion**

User experience for orthopedic braces is far from ideal. Wearers report low appearance satisfaction while wearing a brace, and social interactions are particularly problematic. Wearing a

brace can invite unwanted attention from others. Current brace designs are not all that visually appealing, and consumers are mostly unsatisfied with the design options available to them. Sometimes people choose not to wear their brace due to the way it looks, which makes it an ineffective medical tool.

To some extent or another, expressive designs could help improve the many negative aspects of wearing an orthopedic brace. A wider variety of design options, especially designs for more formal situations, would allow those who wear a brace to use appearance management to better negotiate social interactions. While theories of design now include the importance of emotion and expression in user satisfaction, expressive design is still uncommon in orthopedic braces. Appearance in medical wearables is often neglected in preference for function, but expressive designs could help create braces and other medical devices that consumers enjoy wearing.

## CHAPTER 6

### 6.1 Limitations

Due to the method of distribution and the sampling framework, it is possible that the sample population is not random and therefore not representative of the total population.

Distribution was targeted towards support groups for conditions that are commonly treated with an orthopedic brace, many of which require long-term wear. Almost 68% of the respondents wear a brace daily and will continue to wear it indefinitely. People who wear a brace more are likely to have stronger opinions about brace appearance than those who only need a brace for a short time. The volunteer bias may have resulted in inferences that do not apply to the larger population. However a biased sample group may provide useful information for a specific target market.

### 6.2 Future Research

This study is a beginning to understanding user needs for orthopedic braces, but there is still plenty of information to study. Future research might include

- A survey submitted to a random sample of patients at multiple physical and occupational therapy clinics
- Information from a more diverse sample group, including more variety in age, gender, and ethnicity
- More survey questions related to lifestyle and culture
- Focus groups or in-depth interviews

Another option for future research would be to have consumers evaluate the prototypes for expressively designed braces. Once the prototypes have been approved for medical safety, it would be interesting to work together with a clinic to distribute the new braces and conduct an experiment to find out if expressive design really can improve compliance or promote more positive social interactions.

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## APPENDICES

## **Appendix A: Survey**

### **Q53 Informed Consent Agreement**

You are being asked to take part in a research study. Your participation in this study is voluntary. You have the right to be a part of this study, to choose not to participate or to stop participating at any time without penalty. The purpose of research studies is to gain a better understanding of a certain topic or issue.

You are not guaranteed any personal benefits from being in a study. Research studies also may pose risks to those that participate. In this consent form you will find specific details about the research in which you are being asked to participate. If you do not understand something in this form it is your right to ask the researcher for clarification or more information.

#### **Purpose**

The purpose of the study is to understand how the look of orthopedic braces affects the experiences of people who wear them. Information from this study can help develop brace designs that are more satisfying to wear.

#### **Procedure**

If you agree to participate in this study, you will be asked to complete a survey about your experience wearing a brace. The survey is 47 questions long and will take about 20 minutes to complete.

#### **Risks and Benefits**

There are minimal risks associated with participation in this research. There are no direct benefits to your participation in the research. The indirect benefit is the development of better, more effective orthopedic braces.

## **Confidentiality**

Survey responses are anonymous and data will be stored securely in a password-protected location. No reference will be made in oral or written reports which could link you to the study.

## **Compensation**

There is no direct compensation for participating in this study.

## **Participation**

You must be 18 or older to take this survey.

Participation in this study is not a course requirement and your participation or lack thereof, will not affect your class standing or grades.

Participation in this study is not a requirement of your employment, and your participation or lack thereof, will not affect your job.

## **What if you have questions about this study?**

If you have questions at any time about the study itself or the procedures implemented in this study, you may contact the researcher, Lisa Bledsoe, at [lbleds2@ncsu.edu](mailto:lbleds2@ncsu.edu)

## **What if you have questions about your rights as a research participant?**

If you feel you have not been treated according to the descriptions in this form, or your rights as a participant in research have been violated during the course of this project, you may contact Deb Paxton, Regulatory Compliance Administrator at [dapaxton@ncsu.edu](mailto:dapaxton@ncsu.edu) or by phone at 1-919-515-4514.

Q54 I agree that I am 18 or older and have read and understand the above information. I am agreeing to participate in this study with the understanding that I may choose not to participate or to stop participating at any time without penalty or loss of benefits to which I am otherwise entitled.

- Yes
- No

*Skip To: End of Survey If I agree that I am 18 or older and have read and understand the above information. I am agreeing... = No*

**End of Block: Consent**

---

**Start of Block: Brace type/function**

Q1 Have you worn an orthopedic brace in the last 6 months?

- Yes
- No

*Skip To: End of Survey If Have you worn an orthopedic brace in the last 6 months? = No*

Q2 On what area/joint do you wear the brace? If you wear more than one brace, choose only one for this survey.

- Neck
- Shoulder
- Arm
- Elbow
- Wrist
- Hand
- Back
- Leg
- Knee
- Ankle
- Foot
- Other \_\_\_\_\_

Q3 Was your brace specifically recommended by a medical professional?

- Yes
  - No
- 

Q4 How did you obtain your brace?

- Purchased over-the-counter
  - Provided by doctor or hospital
  - Other \_\_\_\_\_
- 

Q5 What is the primary function of your brace?

- To prevent possible future injury
  - To aid healing after an acute injury or operation
  - To stabilize an area with ongoing problems
  - Other \_\_\_\_\_
- 

Q6 How often do you wear your brace?

- Daily
  - A few times per week
  - A few times per month
  - A few times per year
-

Q7 What is the prescribed/recommended duration of time for wearing the brace?

- Less than 1 week
  - 1-4 weeks
  - 1-3 months
  - 4-6 months
  - 7-12 months
  - More than 1 year
  - Continue to wear indefinitely
- 

Q8 Is the brace visible to others?

- Yes
- No

**End of Block: Brace type/function**

---

**Start of Block: Brace Appearance**

Q10 How visually appealing do you find your brace?

- very appealing
  - Somewhat appealing
  - Neither appealing nor unappealing
  - Somewhat unappealing
  - very unappealing
-

Q11 How satisfied are you with the variety of design options available for your brace type?

- Extremely satisfied
  - Somewhat satisfied
  - Neither satisfied nor dissatisfied
  - Somewhat dissatisfied
  - Extremely dissatisfied
- 

Q12 Rank the following items in order from most important to least important when purchasing a brace with 1 being the most important.

- \_\_\_\_\_ Price
  - \_\_\_\_\_ Color
  - \_\_\_\_\_ Bulkiness
  - \_\_\_\_\_ Pattern
  - \_\_\_\_\_ Fit/size
  - \_\_\_\_\_ Fashionability
  - \_\_\_\_\_ Durability
- 

Q50 Describe your ideal brace:

\_\_\_\_\_

---

Q13 Have you ever modified the appearance of your brace?

- Yes
- No

*Skip To: End of Block If Have you ever modified the appearance of your brace? = No*

Q15 Please describe any modifications you have made to the appearance of your brace.

---

**End of Block: Brace Appearance**

---

**Start of Block: Decision to wear**

Q16 Do you ever choose not to wear your brace because of the way it looks?

- Yes
- No

*Skip To: End of Block If Do you ever choose not to wear your brace because of the way it looks?  
= No*

Q17 How often do you choose not to wear your brace because of the way it looks?

- Rarely
- Sometimes
- About half the time
- Most of the time
- Always

---

Q18 Please elaborate on why you choose not to wear your brace due to appearance. Are there certain situations where you prefer not to wear it? Are there social or personal factors involved?

---

**End of Block: Decision to wear**

---

**Start of Block: User Experience**

Q20 When I wear my brace I feel confident about my appearance.

- Strongly agree
  - Somewhat agree
  - Neither agree nor disagree
  - Somewhat disagree
  - Strongly disagree
- 

Q21 When I wear my brace I feel that my injury is conspicuous to others.\*

- Strongly agree
  - Somewhat agree
  - Neither agree nor disagree
  - Somewhat disagree
  - Strongly disagree
- 

Q22 When I wear my brace I do not feel like my appearance is true to my personality\*

- Strongly agree
  - Somewhat agree
  - Neither agree nor disagree
  - Somewhat disagree
  - Strongly disagree
-

Q23 When I wear my brace in public, strangers ask about my injury.

- Strongly agree
  - Somewhat agree
  - Neither agree nor disagree
  - Somewhat disagree
  - Strongly disagree
- 

Q24 When I wear my brace, I feel satisfied with my body.

- Strongly agree
  - Somewhat agree
  - Neither agree nor disagree
  - Somewhat disagree
  - Strongly disagree
- 

Q25 People treat me differently when I'm wearing my brace.\*

- Strongly agree
  - Somewhat agree
  - Neither agree nor disagree
  - Somewhat disagree
  - Strongly disagree
-

Q26 I am hesitant to wear my brace in social situations.\*

- Strongly agree
  - Somewhat agree
  - Neither agree nor disagree
  - Somewhat disagree
  - Strongly disagree
- 

Q27 I feel good about myself when wearing my brace.

- Strongly agree
  - Somewhat agree
  - Neither agree nor disagree
  - Somewhat disagree
  - Strongly disagree
- 

Q51 I am uncomfortable when people ask me questions about my injury.\*

- Strongly agree
  - Somewhat agree
  - Neither agree nor disagree
  - Somewhat disagree
  - Strongly disagree
-

Q28 When I wear my brace I feel ugly\*

- Strongly agree
  - Somewhat agree
  - Neither agree nor disagree
  - Somewhat disagree
  - Strongly disagree
- 

Q29 When I wear my brace, I feel self conscious about my appearance. \*

- Strongly agree
  - Somewhat agree
  - Neither agree nor disagree
  - Somewhat disagree
  - Strongly disagree
- 

Q30 When I wear my brace, I am afraid I will appear weak to others.\*

- Strongly agree
  - Somewhat agree
  - Neither agree nor disagree
  - Somewhat disagree
  - Strongly disagree
-

Q31 My brace has no effect on how I feel about myself.

- Strongly agree
  - Somewhat agree
  - Neither agree nor disagree
  - Somewhat disagree
  - Strongly disagree
- 

Q32 My brace has no effect on how I feel about my body.

- Strongly agree
- Somewhat agree
- Neither agree nor disagree
- Somewhat disagree
- Strongly disagree

**End of Block: User Experience**

---

**Start of Block: Clothing Function**

Q33 I prefer to wear clothing that is fashionable and exciting

- Strongly agree
  - Somewhat agree
  - Neither agree nor disagree
  - Somewhat disagree
  - Strongly disagree
-

Q34 I prefer to wear clothing that conceals problem areas

- Strongly agree
  - Somewhat agree
  - Neither agree nor disagree
  - Somewhat disagree
  - Strongly disagree
- 

Q35 I prefer clothing that is more functional than stylish

- Strongly agree
  - Somewhat agree
  - Neither agree nor disagree
  - Somewhat disagree
  - Strongly disagree
- 

Q36 I prefer to wear clothing that makes me look unique

- Strongly agree
  - Somewhat agree
  - Neither agree nor disagree
  - Somewhat disagree
  - Strongly disagree
-

Q37 I prefer to wear clothing that impresses people

- Strongly agree
  - Somewhat agree
  - Neither agree nor disagree
  - Somewhat disagree
  - Strongly disagree
- 

Q38 I prefer to wear clothing that makes me feel better about myself

- Strongly agree
  - Somewhat agree
  - Neither agree nor disagree
  - Somewhat disagree
  - Strongly disagree
- 

Q39 I prefer to wear clothing that is comfortable

- Strongly agree
  - Somewhat agree
  - Neither agree nor disagree
  - Somewhat disagree
  - Strongly disagree
-

Q40 I prefer to wear clothing that gives me self-confidence

- Strongly agree
  - Somewhat agree
  - Neither agree nor disagree
  - Somewhat disagree
  - Strongly disagree
- 

Q41 I prefer to wear clothing that is unusual

- Strongly agree
  - Somewhat agree
  - Neither agree nor disagree
  - Somewhat disagree
  - Strongly disagree
- 

Q42 I prefer to wear clothing with enhanced performance qualities

- Strongly agree
  - Somewhat agree
  - Neither agree nor disagree
  - Somewhat disagree
  - Strongly disagree
-

Q43 I prefer to wear clothes that do not call attention to my body

- Strongly agree
  - Somewhat agree
  - Neither agree nor disagree
  - Somewhat disagree
  - Strongly disagree
- 

Q44 I will wear any available clothing regardless of style or appearance

- Strongly agree
- Somewhat agree
- Neither agree nor disagree
- Somewhat disagree
- Strongly disagree

**End of Block: Clothing Function**

---

**Start of Block: Demographics**

Q45 What is your age?

- 18 - 24
  - 25 - 34
  - 35 - 44
  - 45 - 54
  - 55 - 64
  - 65 - 75
  - over 75
-

Q46 What is your gender identification?

- Male
  - Female
  - I prefer not to respond
- 

Q47 What is your ethnicity?

- White
  - Black or African American
  - American Indian or Alaska Native
  - Asian
  - Native Hawaiian or Pacific Islander
  - Other
  - I prefer not to respond
- 



Q50 What is your country of residence?

▼ Afghanistan ... Zimbabwe

**End of Block: Demographics**

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## Appendix B: Transcript of Open Responses

\*Responses have not been edited for spelling, grammar, or content

### Describe your ideal brace:

1. One that either blends in so that it's not noticeable at all or one that allows for some fun (bright colors/patterns)
2. Ideal brace would be lightweight, washable, and breathable. Closure would not be velcro. It would come in variety of colors or designs.
3. All black with the twist knobs to tighten the wrist guard
4. Custom-made, with flexibility of choice with materials and design
5. Comfortable, lightweight, non-thermal, supportive, and something that I would be happy to wear while out and about.
6. Comfortable and effective
7. Colorful Pattern
8. Sleek but supportive and comfortable
9. Invisable
10. Less bulky to be able to wear under clothes
11. One that is not bulky and won't show an outline under long pants. Also, most are black but a flesh coloring would be less visible while wearing shorts. Comfort is huge as most braces aren't. Breathable materials and good support.
12. Does not look out of place and draw negative attention to my injury
13. I don't have an ideal brace. I want one that works. I previously have not considered aesthetic design in choosing a brace due to lack of availability of overall market segment of braces.
14. Comfortable
15. Lightweight, fits my wrist, waterproof (and doesn't smell), can be used with a cover, doesn't cut off circulation to my thumb.
16. one that fits small adults and breathes. No exposed scratchy Velcro.
17. Light weight, fits well, functional
18. Able to wear under clothing to hide it, able to choose different colours if it must be on show, easy to put on and take off. Durable and able to be used when swimming/showering, padded with a good fit (able to resize for swelling), comes with an accessory kit (able to change colour & style) optional extra, does the bloody job it is made for and keeps the joint stable - not pathetic like some of them.
19. Lightweight, supportive, not embarrassing to wear, comfortable.
20. Something with personality but QUALITY

21. Something that doesn't make me look like a robot and doesn't cut/chafe/bruise
22. I would like it to look less like a Velcro brace from Walgreens and more designed specifically for my arm. Some of my co-workers think I just wear it for sympathy/ bought it without a prescription. I think if it looked more custom, they would believe me. I also need it to be durable and adjustable. I'd rather have buckles instead of Velcro, and washable.
23. Comfortable, not bulky, compatible with other braces on same body part
24. Slender, with a soft breathable, washable outer cover. Prefer choice of covers.
25. Something comfortable, breathable, adjustable, preferably in black so to match everything and anything worn
26. I would love a hinged knee brace that doesn't cost a million dollars
27. One that is low profile, but durable. With color options or replaceable parts (for when they wear down with time). Since mine are ankle braces I would love for them to be adaptable in different shoes, currently I can only wear sneakers due to the ankle braces.
28. Comfortable, streamline and appealing
29. One that helps. Stays in place. Non bulky
30. Non slip, wrap around, open so it's not hot, harder plastic.
31. Easy to disassemble and clean, must be able to be submerged, must have washing machine safe removable padding.
32. Big enough to fit my body type, pink,
33. Low-key and functional in a daily setting without getting in the way.
34. Sturdy, made with durable materials, non-irritating, ideally attractive
35. One that works and does what it's supposed to
36. Invisible and sturdy
37. Something that fits snug and doesn't look terrible
38. Sleek, doesn't make me sweat or overheat, isn't bulky and is customizable. Preferably aesthetically appealing.
39. Easy to wear without sliding off, doesn't fall apart with extended wear.
40. One which doesn't cause pain, and keeps my kneecap in place. As streamlined as possible.

**Please describe any modifications you have made to the appearance of your brace:**

1. On a previous brace, I actually took Sharpie markers to it and drew flowers on it.
2. Painted them mostly, or tried to cover them with jewelry.
3. Changed color of straps
4. Changed the padding to memory foam and added a blue foam "sock" to make the brace more comfortable. It is a walking cast (or air boot), added a ribbon for some colour and extra velcro so that the brace closes properly (before the velcro straps hung down and got in the way of walking when the brace was tightened) added extra glue for under the velcro after it fell off (only had had the brace a week, and was on crutches), added diamontes to the foot straps when I added the glue and also glued the velcro straps to the "spine" of the brace so that when the brace is removed the straps stay in order and in place making it much easier to put back on.
5. Cut off extra Velcro straps because they are unnecessairly long and look stupid.
6. I added Velcro when it wore out, which was more changing the functionality but also changed the appearance some.
7. Ductape decorarions
8. Paint
9. Fabric covers
10. Cover
11. I have decorated it with washi tapes
12. Straps were super long - trimmed them. Turned out to be a bad idea. Brace can now only be worn under clothing and some sleeves are just incompatible with the bulk.
13. I have painted over unsightly brand lables
14. I have dyed a few compression cuffs, and I put buttons and patches on my braces

**Please elaborate on why you choose not to wear your brace due to appearance. Are there certain situations where you prefer not to wear it? Are there social or personal factors involved?**

1. If it's going to be very noticeable with my outfit (I'm in a skirt, for example), I'll skip it because it's so obvious.
2. People notice it and ask questions. While their intentions are usually kind, I don't like to explain my condition. Also, a brace will ruin an otherwise perfect outfit.
3. Social functions, particularly if formal and some work situations
4. I usually only wear my wrist brace while typing or driving, but if I've only driven to the shops, I'll usually take them off before I get out of the car. I normally don't need them in other situations anyway, but if I did, I would be self-conscious about wearing them, especially if I were dressed up.
5. I don't like the way it looks
6. Too bulky to fit in my shirt
7. I don't like the way they don't fit well over my bigger thighs.
8. Would you ever change a shirt if you saw it didn't match your outfit? It is this situation.
9. Don't like to wear in public
10. People ask me frequently what happened, it's bulky, it only comes in black or blue
11. Unable to swim/shower in it, unable to hide brace effectively for parties/outings, get left out of canoe trips if turn up in brace, unable to walk on the beach with brace, playing soccer - get left out as the brace might injure a fellow player.
12. In certain situations like when it's very hot and sandals are worn, or to formal events I generally choose not to wear the brace if possible.
13. I don't like the unwarranted negative attention
14. When I want to look elegant or professional
15. I don't like wearing braces when I am wearing a dress or going to a formal event. If the brace was less bulky and frumpy, this would be less of an issue, but the metal/cloth braces are all very frumpy. I wish I could get a sleek wrist brace that looks like my custom carbon-fiber knee brace, which is made of hard materials and not frumpy cloth.
16. The bulky white brace becomes the only topic of conversation and all that people see about me. They subconsciously talk louder and slower when I wear it.
17. It's grey and blue. I had no choice in color options. Also the velcro tends to catch on clothing. If I'm wearing something nice I don't want to ruin the fabric from the velcro
18. I don't like to wear it if I'm dressed up or if I'm wearing another brace somewhere else on my body

19. When I have to give presentations for work and wear a dress I choose not to wear my brace as I don't want to wear tennis shoes. The braces are very noticeable went trying to wear outfits that show my legs. I also sometimes choose not to wear them during the summer as I love to wear Chaco sandals and the braces do not work in them.
20. Its annoying
21. Social factors, bullying, visable braces make me an easy target to criminal activity in unsafe locations
22. I hate the Velcro straps and the metal bracket
23. Social situations usually result in full removal.
24. Depending on what type of clothes i wear for social situations will determine if i wear my leg braces or not.
25. I only wear it when it can be hidden
26. Because it is ugly and bulky
27. It makes me feel awkward. But then not wearing it all the time makes me feel like when I do, I'm suddenly somehow faking it.
28. More formal things, or I wanted to wear a cute dress...and my brace looked stupid
29. Social gatherings, where I need to wear dressier clothing.
30. Was in a wedding and didn't want to wear in nice pictures
31. If I have to wear something "nice" to an event with people I don't know very well, I'm likely to leave the brace at home or use a smaller compression cuff that's easier to hide instead (even though it doesn't provide as much stability). It can be very awkward to explain to strangers that I have to wear braces for a condition that they've never heard about.
32. I wear it at work and when I absolutely have to. When I had more of a choice to not wear it I would never wear it going out and socializing

## Appendix C: eIRB Exempt Status

North Carolina State University Mail - Lamar - 12573 - IRB Protocol assigned Exempt status

7/19/18, 8:08 PM

**NC STATE**

Lisa Bledsoe <lmbleds2@ncsu.edu>

### Lamar - 12573 - IRB Protocol assigned Exempt status

1 message

**IRB Administrative Office** <pins\_notifications@ncsu.edu>  
 Reply-To: debra\_paxton@ncsu.edu  
 To: lmbleds2@ncsu.edu

Mon, Jan 8, 2018 at 4:34 PM

Dear Lisa Bledsoe:

Date: January 8, 2018  
 IRB Protocol 12573 has been assigned Exempt status  
 Title: The Importance of Expressive Design in Orthopedic Braces  
 PI: Lamar, Traci Ann May

The research proposal named above has received administrative review and has been approved as exempt from the policy as outlined in the Code of Federal Regulations (Exemption: 46.101. Exempt b.2). Provided that the only participation of the subjects is as described in the proposal narrative, this project is exempt from further review. This approval does not expire, but any changes must be approved by the IRB prior to implementation.

1. This committee complies with requirements found in Title 45 part 46 of The Code of Federal Regulations. For NCSU projects, the Assurance Number is: FWA00003429.
2. Any changes to the protocol and supporting documents must be submitted and approved by the IRB prior to implementation.
3. If any unanticipated problems or adverse events occur, they must be reported to the IRB office within 5 business days by completing and submitting the unanticipated problem form on the IRB website: <http://research.ncsu.edu/sparcs/compliance/irb/submission-guidance/>.
4. Any unapproved departure from your approved IRB protocol results in non-compliance. Please find information regarding non-compliance here: [http://research.ncsu.edu/sparcs-docs/irb/non-compliance\\_faq\\_sheet.pdf](http://research.ncsu.edu/sparcs-docs/irb/non-compliance_faq_sheet.pdf).

Please let us know if you have any questions.

Sincerely,

Deb Paxton  
 919.515.4514  
 IRB Administrator  
[dapaxton@ncsu.edu](mailto:dapaxton@ncsu.edu)  
 NC State IRB Office

Jennie Ofstein  
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<https://mail.google.com/mail/u/0/?ui=2&ik=2296ddb9d0&jsver=hlCm...cat=Thesis&search=cat&th=160d7b264886651d&siml=160d7b264886651d> Page 1 of 1

Showing 1 to 1 of 1 entries

Protocol No.	Title	Department	PI	Status	Submission Date	Last Status Change	
12573	The Importance of Expressive Design in Orthopedic Braces	Textile & Apparel, Technology & Management	Lamar, Traci Ann May	Exempt	01/02/2018	01/08/2018	Select View PDF
Filter Protocol N	Filter Title	Filter Department	Filter PI	Filter Status			

[Return to Main Menu](#)

## Appendix D: Process for Creating Prototypes

### Step 1: Fashion Research

Current trends in fashion combined with the consumer needs described in the survey responses guided the initial ideation. Ideas for wrist braces were based mostly in modern designer jewelry, and ideas for knee braces were based on leggings and shoes.

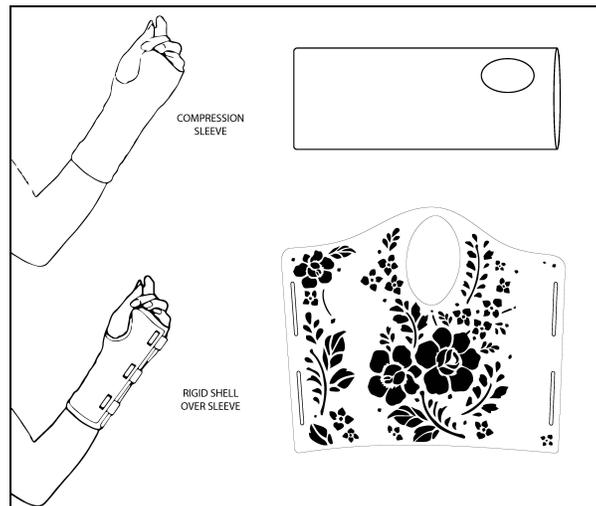


Photos found via Pinterest. Top left by Versace; top center by Any Tera; top right by Nicolas Taralis; bottom left by Alexander McQueen; bottom center from Nasty Gal; bottom right designer unknown

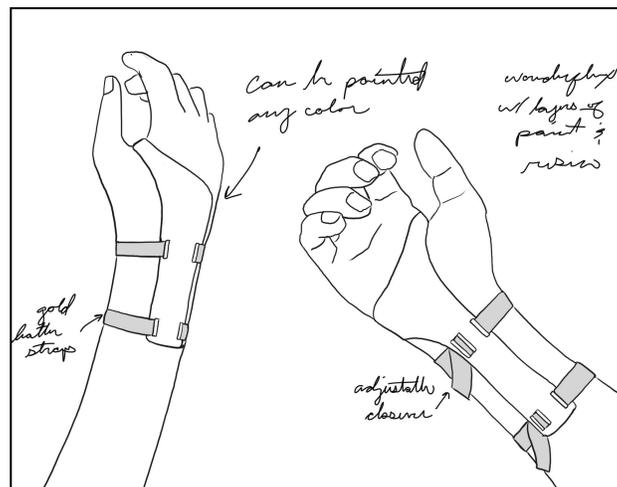
## Step 2: Idea Sketches

There were four initial sketches, two for a wrist brace and two for a knee brace. Both wrist brace ideas featured a rigid exoskeleton instead of multiple layers of foam, metal, and fabric. One knee brace idea included a brace integrated into a pair of leggings and the other idea was for a corset-like structure. The primary constraints deciding which sketches would become prototypes was cost, the availability of the necessary technology, and the time available to learn how to use it.

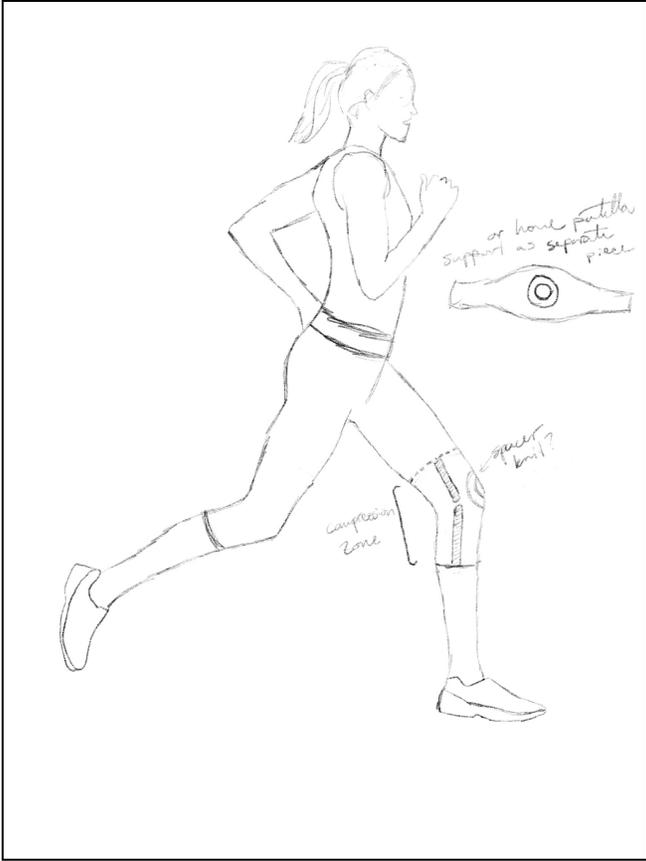
### Wrist Brace #1



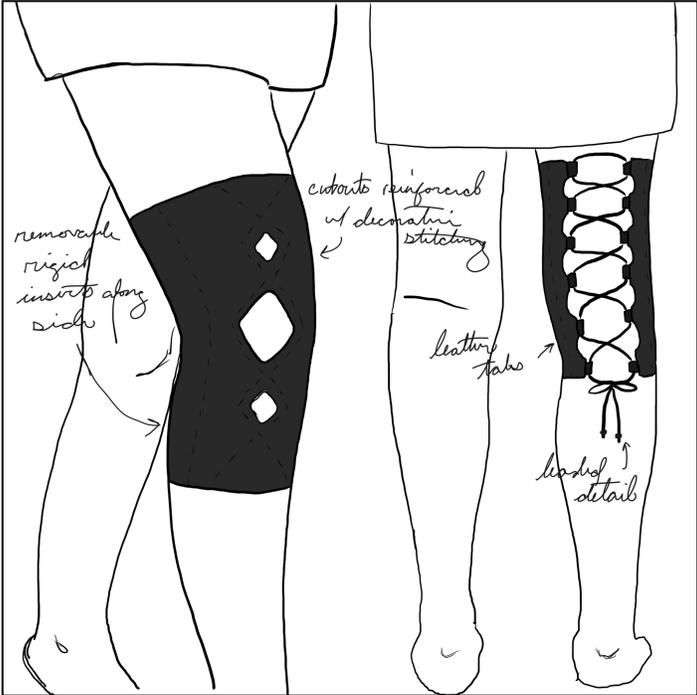
### Wrist Brace #2



**Knee Brace #1**



**Knee Brace #2**



### **Step 3: Patterning**

Patterns for the braces were traced and modified from existing braces to ensure proper fit and support. For the wrist brace, sections of the original tracing were cut away in areas that did not require rigid support. For the knee brace, only the front of the brace was traced. The sides were extended using a French curve.

### **Step 4: Construction**

**Knee Brace:** After cutting the knee brace according to the pattern, the two layers of the body were sewn right sides together with the tabs facing inward. A specialized knit stitch allowed the prototype to maintain its stretch properties. The body was then turned so that the right side faced outwards and topstitched along the bottom and sides. The top of each layer was hemmed separately. The quilting pattern was transferred to the front and stitched including the packets for the removable stays. After quilting, the center hole for the knee was cut after which the raw edges were melted and stitched together. A ribbon was laced through the tabs to create the closure.

**Wrist Brace:** Two layers of thermoplastic were bonded together by heating in a pan with boiling water. The brace pattern was traced onto the plastic and cut with a bandsaw. The underside of the brace was heated with a heat gun and molded onto a shaped metal piece from a hospital issue brace. Using the heat gun, the plastic was folded and the top side molded. Because the melting point of the plastic was low, it could be molded directly on the hand. After cutting the holes for the straps, all edges were trimmed and sanded until smooth. The abstract surface design was applied with layers of alcohol ink and sealed with a two-part epoxy resin. The resin cured for 24 hours after which the knit lining was applied with contact cement. The final step was assembling the straps.